Advances in Intelligent Systems and Computing 362

Jiuping Xu
Stefan Nickel
Virgilio Cruz Machado
Asaf Hajiyev *Editors*

Proceedings of the Ninth International Conference on Management Science and Engineering Management

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Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

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Editors
Jiuping Xu
Business School
Sichuan University
Chengdu, Sichuan
China

Virgilio Cruz Machado
Industrial Engineering
Universidade Nova de Lisboa
Lisbon
Portugal

Stefan Nickel
Karlsruhe Institute of Technology
Karlsruhe
Germany

Asaf Hajiyev
Azerbaijan National Academy of Sciences
Baku
Azerbaijan

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Preface for Volume 1

Welcome to the proceedings of the Ninth International Conference on Management Science and Engineering Management (ICMSEM2015) held from July 21 to 23, 2015 at Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

The International Conference on Management Science and Engineering Management is the annual conference organized by the International Society of Management Science and Engineering Management (ISMSEM). The goals of the conference are to foster international research collaborations in Management Science and Engineering Management as well as to provide a forum to present current research results in the forms of technical sessions and round table discussions during the conference period in a relaxed and enjoyable atmosphere. This year, 971 papers from 35 countries were received and 132 papers from 15 countries were accepted for presentation or poster display at the conference after a serious review. These papers are from countries including Spain, Australia, Germany, Russia, Saudi Arabia, Turkey, UK, Canada, Pakistan, China, USA, Japan, Portugal, Iran, and Azerbaijan. They are classified into eight parts in the proceedings which are Intelligent Systems, Logistics Engineering, Information Technology, Risk management, Computing Methodology, Project Management, Industrial Engineering and Decision Making Systems. The key issues of the Ninth ICMSEM cover various areas in MSEM, such as Decision Making Methods, Computational Mathematics, Information Systems, Logistics and Supply Chain Management, Relationship Management, Scheduling and Control, Data Warehousing and Data Mining, Electronic Commerce, Neural Networks, Stochastic models and Simulation, Heuristics Algorithms, and Risk Control. In order to further encourage the state-of-the-art research in the field of Management Science and Engineering Management, ISMSEM Advancement Prize for MSEM will be awarded at the conference for these researchers.

A total of 132 papers were accepted and they were divided into two proceedings with 66 papers in each proceedings. To find out the research topics among the accepted papers, the NodeXL was applied. To begin with, keywords from the first proceedings were excerpted as follows: Coupled technology, Poly-cell local support, Finite element method, Elasticity, Behavioral research, Intelligent systems, Work result, Qualitative research, Demographic Characteristics, Educational Interaction, Social Media, Matter element model, Extension set, Entrepreneurship education, Quality management, Projection pursuit, Combined model, Discharged patients forecasting, Earthquakes, Marking System, Multidimensional Scene, Principal component analysis, Executive compensation, Performance, Decision Making, Efficiency, Decision trees, Binary decision diagrams, Forecasting, Stochastic systems, Fuzzy control, Dynamic programming, Supply chain management, Distribution of goods, Bi-level modeling, Genetic algorithms, Logistics engineering, Buyback contract, Equilibrium model, Variational inequalities, Fuzzy demand price, Integrated inventory model, Carbon mission trade, Economic order quantity (EOQ), Vehicle routing, Uncertain demands and traveling time, Particle swarm optimization (PSO), Supplier selection, Gray relational analysis method, Entropy, Knowledge Flow, Collaborative Innovation, Running Mechanism of Water resources, Fuzzy sets, Life cycle, Condition monitoring, Wind power, Offshore Wind Turbines, Perspective of spatial structure, Selection, Risk assessment, Aviation, Prognostics, State of health, State estimation, Adaptive learning, Uncertainty analysis, Green supply chain, Information technology, Public security perception, Influencing factors, Mobile internet, Linear bi-level programming, Random fuzzy variable, Chance constraints, Interactive programming technique, Web forum, Message board, Tourist products, Public transport status, Assurance system, Economic fluctuation, Asymmetry, Markov Regime-switching model, Big data, University brand, Harnessing and boosting, Electronic commerce, Repeated game, Price competition, Multiple attribute decision making (MADM), The 2-tuple linguistic model, Group decision making, Integrated model, Factor analysis, Performance improvement, Maintenance, Net Present Value (NPV), Regression analysis, Increasing number of parameters, Least squares approximations, Confidence band, Sensor optimization selection, Aircraft engines, mHealth, Health care, Mobile IT, Patient-centered, Research and development management, Portfolio selection, Multiobjective optimization, Mixed integer programming, Large engineering, Pollution, Risk management, Game theory, Distributive justice, Banking employees, Knowledge chain, Innovation, Adverse selection, Mixed asymmetric information, Incentive contract, Small and medium-sized enterprises, Multiple attribute decision making, Structural equation modeling.

The significance of the keywords not only lies in its frequency or ratio. The connection between the keywords is very important in our study of how these papers revolve around the theme of Management Science (MS). The field of MS provides a set of concepts and metrics to systematically study the relationships between the keywords. The methods of information visualization have also become valuable in helping us to discover patterns, trends, clusters, and outliers, even in complex social networks. In the preface, the open-source software tool NodeXL was designed especially to facilitate learning the concepts and methods of MS as a key component.

Using the NodeXL, a total of 306 keywords involved in the 66 papers were analyzed. To begin with, the preliminary processing was executed on all the keywords. Except for a unified expression of words, all the keywords with the same meaning and the words including the meaning of similar keywords have been unitized. Such as “multiobjective problems”, “multiobjective models,” and “multiobjective optimization” have finally been unified to “multiobjective optimization.” Through the preliminary processing, the keywords have reduced to 284, making it possible to constitute network efficiently.

These processed keywords represented as the vertexes in NodeXL will be visualized in a network diagram. In the network diagram, the vertex sizes have been set to depend on a number of other vertexes associated with it. The more the vertex connects with other vertexes, the higher centrality it would be, which reflects the keyword’s important status in the field of MS. In other words, this keyword is likely to represent an important issue in MS. At the same time, the vertex shapes have been set to depend on their betweenness and closeness centrality. When the degree of a vertex’s betweenness and closeness centrality is beyond a certain value, the shape of this vertex would be square. The aim is to find out some key concepts in the field of MS, these key concepts are likely to be the important nodes that connect with other research topics.

Through the above steps, a network constituted by the keywords representing the relationship between them can be demonstrated in Fig. 1. It shows that intelligent systems, information technology, multiobjective optimization, logistics engineering, supply management, risk management, and genetic algorithms are key concepts as the important nodes which connected with other research topics. In other words, they are key issues about MS in the accepted 66 papers in this volume.

In this volume, the proceedings concentrate on intelligent systems, logistics engineering, information technology, risk management. To begin with, intelligent systems are the basic MSEM tools, as they provide a foundation for the discussion of practical management problems. Genetic algorithms and simulation are their key concepts. In this part, Gen et al. introduce how to design hybrid genetic algorithms (HGA) and multiobjective hybrid genetic algorithms (Mo-HGA) for solving practical manufacturing scheduling problems for the hard disk device (HDD) and the thin-film transistor-liquid crystal display (TFTLCD) manufacturing systems,

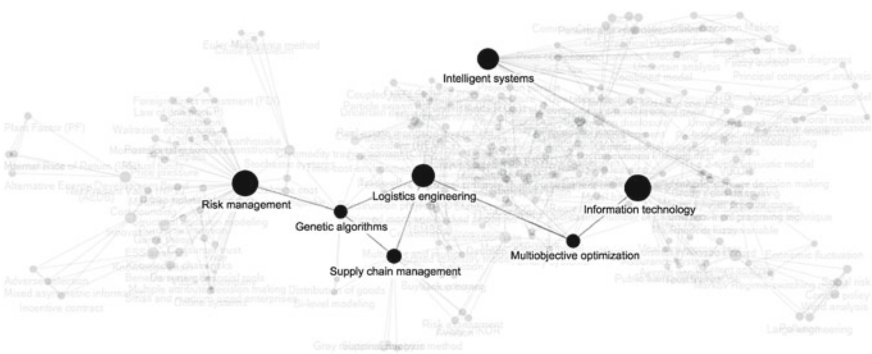

Fig. 1 Research topics in MS for the ninth ICMSEM

respectively. Mushtaq and Rehman address the use of social media for educational interaction and explore the influence of demographic characteristics on the use of social media in faculty members. Zhang et al. propose a projection pursuit combinatorial model (PPCM), which is applied to forecast the numbers of daily discharged patients through 3 years' time series data. Comparing with the forecasting results from ARIMA model, the new model produces a better forecasting performance. Ma and He propose a new method named as MPG/FEM method which is constructed by coupling the meshfree poly-cell Galerkin method (MPG) with the finite element method (FEM) for the analysis of elasticity problems.

Logistics engineering, the second part, is a field of engineering dedicated to the scientific organization of the purchase, transport, storage, distribution, and warehousing of materials and finished goods. Scholars in this section tend to focus on the accomplishment of desired goals and objectives by using restricted resources efficiently and effectively. Ping et al. demonstrate that a buyback contract can coordinate the supply chain under group buying, and how its contract terms critically depend on the quantity threshold above which group buying deal is activated. Segura et al. present a novel maintenance management research based on an economic study of the Life Cycle Cost (LCC) of CMS for offshore wind turbines. Yan et al. study the vehicle routing optimization problem with uncertain demands and traveling time. Xu et al. study the dynamic optimal allocation of irrigation water resources for multi-crop in multiple agricultural subareas and employ the fuzzy random simulation to deal with the uncertainty of seasonal inflow and rainfall.

The third part is information technology. Information technology (IT) is the application of computers and telecommunications equipment to store, retrieve, transmit, and manipulate data, often in the context of a business or other enterprise. IT is playing an increasingly dominant part in modern society. Hajiyev and Narmina suggest a new method for estimating of unknown parameters, choice of an optimal number of unknown parameters, and construction of a confident band for unknown function in these models. Görlitz proposes an mHealth concept for stroke patients and their caregivers that combines individual information with mobile IT and serious games to support the rehabilitation, therapy adherence, and secondary stroke prevention. Wu et al. present an intergraded multiple attribute group decision-making (MADGM) approach combining the consensus process and VIKOR method. Zhou et al. employ the interactive programming technique to deal with a class of linear bi-level programming with random fuzzy coefficients, which has no mathematical meaning because of the uncertain factors.

Risk management, the last part, is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. In this part, Tahir and Sabir aim to highlight an error in the prevailing present value (PV) approach with compounding for bond evaluation providing evidence regarding inappropriate use of compounding and through analyzing the two difference cases with illustrations. Akram et al. aim to determine the relationship between organizational justice and employee job satisfaction. The results showed that distributive justice has positive and significant impact on job satisfaction. Liu shows arbitrage equilibrium exists in a non-competitive context and explicit the role of elasticity in the relation of arbitrage and equilibrium in the non-Walrasian market. Zhang applies multiple attribute decision-making method of SMEs to four enterprises in risk assessment, and the results show that the multiple attribute decision-making method is effective and feasible.

The four parts containing 66 papers were hot research topics in MS. In addition to the high-quality proceedings, the conference also provides a suitable environment for discussions and exchanges of research ideas among participants during its well-organized conference. Although we will present our research results in technical sessions and participate in round table discussions during the conference period, we will have extra and fruitful occasions to exchange research ideas with colleagues in this relaxed and enjoyable atmosphere of sightseeing.

We want to take this opportunity to thank all participants who have worked hard to make this conference a success. We appreciate the help from International Society of Management Science and Engineering Management and Sichuan University in conference organization. We also appreciate Springer-Verlag London for the wonderful publication of the proceedings. We are also grateful to Prof. Stefan Nickel forf being a General Chair and Dr. Roland Görlitz for being the Organizing Committee Chair. Besides, we appreciate great support from all members of the Organizing Committee, Local Arrangement Committee, and Program Committee as well as all participants who have worked hard to make this conference a success. Finally, we want to appreciate all authors for their excellent papers to this conference. Due to these excellent papers, ISMSEM Advancement Prize for MSEM will be awarded again at the conference for the papers which describe a practical application of Management Science and Engineering Management. The Tenth International Conference on Management will be hosted by Azerbaijan National Academy and Ministry of Communication and High Technologies of Azerbaijan, Baku, Azerbaijan in July 2016. Professor Dr. Asaf Hajiyev will be the Organizing Committee Chair for 2016 ICMSEM. We sincerely hope that you can submit your new findings on MSEM and share your ideas in Azerbaijan.

Karlsruhe, Germany
May 2015

Jiuping Xu
Stefan Nickel
Virgilio Cruz Machado
Asaf Hajiyev

Preface for Volume 2

Welcome to the proceedings of the Ninth International Conference on Management Science and Engineering Management (ICMSEM2015) held from July 21 to 23, 2015 at Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

The International Conference on Management Science and Engineering Management is the annual conference organized by the International Society of Management Science and Engineering Management (ISMSEM). The goals of the conference are to foster international research collaborations in Management Science and Engineering Management as well as to provide a forum to present current research results in the forms of technical sessions and round table discussions during the conference period in a relaxed and enjoyable atmosphere. This year, 971 papers from 35 countries were received and 132 papers from 15 countries were accepted for presentation or poster display at the conference after a serious review. These papers are from countries including Spain, Australia, Germany, Russia, Saudi Arabia, Turkey, UK, Canada, Pakistan, China, USA, Japan, Portugal, Iran and Azerbaijan. They are classified into 8 parts in the proceedings which are Intelligent Systems, Logistics Engineering, Information Technology, Risk Management, Computing Methodology, Project Management, Industrial Engineering and Decision Making Systems. The key issues of the Ninth ICMSEM cover various areas in MSEM, such as Decision Making Methods, Computational Mathematics, Information Systems, Logistics and Supply Chain Management, Relationship Management, Scheduling and Control, Data Warehousing and Data Mining, Electronic Commerce, Neural Networks, Stochastic models and Simulation, Heuristics Algorithms, and Risk Control. In order to further encourage the state-of-the-art research in the field of Management Science and Engineering Management, ISMSEM Advancement Prize for MSEM will be awarded at the conference for these researchers.

132 papers were accepted and they were divided in two proceedings, with 66 papers in each proceedings. In order to find out the research topics among the accepted papers, the NodeXL was applied. To begin with, key words from 66 papers were excerpted as follows: Decision making Systems, Safety assessment, Industrial clusters, Knowledge based companies, Fuzzy dematel, Project

management, Risk management, Maintenance management, Cooperative game, Computing methodology, Allocation strategy, Group decision-making, Customer satisfaction index, Perceived equity, Customer loyalty, Institutional policy, Industrial engineering, Automobile market, Targeted effect, Spillover effect, Logistics engineering, Development strategy, Path model, Internal resources, Brand status, Entropy-fuzzy comprehensive evaluation model, Relationship diagraph, Perceptive value, Store image, Consumer satisfaction, Functional mechanism, Dynamic value chain, Fuzzy analytic hierarchy process (FAHP), Time-cost-environment, Construction project, Genetic algorithm, Capital stork, Energy project selection, Fixed-capital price index, Inventory, Depreciation, Energy project selection, Supplier selection, Logistics outsourcing, Automotive manufacturing, Science parks, Water quality, English heritage, Uncertainty, National trust, Concentrated solar plants, Wavelet transform, Perceived price, Index system, Water quality, Evaluation, Catastrophe theory, R&D project, Portfolio selection, Mixed integer programming, Industry structure, Optimization model, Low-carbon economy, Sustainable development, Brand marketing strategy, Marketing performance, Real-time scheduling, Hierarchical medical examination, Simulation, Empirical analysis, Entropy method, Differentiation strategy, Breakthrough innovation, Contribution rate, Technological progress, Coal enterprise, Soft sandstone, Remixing soil, Land reclamation, Resource utilization, Salvage cost, Error correction model, Stochastic game, Economic efficiency, DEA method, Pay strategy, Organizational performance, Industrial relations, Organization climate, Financial characteristic, Wind turbines, Fast Fourier transform, Factor analysis, Electricity industry, Economic development, Contribution ratio, Lean, Assessment tool, Fuzzy evaluation, Customer value attribute, Experimental research, Corporate value, Construction industry, Analytic hierarchy process, Resource uncertainty, Cooperative mechanism, Control system, Perceived opportunities, Travel intention, Contingent contract, Evolution characteristics.

The significance of the keywords not only lies in its frequency or ratio. The connection between the keywords is very important in our study of how these papers revolve around the theme of Engineering Management (EM). The field of EM provides a set of concepts and metrics to systematically study the relationships between the keywords. The methods of information visualization have also become valuable in helping us to discover patterns, trends, clusters, and outliers, even in complex social networks. In the preface, the open-source software tool NodeXL was designed especially to facilitate learning the concepts and methods of EM as a key component. Using the NodeXL, the total 407 keywords involved in the 66 papers were analyzed. To begin with, the preliminary processing was executed on all the keywords. Except for a unified expression of words, all the keywords with the same meaning and the words including the meaning of similar keywords have been unitized. Such as "Industrial engineering," "Industry engineering," and "Industrial project" have finally been unified to "Industrial engineering". Through the preliminary processing, the keywords have reduced to 361, making it possible to constitute network efficiently. These processed keywords represented as the vertexes in NodeXL will be visualized in a network diagram. In the network diagram, the vertex sizes have been set to depend on the number of other vertexes associated with it. The more the vertex connects with other vertexes, the higher its centrality would be, which reflects that the keyword's important status in the flied of EM. In other words, this keyword is likely to represent an important issue in EM. At the same time, the vertex shapes have been set to depend on their betweenness and closeness centrality. When the degree of a vertex's betweenness and closeness centrality is beyond a certain value, the shape of this vertex would be square. The aim is to find out some key concepts in the field of EM, these key concepts are likely to be the important nodes that connect with other research topics. Through the above steps, a network constituted by the keywords representing the relationship between them can be demonstrated in Fig. 2.

Figure 2 shows that decision-making systems, industrial engineering, project management, computing methodology, multiobjective optimization, scheduling, entropy method, simulation, innovation, and evaluation are key concepts as the important nodes which connected with other research topics. In other words, they are key issues about EM in the accepted 66 papers in this volume.

In this volume, the proceedings concentrate on computing methodology, project management, industrial engineering, and decision-making system. To begin with, computing methodology is the theoretical foundation of dealing with problems in management science and engineering management. In this part, Yüzbasi and Ahmed suggest shrinkage ridge regression estimators for a multiple linear regression model, and compare their performance with some penalty estimators which are lasso, adaptive lasso, and SCAD. Jafarova and Aliyev use Oracle Data Mining to investigate *k*-means clustering algorithm. The result of investigation allows to group 40 banks with 18 parameters in 10 centralized clusters, and at the same time shows the attributes and rules of clustering. This allows for comparison of parameters of banks and the association of banks in their specialization. Chen et al. provide a new CSI model on the basis of the present research achievements and the characteristics of consumer behavior in China. Zhou and Yang focus on the model of third-party rating results in connection with the performance control system of MFIs, to provide a reference for the establishment a comprehensive evaluation system for MFIs institutions.

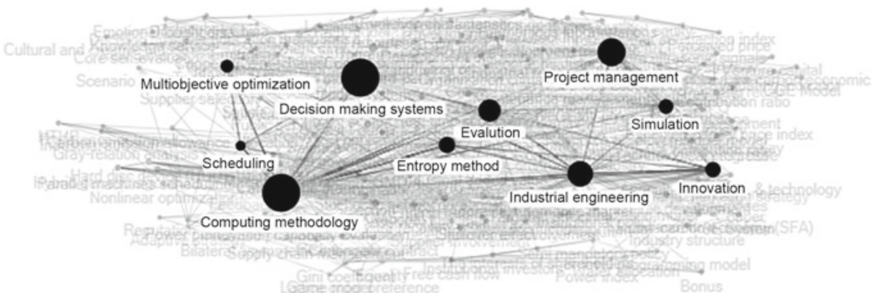

Fig. 2 Research topics in EM for the ninth ICMSEM

The second part is project management. Project management is the discipline of planning, organizing, securing, and managing resources to bring about the successful completion of specific project goals and objectives. Scholars in this part tend to focus on the accomplishment of desired goals and objectives by using restricted resources efficiently and effectively. Gómez et al. propose a novel approach for FDD based on long-range ultrasonic technology, together with a signal processing of ultrasonic waves employing wavelet transforms using a variable window size. Aleksandra and Oleg consider the realization of "compromise" through the scenario approach as effective choice of feedback coefficients of trading strategy. Luo et al. research on the technological transition of soft sandstone from a single control object to a comprehensive resource utilization object and propose a feasible resource utilization method for soft sandstone in the Mao wu su Sand Land based on the Land Consolidation Project practice and experimental analysis. Cao et al. calculate the optimal effort level of management fund institution with taking reputation into account using multi-stage dynamic game model of financing. It helps to resolve the moral hazard problem of fund managers and provides theory guide for raising of post-disaster reconstruction fund.

Industrial engineering, the third part, is the branch of engineering which deals with the optimization of complex processes or systems. In this part, Raúl et al. focus on the successful application of dependable embedded computer systems for the reliable implementation of wind turbine condition monitoring and control technologies. Schröders and Machado develop an assessment tool that helps an organization to implement lean in a sustainable way. Initially, the success factors of a lean approach have been identified and different business models have been reviewed. The research has shown that there are four main categories of crucial factors, including 24 criteria in total. Wang and Yu take the listed companies in construction industry as research samples. It has unscrambled the development rules of internal control quality in construction enterprises from two aspects: self-evaluation and verification, and goal achievement, and has further analyzed the impact of the internal control quality on the corporate value. Li et al. examine the effectiveness of an institutional policy-tax-reduction for low-emission vehicles policy-implemented in China automobile market and find that the institutional policy has positive targeted effect on small-engine cars and negative spillover effect on big-engine cars.

The fourth part focuses on decision-making systems. It is computer-based information systems which support knowledge management, decision making, and management reporting and assist managers in making decisions in highly uncertain and complex environments that Decision-Making Systems emphasize on. Rehman et al. highlight the moderating role of decisional intelligence in predicting the relationship among work-family conflict and decision-making styles. They also describe both academic and professional issues and its findings can be comprehensively utilized for the betterment of higher education sector of Pakistan. Pliego and García present an approach employing Binary Decision Diagram applied to the Logical Decision Tree, which allows addressing a Main Problem by establishing different causes, called Basic Causes and their interrelations. Liu and Liu establish a mechanism model on how store image influences consumers and loyalty in drug retail. They discover that store image influences brand loyalty through four different approaches, in which there are three mediating variables of perceptive value, consumer satisfaction, and brand trust. Guo et al. propose a dynamic group decision approach with intuitionistic fuzzy entropy and lattice order preference, where preference relations' possibility with respect to decision makers is represented by intuitionistic fuzzy number.

The four parts containing 66 papers were hot research topics in EM. Except the high-quality proceedings, the conference also provides a suitable environment for discussions and exchanges of research ideas among participants during its well-organized conference. Although we will present our research results in technical sessions and participate in round table discussions during the conference period, we will have extra and fruitful occasions to exchange research ideas with colleagues in this relaxed and enjoyable atmosphere of sightseeing.

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Organization

ICMSEM 2015 was organized by International Society of Management Science and Engineering Management, Sichuan University (Chengdu, China), Karlsruhe Institute of Technology (Karlsruhe, Germany). It was held in cooperation with Advances in Intelligent Systems and Computing (AISC) of Springer.

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Multiobjective Hybrid Genetic Algorithms for Manufacturing Scheduling: Part I Models and Algorithms

Mitsuo Gen, Lin Lin and Wenqiang Zhang

Abstract In real world manufacturing systems there are many combinatorial optimization problems (COP) imposing on more complex issues, such as complex structure, nonlinear constraints, and multiple objectives to be handled simultaneously. Manufacturing scheduling is one of the important and complex COP models, where it can have a major impact on the productivity of a production process. Moreover, the COP models make the problem intractable to the traditional optimization techniques because most of scheduling problems fall into the class of NP-hard combinatorial problems. In order to develop effective and efficient solution algorithms that are in a sense good, i.e., whose computational time is small as within 3 min, or at least reasonable for NP-hard combinatorial problems met in practice, we have to consider: quality of solution, computational time and effectiveness of the nondominated solutions for multiobjective optimization problem (MOP). When solving any NP-hard problem, a genetic algorithm (GA) based on principles from evolution theory is most powerful metaheuristics. In this paper, we concern with the design of hybrid genetic algorithms (HGA) and multiobjective HGA (Mo-HGA) to solve manufacturing scheduling problems. Firstly we introduce typical models in manufacturing scheduling systems such as parallel machines scheduling (PMS), flexible job-shop scheduling problem (FJSP) and assembly line balancing (ALB) problem. Secondly to solve NP-hard COP models, we introduce design scheme of HGA combined with fuzzy logic controller (FLC) and multiobjective HGA (Mo-HGA) with several fitness assignment mechanisms. For demonstrating computational experiments by HGA and Mo-HGA, the effectiveness of the HGA for the HDD (hard disc device) and Mo-HGA

M. Gen (✉)
Fuzzy Logic Systems Institute, Tokyo University of Science,
Tokyo 162-0825, Japan
e-mail: gen@flsi.or.jp

L. Lin
School of Software Technology, Dalian University of Technology,
Dalian 116024, People's Republic of China

W. Zhang
College of Information Science & Engineering, Henan University
of Technology, Zhengzhou 450001, People's Republic of China

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for TFT-LCD (thin-film transistor-liquid crystal display) module assembly problems as a practical manufacturing model, respectively is demonstrated in the concatenated paper Part II.

Keywords Hybrid genetic algorithms (HGA) · Multiobjective HGA (Mo-HGA) · Manufacturing scheduling · Parallel machines scheduling (PMS) · Hard disc device (HDD)

1 Introduction

In real world manufacturing systems there are many combinatorial optimization problems (COP) imposing on more complex issues, such as complex structure, non-linear constraints, and multiple objectives to be handled simultaneously. Manufacturing scheduling is one of the important and complex COP models, where it can have a major impact on the productivity of a production process. Moreover, the COP models make the problem intractable to the traditional optimization techniques because most of scheduling problems fall into the class of NP-hard combinatorial problems. In order to develop effective and efficient solution algorithms that are in a sense good, i.e., whose computational time is small as within 3 min, or at least reasonable for NP-hard combinatorial problems met in practice, we have to consider three important issues:

(1) Quality of solution, (2) Computational time and (3) Effectiveness of the non-dominated solutions for multiobjective optimization problem (MOP).

When solving any NP-hard problem, a genetic algorithm (GA) based on principles from evolution theory is one of very powerful metaheuristics [1].

The semiconductor industry has grown rapidly and subsequently production planning problems have raised many important research issues. Because of short product lifecycles, it is crucial to rapidly respond to various customer needs and deliver products on time in high-tech semiconductor manufacturing industries such as the various semiconductor devices including IC chips, LSI chips & microprocessors, thin-film transistor-liquid crystal display (TFT-LCD) and hard disc device (HDD). The HDD and TFT-LCD manufacturing is capital and technology intensive industry. Facing the fierce competitive pressures, it is important to enhance productivity and operational efficiency. Manufacturing scheduling of TFT-LCD module assembly system is a key issue to enhance manufacture efficiency that could satisfy customer demand on time [2].

By focusing on realistic settings, a module assembly process was formulated for use in the HDD and TFT-LCD industries as a generalization of the flexible job-shop scheduling problem (FJSP) and assembly line balancing (ALB) model, respectively. On a flexible job-shop floor, workstations employ non-identical parallel machines scheduling (PMS) model and reentrant flow-shop scheduling (RFS) model that exhibit distinct production velocities. An operation can be processed using an available machine from a given workstation. For example, the TFT-LCD module assembly scheduling problem can be divided into two subproblems: the routing (i.e., assigning each operation to machines) and scheduling problems (i.e., determining the start time of each operation to machines). The following factory-specific factors complicate the TFT-LCD module assembly scheduling problem. [3] reported detailed definitions to avoid ambiguity of terms commonly used by different communities: complete schedule, flexible schedule, conditional schedule, predictive schedule, executable schedule, adaptive scheduling system, robust predictive schedule and table predictive schedule. However, to find the optimal solutions of manufacturing scheduling gives rise to complex combinatorial optimization, unfortunately, most of them fall into the class of NP-hard combinatorial problems.

Furthermore, many researches are focusing on the manufacturing scheduling problems such as parallel machine system (PMS), job-shop scheduling problem (JSP), flexible job-shop scheduling problem (FJSP) and by genetic algorithms. The PMS model has been widely used in many manufacturing environments and [4] proposed a genetic algorithms for solving minmax earliness/tardiness scheduling in identical parallel machine system problem. Cheng and Gen [5] expanded the memetic algorithm to solve the minmax PMS problem. The memetic algorithm is a kind of hybrid version of the genetic algorithms and the local optimizer in order to enhance the performance of the genetic algorithms.

In the job-shop scheduling problem (JSP) consisting of a set of jobs and a set of machines, the JSP model is to establish a permutation of operations on each machine subject to precedence constraints to minimize production time completed. This problem is one of the best known models of the difficult combinatorial optimization problems. Cheng et al. [5, 6] reported a tutorial survey of JSP using genetic algorithms: representation and hybrid genetic search strategies, respectively. Kachitvichyanukul et al. [7] proposed a two-stage genetic algorithm (2S-GA) for multiobjective JSP (MoJSP). The 2S-GA is proposed with three criteria: minimizing makespan, minimizing total weighted earliness, and minimizing total weighted tardiness. Gao et al. [8] reported a hybrid genetic algorithm for solving flexible job-shop scheduling problem (FJSP) model with maintenances and Gao et al. [9] proposed a hybrid of genetic algorithm with bottleneck shifting method for solving multiobjective FJSP problems. Gao et al. [10] also proposed a hybrid genetic algorithm (HGA) combined with variable neighborhood descent (VND) method for solving multiobjective FJSP model (MoFJSP). Gen et al. [11] proposed a multistage-based GA (MsGA) with bottleneck shifting developed for treating the multiobjective FJSP model.

Since the 1960s, there has been being an increasing interest in imitating living beings to solve the hard optimization problems. An evolutionary algorithm (EA) such as a genetic algorithm (GA) is a generic population-based meta-heuristic optimization algorithm [12–14]. An EA uses some mechanisms inspired by biological evolution: reproduction, mutation, recombination, and selection. Handa et al. [15] gave a comprehensive overview of recent advances of evolutionary computation (EC) studies. GAs have attracted significantly attention with respect to complexity scheduling, which is referred to evolutionary scheduling, it is vital research domain at interface of two important sciences C artificial intelligence and operational research [16].

Even if EAs have attracted significantly attention with respect to above complexity scheduling problems, it has a disadvantage: we have to design a specialized EA for each practical scheduling problem with the problem's specificity. So that means each class of EAs doesn't have a wide range of applications on manufacturing scheduling. Recently Gen and Lin [1] surveyed multiobjective evolutionary algorithm for manufacturing scheduling problems. In order to design an effective GA with the problem's specificity, we have to consider (1) how to design a representation and a way of population initialization; (2) how to evaluate an individual by a fitness function; (3) how to improve population by evolutionary operators. In this paper, we focus on the effective multiobjective hybrid genetic algorithm for applying to manufacturing scheduling, in particular HDD and TFT-LCD module assembly problems.

The rest of this paper is organized as follows: Sect. 2 introduces typical manufacturing scheduling models such as parallel machine scheduling (PMS) model, flexible job-shop scheduling problem (FJSP) and assembly line balancing (ALB) problem. A design scheme for hybrid genetic algorithms (HGA) and fuzzy logic controller (FLC) for tuning GA parameters introduce in Sect. 3. The basic concept for a multiobjective optimization problem (MOP) summarizes and multiobjective HGA (Mo-HGA) with several fitness assignment mechanisms introduces in Sect. 4. Finally, the conclusion of this paper are drawn in Sect. 5.

2 Manufacturing Scheduling Models

2.1 Parallel Machine Scheduling Model

Scheduling is to simply assign a set of jobs to a set of machines with respect to operational constraints such that optimal usage of available resources is obtained. Because of the growing cost of raw material, labor, energy and transportation, scheduling plays an essential role in production planning of manufacturing systems, and it is one of the most important issues for survival in the modern competitive market place. Parallel machine scheduling (PMS) has been widely used in many manufacturing environments [4]. It is an extension of the fundamental single-machine scheduling, and can also be regarded as a production scheduling stage in a flexible flow shop or flexible job-shop. In the PMS problem an objective is to minimize the maximum weighted absolute lateness. It is known as one of non-regular performance measures. In recent years, scheduling research involving non-regular performance measures has received much attention from practitioners as well as researchers to respond to the increasing competitive pressure in domestic and international market. There are two non-regular performance measures commonly used in machine scheduling: minsum and minmax. A minsum problem attempts to minimize the sum of weighted absolute deviation of job completion time about the due date to reduce customers' aggregate disappointment; while a minmax problem attempts to minimize the maximum weighted absolute deviation of job completion time about the due date to reduce a customer's maximum disappointment. Li and Cheng [17] have shown that the minmax scheduling problem is NP-complete even for a single machine system.

In general, we know that there are two essential issues to be dealt with in PMS problems: (1) Job partition among machines (combination nature) and (2) Job sequence within each machine (permutation nature).

That is, the problem involves both permutation and combination components. Most PMS problems have been shown to be NP-complete [13]. That is, the PMS problem involves a combination of the permutation component and the combination component and is much difficult to solve than the single machine scheduling problem. Parallel machine scheduling problem has been one of the topics of interest for many researchers in the past few decades. Most of these studies considered the machines as only resource which is restricted. However, in real life manufacturing systems other resources such as machine operators and tools are constrained and it is illogical to consider that there are always enough resources for processing a job.

Cheng and Gen [12] applied the memetic algorithm to solve the minmax parallel machine scheduling problem. The memetic algorithm is a kind of hybrid version of the genetic algorithms and the local optimizer in order to enhance the performance of the genetic algorithms. The genetic algorithm is used to evolve the job partition among machines and the job sequence within each machine whereas a local optimizer is used to adjust the job order to form a V-shaped scheduler for each machine. Experiment results shown that the hybrid approach outperforms the genetic algorithms and conventional heuristic.

Balin [18] proposed genetic algorithm a new crossover operator and a new optimality criterion for solving the non-identical parallel machine scheduling (Nonident-MPS) problem consisting of the n independent jobs and the m non-identical parallel machines in order to minimize makespan with a definite processing time with a different processing time on each machine. The GA proposed here is suitable for the Nonident-MPS problem of minimizing the maximum completion time (makespan). GA can be applied to non-identical parallel machine scheduling problem involving setup times, ready times and/or due dates in order to minimize the maximum flow time, number of tardy jobs or total tardiness [18]. Balin [19] proposed genetic algorithm embedded with a simulation model for solving non-identical parallel machine scheduling problem with fuzzy processing times (Nonident-FuzzyPMS) by minimizing maximum completion time (makespan).

Li et al. [20] proposed metaheuristics and exact methods to solve a multiobjective parallel machines scheduling (MoPMS) problem, $Pm|s_{ij}, r_j|C_{\max}, T_j$ in which consists in scheduling n independent jobs on m identical parallel proposed machines and the job data such as processing times, release dates, due dates and sequence dependent setup times are considered where s_{ij} and r_j are the sequence dependent setup times if job j is the immediate successor of the job i on the same machine and the release of job j, respectively and $C_{\max}$, T_j are the makespan and the tardiness of job j. They formulated a mixed integer linear program (MILP) model for the MoPMS problem for solving it by CPLEX solver and proposed the nondominated sorting genetic algorithm (FLC-NSGA-II) coupled with a fuzzy logic controller (FLC) to solve the problem. The role of the fuzzy logic is to better set the crossover and the mutation probabilities in order to update the search ability as demonstrated in hybrid genetic algorithm (HGA) by Yun and Gen [16] as introducing in Subsection 3.2 Fuzzy Logic Controller for Tuning Parameters and also auto-tuning strategy for balancing between exploration and exploitation by Lin and Gen [21]. The experimental results for the MoPMS problem shown the advantages and the efficiency of the FLC-NSGA-II [20].

The flexible flow-shop scheduling (FSS) problem may be seen as a generalization of two particular types of scheduling problems: the PMS problem and the flow-shop scheduling problem (FSP). The key decision of the PMS problem is the allocation of jobs to machines whereas the key decision of FSP is the sequence of jobs through the manufacturing shop floor. The FSS problem has been widely studied in the literature. The machines considered in each stage of the flexible flow-shop problem are different and can be identical machines [22]. The main consequence of the reentrant flow nature is that wafers at different stages in their semiconductor manufacturing cycle have to compete with each other for the same machines. This is a reentrant flow-shop scheduling (RFS) model, in the RFS problem all jobs have the same routing over the machines of the shop and the same sequence is traversed several times to complete the jobs. Chen et al. [23] proposed a hybrid genetic algorithm for solving the reentrant flow-shop scheduling problem.

Recently hybrid genetic algorithms (HGAs) are proposed to solve the complex re-entrant scheduling problem with time windows constraint in manufacturing HDD devices with lot size. This problem can be formulated as a deterministic $Fm|fmls, rcrc, temp|C_{MAX}$ problem for finding the scheduling operations of machines in a flow-shop environment processing *fmls* job families with the objective of minimising the makespan, C_{MAX} [24, 25]. Sangsawang et al. [26] proposed metaheuristics optimization approaches for solving the two-stage reentrant FFS (RFFS) problem with blocking constraint (FFS|2-stage,rcrc,block|Cmax) in which they applied a hybrid GA and a hybrid particle swarm optimization (HPSO) with Cauchy distribution.

2.2 Flexible Job-Shop Scheduling Model

Machine scheduling problems arise in diverse areas such as flexible manufacturing system, production planning, computer design, logistics, communication, etc. A common feature of many of these problems is that no efficient solution algorithm is known yet for solving it to optimality in polynomial time. The classical job-shop scheduling problem (JSP) is one of the most well-known machine scheduling problems. JSP is among the hardest combinatorial optimization problems [27]. Because of its inherent intractability, heuristic procedures are an attractive alternative. Most conventional heuristic procedures use a priority rule, i.e., a rule for choosing an operation from a specified subset of as yet unscheduled operations. In recent years, an interest in using probabilistic search methods to solve JSP has been growing rapidly. These approaches comprise the emergence of promise for conquering the combinatorial explosion in a variety of decision-making arenas. Van Laarhoven et al. [28] proposed a simulated annealing for solving job-shop scheduling problem and Dell'Amico and Trubian [29] proposed a tabu search for solving the job-shop scheduling problem. Gen et al. [30] proposed a genetic algorithm for solving the job-shop scheduling problem. Cheng et al. [6, 31] reported a tutorial survey of JSP using genetic algorithms: representation and hybrid genetic search strategies, respectively.

Flexible job-shop scheduling problem (FJSP) is an extension of the traditional job-shop scheduling problem, which provides a closer approximation to real scheduling problems. In the job-shop scheduling problem (JSP), there are n jobs that must be processed on a group of m machines. Each job i consists of a sequence of m operations $(o_{i1}, o_{i2}, \ldots, o_{im})$, where o_{ik} (the kth operation of job i) must be processed without interruption on a predefined machine m_{ik} for p_{ik} time units. The operations $o_{i1}, o_{i2}, \ldots, o_{im}$ must be processed one after another in the given order and each machine can process at most one operation at a time. In a flexible job-shop, each job i consists of a sequence of n_i operations $(o_{i1}, o_{i2}, \ldots, o_{ini})$. The FJSP extends JSP by allowing an operation o_{ik} to be executed by one machine out of a set A_{ik} of given machines. The processing time of operation o_{ik} on machine j is $p_{ikj} > 0$. The FJSP problem is to choose for each operation o_{ik} a machine $M(o_{ik}) \in A_{ik}$ and a starting time s_{ik} at which the operation must be performed.

Mastrolilli and Gambardella [32] proposed two neighborhood functions for the FJSP problem. They proposed a tabu search procedure and provided an extensive computational study on 178 FJSP problems and 43 JSP problems. The flexible job-shop scheduling problem is to assign each operation to an available machine and sequence the operations assigned on each machine in order to minimize the makespan, that is, the time required to complete all jobs. The multiobjective FJSP model (MoFJSP) will be formulated as a multiobjective 0–1 mixed integer programming (M0-1MIP) model as follows [11]:

$$\min t_M = \max_{i,k} \{c_{ik}\}, \tag{1}$$

$$\min W_M = \max_{j} \left\{W_j\right\}, \tag{2}$$

$$\min W_T = \sum_{j=1}^{m} W_j, \tag{3}$$

$$s.t. c_{ik} - t_{ikj} x_{ikj} - c_{i(k-1)} \geq 0, \quad k = 2, \ldots, K_i; \forall i, j \tag{4}$$

$$\left[\left(c_{hg} - c_{ik} - t_{hgj}\right) x_{hgj} x_{ikj} \geq 0\right] \vee \left[\left(c_{ik} - c_{hg} - t_{ikj}\right) x_{hgj} x_{ikj} \geq 0\right], \forall (i,k), (h,g), j \tag{5}$$

$$\sum_{j=1}^{m} x_{ikj} = 1, \forall k, i \tag{6}$$

$$x_{ikj} \in \{0, 1\}, \forall j, k, i \tag{7}$$

$$c_{ik} \geq 0, \forall k, i \tag{8}$$

The objective functions accounts Eq. (1) is to minimize the makespan, Eq. (2) is to minimize the maximal machine workload (i.e., the maximum working time spent at any machine), Eq. (3) is to minimize the total workload (i.e., the total working time over all machines). Equation (4) states that the successive operation has to be started after the completion of its precedent operation of the same job, which represents the operation precedence constraints. Equation (5) is a disjunctive constraint, where one or the other constraint must be observed. Equation (6) states that one machine must be selected for each operation. Equations (7) and (8) are variable restrictions. Gao et al. [8] developed a new hybrid GA to solve the flexible job-shop scheduling problem with non-fixed availability constraints. Gao et al. [10] also proposed a hybrid genetic algorithm (HGA) combined with variable neighborhood descent (VND) method for solving multiobjective FJSP model (MoFJSP). Gen et al. [11] proposed a multistage-based GA (MsGA) with bottleneck shifting developed for treating the multiobjective FJSP model. The realistic FJSP model combined sequence-dependent setup time (SDST) constraints will be considered manufacturing scheduling systems for the TFT-LCD (thin-film transistor-liquid crystal display).

2.3 Assembly Line Balancing Model

An assembly line (AL) is a manufacturing process consisting of various tasks in which interchangeable parts are added to a product in a sequential manner at a station to produce a finished product. Assembly lines are the most commonly used method in a mass production environment, because they allow the assembly of complex products by workers with limited training, by dedicated machines and/or by robots. The assembly line balancing (ALB) model is not only include the operation sequence between stations, but also need to consider that how to group the operations among stations so that the precedence relations are not violated and a given objective function is optimized.

Since, ALB model falls into the NP-hard class of combinatorial optimization problems [33], in recent years, to provide an alternative to traditional optimization techniques, numerous research efforts have been directed towards the development of heuristics and meta-heuristics. While heuristic methods generating one or more feasible solutions were mostly developed until mid 90s; meta-heuristics such as tabu search [34], simulated annealing, genetic algorithms [29] and ant colony optimization [35] have been the focus of researchers in the last decade.

Among the meta-heuristics, the application of Genetic Algorithms (GAs) received a considerable attention from the researchers, since it provides an alternative to traditional optimization techniques by using directed random searches to locate optimum solutions in complex landscapes and it is also proven to be effective in various combinatorial optimization problems. GAs are powerful and broadly applicable stochastic search and optimization techniques based on principles from evolutionary theory [13]. Falkenauer and Delchambre [36] were the first to solve ALB problem with GAs. Following Falkenauer and Delchambre, application of GAs for solving ALB model was studied by many researchers, [37–39]. However, most of the researchers focused on the simplest version of the problem, with single objective and ignored the recent trends, i.e., mixed-model production, u-shaped lines, robotic lines and etc., in the complex assembly environments, where ALB models are multiobjective in nature [40, 41].

The basic version of the ALB model is the simple assembly line balancing (sALB) model. The simple assembly line is a single-model assembly line that is capable of producing only one type of product. A simple ALB model capable of producing only one type of product consists of stations ($i = 1, \ldots, m$) arranged along a conveyor belt or a similar mechanical material handling equipment. The workpieces (jobs) are consecutively launched down the line and are moved from station to station. At each station, certain tasks are repeatedly performed regarding the cycle time (maximum or average time available for each workcycle). The decision problem of optimally partitioning, i.e., balancing, the assembly work among the stations with respect to a given objective function is known as sALB problem. Manufacturing a product on an assembly line requires partitioning the total amount of work into a set of elementary operations named tasks $j = 1, \ldots, n$. Performing a task j takes certain task time t_j and requires certain equipment of machines and/or skills of workers. Due to technological and organizational conditions precedence constraints between the tasks have to be observed. These elements can be summarized and visualized by a precedence network. It contains a node for each task, node weights for the task processing times and arcs for the precedence constraints.

Any type of sALB model consists in finding a feasible line balance, i.e., an assignment of each task to a station such that the precedence constraints are fulfilled. The set of tasks S_i assigned to a station i ($i = 1, \ldots, m$) constitutes its station load, the cumulated task time:

$$t(S_i) = \sum_{j \in S_i} t_j, \tag{9}$$

is called station time. When a fixed common cycle time c_T is given, a line balance is feasible only if the station time of neither station exceeds c_T. In case of $t_{Si} < c_T$, the station i as an idle time of $(c_T - t_{Si})$ time units in each cycle.

After defining the indices, parameters and decision variable [11, 21, 42], we formulate the following multiobjective 0–1 integer programming model:

$$\max E = \frac{1}{mc_T} \sum_{j=1}^{n} t_j x_{ij} \tag{10}$$

$$\min \ m = \sum_{i=1}^{M} \max_{1 \le j \le n} \{x_{ij}\} \tag{11}$$

$$\min V = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(u_i - \overline{u})^2} \tag{12}$$

$$s.t. \sum_{i=1}^{M} x_{ij} = 1, \forall j \tag{13}$$

$$\sum_{i=1}^{M} i x_{ik} \le \sum_{i=1}^{M} i x_{ij}, \forall j; \forall k \in \Pr e(j) \tag{14}$$

$$t(S_i) = \sum_{j \in S_i} t_j = \sum_{j=1}^{n} t_j x_{ij} \le c_T, \forall i \tag{15}$$

$$x_{ij} = 0 \; or \; 1, \forall i, j. \tag{16}$$

In this mathematical model, the first objective Eq. (10) of the model is to maximize the line efficiency. The second objective Eq. (11) is to minimize the number of stations actually employed. The third objective Eq. (12) of the model is to minimize the variation of workload. The constraints given in Eqs. (13)–(16) are used to formulate the general feasibility of the problem. The constraint given in Eq. (13) states that each task must be assign to one and only one station. Equation (14) represents the precedence constraints and it states that the direct predecessor of task j must be assign to a station, which is in front of or the same as the station that task j is assigned in. This constraint stresses that if a task is assigned to a station, then the predecessor of this task must be already assigned to a station. Equation (15) denotes that the available time at each station should be less than or equal to the given cycle time. Constraint given in Eq. (16) represents the usual integrity restriction.

For designing a chromosome representation with encoding method, there are several methods to suit the characteristics of ALB model [41]: Task-based Encoding, Embryonic Encoding, Workstation-based Encoding, Grouping-based Encoding, and Heuristic-based (Indirect) Encoding. In the past decades, robots have been extensively used in assembly lines as called robotic assembly lines (rALs). An assembly robot can work 24 h a day without worries or fatigue. Goals for implementation of robotic assembly lines include high productivity, quality of product, manufacturing flexibility, safety, decreasing demand of skilled labor, and so on. Different robot types may exist at the assembly facility. Unlike manual assembly lines, where actual processing times for performing task vary considerably and optimal balance is rather of theoretical importance, the performance of rALs depends strictly on the quality of its balance. As extended from sALB, robotic assembly line balancing (rALB) is also NP-hard [43]. Lin et al. [44] proposed a hybrid genetic algorithm for robot-based ALB problem, Gao et al. [45] reported an efficient approach Based on GA for solving type II robotic assembly line balancing problems, Zhang et al. [46] and Zhang and Gen [47] proposed multiobjective GA for ALB Problems with worker allocation and considering demand ratio-based cycle time, respectively.

3 Hybrid Genetic Algorithms

3.1 Genetic Representations and Operations

Major Advantages of GA: GA has received considerable attention regarding their potential as a novel optimization technique. Three major advantages exist when applying GA to various combinatorial optimization problems [11]:

Adaptability: GA does not have much mathematical requirements about the optimization problems. Because of the evolutionary nature, GA will search for solutions without regard to the specific inner workings of the problem. GA can handle any kind of objective functions and any kind of constraints, i.e., linear or nonlinear, defined on discrete, continuous, or mixed search spaces.

Robustness: The use of evolution operators makes GA very effective in performing global search (in probability), whereas most of conventional heuristics usually perform local search. It has been proved by many studies that GA is more efficient and more robust in locating an optimal solution and reducing a computational effort than other conventional heuristics.

Flexibility: GA provides us with a great flexibility to hybridize with domain-dependent heuristics to make an efficient implementation for a specific problem.

Applicability: The practical software packages based on GA such as ERP and Simulation are standard usages in the real world.

The original form of genetic algorithms (GAs) was described by Goldberg [48] and Michalewicz [14] expanded GA to evolution programs by combined with data structure. Gen and Lozano [49] proposed fuzzy logic controllers for adapting parameters in genetic algorithm. GA is a stochastic search technique based on the mechanism of natural selection and natural genetics. The central theme of research on GA is to keep a balance between exploitation and exploration in its search to the optimal solution for survival in many different environments. Features for self-repair, self-guidance, and reproduction are the rules in biologic systems, whereas they barely exist in the most sophisticated artificial systems. GA has been theoretically and empirically proved to provide a robust search in complex search spaces. Many research papers and dissertations have established the validity of GA approach in function optimization problems and application problems [11–13, 50].

Genetic Representation: In general, two ways exist to generate the initial population, i.e., a set of solution candidates, heuristic initialization and random initialization, by using an encoding procedure satisfying system constraints and/or a boundary condition. How to present a solution of the scheduling problem into a chromosome is a key issue for GAs. For evaluating the effectiveness of the different chromosome representation, there are several critical issues are summarized by Gen and Lin [21].

Space: Chromosomes should not require extravagant amounts of memory.

Time: The time complexities of evaluating, recombining, and mutating chromosomes should be small.

Feasibility: All chromosomes, particularly those generated by simple crossover (i.e., one-cut point crossover) and mutation, should represent feasible solutions.

Uniqueness: The mapping from chromosomes to solutions (decoding) may belong to one of the following three cases: 1-to-1 mapping, n-to-1 mapping and 1-to-n mapping. The 1-to-1 mapping is the best one among three cases and 1-to-n mapping is the most undesired one.

Heritability: Offspring of simple crossover (i.e., one-cut point crossover) should represent solutions that combine substructures of their parental solutions.

Locality: A mutated chromosome should usually represent a solution similar to that of its parent.

We need to consider these critical issues carefully when designing an appropriate representation so as to build an effective GA. As known, scheduling problem is the implement of production plan, with considering production processes, lot-size, amount and customer requirements etc. And scheduling problem is how to decide the resources assignment to the production, with considering constrains of resources capabilities and capacities. There are two decision making parts for scheduling optimization: (1) operation sequencing and (2) resources assignment.

Representation for Operation Sequencing and Resource Assignment: In the past few decades, the following 6 representations for the job-shop scheduling problem (JSP, an operation sequencing problem with considering the precedence constraints of operations) have been proposed [13]:

Operation-based representation, Job-based representation, Preference list-based representation, Priority rule-based representation, Completion time-based representation, Random key-based representation.

The flexible job-shop scheduling problem (FJSP) is expanded from the traditional JSP, which possesses wider availability of machines for all the operations (a combinatorial optimization problem considering both of the operation sequence and the resource assignment). The following 4 representations for FJSP have been proposed [13].

Parallel machine-based representation, Parallel jobs representation, Operations machines-based representation, Multistage operation-based representation.

Cheng and Gen [51] proposed a priority-based representation firstly in evolution program for solving resource-constrained project scheduling problem (RcPSP). This representation encodes a schedule as a sequence of operations and each gene stands for one operation [12]. As known, a gene in a chromosome is characterized by two factors: locus, i.e., the position of the gene located within the structure of chromosome, and allele, i.e., the value the gene takes. In this encoding method, the position of a gene is used to represent operation ID and its value is used to represent the priority of the operation for constructing a schedule among candidates. A schedule can be uniquely determined from this priority-based encoding. However, the nature of the priority-based representation is a kind of permutation representations. Generally, this representation will yield illegal offspring when using one-cut point crossover or other simple crossover operators. That means some node's priority may be duplicated in the offspring.

Genetic Operations: When GAs are used, both the search direction to optimal solution and the search speed should be considered as an important factor, in order to keep a balance between exploration and exploitation in search space. In general, the exploitation of the accumulated information resulting from a GA search is done by the selection mechanism, whereas the exploration to new regions of the search space is accounted for by genetic operators. The genetic operators mimic the process of heredity of genes to create new offspring at each generation. The operators are used to alter the genetic composition of individuals during representation. In essence, the operators perform a random search and cannot guarantee to yield an improved offspring. Three common genetic operators exist: crossover, mutation, and selection.

Crossover is the main genetic operator. It operates on two chromosomes at a time and generates offspring by combining both chromosomes' features such as one-cut point, two-cut point, multi-cut point, or uniform crossover. There are several crossover operators proposed for permutation representation, such as partial-mapped crossover (PMX), order crossover (OX), position-based crossover (PX), heuristic crossover, etc.

Mutation is a background operator that produces spontaneous random changes in various chromosomes such as inversion mutation, insertion mutation, displacement mutation, and swap mutation. In GAs, mutation serves the crucial role of either

(1) Replacing the genes lost from the population during the selection process so that they can be tried in a new context or

(2) Providing the genes that were not present in the initial population. Selection (or reproduction) operator is intended to improve the average quality of the population by giving the high-quality chromosomes a better chance to get copied into the next generation.

Selection provides the driving force in a GA. One of the common proportional selections is the so-called roulette wheel selection, and other selection types like tournament selection, elitist selection, (μ, λ) selection, and $(\mu + \lambda)$ selection deterministic procedures that select the best chromosomes from parents and offspring [13].

Multistage-based Hybrid Genetic Algorithms: Considering the GA approach proposed by Kacem et al. [52], it is complex even when you take all the objectives in count, because all the crossover and mutation are based on the chromosome which is described as a constructor of table. Therefore, it will spend more CPU-time for finding solutions. To avoid such kind of loosing and improve the convergence speed at the same time, multistage-based genetic algorithm (MsGA) for solving the flexible job-shop scheduling problems is very useful [53]. There are several stages separating the route from the starting node to the terminal one, and in each stage several states are offered for choosing as shown in Fig. 1. After we make all the decisions for choosing states, we can get a solution, and the fitness of the result is in terms of the different decisions made in the route [50].

It is obvious to find the stage number is just the total operation numbers, and also in each stage, the machines available are treating as the state correspondingly.

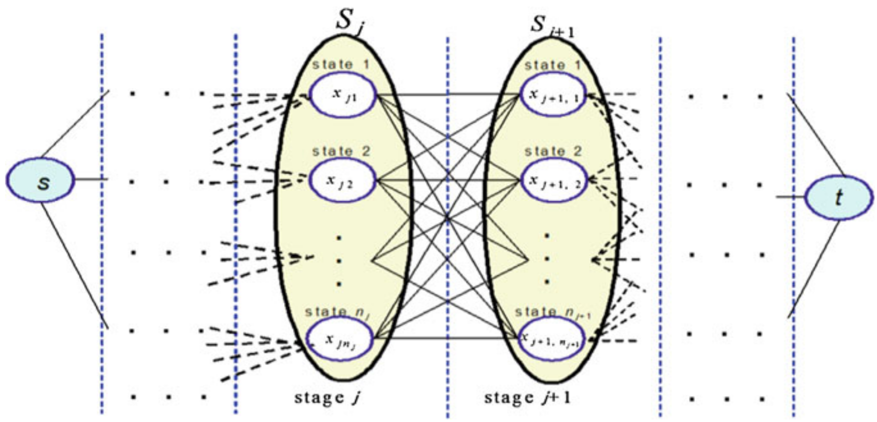


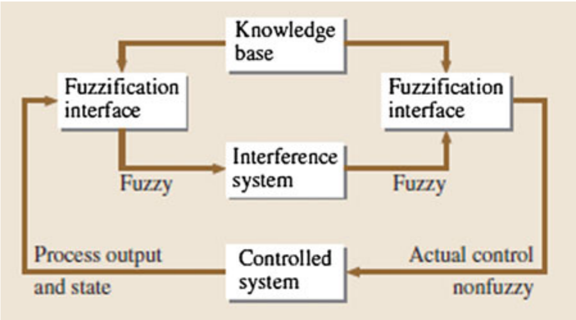
Fig. 1 Multi-stage decision making model of multioperation based genetic algorithm

3.2 Fuzzy Logic Controller for Tuning Parameters

Fuzzy logic is much closer in spirit to human thinking and natural language than the traditional logical systems. In essence, the fuzzy logic controller (FLC) provides an algorithm which can convert a linguistic control strategy based on expert knowledge into an automatic control strategy. In particular, this methodology appears very useful when the processes are too complex for analysis by conventional techniques or when the available sources of information are interpreted qualitatively, inexactly, or with uncertainty [49]. The pioneering work to extend the fuzzy logic technique to adjust the strategy parameters of genetic algorithms dynamically was carried out by Xu and Vukovich [50]. The main idea is to use a FLC to compute new strategy parameter values that will be used by the genetic algorithms [16]. A fuzzy logic controller is comprised of four principal components as shown in the generic structure of a FLC in Fig. 2:

Knowledge base, Fuzzification interface, Inference system, Defuzzification interface.

Fig. 2 Generic structure of a fuzzy logic controller (FLC)



The experts' knowledge is stored in the knowledge base in the form of linguistic control rules. The inference system is the kernel of the controller, which provides an approximate reasoning based on the knowledge base.

One of the main problems related to GA is to find the optimal control parameter values required by the technique. Furthermore, different values may be necessary during the course of a run. There has been more work dedicated to finding the optimal parameters of genetic algorithms, which require different techniques for different problems. A hybrid genetic algorithms (HGA) has been built so that selected control parameters may be dynamically adjusted during the course of evolving a problem solution. In our paper, we use the basic concept of Yun and Gen [16] to adaptively regulate GA operators using fuzzy logic control (FLC). The main scheme of this concept is to use two FLCs: the crossover FLC and mutation FLC as shown in Fig. 3 and it is based on the coordinated strategy between the FLC and GA combined the change of the average fitness at each generation. These two FLCs are implemented independently to adaptively regulate the rates of crossover and mutation operators during genetic search process. For example, in minimization problem, we can set the change of the average fitness at generation t, $\nabla f_{avg}(t)$ as follows:

$$\Delta f_{avg} = \frac{1}{\text{popsize}} \sum_{k=1}^{\text{popsize}} f_k(t) - \frac{1}{\text{offsize}} \sum_{k=1}^{\text{offsize}} f_k(t), \tag{17}$$

where parSize and offSize are the parent size and offspring size, respectively. For the defuzzification table simplified for determining the action of the crossover FLC and mutation FLC with the input and output results of discrimination, it can refer in Yun and Gen [16].

Yun and Gen [16] proposed auto-tuning routine for the parameter crossover and mutation rates based on FLC and the change of the average fitness for enhancing the evolutionary process of the GA as shown in Fig. 4. Lin and Gen [21] also proposed another enhanced auto-tuning strategy for GA for keeping a balance between exploration and exploitation during the evolutionary process. The practical design scheme for HGA combined with FLC routine is introduced in Sect. 2 of the concatenated paper Part II [2].

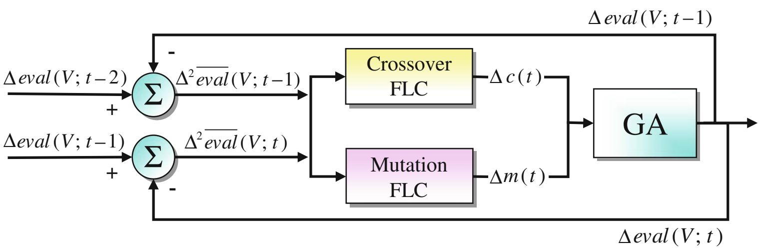


Fig. 3 Coordinated strategy between the FLC and GA

procedure: regulating strategy of FLC
input: GA parameters, $p_C(t-1)$, $p_M(t-1)$, $\Delta f_{avg}(t-1)$, $\Delta f_{avg}(t)$
output: $p_C(t)$, $p_M(t)$

Step 1: the input variables of the FLCs for regulating the GA operators are the changes of the average fitness in continuous two generations (t -1 and t) as follows:

$\Delta f_{avg}(t-1)$, $\Delta f_{avg}(t)$

Step 2: after normalizing $\Delta f_{avg}(t-1)$ and $\Delta f_{avg}(t)$, assign these values to the indexes i and j corresponding to the control actions in the defuzzification table (see Yun and Gen 2003).

Step 3: calculate the changes of the crossover rate $\Delta c(t)$ and the mutation rate $\Delta m(t)$ as follows:

$\Delta c(t) = C_C \times Z(i,j)$, $\Delta m(t) = C_M \times Z(i,j)$

where the contents of $Z(i,j)$ are the corresponding values of $\Delta f_{avg}(t-1)$ and $\Delta f_{avg}(t)$ for defuzzification (see Yun and Gen 2003). The values of 0.02 (C_C) and 0.002 (C_M) are given values to regulate the increasing and decreasing ranges of the rates of crossover and mutation operators.

Step 4: update the change of the rates of the crossover and mutation operators by using the following equations:

$p_C(t) = p_C(t-1) + \Delta c(t)$, $p_M(t) = p_M(t-1) + \Delta m(t)$

The adjusted rates should not exceed the range from 0.5 to 1.0 for the $p_C(t)$ and the range from 0.0 to 0.1 for the $p_M(t)$.

output: $p_C(t)$, $p_M(t)$
end;

Fig. 4 Auto-tuning routine for the parameter crossover and mutation rates based on FLC

4 Multiobjective Hybrid Genetic Algorithms

he multiobjective optimization problems (MOP) have been receiving growing interest from researchers with various backgrounds since early 1960 [40]. There are a number of scholars who have made significant contributions to the problem. Among them, Pareto is perhaps one of the most recognized pioneers in the field. Recently, GAs have been received considerable attention as a novel approach to MOPs, resulting in a fresh body of research and applications known as evolutionary multiobjective optimization (EMO). The basic feature of GAs is the multiple directional and global searches by maintaining a population of potential solutions of potential solutions from generation to generation. The population-to-population approach is hopeful to explore all Pareto solutions. GAs are essentially a kind of metastrategy methods. When applying the GAs to solve a given problem, it is necessary to refine upon each of the major components of GAs, such as encoding methods, recombination operators, fitness assignment, selection operators, constraints handling, and so on, in order to obtain a best solution to the given problem. Because the MOPs are the natural extensions of constrained and combinatorial optimization problems, so many useful methods based on EAs developed during the past two decades. One of special issues in the MOPs is fitness assignment mechanism. Since the 1980s, several fitness assignment mechanisms have been proposed and applied in MOPs [44]. Although most fitness assignment mechanisms are just different approach and suitable to different cases of MOPs, in order to understanding the development of multiobjective GAs (MoGAs), we classify algorithms according to proposed years of different approaches.

MOPs arise in the design, modeling, and planning of many real complex systems in the areas of industrial production, urban transportation, capital budgeting, forest management, reservoir management, layout and landscaping of new cities, energy distribution, etc. [1]. Since the 1990s, EAs have been received considerable attention as a novel approach to MOPs, resulting in a fresh body of research and applications known as EMO. Without loss of generality, a MOP with q objective functions conflicting each other and m constraints can be formally represented as follows:

$$\begin{aligned} \max \ & \left\{z_1 = f_1(\mathbf{x}), z_2 = f_2(\mathbf{x}), \ldots, z_q = f_q(\mathbf{x})\right\} \\ \text{s.t.} \ & g_i(\mathbf{x}) \le 0, i = 1, 2, \ldots, m \\ & \mathbf{x} \in R^n. \end{aligned} \tag{18}$$

We sometimes graph the MOP problem in both decision space and criterion space. S is used to denote the feasible region in the decision space and Z is used to denote the feasible region in the criterion space respectively as follows:

$$S = \left\{\mathbf{x} \in R^n \left| g_i(\mathbf{x}) \le 0, i = 1, 2, \ldots, m \right.\right\}, \tag{19}$$

$$Z = \left\{z \in R^q \left| z_1 = f_1(\mathbf{x}), z_2 = f_2(\mathbf{x}), \ldots, z_q = f_q(\mathbf{x}), \mathbf{x} \in S \right.\right\}, \tag{20}$$

where $x \in R^n$ is a vector of values of q objective functions. In the other words, Z is the set of images of all points in S. Although S is confined to the nonnegative region of R^n and Z is not necessarily confined to the nonnegative region of R^q. There usually exists a set of solutions for the multiple objective cases which cannot be simply compared with each other. Such kind of solutions are called nondominated solutions or Pareto optimal solutions, for which no improvement in any objective function is possible without sacrificing on at least one of other objectives.

Definition 1 For a given point $z_o \in Z$, it is nondominated if and only if there does not exist another point $z \in Z$ such that for the maximization case,

$$\begin{aligned} z_k > z_k^0, & \quad \text{for some } k \in \{1, 2, \ldots, q\}, \\ z_l \ge z_l^0, & \quad \text{for some } 1 \ne k, \end{aligned}$$

where z_0 is a dominated point in the criterion space Z with q objective functions.

When applying the GAs to solve a given MOP problem, it is necessary to refine upon each of the major components of GAs, such as encoding methods, recombination operators, fitness assignment, selection operators, and constraints handling, and so on, in order to obtain a best solution to the given problem. One of special issues in the multiobjective optimization problems is fitness assignment mechanism. Although most fitness assignment mechanisms are just different approach and suitable to different cases of multiobjective optimization problems, in order to understanding the development of multiobjective EAs (MOEAs), we classify algorithms according to proposed years of different approaches:

Nondominated Sorting Genetic Algorithm II [54]: Srinivas and Deb developed a Pareto ranking-based fitness assignment and it called NSGA. In each method, the nondominated solutions constituting a nondominated front are assigned the same dummy fitness value. These solutions are shared with their dummy fitness values (phenotypic sharing on the decision vectors) and ignored in the further classification process. Finally, the dummy fitness is set to a value less than the smallest shared fitness value in the current nondominated front. Then the next front is extracted. The procedure of NSGA II is repeated until all individuals in the population are classified [54].

Random-weight Genetic Algorithm [55]: Ishibuchi et al. proposed a weighted-sum based fitness assignment method. Weighted-sum approach can be viewed as an extension of methods used in the multiobjective optimizations to GAs. It assigns weights to each objective function and combines the weighted objectives into a single objective function. To search for multiple solutions in parallel, the weights are not fixed and able to uniformly the sample area towards to the whole frontier.

Adaptive Weight Genetic Algorithm [13]: Gen and Cheng utilized some useful information from the current population to readjust weights to obtain a search pressure toward a positive ideal point. For the examined solutions at each generation, we define two extreme points for the kth objective (maximum: z^+, minimum: z^-) as follows:

$$z_k^{\max} = \max\{f_k(\mathbf{x})|\ \mathbf{x} \in P\}, \qquad k = 1,\ 2,\ \ldots,\ q, \tag{21}$$

$$z_k^{\min} = \min\{f_k(\mathbf{x})|\ \mathbf{x} \in P\}, \qquad k = 1,\ 2,\ \ldots,\ q. \tag{22}$$

The weighted-sum objective function for a given chromosome x is given by the following equation:

$$\text{eval}(\mathbf{x}) = \sum_{k=1}^{q} w_k(z_k - z_k^{\min}) = \sum_{k=1}^{q} \frac{z_k - z_k^{\min}}{z_k^{\max} - z_k^{\min}} = \sum_{k=1}^{q} \frac{f_k(\mathbf{x}) - z_k^{\min}}{z_k^{\max} - z_k^{\min}}, \tag{23}$$

where w_k is adaptive weight for the kth objective function as shown in the following equation:

$$w_k = \frac{1}{z_k^{\max} - z_k^{\min}}, k = 1, 2, \ldots, q. \tag{24}$$

The Eq. (7) driven above is a hyperplane defined by the following extreme points in current solutions:

Strength Pareto Evolutionary Algorithm [56]: Zitzler and Thiele proposed strength Pareto Evolutionary Algorithm [57] and an extended version SPEA2 [56] that combines several features of previous MOGA in a unique manner. The fitness assignment procedure is a two-stage process. The individuals in the external nondominated set P' are ranked.

Interactive Adaptive-weight Genetic Algorithm [21]: Lin and Gen proposed an interactive AWGA, which is an improved adaptive-weight fitness assignment approach with the consideration of the disadvantages of weighted-sum approach and Pareto ranking-based approach. They combined a penalty term to the fitness value for all of dominated solutions. Firstly, we calculate the adaptive weight $w_i = 1/(Z_i^{\max} - Z_i^{\min})$ for each objective by using AWGA. Afterwards, we calculate the penalty term $p(v_k) = 0$, if v_k is nondominated solution in the nondominated set P. Otherwise $p(v_k') = 1$ for dominated solution v_k'. Lastly, we calculate the fitness value of each chromosome by combining the i-AWGA method:

$$\text{eval}(v_k) = \sum_{i=1}^{q} w_i (z_i^k - z_i^{\min}) + p(v_k), \quad \forall k \in \text{popSize}. \tag{25}$$

Hybrid Sampling Strategy-based EA: Zhang et al. [58] proposed a hybrid sampling strategy-based evolutionary algorithm (HSS-EA). A Pareto dominating and dominated relationship-based fitness function (PDDR-FF) is proposed to evaluate the individuals. The PDDR-FF of an individual Si is calculated by the following function:

$$\text{eval}(S_i) = q(S_i) + \frac{1}{p(S_i + 1)}, \quad i = 1, 2, \ldots, \text{popSize}, \tag{26}$$

where $p()$ is the number of individuals which can be dominated by the individual S. $q()$ is the number of individuals which can dominate the individual S. The PDDR-FF can set the obvious difference values between the nondominated and dominated individuals. The general structure in the pseudo code of multiobjective hybrid genetic algorithm (Mo-HGA) is described as shown in Fig. 5.

```
procedure: Multiobjective Genetic Algorithm with Preserving Pareto
input: problem data, GA parameters
output: Pareto optimal solutions E(P,C)
begin
    t ← 0;
    initialize P(t) by encoding routine;            // P(t): population
    calculate objectives f_k(P), k=1,…, q by decoding routine;
    evaluate eval(P) by fitness assignment routine and keep the best Pareto solution;
    create Pareto optimal solutions E(P) by nondominated routine;
    while (not terminating condition) do
        create C(t) from P(t) by crossover routine;  // C(t): offspring
        create C(t) from P(t) by mutation routine;
        check-and-repair problem constraints for offspring C(t);
        improve C(t) by local search routine;
        calculate objectives f_k(C), k=1,…, q by decoding routine;
        evaluate eval(C) by fitness assignment routine & update the best Pareto solution;
        update Pareto optimal solution E(P,C) by nondominated routine;
        select P(t+1) from P(t) and C(t) by selection routine;
        tune parameters p_C, p_M by fuzzy logic controller routine;
        t ← t+1;
    end
    output Pareto optimal solutions E(P,C);
end;
```

Fig. 5 Procedure in the pseudo code of multiobjective hybrid genetic algorithm

5 Conclusion

In real world manufacturing systems there are many combinatorial optimization problems (COP) imposing on more complex issues, such as complex structure, non-linear constraints, and multiple objectives to be handled simultaneously. Manufacturing scheduling is one of the important and complex COP models, where it can have a major impact on the productivity of a production process. Moreover, the COP models make the problem intractable to the traditional optimization techniques because most of scheduling problems fall into the class of NP-hard combinatorial problems. Recently, many manufacturing companies are faced with global market demands for a variety of low cost products with a high quality. For responding rapidly to demand fluctuations and reducing costs related to manufacturing scheduling and logistics networks and also for developing effective and efficient solution algorithms that are in a sense good, i.e., whose computational time is small as within 3 minutes, or at least reasonable for NP-hard combinatorial problems met in practice, hybrid genetic algorithm (HGA) and multiobjective HGA (Mo-HGA) have received considerable attention regarding their potential for solving various complex manufacturing and logistics problems.

In this paper, as the typical models in manufacturing scheduling systems we introduced parallel machines scheduling (PMS), flexible job-shop scheduling problem (FJSP) and assembly line balancing (ALB) problem. Secondly to solve NP-hard COP models, we introduced the design scheme of HGA combined with fuzzy logic controller (FLC) to tune GA parameters and multiobjective HGA (Mo-HGA) with local search such as the variable neighborhood descent (VND) routines and several fitness assignment mechanisms for multiobjective optimization problems (MOP). For demonstrating computational experiments by HGA and Mo-HGA, the effectiveness and efficiency of the HGA for the HDD (hard disc device) and Mo-HGA for TFT-LCD (thin-film transistor-liquid crystal display) module assembly problems as a practical manufacturing model, respectively is demonstrated in the concatenated paper Part II [2].

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Multiobjective Hybrid Genetic Algorithms for Manufacturing Scheduling: Part II Case Studies of HDD and TFT-LCD

Mitsuo Gen, Wenqiang Zhang and Lin Lin

Abstract Manufacturing scheduling is one of the most important and complex combinatorial optimization problems, where it can have a major impact on the productivity of a production process. Moreover, most of manufacturing scheduling problems fall into the class of NP-hard combinatorial problems. In this paper, we introduce how to design hybrid genetic algorithms (HGA) and multiobjective hybrid genetic algorithms (Mo-HGA) for solving practical manufacturing scheduling problems for the hard disc device (HDD) and the thin-film transistor-liquid crystal display (TFT-LCD) manufacturing systems, respectively. In particularly, evolutionary representations and the fitness assignment mechanism as well as the hybrid genetic operations are introduced. Through a variety of computational experiments, the effectiveness of these HGA algorithm for HDD and Mo-HGA algorithm for TFT-LCD module assembly as the practical manufacturing scheduling problems are demonstrated. This paper introduces how to design Mo-HGAs for solving the practical multiobjective manufacturing scheduling problems expanded by a multiobjective flexible job-shop scheduling problem (Mo-FJSP; operation sequencing and resources assignment).

Keywords Hybrid genetic algorithms (HGA) · Multiobjective HGA (Mo-HGA) · Manufacturing scheduling · Flexible job-shop scheduling problem (FJSP) · Hard disc device (HDD) · Thin-film transistor-liquid crystal display (TFT-LCD)

M. Gen (✉)
Fuzzy Logic Systems Institute, Tokyo University of Science, Tokyo, Japan
e-mail: gen@flsi.or.jp

W. Zhang
College of Information Science & Engineering, Henan University of Technology, Henan, People's Republic of China

L. Lin
School of Software Technology,
Dalian University of Technology, Dalian, People's Republic of China

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1 Introduction

The semiconductor industry has grown rapidly and subsequently production planning problems have raised many important research issues. Because of short product life cycles, it is crucial to rapidly respond to various customer needs and deliver products on time in high-tech semiconductor manufacturing industries such as the various semiconductor devices including IC chips, LSI chips and microprocessors, thin-film transistor-liquid crystal display (TFT-LCD) and hard disc device (HDD). Scheduling problems for semiconductor manufacturing have the features of scheduling with auxiliary resources, batching processes, multiple orders per job, internal and external scheduling of cluster tools, a large number of processing steps, random equipment failures, waiting time constraints [5, 18], job-shop scheduling problems with reentrance, sequence-dependent setup time (SDST), and sequence-dependent processing time (SDPT) [11]. Flexible manufacturing systems (FMS) allow the dynamic configuration of resources to process distinct products. It is possible to assign each of these products to more than one type of unrelated resource with various efficiencies. Multipurpose resources can perform a wide range of tasks, which allows schedulers to concentrate the workloads among these resources to improve the utilization and reduce resource requirements. A possible negative effect is the reduction of production effectiveness because of the time wasted when a machine performs changeover and configuration to accommodate for the next job. Thus, it is vital to arrange a production schedule that simultaneously considers the values of multiple resources to respond to production requirements rapidly and effectively [11, 19].

The HDD and TFT-LCD manufacturing is capital and technology intensive industry. Facing the fierce competitive pressures, it is important to enhance productivity and operational efficiency. Manufacturing scheduling of TFT-LCD module assembly system is a key issue to enhance manufacture efficiency that could satisfy customer demand on time [6].

By focusing on realistic settings, a module assembly process was formulated for use in the HDD and TFT-LCD industries as a generalization of the flexible job-shop scheduling problem (FJSP), respectively. On a flexible job-shop floor, workstations employ non-identical parallel machines scheduling (PMS) model and reentrant flowshop scheduling (RFS) model that exhibit distinct production velocities. An operation can be processed using an available machine from a given workstation. For example, the TFT-LCD module assembly scheduling problem can be divided into two subproblems: the routing (i.e., assigning each operation to machines) and scheduling problems (i.e., determining the start time of each operation to machines). The following factory-specific factors complicate the TFT-LCD module assembly scheduling problem. Bidotet [2] reported detail definitions to avoid ambiguity of terms commonly used by different communities: complete schedule, flexible schedule, conditional schedule, predictive schedule, executable schedule, adaptive scheduling system, robust predictive schedule and table predictive schedule. However, to find the optimal solutions of manufacturing scheduling gives rise to complex combinatorial optimization, unfortunately, most of them fall into the class of NP-hard combinatorial problems.

The rest of this paper is organized as follows: Sect. 2 introduces hybrid reentrant flow-shop scheduling (RFS) model in HDD manufacturing. The case study of hybrid RFS problem withtime window constraints for HDD module assembly system byhybrid genetic algorithm (HGA) with left-shift routine for improving and fuzzy logic controller (FLC) for tuning parameters introduces and the effectiveness of computational results demonstrates in Sect. 3. After introducing another case study of manufacturing model in TFT-LCD module assembly manufacturing system in Sect. 4, multiobjectivehybrid GA (Mo-HGA) algorithm with TOPSIS (technique for order preference by similarity to ideal solution) introduces how to design a chromosome, treat precedence relationship and fitness assignment mechanism, and clarifies effectiveness and efficiency in the best compromised solution as a quality of solution with reasonable interactive computational time. Finally, the conclusion of the paper and future research are drawn in Sect. 6.

2 Hybrid Reentrant Model in HDD Manufacturing

The semiconductor industry has grown rapidly, and subsequently production planning problems have raised many important research issues. The reentrant flow-shop scheduling (RFS) problem with time windows constraint for hard disk devices (HDD) manufacturing is one such problem of the expanded semiconductor industry. The RFS scheduling problem with the objective of minimizing the makes pan of jobs is considered. This research addresses the HGA with auto-tuning parameters for the deterministic $F_m|fmls, rcrc, temp|C_{\max}$ problem.

A HDD (hard disk device) manufacturing system is one of the most complicated systems depending on several constraints, such as various product families with different processing time and processing flow, high flexibility machines, and one or more time operations on a workstation in the reentry flow of a job. Moreover, controlling processing time constraints is an important issue for an industry which requires high quality production especially in a hard-disk manufacturing system. HDD manufacturing consists of four Main processes as shown in Fig. 1.

SF (slider fabrication)
HGA (head gimbals assembly)
HSA (head stack assembly)
HDD (hard disk drive assembly)

HDD process is consisting of the following two serial one.

Assembly Lines and Backend Process, Backend Process consists of the following eight production stages [16]:

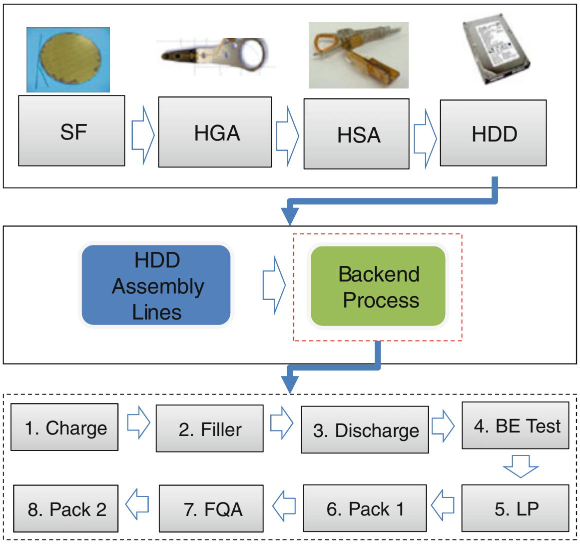

Fig. 1 Main processes of HDD manufacturing

(1) Charge (Helium Charge);
(2) Filler Test;
(3) Discharge (Helium Discharge);
(4) BE test (Backend test);
(5) LP (Label Printing);
(6) Pack 1;
(7) FQA (Sampling constraint);
(8) Pack 2.

In this section, we consider assembly line process for HDD (hard disk drive) manufacturing system as shown in Fig. 2. This is the hybrid flow-shop in a real hard-disk manufacturing system, there are 9 processes with 17 workstations such as a complex parallel machine scheduling (PMS) model introduced in Sect. 2. Each of them has a different number of machines which also have different efficiencies. Some machines might be limited by production constraints, such as machine eligibility restriction and sequence dependent setup time. Moreover, the system still consists of several sub-systems for example, reentrant shop, common machine shop, and permutation shop. Unfortunately, these were located in the single system; it was very difficult to solve all by the optimization techniques.

Nevertheless, planning and scheduling in the above system might be reduced by a simplification. Decomposition of the problem and decrement of the problem size were usually included by many researchers. This should be done to understand and clarify a complicated system [3, 4].

Without any generality of HDD manufacturing system, we can consider a small scale of there entrant flow-shop scheduling (RFS) problem for producing 4 different

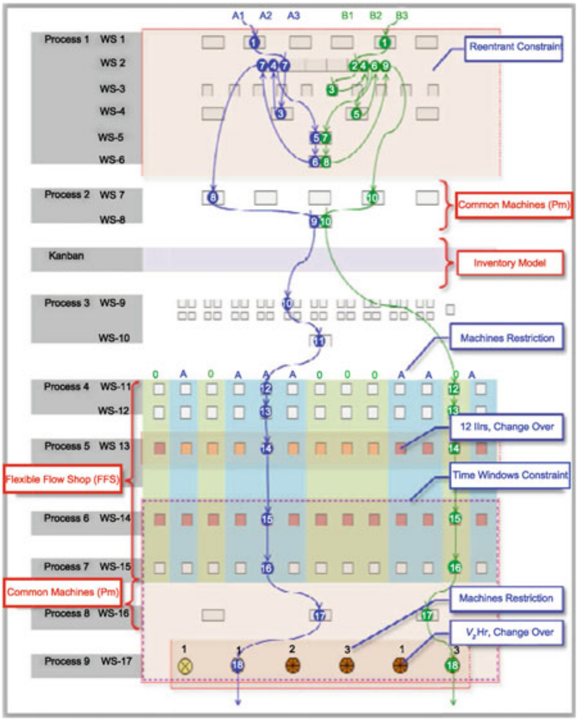

Fig. 2 Real model of HDD manuf. system

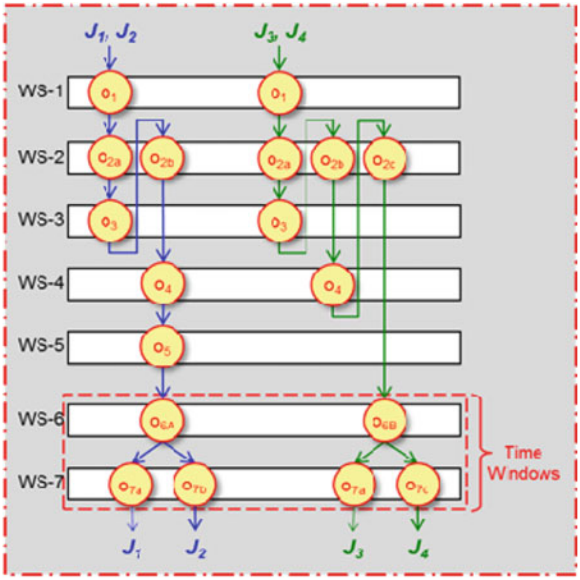

Fig. 3 Processing flow of a simple RFS problem

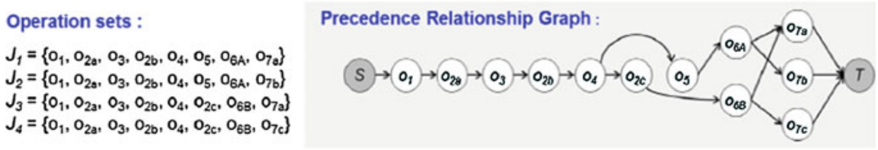

Fig. 4 Precedence relationship graph of simple RFS problem

HDD products under 7 workstations as shown in Fig. 3. Considering the processing flow of a simplified RFS scheduling problem as shown in Fig. 4, there are 4 products (J_1, J_2, J_3, and J_4) with no consideration of lot sizes of jobs. This means all jobs have the same lot sizes. Also, this manufacturing system has 7 workstations with the reentrant workstations (Table 1). Moreover, in this example, there is the time windows constraint ($t_w = 30$ min/lot) for controlling production starting from WS-6 to WS-7.

From the data set, the precedence relationship can be defined by the successors and operation sequence as shown in Table 1. Within these workstations, the jobs will be produced depending on their operation sequences. The graph is then drawn for preparing a chromosome for initial generation, and repairing the chromosome after genetic operators as shown in Fig. 4.

Indeed, the system complexity comes from three important restrictions. First, all products can be produced depending on reentrant flow; they have to produce two family product groups at some workstations. Lastly, they have to produce all products with the completion time of each under the time windows. The objective is to minimize makes pan and reduce loss.

3 Hybrid Genetic Algorithm with Left-Shift Routine and Computational Results

Genetic Representation: Gen et al. [9] proposed an implementation of GA for solving the job-shop scheduling problem. The operation-based representation encoded a schedule as a sequence of operations and each gene standing for one operation was proposed by them [10]. Furthermore, we can apply it to the RFS scheduling problem. After creating the chromosome by the encoding routine, the schedule can be generated. When generating it, an operation can be started whenever its predecessor has been finished and the machine to process it is available. The generated schedule of the example chromosome in Fig. 5 is shown as follows: Schedule $S = (o_{ij}, M_m, s_{ij} - c_{ij})$; o_{ij} denotes operation j in job i; M_m is machine m; s_{ij} means starting operation j in job i and is completing operation j in job i.

$S = \{(o_{1,1}, M_1, 0\text{–}6), (o_{2,1}, M_1, 6\text{–}12), (o_{3,1}, M_1, 12\text{–}18), (o_{4,1}, M_1, 18\text{–}24), (o_{1,2a}, M_2, 6\text{–}13), (o_{1,3}, M_3, 13\text{–}18), (o_{2,2a}, M_2, 13\text{–}20), (o_{2,3}, M_3, 20\text{–}25), (o_{3,2a}, M_2, 20\text{–}27), (o_{3,3}, M3, 27\text{–}32), (o_{4,2a}, M_2, 27\text{–}34), (o_{4,3}, M_3, 34\text{–}39), (o_{1,2b}, M_2,$

Table 1 The operations of a simple example RFS problem

Step	Machine	In the same group of family A				In the same group of family B			
		J_1		J_2		J_3		J_4	
		Operation	Successor	Operation	Successor	Operation	Successor	Operation	Successor
1	WS-1	o_1	o_{2a}	o_1	o_{2a}	o_1	o_{2a}	o_1	o_{2a}
2	WS-2	o_{2a}	o_3	o_{2a}	o_3	o_{2a}	o_3	o_{2a}	o_3
3	WS-3	o_3	o_{2b}	o_3	o_{2b}	o_3	o_{2b}	o_3	o_{2b}
4	WS-2	o_{2b}	o_4	o_{2b}	o_4	o_{2b}	o_4	o_{2b}	o_4
5	WS-4	o_4	o_5	o_4	o_5	o_4	o_{2c}	o_4	o_{2c}
6	WS-2	–	–	–	–	o_{2c}	o_{6B}	o_{2c}	o_{6B}
7	WS-5	o_5	o_{6A}	o_5	o_{6A}	–	–	–	–
8	WS-6	o_{6A}	o_{7a}	o_{6A}	o_{7b}	o_{6B}	o_{7a}	o_{6B}	o_{7c}
9	WS-7	o_{7a}	–	o_{7b}	–	o_{7a}	–	o_{7c}	–

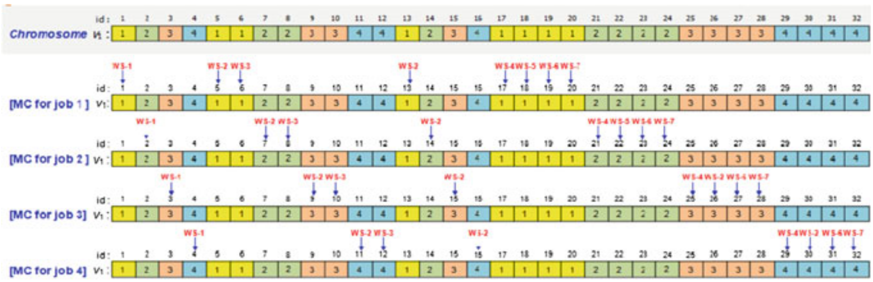

Fig. 5 The illustration of a chromosome with operation-based representations

32–41), ($o_{2,2b}$, M_2, 41–48), ($o_{3,2b}$, M_2, 48–55), ($o_{4,2b}$, M_2, 55–62), ($o_{1,4}$, M_4, 41–95), ($o_{1,5}$, M_5, 95–103), ($o_{1,6A}$, M_6, 103–110), ($o_{1,7a}$, M_7, 110–121), ($o_{2,4}$, M_4, 95–149), ($o_{2,5}$, M_5, 149–157), ($o_{2,6A}$, M_6, 157–164), ($o_{2,7b}$, M_7, 164–174), ($o_{3,4}$, M_4, 149–203), ($o_{3,2c}$, M_2, 203–210), ($o_{3,6B}$, M_6, 210–218), ($o_{3,7a}$, M_7, 218–229), ($o_{4,4}$, M_4, 203–257), ($o_{4,2c}$, M_2, 257–264), ($o_{4,6B}$, M_6, 264–272), ($o_{4,7c}$, M_7, 272–284)}.

The corresponding Gantt chart of this schedule can be drawn as shown in Fig. 6. From the Gantt chart, it is clear that the operation based method can be used for generating the suitable candidate chromosome as shown in Fig. 6. So, this sequence solution has made a 284-min makespan and no loss because there are no jobs exceeding the time windows (30 min between WS-6 and WS-7).

Genetic Operations: For creating offspring by genetic operations we used two-cut point crossover, swap-mutation and insert-mutation operations. For the detailed calculated results by genetic operations, we can get them in [3].

Fitness Function: In the RFS scheduling problem, the objective is to minimize the makespan (zi), so it is directly related with maximizing the system throughput. RFS scheduling in the hard-disk manufacturing system as in this paper, also has to consider the lost lot which exceeded the critical processing time. Equation (1) shown the fitness function of GA where vi is a chromosome vector i; the population is popSize.

$$\mathrm{eval}(v_i) = 1/z_i, i = 1, 2, \ldots, \mathrm{popSize}. \quad (1)$$

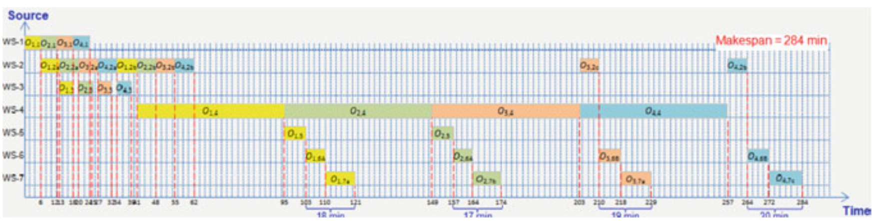

Fig. 6 A Gantt chart of the generated chromosome

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procedure: HGA for RFS model
input: RFS problem data, GA parameters (popSize, maxGen, pM, pC)
output: the best schedule
begin
    t ← 0;                                               // t: generation
    initialize P(t) by operation-based encoding routine;  // P(t): population
    check & repair P(t) time window constraint for all chromosomes;
    evaluate eval(P) by operation-based decoding routine;
    while (not terminating condition) do
        create C(t) from P(t) by two cut-point crossover routine; // C(t): offspring
        create C(t) from P(t) by swap mutation routine;
        create C(t) from P(t) by insert mutation routine;
        check & repair precedence constraint for all offspring C(t);
        check & repair time window constraint for all offspring C(t);
        improve offspring C(t) by left-shift routine;
        evaluate eval(C) by operation-based decoding routine;
        select P(t+1) from P(t) and C(t) by roulette wheel selection routine;
        tune parameters by auto-tuning strategy FLC;
        t ← t + 1;
    end;
    output the best schedule
end;
```

Fig. 7 Overall procedure in the pseudo-code of hybrid GA for solving RFS problem

In addition, RFS scheduling in a hard-disk manufacturing system as in this paper, also has to consider the number of losses as jobs which exceeded the critical processing time. It also is an indication of the effective system even if the loss cannot be reworked.

The overall procedure in the pseudo-code of Hybrid GA for solving the reentrant flow-shop scheduling (RFS) problem for HDD manufacturing system, can be designed in Fig. 7. Regular genetic operations might construct illegal offspring in the next generation. In particular crossover and mutation operations, which are exploration and exploitation for the search space, might not produce a feasible solution. Then, checking and repairing offspring with system constraints should be done carefully.

Checking Precedence Constraint: This paper introduces checking and repairing precedence constraint for all offspring $C(t)$. The steps of *the check and repair routine* for the *precedence constraint* are given as follows:

Step 1. Transform all offspring $C(t)$ by the decoding routine.
Step 2. Compare each offspring $C(t)$ with operation sequences for each job.
Step 3. If there is an illegal offspring $C(t)$, repair it by the operation sequences based on the job.

Checking Time Window Constraint: In the same situation, the time window constraints for all chromosomes/offspring are checked and repaired. The steps for the checking and repairing routine for the time window constraint are as follows:

Step 1. Transform all offspring $C(t)$ by decoding routine.
Step 2. Calculate a time difference between first and last operations in time window zone for each job in $C(t)$.

Step 3. Compare a time difference in each job with the time window constraint to find an illegal job.
Step 4. If there is an illegal job, the first operation shifts to right before the last operation on the same machine.

Local Search (Left-shift Algorithm): After drawing the Gantt chart of a chromosome or an offspring, a local search can be conducted to improve $C(t)$ in order to reduce the idle time. Left-shift algorithm by Abe and Ida [1] is suitable to apply the RFS scheduling problem in this paper. The left-shift procedure is shown by the steps as follows:

To improve the decoded schedule after drawing the Gantt chart, a heuristic of local search, namely the Left-shift algorithm [7] could be used for solving the RFS problem too. It will help to better minimize the makespan than the old Gantt chart [4].

Two types of data problems were generated for all data. They were derived by standardization of industrial case, such as the standardized problem for 17 workstations, and the simple problem for 7 workstations by covered selection (Table 2). In Table 2, all of the processing times on each machine by operations is detailed for the standardized problem data set. Another data set is the simple problem as listed in Table 2. Both of the tables also include the time window details.

Step 1. Transform all offspring $C(t)$ by decoding routine.
Step 2. Calculate all idle times on each machine.
Step 3. Check all idle times to move left side for an operation in each partial sequence by comparing the precedence relationship on the same machine.
Step 4. Repeat steps 2-3 until there are no more left-shift operations.

When considering lot sizes, data is shown in Table 3 for the standardized problem and for the simple problem. So, 11 jobs with 220 lots per period is the problem size for the standardized problem; 4 jobs with 61 lots per period is the simple problem. Additionally, this table shows the different product types with "A" being the first type and "B" being the last type. Also, all of them can be divided into three sub-types.

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The more detailed computational results by the proposed hybrid GA with local search and fuzzy logic controller demonstrated the effectiveness and efficiency by solving a real case of an HDD manufacturing system. The parameters p_C and p_M were variously changed to automatically regulate a suitable balance between exploitation and exploration during the evolutionary process of the hybrid genetic algorithm with fuzzy logic controller (HGA.FLC). Recently Sangsawang et al. [16] proposed metaheuristics optimization approaches for solving the two-stage reentrant FFS (RFFS) problem with blocking constraint (FFS|2-stage,rcrc,block|$C_{\max}$)

Table 2 Data set of processing time and time window of the standardized and simple problems

Machines	Operations	ProcTime (m)	
		Real data (x_i)	Standardized data ($10(y_i + 1)$)
WS-1	o_1	6.5	6
	o_{2a}	10	7
	o_{2b}	10	7
WS-2	o_{2c}	10	7
	o_{2d}	10	7
WS-3	o_3	16	9
WS-4	o_4	2	5
WS-5	o_5	0.3	5
WS-6	o_6	0.3	5
WS-7	o_7	210	54
WS-8	o_8	10	7
WS-9	o_9	15	8
WS-10	o_{10}	8	7
WS-11	o_{11A}	20	10
	o_{11B}	20	10
WS-12	o_{12A}	8	7
	o_{12B}	8	7
WS-13	o_{13A}	10.2	7
	o_{13B}	11.5	8
WS-14	o_{14A}	4.8	6
	o_{14B}	5.6	6
WS-15	o_{15A}	1.5	5
	o_{15B}	1.5	5
WS-16	o_{16}	35	13
	o_{17a}	26.5	11
WS-17	o_{17b}	23	10
	o_{17c}	32	12
WS-1	o_1		6
	o_{2a}		7
WS-2	o_{2b}		7
	o_{2c}		7
WS-3	o_3		5
WS-4	o_4		54
WS-5	o_5		8
WS-6	o_{6A}		7
	o_{6B}		8

WS-14 to WS-17: time windows = 300 min/lot, WS-6 to WS-7: time windows = 30 min/lot

Table 3 Data set of product types and number of lots of the standardized and simple problems

		No. of lots	
Product types	Products	Real data(x_i)	Standardized data ($10(y_i + 2)$)
A1	P-1	100	9
A1	P-2	175	11
A2	P-3	1,243	32
A1	P-4	866	25
A2	P-5	1,137	30
A3	P-6	228	12
B1	P-7	228	12
B2	P-8	510	17
B3	P-9	841	24
B2	P-10	1533	38
B3	P-11	139	10
A1	P-1		9
A2	P-2		30
B1	P-3		12
B3	P-4		10

in which they applied a hybrid GA and a hybrid particle swarm optimization (HPSO) with Cauchy distribution.

4 Manufacturing Model in TFT-LCD Module Assembly

Because of short product lifecycles, it is crucial to rapidly respond to various customer needs and deliver products on time in high-tech industries such as the thin-film transistor-liquid crystal display (TFT-LCD) and semiconductor manufacturing industries. The TFT-LCD manufacturing is capital and technology intensive industry. Facing the fierce competitive pressures, it is important to enhance productivity and operational efficiency. Manufacturing scheduling of TFT-LCD Module Assembly system is a key issue to enhance manufacture efficiency that could satisfy customer demand on time [6]. By focusing on realistic settings, a module assembly process was formulated for use in the TFT-LCD industry as a generalization of the flexible job-shop scheduling problem (FJSP). On a flexible job-shop floor, workstations employ non-identical parallel machines scheduling (PMS) that exhibit distinct production velocities. An operation can be processed using an available machine from a given workstation. The TFT-LCD module assembly scheduling problem can be divided into two subproblems: the routing (i.e., assigning each operation to machines) and scheduling problems (i.e., determining the start time of each operation to machines).

Table 4 Computational result by GA and HGA for the standardized and the simple problems

Problem types	Parameters			GA without time window			HGA with time window	
	popSize	maxGen	Makspan (m)	Loss	CPU (m)	Makespan (m)	Loss	CPU (m)
Simple without lot size	10	100	267.2	1.2	0.03	266.6	0	0.09
	20	1000	266	1.1	0.62	266	0	1.21
Standard without lot size	10	1000	784.9	0.8	2.35	720.5	0	11.83
	20	2000	770.8	0.7	9.11	718.2	0	29.4
Simple with lot size	10	100	3,908.30	0.9	0.04	3,854.60	0	0.08
	20	1000	3,829.60	0.4	0.56	3,820.30	0	1.09
Standard with lot size	10	1000	16,270.80	1.9	2.36	14,332.80	0	11.72
	20	2000	15,789.40	0.7	8.97	14,128.00	0	29.51

The following factory-specific factors complicate the TFT-LCD module assembly scheduling problem.

The TFT-LCD module assembly production is one of FJSP models that is critical to satisfy the customer demands on time. On the module assembly shop floor, each workstation has identical and non-identical parallel machines that access the jobs at various processing velocities depending on the product families. To satisfy the various jobs, the machines need to be set up as the numerous tools to conduct consecutive products. This study aims to propose a novel approach to address the TFT-LCD module assembly scheduling problem by simultaneously considering the following multiple and often conflicting objectives such as the makespan, the weighted number of tardy jobs, and the total machine setup time, subject to the constraints of product families, non-identical parallel machines, and sequence-dependent setup times [6].

The TFT-LCD manufacturing process is divided into three main stages: Array/CF (color filter) process, Cell process, and Module process (Fig. 8). The Array/CF process is similar to semiconductor wafer fabrication except that transistors are built up on the glass substrate instead of silicon wafer, and the processes are also re-entrant flow. The Cell process attaches the Array substrate and CF substrate together, and fills the liquid crystal between two substrates. The Module process, the final stage, is to assemble all customized components as the finished goods. The Module process stage involves six workstations that assemble customized components (e.g., integrated circuit, printed circuit board, driver board, backlight, and chassis) onto the panels to complete the final TFT-LCD production:

(1) The IC (integrated circuit) bonding.
(2) The PCB (printed circuit board) bonding.
(3) The components assembly.
(4) The burn-in test.
(5) The inspection.
(6) The packing and shipping.

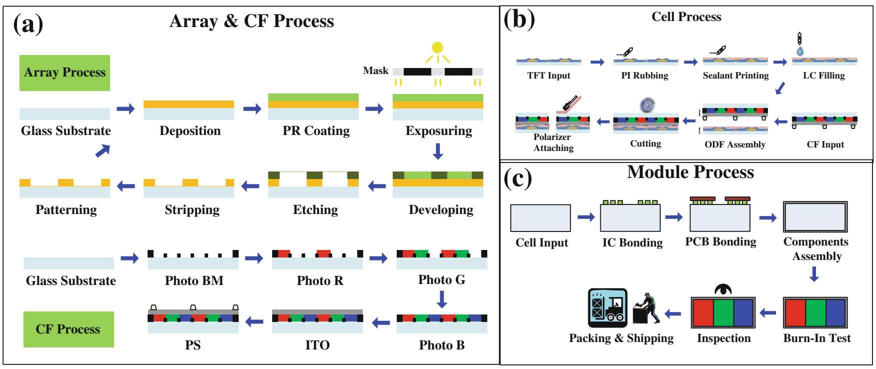

Fig. 8 Three main stages of the TFT-LCD manufacturing process: **a** Array process, **b** Cell process, and **c** Module process

The module assembly process is the final stage of TFT-LCD manufacturing process, and the finished goods are directly shipping to customers. Therefore, it is very important to deliver product on time. In order to keep efficiency and commit customer’s due date, the Module assembly scheduling problem should be considered the following multiple and conflicting objectives simultaneously: minimizing makespan, minimizing total workload, and maximizing confirmed line item performance (CLIP) rate. The CLIP is a measure of customer satisfaction reliability, meaning the percentage of order requests that was delivered as promised (i.e., commit customer’s due date). The CLIP has been used as the major key performance indicator in high-tech industry [14]. However, if the scheduling in order to commit the customer’s due date, its lead to a larger makespan and workload [17]. It’s dilemma to minimize makespan, total workload and maximize CLIP rate at the same time in the shop-floor manufacturing environment. The minimizing makespan and minimizing total work load are the effective objectives, and the maximizing CLIP rate is the objective that directly related to customer service by keeping manufacture efficiency and committing customer’s due date. Therefore, this paper considers the conflicting objectives simultaneously to find a suitable compromised schedule.

On the module assembly shop floor, the manufacturing process consisting of five workstations with 10 machines (WS-1: JI with 3 m/c, WS-2: 3D VAS with 1 m/c, WS-3: Packer with 1 m/c, WS-4:MA with 2 m/c and WS-5:3D Cal. with 1 m/c) depend on the product family. Figure 9 shows the jobs with different product families and access to different routes. For instance, for Job 4 in Fig. 9, one of the products is a 3D-type panel, which requires laminating the 3D glass substrate onto the panel after the cell process. It must then pass through the IC and PCB bonding, components assembly, and the test workstations. Before shipping, 3D products must pass through the 3D calibration workstation to calibrate the 3D product picture settings. In addition, two types of shipments exist depending on customer demand: semi-finished and finished goods. Semi-finished goods do not require assembling the customized electric components onto the panel.

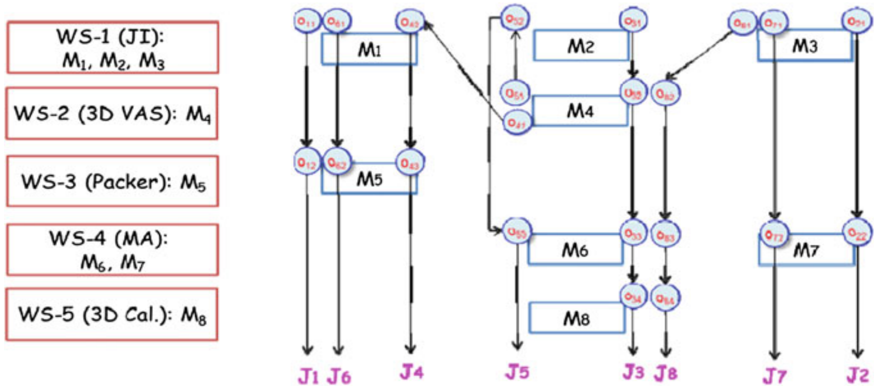

Fig. 9 Processing flow in module assembly for the TFT-LCD manufacturing

Jobs can be assigned to non-identical machines and a high speed processing velocity is chosen to improve production efficiency. Choosing the fast processing time, the job could be finished quickly with earlier completion time. However, if all jobs are assigned to the fast processing time machine, the job must queue and also delay the completion time. Furthermore, jobs in varying product families require machine setup tools, increasing the total setup time and prolonging the job completion time.

Various product families can be produced using the varying process on a non-identical machine shop floor. The module assembly scheduling system requires selecting which job operation passes through which machine and determining the start time of each operation in each machine. Therefore, this study was conducted to solve the complex scheduling problem that considers incompatible product families, non-identical parallel machines, and sequence-dependent setup time (SDST) constraints in a real production system. There are several product types based on its specification (panel size, display type, shipping type, etc.) and Table 5 is product family case in Module Assembly for the TFT-LCD manufacturing.

The module process stage involves five workstations in which customized components (i.e., integrated circuit (IC), printed circuit board (PCB), driver board, backlight, and chassis) are assembled onto the panel.

(1) IC and PCB bonding (Workstation 1): Bonding the IC and PCB components onto the panel.
(2) The 3D substrate lamination (Workstation 2): Laminating the 3D substrate on the cell panel if the product is a 3D type.
(3) Semi-finished goods packing (Workstation 3): Semi-finished goods are packed to ship to the customer.
(4) Component assembly and testing (Workstation 4): Assembling customized electric components onto the panel.
(5) The 3D calibration (Workstation 5): Calibrating 3D product picture setting.

Table 5 Product family cases in module assembly for the TFT-LCD manufacturing

Job	Lot size	Due date	Display type	Operation sequence	Product type
i	q_i	d_i (k s)		o_{ik}	
1	250	45	2D	o_{11}, o_{12}	Small Size_SKD
2	500	65	2D	o_{21}, o_{22}	Large Size_Module
3	400	60	$3D\_OGS$	$o_{31}, o_{32}, o_{33}, o_{34}$	Large Size_Module
4	200	60	$3D\_GPR$	o_{41}, o_{42}, o_{43}	Small Size_SKD
5	500	95	$3D\_GPR$	o_{51}, o_{52}, o_{53}	Large Size_Module
6	600	32	2D	o_{61}, o_{62}	Small Size_SK
7	400	75	2D	o_{71}, o_{72}	Large Size_Module
8	600	95	$3D\_OGS$	$o_{81}, o_{82}, o_{83}, o_{84}$	Large Size_Module

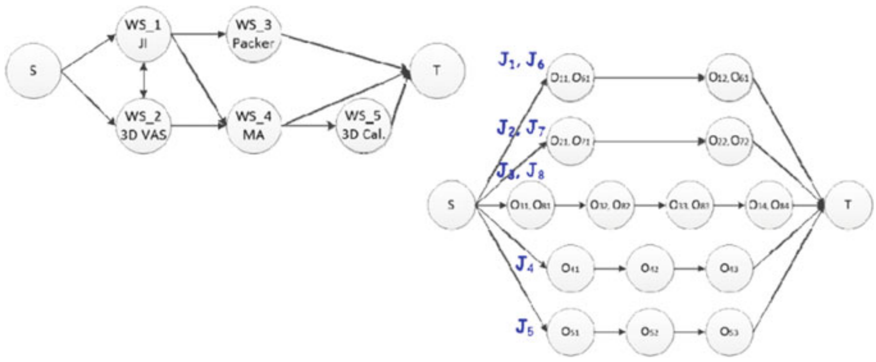

Fig. 10 Precedence relationship graph in module assembly for the TFT-LCD manufacturing

Based on the precedence relationship of the processing flow in TFT-LCD module assembly, the following five different types of routes created as shown in Fig. 10.

The module process is the final stage of TFT-LCD manufacturing system, and the finished products are directly shipping to customers. The module assembly scheduling problem consider the multiple conflicting objectives simultaneously:

(1) Minimizing makespan.
(2) Minimizing total workload.
(3) Maximizing CLIP (confirmed line item performance).

Constraints:

(1) Incompatible product families: The jobs requiring the same recipe can be regarded as a product family and have the same processing time in one machine. Incompatible product families cannot be processed together in one machine.
(2) Parallel machines.
(3) Sequence dependent setup time (SDST): With variety customers and product families, a machine setup time is required if two consecutive jobs of different product families in the same machine.

The TFT-LCD module assembly scheduling problem is formulated as a multi-objective mixed-integer linear programming (Mo-MILP) model as shown in Chou et al. [6].

5 Multiobjective Hybrid GA with TOPSIS and Computational Result

Genetic Representation: A common representation of the FJSP problem is designed using a two-vector chromosome that names all the operations of a job by using the same symbol, and interprets them according to the order of occurrence in the sequence

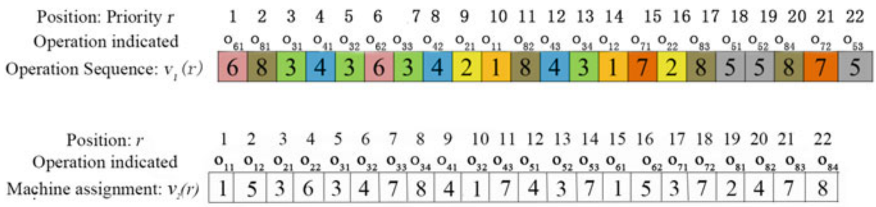

Fig. 11 Scheme of operation sequence vector v1 and machine assignment vector v_2

of a given chromosome [10]. The TFT-LCD module assembly scheduling problem is a combination of operation scheduling and machine assignment decisions. Therefore, in this study, the chromosome was designed as two parts: an operation sequence vector (v_1) and a machine assignment vector (v_2). The evaluated TFT-LCD module assembly scheduling problem comprised eight jobs and eight machines, where each job required several operations. The operation sequence vector v_1 shows that each job i appears nitimes, indicating niordered operations. An example of the operation sequence vector is shown in Fig. 11. The machine assignment vector $v_2(r)$ shows that the machine selected for the operation is indicated at position r, and shown in Fig. 11. For example, the position 1 in $v_1(1)$ indicates o_{61} (i.e., the first operation of Job 6), and Position 1 in $v_2(1)$ denotes that machine 1 is assigned to o_{11}. The main advantage of a two-vector representation is that each possible chromosome always depicts a feasible candidate.

Population Initialization (Encoding Routine): To guarantee the quality and diversity of an initial population, a mixed strategy is used to generate chromosomes that include an operation sequence vector and a machine assignment vector. First, a random rule strategy is applied to randomly initialize the operations in a sequence vector. Second, minimal processing time and random rule strategies are applied to generate the machine assignment vector, as follows:

(1) The minimal processing time strategy [13, 15] is used to locate the machine that exhibits a minimal processing time for the permuted operation, and then adds its processing time to every subsequent entry.

(2) The random rule strategy randomly assigns a machine to each operation.

In this study, the random rule strategy was used to initialize the operation sequences, in which 50 % of the machine assignment vectors were generated using the minimal processing time strategy, and the remaining 50 % were generated using the random rule strategy.

Left-shift Based Decoding: This study used left-shift based decoding, where each operation was shifted left until it was as compact as possible to reduce the machine idle time. This strategy is used to search for the earliest available time interval $[t_i^E, t_i^L]$ to allocate the permuted operation to a machine based on the operation sequence vector. If the time span is sufficient from the beginning to ending, is allocated in the time interval; otherwise, is allocated at the end of machine. The following relationship formulated in Eq. 2):

$$\begin{cases} \max\left\{t_j^E + s_{hgikj},\ t_{i,k-1}^C\right\} + p_{ikj} \leqslant t_j^L, & \text{if } k \geqslant 2 \\ t_j^E + p_{ikj} \leqslant t_j^L, & \text{if } k = 1. \end{cases} \tag{2}$$

Left-shift based decoding sequentially allocates each operation to an assigned machine in the order represented in the operation sequence vector. The detailed example of the process by the left-shift based decoding is shown in Chow et al. [6].

Genetic Operations: In the two-vector representation, each gene of the operation sequence vector does not indicate a specific job's operation but refer to its context-dependent. This reason causes the crossover procedure cannot inherit their parental characteristics at the form of two-vector representation. We used the order crossover in this study for the operation sequence vector and the procedure is as follows.

Step 1. Randomly select a subsection of the operation from one parent.
Step 2. Conduct an offspring by copying the subsection of the parent, including the operation sequence and machine assignment in the corresponding position.
Step 3. Delete the operations that are already in the offspring from the second parent.
Step 4. Allocate the operations and assigned machines to the unfixed positions of the offspring from left to right, according to the sequence in the second parent.

The conventional mutation operator is used to randomly generate offspring [13]. In this study, the objective functions of makespan and total machine setup time are used to minimize the production time. An artificial mutation was developed, combining the minimal processing time concept and mutation operator, reallocating the machine that exhibits the minimal processingtime to the operation [15]. In the operation sequence vector, a gene of certain probability is selected and the operations are randomly exchanged with the machine that was assigned to the operation. In the machine assignment vector, the job that exhibits the longest total processingtime is selected and the machine that exhibits the maximal processing time is reallocated to the minimal processingtime to the corresponding operation. The offspring generated by artificial mutation may exhibit a superior makespan compared with the makespan before the convergence was accelerated. In addition, immigration strategy was used to randomly generate new chromosomes and prohibit rapid convergence.

Local Search (Variable Neighborhood Descent): Local search can be used to improve the convergence speed, yielding superior solutions. The variable neighborhood descent (VND) approach is considered a local search algorithm that produces a new solution from the current population by making a slight change before it is inserted into the population [8]. The VND approach is employed to sequentially identify and exchange critical operations and find a new schedule that exhibits a small makespan in the multiobjective module assembly scheduling problem. The makespan of a scheduling solution is defined by the length of its critical path; that is, the makespan cannot be reduced while adjusting the current critical paths. Any operationon the critical path is called a critical operation.

This study employed the VND approach to determine a schedule that yielded a small makespan. To reduce computational loading, only one critical operation is moved at a time and inserted into an available idle time interval. Therefore, the single moving operation of the VND procedure is as follows:

(1) Deleting a critical operation;
(2) Finding an assignable idle time interval;
(3) Allocating the deleted into the found time interval.

TOPSIS: The technique for order preference by similarity to the ideal solution (TOPSIS) is to derive the best compromised solution among Pareto optimal solutions. TOPSIS evaluation mechanism quickly conduct a best compromised schedule into the manufacturing system and TOPSIS is considering the best alternative should have the shortest distance from the ideal solution (A^+) [12]. To prioritize the Pareto non-dominated solutions based on objective functions that decision maker concerned. TOPSIS evaluation mechanism ranks the best compromised scheduling from all alterative solutions and the detailed procedure is shown in Chou et al. [6]. Decision makers design the preference of objective functions:

Normalized weight vector; $w_1 + w_2 + w_3 = 1$;
Minimize makespan: weight w_1;
Minimize total workload: weight w_2;
Maximize CLIP weight: w_3

Overall Procedure of Mo-HGA: This study combined the auto-tuning strategy [20] to dynamically regulate the parameters for the multiobjective hybrid genetic algorithm (Mo-HGA) by employing a fuzzy logic controller (FLC). Two FLCs, the crossover and mutation FLCs, were implemented to adaptively regulate the rates of crossover and mutation operators during the genetic search process as introduced in [20] FLC for tuning parameters. This enabled the automatic tuning of the parameters of the Mo-HGA depending on the convergence situation of the current generation.

```
procedure: Multiobjective Hybrid Genetic Algorithm (Mo-HGA)
input: data set, GA parameters (popSize, maxGen, pC, pM)
output: the best implement schedule
begin
  t ← 0;                                        // t: generations
  initialize P(t) by encoding routine;          // P(t): population
  calculate objectives fi(P), i = 1, 2, 3 by decoding routine;
  evaluate eval(P) by fitness assignment routine and keep the best Pareto solution;//TOPSIS
  create Pareto E(P) by nondominated routine;   // Fast non-dominated sort
  while (terminating condition) do
    create C(t) from P(t) by crossover routine;  // C(t): offspring
    create C(t) from P(t) by mutation routine;
    improve C(t) by variable neighborhood descent (VND) routine;
    calculate objectives fi(C), i = 1, 2, 3 by decoding routine;
    evaluate eval(C) by fitness assignment routine and update the best Pareto solution;//TOPSIS
    update Pareto E(P, C) by nondominated routine;
    select P(t+1) from P(t) and C(t) by elitism strategy routine;
    tune parameters pC, pM by fuzzy logic controller routine;
    t ← t + 1;
  end
output the best schedule;
end;
```

Fig. 12 Overall procedure of Mo-HGA for solving TFT-LCD module assembly scheduling problem

The overall procedure in the pseudo-code of Mo-HGA for solving designed for solving TFT-LCD module assembly scheduling problem as shown in Fig. 12.

A small-scale case was used to demonstrate the applicability of the proposed Mo-HGA. In this case, eight jobs involving 22 operations were arranged to eight machines on the shop floor, and the job quantity, product family, and operation sequences are listed in Table 5. The operation processing time of this small-scale case is shown in Table 6. The processing time of these 22 operations were designed on the basis of empirical setting that depends on the job quantity and production velocity of the machine. The sequence-dependent setup time between the product families is shown in Table 7.

Schedule $S = \{(o_{ij}, M_m, s_{ij} - c_{ij})\}$; o_{ij} denotes operation j in job i; M_m is machine m; s_{ij} means starting operation j in job i and c_{ij} is completing operation j in job i. Here is one of Pareto optimal solutions with three objective function values and Gantt chart (Fig. 13) by Mo-HGA as follows:

Table 6 Processing time of the small-scale case

Processing time (s)	M1	M2	M3	M4	M5	M6	M7	M8
o_{11} –	5,750	–	–	–	–	–	–	–
o_{12} –	–	–	–	–	6,250	–	–	–
o_{21} –	–	25,000	17,500	–	–	–	–	–
o_{22} –	–	–	–	–	–	25,000	15,000	–
o_{31}	–	20,000	14,000	–	–	–	–	–
o_{32}	–	–	–	6,000	–	–	–	–
o_{33}	–	–	–	–	–	20,000	12,000	–
o_{34}	–	–	–	–	–	–	–	24,000
o_{41}	–	–	–	3,000	–	–	–	–
o_{42}	4,600	–	–	–	–	–	–	–
o_{43}	–	–	–	–	–	–	5,000	–
o_{51}	–	–	–	7,500	–	–	–	–
o_{52}	–	25,000	17,500	–	–	–	–	–
o_{53}	–	–	–	–	–	25,000	15,000	–
o_{61}	13,800	–	–	–	–	–	–	–
o_{62}	–	–	–	–	15,000	–	–	–
o_{71}	–	20,000	14,000	–	–	–	–	–
o_{72}	–	–	–	–	–	20,000	12,000	–
o_{81}	–	30,000	21,000	–	–	–	–	–
o_{82} –	–	–	–	9,000	–	–	–	–
o_{83} –	–	–	–	–	–	30,000	18,000	–
o_{84}	–	–	–	–	–	–	–	36,000

Table 7 Sequence-dependent setup time between the product families

Setup Time (s)	o_{11}	o_{12}	o_{21}	o_{22}	o_{31}	o_{32}	o_{33}	o_{34}	o_{41}	o_{42}	o_{43}	o_{51}	o_{52}	o_{53}	o_{61}	o_{62}	o_{71}	o_{72}	o_{81}	o_{82}	o_{83}	o_{84}
o_{11}	–	–	–	–	–	–	–	–	–	7,200	–	–	–	–	–	–	–	–	–	–	–	–
o_{12}	–	–	–	–	–	–	–	–	–	–	1,800	–	–	–	–	–	–	–	–	–	–	–
o_{21}	–	–	–	–	7,200	–	–	–	–	–	–	–	7,200	–	–	–	–	–	7,200	–	–	–
o_{22}	–	–	–	–	–	–	3,600	–	–	–	–	–	–	3,600	–	–	–	–	–	–	3,600	–
o_{31}	–	–	7,200	–	–	–	–	–	–	–	–	–	7,200	–	–	–	7,200	–	–	–	–	–
o_{32}	–	–	–	–	–	–	–	–	7,200	–	–	7,200	–	–	–	–	–	–	–	–	–	–
o_{33}	–	–	–	3,600	–	–	–	–	–	–	–	–	–	3,600	–	–	–	3,600	–	–	–	–
o_{34}	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
o_{41}	–	–	–	–	–	7,200	–	–	–	–	–	7,200	–	–	–	–	–	–	–	7,200	–	–
o_{42}	7,200	–	–	–	–	–	–	–	–	–	–	–	–	–	7,200	–	–	–	–	–	–	–
o_{43}	–	1,800	–	–	–	–	–	–	–	–	–	–	–	–	–	1,800	–	–	–	–	–	–
o_{51}	–	–	–	–	–	7,200	–	–	7,200	–	–	–	–	–	–	–	–	–	–	7,200	–	–
o_{52}	–	–	7,200	–	7,200	–	–	–	–	7,200	–	–	–	–	–	–	7,200	–	7,200	–	–	–
o_{53}	–	–	–	3,600	–	–	3,600	–	–	–	3,600	–	–	–	–	–	–	3,600	–	–	3,600	–
o_{61}	7,200	–	–	–	–	–	–	–	–	7,200	–	–	–	–	–	–	–	–	–	–	–	–
o_{62}	–	1,800	–	–	–	–	–	–	–	–	1,800	–	–	–	–	–	–	–	–	–	–	–
o_{71}	–	–	–	–	7,200	–	–	–	–	–	–	–	7,200	–	–	–	–	–	7,200	–	–	–
o_{72}	–	–	–	–	–	–	3,600	–	–	–	–	–	–	3,600	–	–	–	–	–	–	3,600	–
o_{81}	–	–	7,200	–	–	–	–	–	–	–	–	–	7,200	–	–	–	7,200	–	–	–	–	–
o_{82}	–	–	–	–	–	–	–	–	7,200	–	–	7,200	–	–	–	–	–	–	–	–	–	–
o_{83}	–	–	–	3,600	–	–	–	–	–	–	–	–	–	3,600	–	–	–	3,600	–	–	–	–
o_{84}	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

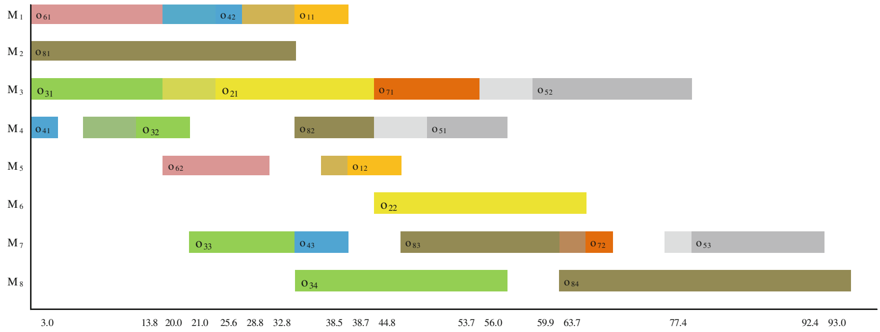

Fig. 13 Gantt chart of Pareto optimal solution

Schedule: $S = o_{61}, o_{81}, o_{31}, o_{41}, o_{32}, o_{62}, o_{33}, o_{42}, o_{21}, o_{11}, o_{82}, o_{43}, o_{34}, o_{12}, o_{71}, o_{22}, o_{83}, o_{51}, o_{52}, o_{84}, o_{72}, o_{53} = (o_{61}, M_1, 0\text{–}13.8), (o_{81}, M_2, 0\text{–}30.0), (o_{31}, M_3, 0\text{–}14.0), (o_{41}, M_4, 0\text{–}3.0), (o_{32}, M_4, 14.0\text{–}20.0), (o_{62}, M_5, 13.8\text{–}28.8), (o_{33}, M_7, 20.0\text{–}32.0), (o_{42}, M_7, 21.0\text{–}25.6), (o_{21}, M_3, 21.2\text{–}38.7), (o_{11}, M_1, 32.8\text{–}38.55), (o_{82}, M_4, 30.0\text{–}39.0), (o_{43}, M_7, 32.0\text{–}37.0), (o_{34}, M_8, 23.0\text{–}56.0), (o_{12}, M_5, 38.55\text{–}44.8), (o_{71}, M_3, 38.7\text{–}52.7), (o_{22}, M_6, 38.7\text{–}63.7), (o_{83}, M_7, 39.0\text{–}57.0), (o_{51}, M_4, 46.2\text{–}53.7), (o_{52}, M_3, 59.9\text{–}77.4), (o_{72}, M_7, 60.6\text{–}72.6), (o_{53}, M_7, 77.4\text{–}92.4), (o_{84}, M_8, 57.0\text{–}93.0)$

Three objectives: Makespan: 93 (K s), Total workload: 310.9 (K s), CLIP: 100 (%).

Tables 8 and 9 is shown objective function values by Mo-GA, Mo-HGA.VND and Mo-HGA.VND.FLC for 8-Job/8-Machine and 40-Job/22-Machine respectively. Comparing the Mo-GA, Mo-HGA with VND, Mo-HGA with VND & FLC experiment results using TOPSIS, the Mo-HGA with VND & FLC could get the best compromised schedule.

The each objective function value by Mo-HGA.VND.FLC for 40-Job/22-Machine in Table 10 is shown three cases of the different computational time such as 60, 180 (s) and more than 22 generations.

To solve the multiobjective scheduling problem for the TFT-LCD module assembly system by using LINGO for comparing with the Mo-HGA proposed, Chou et al. [6] also formulated a fuzzy multiobjective mixed-integer linear programming (FMo-MILP) model to obtain the compromised solution as a benchmark by using fuzzy multiobjective programming, a fuzzy goal, and fuzzy constraints [21] A quality criterion, the optimality gap, was defined to show the percentage of deviation of the values of the multiobjective programming approaches (i.e., the FMo-MILP and the Mo-HGA) from the values of LINGO, according to the following equation [17]:

$$\text{Optimality Gap} = (\text{Approach - LINGO})/\text{LINGO} \times 100\,(\%). \tag{3}$$

The optimality gaps of the small-scale test problems, compared to the compromised solution of multiobjective programming approaches with an aspiration level, are shown in Tables 11 and 12. The results show that the FMO-MILP and the MO-

Table 8 Objective function values by Mo-GA, Mo-HGA.VND and Mo-HGA.VND.FLC for 8-Job/8Mc

8 Jobs with 8 Machines	MO-GA			MO-HGA with VND			MO-HGA with VND & FLC		
Terminating Time (s)	CM (K s)	WT (K s)	CLIP (%)	CM (K s)	WT (K s)	CLIP (%)	CM (K s)	WT (K s)	CLIP (%)
60	94.2	308.9	85.5	93	310.9	100	93	310.9	100
180	94.2	308.9	85.5	93	310.9	100	93	310.9	100

Terminating with same objective values over 50 generations

8 Jobs with 8 Machines	MO-HGA				MO-HGA with VND with VND & FLC				MO-HGA			
popSize: 200	CM (K s)	WT (K s)	CLIP (%)	CPU (s)	CM (K s)	WT (K s)	CLIP (%)	CPU (s)	CM (K s)	WT (K s)	CLIP (%)	CPU (s)
	94.2	308.9	85.5	22	93	310.9	100	112	93	310.9	100	118

Table 9 Objective function values by Mo-GA, Mo-HGA.VND and Mo-HGA.VND.FLC for 40-Job/22Mc

40 Jobs with 22 Machines	MO-GA			MO-HGA with VND			MO-HGA with VND & FLC		
Terminating Time (s)	CM (K s)	WT (K s)	CLIP (%)	CM (K s)	WT (K s)	CLIP (%)	CM (K s)	WT (K s)	CLIP (%)
60	5057.5	43386.6	64.55	2121	7606.1	69.13	278.8	1429.5	91.82
180	7007.5	51296.9	67.43	256.5	1385.5	97.71	259	1377	94.44

Terminating with same objective values over 20 generations

40 Jobs with 22 Machines	MO-GA				MO-HGA with VND				MO-HGA with VND & FLC			
	CM (K s)	WT (K s)	CLIP (%)	CPU (s)	CM (K s)	WT (K s)	CLIP (%)	CPU (s)	CM (K s)	WT (K s)	CLIP (%)	CPU (s)
	5242.5	44870.4	25.7	35.6	259.5	1368.5	97.71	416	258	1372.5	97.71	311

Table 10 Objective function values by Mo-HGA.VND.FLC for 40-Job/22Mc

40 Jobs with 22 Machines	MO-HGA with VND & FLC		
Terminating Condition	C_m (k s)	W_t (k s)	*CLIP* (%)
Computational time>60 s	278.8	1429.5	91.8
Computational time>180 s	259.0	1377.0	94.4
Same result over 20 generations	258.0	1372.5	97.7

Table 11 Experimental result of FMo-MILP and Mo-HGA

Test Problem	MO-MILP (LINGO)			FMO-MILP (LINGO)	MO-HGA	Aspiration Level
	$C_{\max}$	W_{NT}	S_T	$(C_{\max}, W_{NT}, S_T)$	$(C_{\max}, W_{NT}, S_T)$	
P1	50.0	0.37	0	(69.7, 0.37, 7.2)	(69.7, 0.37, 7.2)	(50.0, 0.37, 0)
P2	60.5	0.34	10.8	(72.5, 0.34, 10.8)	(72.5, 0.34, 10.8)	(60.5, 0.34, 10.8)
P3	76.2	0.16	10.8	(78.6, 0.18, 14.4)	(78.6, 0.18, 14.4)	(76.2, 0.16, 10.8)

Table 12 Optimality gaps of small-scale test problems

Test problem	FMO-MILP			MO-HGA		
	$C_{\max}$ (%)	W_{NT} (%)	S_T (%)	$C_{\max}$ (%)	W_{NT} (%)	S_T (%)
P1	39.4	0		39.4	0	
P2	19.8	0	0	19.8	0	0
P3	3.1	12.5	25.0	3.1	11.1	25.0

HGA yield the same optimality gaps for each test problem.These two approaches have the values close to the aspiration level. Detailed computational results refer Chou et al. [6].

As introduced computational results for the various scale of multiobjective scheduling problems for the TFT-LCD module assembly system by using LINGO for comparing with the Mo-HGA, it clearly demonstrated that multiobjective hybrid genetic algorithm with VND and FLC routines (Mo-HGA.VND.FLC) proposed is effectiveness and efficiency in the best compromised solution as a quality of solution with reasonable interactive computational time for NP-hard multiobjective optimization problem in practice.

6 Conclusions

Manufacturing scheduling is one of the important and complex combinatorial optimization problems, where it can have a major impact on the productivity of a production process. Moreover, most of scheduling problems fall into the class of NP-hard combinatorial problems. Recently, many manufacturing companies are faced with global market demands for a variety of low cost products with a high quality. For responding rapidly to demand fluctuations and reducing costs related to manufacturing scheduling and logistics networks, hybrid genetic algorithm (HGA) and multiobjective HGA (Mo-HGA)have received considerable attention regarding their potential for solving various complex manufacturing and logistics problems.

In this paper, we introduced how to design Hybrid GA and Mo-HGA with parameter tuning by the fuzzy logic controller (FLC) and local search such as the left-ship routine and variable neighborhood descent (VND) routines to solve manufacturing scheduling problems for hard disc device (HDD) and thin-film transistor-liquid crystal display (TFT-LCD), respectively. In particularly, the FLC for tuning crossover and mutation rates, the fitness assignment mechanism for multiobjective optimization problems (MOP) and genetic representations as well as the hybrid evolutionary operations are combined. Through a variety of numerical experiments, the effectiveness and efficiency of the HGA for HDD and Mo-HGA.VND.FLC for TFT-LCD module assembly as the practical applications of manufacturing scheduling problems are demonstrated. This paper also introduced how to design Mo-HGAs for applying a multiobjective flexible job-shop scheduling problem (Mo-FJSP; operation sequencing and resources assignment) to the practical manufacturing scheduling problems.

As future researches in multiobjective scheduling problems, it is to apply hybrid sampling strategy-based evolutionary algorithms [9] to real case study. Another topics is to enhance the evolutionary process by combining hybrid genetic algorithm with another metaheuristics such as PSO, DE or EDA.

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Stock Price Forecasting Based on Multi-Input Hamacher T-Norm and ANFIS

Fengyi Zhang and Zhigao Liao

Abstract This study proposed the expression and some feathers of multi-input Hamacher T-norm first, then constructed the multi-input Hamacher T-norm based ANFIS, finally forecasted the stock price of Pingan Bank (000001) from Jan. 4, 2014 to AUG. 28, 2014, by constructing a model based on Multi-input Hamacher T-norm and ANFIS (Adaptive Neuro-Fuzzy Inference System). 5-cross fold validation has been used in this study to recognize the its best performance in MSE (Mean Square Error), MAE (Mean Absolute Error) and MAPE (Mean Absolute Percentage Error) belongs to high prediction accuracy, while it's also superior to regular ANIFS. Therefore, Multi-input Hamacher T-norm could improve the performance of ANFIS in stock price forecasting.

Keywords Stock price forecasting · ANFIS · Multi-input hamacher T-norm

1 Introduction

Stock price is tightly related to domestic economy, however, it usually fluctuates severely and nonlinearly, so it is of great value to predict stock price. Stock price shows chaotic feather in short time, while the tendency of price changing emerges throughout historical data. Generally, historical data implicates the rule which stock price fluctuation abide by [1]. However, traditional forecasting methods which base on linear analysis technology can't dig out the intrinsic rule of stock price fluctuation well.

Employing artificial intelligence technology to forecast stock price has already yielded many great achievements: Kazema et al. [1] combined chaos-fire algorithm and SVM (Support Vector Machine) to forecast several stock in NASDAQ, and achieved fine results; Oliveira et al. [2] applied ANN (Artificial Neural Network) to

F. Zhang (✉) · Z. Liao
Department of Management, Guangxi University of Science and Technology, Liuzhou 545000, People's Republic of China
e-mail: Feng-yi_Zhang@163.com

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study the rise-fall situation of a certain stock in Brazil Stock price and the prediction accuracy reached 93.62 %. Aghabozorgi and Teh [3] employed 3-Stage Clustering Method to forecast stock price, and they finally verified that this method is effective. Zuo and Kita [4] used Bayes ANN to predict NIKKEI225 index and stock price of Toyota, and testified that Bayes ANN is superior to traditional time-series algorithm in the aspect of covariance and MSE (Mean Square Error).

ANFIS (Adaptive Neuro-Fuzzy Inference System), which belongs to typical T-S models, combines Fuzzy Inference System with ANN greatly and has been widely applied in many fields [5–8]. Fuzzy Inference System is an effective model which can be used to handle unknown or difficult-to-construct system. The design of Fuzzy Inference System do not depend on the object's model, however, it much lies on the experience of experts. While employing Fuzzy Inference System, it's not wise to expect to achieve satisfying results, in case of lacking of expertise or the method to transform these expertise into "IF THEN" form correctly. For ANN, it gains advantages in self-organizing and self-learning, but it usually can't deal with structural knowledge: besides a great many of training data and the process of self-learning, it still needs Parallel distributed structure to estimate the relation between input and output.

In order to improve the online access speed of ANFIS T-S rules for complex system, various clustering algorithms have been used to construct a new multidimensional structure of ANFIS, which combined mechanism of T-S fuzzy inference and clustering algorithm from the perspective of knowledge discover. In this paper, we select Hamacher T-norm to tackle the intersection operation for two reasons:

(1) Algebraic product T-norm is used widely in ANFIS, and when equals to 1, the Hamacher T-norm is actually an algebraic product T-norm, which means it is not conflicting with the regular ANFIS.
(2) Hamacher product T-norm, a clustering of fuzzy product T-norms, differs depending on λ. So, to select the most suitable fuzzy T-norm by changing the numerical parameter λ is advisable.

The purpose of this study is to validate the practicality of Multi-input Hamacher T-norm applied in ANFIS to predict stock price in Chinese Stock market. The rest of the study is organized as follows. Section 2 provides some necessary background information and details of the proposed model, the Sect. 3 depicts the methods that have been used to transform original data and to validate results. Then the simulation process and results are discussed in Sect. 4. Finally, Sect. 5 presents the summary of this study.

2 Background

In this section, the basic theory of ANFIS model and Hamacher T-norm has been used in this experiment will be introduced.

2.1 Adaptive Network Based Fuzzy Inference System (ANFIS)

Both artificial neural network and fuzzy logic are used in ANFIS architecture [9]. ANFIS consists of if-then rules and couples of input-output. For ANFIS training, learning algorithms of neural network are also used. To simplify the explanations, the fuzzy inference system under consideration is assumed to have two inputs (x and y) and one output (f). For a regular ANFIS model, a typical rule set with basic fuzzy if-then rules can be expressed as if x is A_1 and y is A_2, then $f_1 = p_1 x + q_1 y + r_1$, where p is linear output parameters. The ANFIS architecture with two inputs and one output are as shown in Fig. 1.

This architecture is formed by five layers and nine if-then rules:

Layer-1: Every node i in this layer is a square node with a node function.

$$O_{1,i} = \mu_{A_i}(x), \quad O_{1,3+j} = \mu_{B_j}(y) \;\; i, j = 1, 2, \tag{1}$$

where x and y are inputs to node i, and A_i and B_i are linguistic labels for inputs. In other words, $O_{1,i}$ is the membership function of A_i and B_i. Usually $\mu_{Ai}(x)$ and $\mu_{Bi}(y)$ are chosen to be bell-shaped with maximum equaling to 1 and minimum equaling to 0, such as

$$\mu_{A_i}(x) = exp(-((x - a_i)/(c_i))^2), \tag{2}$$

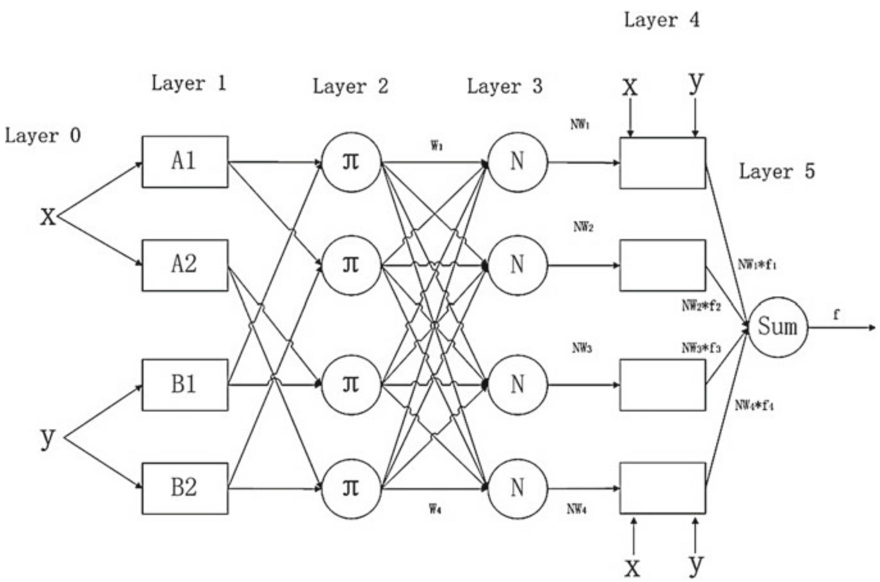

Fig. 1 The structure of regular ANFIS

where a_i, c_i is the parameter set. These parameters in this layer are referred to as premise parameters.

Layer-2: Every node in this layer multiplies the incoming signals and sends the product out. For instance,

$$O_{2,2(i-1)+j} = \mu_{A_i}(x) * \mu_{B_j}(y), \quad i, j = 1, 2. \tag{3}$$

Each node output represents the firing strength of a rule.

Layer-3: Every node in this layer calculates the ratio of the rule's firing strength to the sum of all rule's firing strengths:

$$O_{3,i} = \tilde{w}_i = w_i/(w_1 + w_2 + \cdots + w_9), \quad i = 1, 2, \ldots, 4. \tag{4}$$

Layer-4: Every node i in this layer is a square node with a node function

$$O_{4,i} = \tilde{w}_i * f_i = \tilde{w}_i(p_{i,1}x_1 + p_{i,2}x_2), \quad i = 1, 2, \ldots, 4, \tag{5}$$

where w_i is the output of layer 3 and $p_{i,1}$, $p_{i,2}$, $p_{i,3}$ is the parameter set parameters in this layer will be referred to as consequent parameters.

Layer-5: The single node in this layer computes the overall output as the summation of all incoming signals:

$$O_{5,i} = \sum \tilde{w}_i * f_i = \frac{\sum w_i * f_i}{\sum w_i}. \tag{6}$$

2.2 Hamacher T-Norm

Hamacher T-norm as a kind of T-norms with parameter, satisfies boundary conditions ,commutativity, associativity and monotonicity. The parameter of Hamacher T-norm is also monotonous, and its expression is given below:

$$T_\lambda(x, y) = \frac{xy}{\lambda + (1 - \lambda)(x + y - xy)}, \tag{7}$$

where $\lambda > 0$. Especially, when $\lambda = 1$, Hamacher T-norm equals to algebraic product T-norm.

It is easy to recognize that algebraic product T-norm is an special Hamacher T-norm which has a constant parameter λ. However, employing a constant parameter λ is not always appropriate. For any rule, there must be a corresponding parameter λ suited for it. It is wise to use back-propagation algorithm to determine the corresponding λ.

3 Proposed System

The output of layer-2 $O_{2,2(i-1)+j}$ refers to the result of intersection operation between $\mu_{A_i}(x)$ and $\mu_{B_j}(y)$, which means the membership degree that x_1 belongs to A_i and x_2 belongs to B_j. It is common to use algebraic product T-norm "$*$" to deal with the membership degree in intersection operation, but as is well-known that algebraic product T-norm is not proper in any situation. What (7) shows is that, algebraic product T-norm is a special Hamacher T-norm whose parameter is constant to 1. So modifying the parameter to suit to the data pairs is a meaningful way to overcome the dilemma. It is not easy to determine the value of λ that should be served in Hamacher T-norm to handle intersection operation. Iliadis et al. have tried to use other constant λ to obtain better performance but not all always resulted in good situation [1]. It is a good solution to make ANFIS to adaptively select its own λ for each rule. If ANFIS could select λ for each rule respectively, according to the training data pairs, it is more likely to fit to the performance curve and close to the inherent law. Back-propagation Algorithm could be adopted in the process of determining the parameter of each rule, but this method needs to obtain $\frac{\partial T_\lambda(x,y)}{\partial x}$ and $\frac{\partial T_\lambda(x,y)}{\partial \lambda}$ which is the gradient of $T_\lambda(x, y)$.

3.1 Multi-Input Hamacher T-Norm

Calculating $\frac{\partial T_\lambda(x,y)}{\partial x}$ and $\frac{\partial T_\lambda(x,y)}{\partial \lambda}$ is easy, ANFIS may have more than two inputs and how to calculate their gradients is a real problem. More attention should be paid on how to calculate their gradient with more than 2 inputs. Now the definition of multi-input Hamacher T-norm is given below.

$T_\lambda(A_n)$ is multi-input Hamacher T-norm on A_n which has n elements, where $A_n = \{a_1, a_2, \ldots, a_n\}$ and $\forall i \in N^+, 2 \le n, 0 \le a_i \le 1$. $T_\lambda(A_n) = T_\lambda(T_\lambda(A_{n-1}), a_n)$. Especially, when $n = 2$, $T_\lambda(A_2) = T_\lambda(a_1, a_2)$.

The definition given above is recursive definition, in other word the meaning of upper layer is corresponding to the lower one and the lowest is clarified. To express it clearly, a useful tool $\chi^j(A_n)$ has been used. The definition and features of it are given below: $\chi^j(A_n) = \sum_{c_1,\ldots,c_j \in \{1,\ldots,n\}, c_1 \ne \cdots \ne c_j} a_{c_1} a_{c_2} a_{c_3} \cdots a_{c_j}$, where $n \in N^+, n \ge 2$ and $j \in N, j \le n$. Especially, $\chi^j(A_n) = \sum_{c_1,\ldots,c_j \in \{1,\ldots,n\}, c_1 \ne \cdots \ne c_j} a_{c_1} a_{c_2} a_{c_3} \cdots a_{c_j}$. For example, $\chi^2(A_4) = a_1a_2 + a_1a_3 + a_1a_4 + a_2a_3 + a_2a_4 + a_3a_4$.

Corollary 1 *When* $j \ne n$, $\chi^j(A_n) = \chi^j(A_{n-1}) + a_n \chi^{j-1}(A_{n-1})$.

The proof is given in Appendix A.

Corollary 2 *When* $j \doteq n$, $\chi^n(A_n) = a_n \chi^{n-1}(A_{n-1})$.

The proof is given in Appendix A.

Corollary 3 $\frac{\partial \chi^j(A_n)}{\partial a_k} = \chi^{j-1}(A_n \backslash a_k)$*, where* $j, k \in N$ *and* $j, k \neq n$. $A_n \backslash a_k = \{a_1, a_2, \ldots, a_{k-1}, a_{k+1}, \ldots, a_n\}$.

The proof is given in Appendix A.

One evident feature of multi-input Hamacher T-norm is the monotonicity with respect to λ. After concise proof, the feature and the expression of $T_\lambda(A_n)$ are confirmed below:

Proposition 1 $T_\lambda(A_n)$ *is decreasing with respect to* λ*. Especially, when* $\forall i \in [1, n+1] T_\lambda(A_n)$ *and* $a_i \neq 0$, $T_\lambda(A_n)$ *is strictly decreasing with respect to* λ*.*

The proof is given in Appendix B.

Proposition 2 $T_\lambda(A_n) = \frac{\chi^n(A_n)}{\lambda^{n-1} + \sum\limits_{j=1}^{n-1} \lambda^{n-j-1}(1-\lambda)^j \chi^j(A_n) - \sum\limits_{i=1}^{n-1} (1-\lambda)^i \chi^n(A_n)}$.

The proof is given in Appendix B.

Proposition 3 $\frac{\partial T_\lambda(A_n)}{\partial \lambda} = \frac{-\chi^n(A_n) R_n}{Q_n^2}$*, where* $Q_n = \lambda^{n-1} + \sum\limits_{i=1}^{n-1} \lambda^{n-i-1}(1-\lambda)^i \chi^i (A_n) - \sum\limits_{i=1}^{n-1} (1-\lambda)^i \chi^n(A_n)$ *and* $R_n = (n-1)\lambda^{n-2} + \sum\limits_{i=1}^{n-1} \lambda^{n-i-2}(1-\lambda)^{i-1} [(n-1) - (n-1)\lambda - i]\chi^i(A_n) + \sum\limits_{i=1}^{n-1} i(1-\lambda)^{i-1}\chi^n(A_n)$.

The proof is given in Appendix B.

3.2 Multi-Input Hamacher T-Norm Based ANFIS

The proposed model differs from regular ANFIS in that, it makes Hamacher parameter variable and adaptive by adopting back-propagation algorithm, and needs to calculate the gradient with respect to each parameter and input.

As is given above, the gradient of Hamacher T-norm's parameter and inputs have been achieved by Proposition 3. Different from the regular ANFIS, the output of layer-2 for a proposed model which has 3 inputs is given below:

$$O_{2,3^2(i-1)+3(j-1)+k} = T_\lambda(A_3), \tag{8}$$

where $A_3 = \{\mu_{A_i}(x), \mu_{B_j}(y), \mu_{C_k}(z)\}$.

Each rule has same position in regular ANFIS, because their λ have been uniformly set to 1, which hammers the system to find the most significant rule adaptively. However, proposed model's each rule with different λ in the end can lay the foundation for measuring the importance of itself. Both the IF part and the THEN part correlate to the λ and the principle of updating is to minimize the error, which guarantees that updated λ is harmonious to the system. w_i is the weight of ith rule and decreasing with respect to λ according to Proposition 1 and Eq. (8). It means that the less λ leads to bigger w_i, then bigger $\tilde{w}_i$, so the ith rule plays a more important role in proposed model.

In addition, this model involves the field that the others have never touched upon. This field is attached to the improvement in fuzzy reasoning, and it could be combined with the improvement both in fuzzy reasoning and in other process, because it provides a new methodology for handling intersection operation.

With the variable and adaptive parameter, the prediction ability of proposed model may be improved; the parameter is modified according to the gradient and so as to fit to the inherent law. Empirical study will be given in next section, which proves that the proposed one overweighs the regular ANFIS.

4 Simulation

This section presents the source and processing method of original data, provides simulation procedure, evaluating index and corresponding evaluating method.

1. Data Processing

Every input of each dimension should be transformed into the interval [0, 1] by employing Eq. (9), as the final input; Every output should be transformed by employing Eq. (10), which could restore the output.

$$N_{y_i} = \frac{y_i - \min(y)}{\max(y) - \min(y)}, \tag{9}$$

$$y_i = \min(y) + N_{y_i}(\max(y) - \min(y)). \tag{10}$$

2. Model Validation

5-fold cross validation has been used in this study, $E1$, $E2$, $E3$, $E4$ and $E5$ was used to mark the 5 experiments. Let the real stock price of s-th group, the average stock price of test data and the simulation results be marked as y_s, y_s and $\hat{y}_s$ respectively. Two relative index (MAE and MSE) and one absolute index have been employed to validate the simulation performance, in the consideration of relativity and absolution of error. The confine of all error index are given below:

$$MAE = \frac{1}{n}\sum_{s=1}^{n}\left|y_s - \hat{y}_s\right|, \tag{11}$$

$$\mathrm{MAPE} = \frac{1}{n}\sum_{s=1}^{n}\left|\frac{y_s - \hat{y}_s}{y_s}\right|, \tag{12}$$

$$MSE = \frac{1}{n}\sum_{s=1}^{n}(y_s - \hat{y}_s)^2. \tag{13}$$

Among them, MSE played the dominant role and others offered additional decision support.

3. Simulation Results and Analysis

The historical data of Pingan Bank (000001) from 2014-1-4 to 2014-8-29 was downloaded from Shenzheng Stock Exchange, consisted of 155 data pairs. Opening price, close price, maximum price, minimum price and volume of transactions are input while the close price of the next day is output. To begin with, all data has been processed in the way mentioned above, each value has been projected into the interval [0, 1]; furthermore, 5 kinds of experiment data combination consists of train set, validation set and test set were given, and train set were used to train the model while validation set were used to be the stop-criterion; finally, the trained model has been used to predict the output of test set, then the validation index.

Table 1 MSE of proposed ANFIS with different number of clustering centers

Value	E1	E2	E3	E4	E5	Average
MSE	2.0777	2.2004	2.2656	2.1467	0.3439	1.8069
MAE	1.3423	1.4321	1.5323	1.4014	0.9782	1.3372
MAPE	0.2412	0.2873	0.3012	0.2671	0.1702	0.2534

Table 2 Validation index between proposed ANFIS and regular ANFIS

Value	MSE	MAE	MAPE
Proposed ANFIS	1.8069	1.3372	0.2534
Regular ANFIS	2.3729	1.7263	0.4012

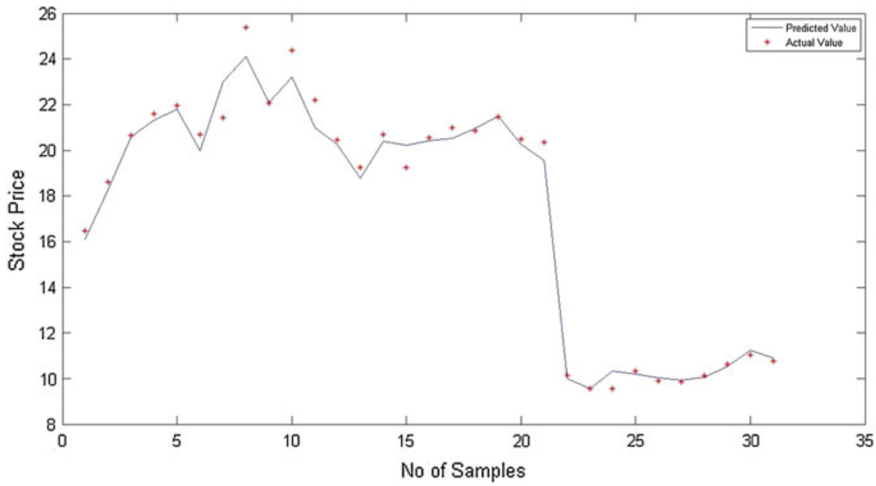

Fig. 2 Comparison between proposed ANFIS results and actual results

Table 1 offers each MSE, MAE and MAPE between simulation result and real price in 5 different experiments, and the average MSE, MAE and MAPE are 1.8069, 1.3372 and 0.2534. Table 2 provides every 3 validation index of proposed ANFIS and regular ANFIS in average, which evidently shows that proposed ANFIS is superior to regular ANFIS. Figure 2 depicts the details between predicted results and real price, which indicates proposed model has an amazing prediction ability.

5 Conclusion

Hamacher T-norm is a wildly used T-norm to handle intersect in fuzzy religion; However, the Hamacher T-norm with multi-input is still unknown. This study gave the expression and some feathers of multi-input Hamacher T-norm first, then constructed the multi-input Hamacher T-norm based ANFIS to learn the intrinsic relation between Pingan Bank close price and its 7 factors, from the train set; finally, comparison between proposed ANFIS and regular ANFIS has been made, while verified the superiority of proposed ANFIS. In all 3 aspects, MSE, MAE and MAPE, the performance of proposed ANFIS overcomes regular ANFIS. In Conclusion, the combination of Multi-input Hamacher T-norm and ANFIS promotes the prediction ability of stock price and other advantages would be found in the future.

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Appendix A

Proof When $0 \leq j < n1 \leq i \leq n$,

$$\chi^{j}(A_n) = \sum_{c_1,\ldots,c_j \in \{1,\ldots,i-1,i+1,\ldots,n\}, c_1 \neq \cdots \neq c_j} (a_{c_1} a_{c_2} a_{c_3} \cdots a_{c_j})$$
$$= \sum_{c_1,\ldots,c_j \in \{1,\ldots,i-1,i+1,\ldots,n\}, c_1 \neq \cdots \neq c_j} (a_{c_1} a_{c_2} a_{c_3} \cdots a_{c_j})$$
$$+ a_i \sum_{c_1,\ldots,c_j - 1 \in \{1,\ldots,i-1,i+1,\ldots,n\}, c_1 \neq \cdots \neq c_{j-1}} (a_{c_1} a_{c_2} a_{c_3} \cdots a_{c_{j-1}})$$
$$= \chi^{j}(A_n \backslash a_i) + a_i \chi^{j-1}(A_n \backslash a_i).$$

Which completes the proof.

Proof When $j \neq n$,

$$\chi^{n}(A_n) = a_1 a_2 a_3 \cdots a_n = a_n(a_1 a_2 a_3 \cdots a_n) = a_n \chi^{n}(A_n).$$

Which completes the proof.

Proof When $0 \leq j < n, 1 \leq i \leq n$,

$$\frac{\partial \chi^j(A_n)}{\partial a_i} = \frac{\partial \chi^j(A_n \backslash a_i)}{\partial a_i} + \frac{\partial(a_i \chi^{j-1}(A_n \backslash a_i))}{\partial a_i} = \chi^{j-1}(A_n \backslash a_i).$$

Which completes the proof.

Appendix B

Proof $\lambda_1, \lambda_2 \in [0, +\infty]$ and $\lambda_1 < \lambda_2$, when $n = 1, T_{\lambda_1}(A_2) = T_{\lambda_1}(a_1, a_2) \geq T_{\lambda_2}(a_1, a_2) \geq T_{\lambda_2}(A_2)$. Especially, when $a_1, a_2 \neq 1$ and $a_1, a_2 \neq 0, T_\lambda(A_n)$ is strictly decreasing with respect to λ. The proposition is confirmed.

Assume when $n = t-1$,the proposition is right too, then when $n = t$, $T_{\lambda_1}(A_{t+1}) = T_{\lambda_1}(T_{\lambda_1}(A_t), a_{t+1}) \geq T_{\lambda_1}(T_{\lambda_2}(A_t), a_{t+1}) \geq T_{\lambda_2}(T_{\lambda_2}(A_t), a_{t+1}) = T_{\lambda_2}(A_{t+1})$. Especially, when $\forall i \in [0, n+1], a_i \neq 1$ and $a_i \neq 0$, $T_\lambda(A_n)$ is strictly decreasing with respect to λ.

Proof The proof is given below: Let

$$\mathrm{Q}_n = \lambda^{n-1} + \sum_{j=1}^{n-1}, \lambda^{n-j-1}(1-\lambda)^j \chi^j(A_n) - \sum_{i=1}^{n-1}(1-\lambda)^i \chi^n(A_n),$$

so $T_\lambda(A_n) = \frac{\chi^n(A_n)}{Q_n}$. When $n = 2$,

$$\begin{aligned} T_\lambda(A_2) &= \frac{a_1 a_2}{\lambda + (1-\lambda)(a_1 + a_2 - a_1 a_2)} \\ &= \frac{a_1 a_2}{\lambda + (1-\lambda)(a_1 + a_2) + (\lambda - 1)a_1 a_2} \\ &= \frac{\chi^2(A_2)}{\lambda^{2-1} + \sum_{j=1}^{2-1} \lambda^{1-j}(1-\lambda)^j \chi^j(A_2) - \sum_{i=1}^{2-1}(\lambda-1)^i \chi^2(A_2)} \\ &= \frac{\chi^2(A_2)}{Q_2} \end{aligned}$$

The proposition is right.

Assume when $n = t$, proposition is right too. So, $T_\lambda(A_t) = \frac{\chi^t(A_t)}{Q_t}$,

$$T_\lambda(A_{t+1}) = \frac{\frac{\chi^t(A_t)}{Q_t} a_{t+1}}{\lambda + (1-\lambda)(\frac{\chi^t(A_t)}{Q_t} + a_{t+1}) - (1-\lambda)a_{t+1}\frac{\chi^t(A_t)}{Q_t}}$$

$$= \frac{\chi^{t+1}(A_{t+1})}{\lambda Q_t + (1-\lambda)\chi^t(A_t) - (1-\lambda)\chi^{t+1}(A_{t+1}) + (1-\lambda)a_{t+1}Q_t},$$

$$\lambda Q_t = \lambda \sum_{j=0}^{t-1} \lambda^{t-j-1}(1-\lambda)^j \chi^j(A_t) + \lambda \tfrac{(1-\lambda)^t - (1-\lambda)}{\lambda} \chi^t(A_t)$$
$$= \sum_{j=0}^{t-1} \lambda^{t-j}(1-\lambda)^j \chi^j(A_t) + [(1-\lambda)^t - (1-\lambda)]\chi^t(A_t),$$
$$(1-\lambda)a_{t+1}Q_t = \sum_{j=0}^{t-1} \lambda^{t-j-1}(1-\lambda)^{j+1} a_{t+1}\chi^{j+1-1}(A_t) + \tfrac{[(1-\lambda)^{t+1}-(1-\lambda)^2]}{\lambda} a_{t+1}\chi^t(A_t)$$
$$= \sum_{j=1}^{t} \lambda^{t-j}(1-\lambda)^j a_{t+1}\chi^{j-1}(A_t) + \tfrac{[(1-\lambda)^{t+1}-(1-\lambda)^2]}{\lambda} \chi^{t+1}(A_{t+1})$$
$$\lambda Q_t + (1-\lambda)\chi^t(A_t) - (1-\lambda)\chi^{t+1}(A_{t+1}) + (1-\lambda)a_{t+1}Q_t$$
$$= \lambda^t + \sum_{j=1}^{t-1} \lambda^{t-j}(1-\lambda)^j \chi^j(A_t) + \sum_{j=1}^{t} \lambda^{t-j}(1-\lambda)^j a_{t+1}\chi^{j-1}(A_t)$$
$$+ [(1-\lambda)^t - (1-\lambda)]\chi^t(A_t) + \tfrac{[(1-\lambda)^{t+1}-(1-\lambda)^2]}{\lambda} a_{t+1}\chi^{t+1}(A_{t+1})$$
$$+ (1-\lambda)\chi^t(A_t) - (1-\lambda)\chi^{t+1}(A_{t+1}))$$
$$= \lambda^t + \sum_{j=1}^{t-1} \lambda^{t-j}(1-\lambda)^j (\chi^j(A_t) + a_{n+1}\chi^{j-1}(A_t) + (1-\lambda)^t f(a_{t+1})\chi^{t-1}_{t-1,f(\cdot)}(A_t) +$$
$$(1-\lambda)^t\chi^t(A_t) - (1-\lambda)\chi^{t+1}(A_{t+1})$$
$$+ \tfrac{[(1-\lambda)^{t+1}-(1-\lambda)^2]}{\lambda} \chi^{t+1}(A_{t+1})$$
$$= \lambda^t + \sum_{j=1}^{t-1} \lambda^{t-j}(1-\lambda)^j \chi^j(A_{t+1}) + (1-\lambda)^t(\chi^t(A_{t+1}) - \chi^t(A_t) + (1-\lambda)^t\chi^t(A_t) +$$
$$\tfrac{(1-\lambda)^{t+1}-(1-\lambda)^2-\lambda+\lambda^2}{\lambda} \chi^{t+1}(A_{t+1})$$
$$= \lambda^t + \sum_{j=1}^{t-1} \lambda^{t-j}(1-\lambda)^j \chi^j(A_{t+1}) + (1-\lambda)^t(\chi^t(A_{t+1}) - \chi^t(A_t) + (1-\lambda)^t\chi^t(A_t) +$$
$$\tfrac{(1-\lambda)^{t+1}-(1-\lambda)^2-\lambda+\lambda^2}{\lambda} \chi^{t+1}(A_{t+1})$$
$$= \lambda^t + \sum_{j=1}^{t} \lambda^{t-j}(1-\lambda)^j \chi^j(A_{t+1}) + \tfrac{(1-\lambda)^{t+1}-(1-\lambda)}{\lambda} \chi^{t+1}(A_{t+1})$$
$$= \lambda^t + \sum_{j=1}^{t} \lambda^{t-j}(1-\lambda)^j \chi^j(A_{t+1}) - \sum_{i=1}^{t} (1-\lambda)^i \chi^{t+1}(A_{t+1})$$
$$= Q_{t+1}.$$

So, $T_\lambda(A_{t+1}) = \frac{\chi^{t+1}}{Q_{t+1}}$.

In conclusion, when $n \in N^+$, $T_\lambda(A_n) = \dfrac{\chi^n(A_n)}{\lambda^{n-1} + \sum\limits_{j=1}^{n-1} \lambda^{n-j-1}(1-\lambda)^j\chi^j(A_n) - \sum\limits_{i=1}^{n-1}(1-\lambda)^i\chi^n(A_n)}$.

Which completes the proof.

Proof $\frac{\partial Q_n}{\partial \lambda} = (n-1)\lambda^{n-2} + \sum_{i=1}^{n-1}(n-i-1)\lambda^{n-i-2}(1-\lambda)^i \chi^i(A_n) - \lambda^{n-i-1}(1-\lambda)^{i-1}$
$\chi^i A_n + \sum_{i=1}^{n-1} i(1-\lambda)^{i-1}\chi^n(A_n)$
$= (n-1)\lambda^{n-2} + \sum_{i=1}^{n-1}(n-i-1)\lambda^{n-i-2}(1-\lambda)^i\chi^i(A_n) - \lambda^{n-i-1}(1-\lambda)^{i-1}\chi^i A_n +$
$\sum_{i=1}^{n-1} i(1-\lambda)^{i-1}\chi^n(A_n) + + \sum_{i=1}^{n-1} i(1-\lambda)^{i-1}\chi^n(A_n)$
$(n-1)\lambda^{n-2} + \sum_{i=1}^{n-1}\lambda^{n-i-2}(1-\lambda)^{i-1}((n-1)-(n-1)\lambda-i)\chi^i(A_n) + \sum_{i=1}^{n-1} i(1-\lambda)^{i-1}$
$\chi^n(A_n) = R_n$.

$$\frac{\partial T_n(A_n)}{\partial \lambda} = \frac{\partial \frac{\chi^n(A_n)}{Q_n}}{\partial \lambda} = \frac{-\chi^n(A_n)R_n}{Q_n^2}.$$

Which completes the proof.

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Projection Pursuit Combinatorial Model and Its Application to Discharged Patients Forecasting

Xinli Zhang, Ting Zhu, Le Luo and Li Luo

Abstract Projection Pursuit is a statistical method to handle high-dimensional data. The key of this method is to find the best projection direction. With the development of computing technology, the genetic algorithm is introduced to improve the optimization of projection direction. Based on the projection pursuit method and the flexible structure of neural network, we propose a projection pursuit combinatorial model (PPCM). The combination strategy is characterized and the process of parameters optimization is offered as well. The PPCM is applied to forecast the numbers of daily discharged patients through 3 years' time series data. Comparing with the forecasting results from ARIMA model, the new model produces a better forecasting performance.

Keywords Projection pursuit · Combined model · Discharged patients forecasting

1 Introduction

Projection Pursuit (PP) is a statistical method to handle high-dimensions data [1], which includes some branches, such as Projection pursuit clustering, principle recognition, projection pursuit regression, projection Pursuit time series, projection pursuit density estimation [2–5]. The key of these PP methods is to find the best projection directions [6]. With the development of computing technology, the genetic algorithm (GA) is introduced to optimizing the projection direction parameters [7, 8]. Comparing with the traditional optimization algorithm, GA presents the better applicability in practice. In the time of big data, some new methods depending on the computer power have been put forward for PP regression and prediction as well [9–11]. To learn the favorable structure of artificial neural network, Hwang [12] proposed projection pursuit learning network (PPLN) for multiple regression analysis, which

X. Zhang (✉) · T. Zhu · L. Luo · L. Luo
Business School, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: zhangxinli1231@163.com

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shows good performance for nonlinear simulation. In Hwang's PP model, the least square method was used to optimize model's parameters. For keeping the PPLN's merit for nonlinear simulation and meanwhile avoiding the optimization demerits of the least square method which requires function to be continuity, this paper constructs a projection pursuit combinatorial model (PPCM) with the structure of multi-inputs to one-output, and introduces Genetic Algorithm to optimize the projection direction, another way, uses the least square method to optimize the other parameters on regression. The overall optimization and realization process of the PPCM is offered as well. As an application example, a multi-factors model has been built for the daily discharged patients forecasting with PPCM. The forecasting performance of this model is then evaluated against a benchmark that is consistent with the assumptions of commonly-used ARIMA model.

The paper is organized as follows. Section 2 introduces some important concepts of Projection Pursuit Regression and Artificial Neural Networks in the paper. Section 3 describes projection pursuit learning network. Section 4 proposes projection pursuit combinatorial model. Section 5 presents the application to forecasting discharged patients, including data, results and corresponding evaluation. Finally, our conclusions are presented in Sect. 6.

2 Projection Pursuit Regression and Artificial Neural Network

Projection Pursuit Regression (PPR) is a special regression method which can treat high-dimension data especially. The basic idea of PPR is to regress after projection, which can decrease the dimensions efficiently. The projection idea can be absorbed in multivariate analysis. Meanwhile, for the nonlinear problem of real data, Artificial Neural Network (ANN) with flexible structure can give better performance in forecasting. So in the new combined model, we introduce PPR to get the projection idea and ANN to form the flexible structure respectively.

2.1 Projection Pursuit Regression

Based on the idea of projection pursuit, Friedman and Stutzel [3] put forward the projection pursuit regression (PPR) method firstly, its main purpose is to estimate smooth functions in high dimensional space, and to approximate the regression function weighted with the numbers of ridge functions. The mathematical expression of PPR is:

$$Y = \bar{Y} + \sum_{m=1}^{M} \beta_m g_m \left(\sum_{j=1}^{p} \alpha_{mj}^T X \right), \ (m = 1, 2, \ldots, M; \ j = 1, 2, \ldots, p), \tag{1}$$

where, X is m-dimensional independent variable, Y is the response variable, $\bar{Y}$ is the mean of the response variable Y, m is the number of approximation function, β_m is the weight value, which means the contribution value of the mth ridge function to the response variable. g_m represents the mth smooth ridge function. α_{mj} is the jth component projection direction of the mth smooth ridge function. p is the dimensions of the input space. Requirements for Eq. (1) are $\sum_{j=1}^{p} \alpha_j^2 = 1, E(g) = 0, E(g^2) = 1$.

2.2 The Artificial Neural Network

In artificial neural network, X is the input variables vector, Y is the output variables vector, the mapping relationship between X and Y may be $Y = f(X)$, which is often complex and unknown in theory. For describing this input-output relationship, the artificial neural network is to imitate the biological nervous system to find the relationship from X to Y. While using a neuron function to describe the input-output relationship, then BP neural network model with p inputs, single-output and three hidden layers has the form as follows:

$$y = \sum_{i=1}^{m} w_i \varphi_i \left(\sum_{j=1}^{p} w_{ji} x_j - \theta_i \right), \tag{2}$$

where, m is the number of hidden layer nodes, p is the number of input-layer nodes, i.e. the number of input variables, w_i is the weight for the ith hidden layer node to the output node, the ith hidden layer neurons function is φ_i, such as S type function, $\varphi(x) = 1/(1 + e^{-x})$, w_{ji} is the weight for the jth input node to the ith hidden layer node, θ_i is the threshold for the ith neuron.

3 Projection Pursuit Learning Network

In order to improve the nonlinear approximation ability of simulation, we construct the flexible structure taking advantages of neural network, and approach the dimensionality reduction idea from PP to create a new projection pursuit combinatorial model (PPCM) to improve the fitting efficiency for nonlinear problem.

The neural network with three hidden-layers has been proved that can approximate any nonlinear function efficiently, so the PPCM structure discussed in this article comes from Hwang's research [12] called Projection pursuit learning network (PPLN), which has multiple-inputs, single-output, and one hidden layer. Another key part of PPLN structure is the form of neurons function, it is *Hermite* function. The orthogonal *Hermite* polynomial fitting the one-dimensional ridge function is Eq. (3).

$$h_r(z) = (r!)^{-\frac{1}{2}} \pi^{\frac{1}{4}} 2^{-\frac{r-1}{2}} H_r(z) \varphi(z), \quad -\infty < z < \infty, \tag{3}$$

where $r!$ represents r factorial; $z = \alpha^T X$; the formula of the standard Gaussian equation φ is $\varphi(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$; $H_r(z)$ is the Hermit polynomial extended as $H_0(z) = 1$, $H_1(z) = 2z, \ldots, H_r(z) = 2(zH_{r-1}(z) - (r-1)H_{r-2}(z))$.

The function of projection pursuit learning network is described as Eq. (4).

$$f(X) = \sum_{i=1}^{M} \sum_{j=1}^{r} c_{ij} h_{ij}(\alpha_i^T X), \tag{4}$$

where, r is the order of *Hermite* polynomial, c is the polynomial coefficient, h represents orthogonal *Hermite* polynomial. According to Eq. (3), the numerical calculation shape of *Hermite* polynomial ($r = 3$) shows in Fig. 1. The curve has some good properties such as continuous and smooth and nonlinear, which are benefit for the calculation of the function parameters.

If polynomial orders r was determined, c can be obtained by least squares method [12], let $Y = (f(z_1), f(z_2), \ldots, f(z_n))^T$, $h = (h_1(z_1), h_2(z_1), \ldots, h_r(z_1))^T$ $(l = 1, 2, \ldots, n)$, then

$$H = \begin{pmatrix} h_1^T \\ h_2^T \\ \vdots \\ h_r^T \end{pmatrix}.$$

Set $C = (c_1, c_2, \ldots, c_r)^T$, to make

$$\min_C \| Y - HC \|^2 . \tag{5}$$

The coefficient c can be derivative as:

$$C = (H^T H)^{-1} H^T Y. \tag{6}$$

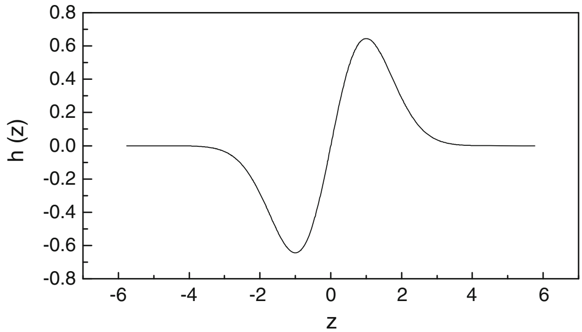

Fig. 1 The curve of Hermit Polynomial ($r = 3$)

In practice, it has been proved that the interpolation and extension performance of the *Hermite* Polynomial interpolation is better than the piecewise linear regression curve in the projection pursuit regression.

Sometimes in order to speed up the convergence, introducing bias terms θ, then the function is changed to:

$$f(X) = \sum_{i=1}^{M}\sum_{j=1}^{r} c_{ij} h_{ij}(\alpha_i^T X - \theta_i), \tag{7}$$

The symbolic names in the above equation are same as the former of Eq. (4).

Comparing Eqs. (7) and (2), if Hermit polynomial represents neurons function, then polynomial coefficients c means weights w, we can find that the form of Eq. (7) are same as ones of Eq. (2), so the optimization strategy for BP is helpful for PPLN as well.

4 Projection Pursuit Combinatorial Model

4.1 The Basic Idea

The BP neural network model and projection pursuit regression model need the more efficient algorithms in the optimization of parameters in order to improve model convergence performance.

Traditional projection pursuit model often uses the Gauss-Newton method to optimize the projection direction. The method to optimize the parameters in this way, often need to solve a matrix equation, which must be continuous derivative, and the derivative matrix must be non-singular matrix. Due to the complexity of real data, it is difficult to fully ensure such requirements and restrictions, so the usages of projection pursuit model to solve some complex problems are affected in practice. This paper introduces the genetic algorithm for PPLN and also finds strategies for optimizing the parameters in Eq. (4). From the view of Eq. (4), two groups of parameters need to be optimizing, which are the projection direction and the polynomial coefficients c.

In this paper, based on the projection pursuit method, added with the flexible structure of neural network and convergence strategy, we propose a new model called projection pursuit combinatorial model (PPCM). In new model, the genetic algorithm is used for the optimization of projection direction a. Another way, because the polynomial is smooth and integrable, so according to the Eq. (6), polynomial coefficient c is calculated using the least squares method, the polynomial order r can be finalized based on experience presupposing. Following that, we introduce the modeling process and discuss the feats of the new model as follows.

4.2 The Modeling Process

The process of parameters optimization using genetic algorithm method and least squares method are developed as follows,

(1) Select the m initial directions, given real number encoding, then calculate the value of one-dimensional projection $z_i = a^T X_i (i = 1, 2, \ldots, n)$, n is the total number of samples;
(2) For the scattered points z_i, y_i, use the orthogonal *Hermite* Polynomial to approach the sample scatters. The optimizing of coefficients c of the polynomial is completed by the least squares method, and then used to calculate $\hat{y}_i$ according to Eq. (4). The optimization objective is maximizing the fitness value $\frac{1}{Q^2}$, Q is from Eq. (8):

$$Q = \frac{1}{n} \sum_{i=1}^{n} (y_i - \hat{y}_i). \tag{8}$$

(3) According to the fitness value, finish the genetic algorithm operation process including hybridization, mutation and selection. Through above GA process, select the 3 m groups of optimum directions at last.
(4) In accordance with the first step 1, re-calculate the objective function (8) again.
(5) Corresponding to the smaller fitness value, select m new generation directions from $3m$ target directions.
(6) Back to the first step to the next cycle optimization, until finish a certain number of cycles.
(7) Corresponding to the minimum value of the objective functions, elect the projection direction and fitting polynomial coefficients c, and then calculate the fitting residual: $R_i = y_i - \sum_{j=1}^{r} c_j h_j (a^T X_i)$. If meet the requirements of the output model index, then go to finish, otherwise.
(8) Use R_i instead of y_i back to the first step of function optimization, until you meet certain requirements, then stop increasing the number of function to output the final results.

The key note in the entire modeling process is the calculation of the objective function. The main purpose of genetic algorithm optimization is to find the best direction of projection. At the same time of optimizing projection direction a, we take into account the optimization of c as well, so that the objective function should be calculated twice in a loop. In model (7) with an error term θ, the optimization algorithm is basically same. θ can be optimized at the same loop of the optimization of the projection direction a.

A large circle of the optimization process is still using the residuals fitting strategy. The learning effect of previous neurons will affect the next neuron in optimization loop. On the other hand, the optimization process for parameter a and c is independent comparatively, every group parameter has its own optimization method.

4.3 The Three Key Issues About PPCM

(1) The model includes three types of parameters which are a, θ, c, the projection direction of optimization is the key work, and good optimization algorithm can improve the quality of the realization of the whole model. The projection direction a is the linear projection matrix of the variables, and can be obtained by derivation of the error in theory. However, the total error cannot be calculated directly, we need a step-by-step iterative optimization method. Threshold θ can be worked as same manner as the optimization of projection direction. Neuron functions based on some parameters are given in the form of such *Hermite* polynomials. Through realizing the minimum total error of the target values, the coefficients can be directed through the derivative of the form given in Eq. (6). Therefore, the last difficulty in optimizing parameters, is that the optimization of the projection direction a.
(2) There are a wide range of options for the fitting function of PPCM. The selecting principle is to achieve the least residual error between sample values and estimating values. Here thinking about nonlinear regression analysis, we use the polynomial to achieve approximation function. For reducing residual error, there are different units' functions in different projection directions.
(3) In order to avoid the phenomenon of over fitting, in the optimization process of neuron function, the adding strategy can be used to determine the number of neuron functions. The strategy is to increase only one unit function in every time, the model's neuron number starts from zero, then increases one by one, and then through the back fitting, from small to large, to finalize the adding of neuron functions. In every adding step, we must insure that the former has got the best fitting.

5 The Application to Forecasting Discharged Patients

The statistical method and artificial neural network has been used to do the research on healthcare. Murante [13] introduced a multilevel approach to looking for the influence of hospitalization experience and institutional, characteristics on inpatient satisfaction. Xu [14] used artificial neural network modeling daily patient arrivals at Emergency Department and quantifying the relative importance of contributing variables. For forecasting time series in health care, Mohammadi [15] offered a new hybrid evolutionary based RBF networks method to forecast emergency supply demand. This paper offers a new model to forecast the amount of a patient flow.
1. Data Selection

As the application of PPCM, a case study on discharge patients forecasting at a typical Chinese teaching hospital is presented. Data used in this case comes from the Healthcare Information System (HIS) of this hospital. The sample data consists of daily discharge amount from year 2011 to year 2013. The data points in three years are more than 1000. We draw time series curve of year 2011 showed in Fig. 2.

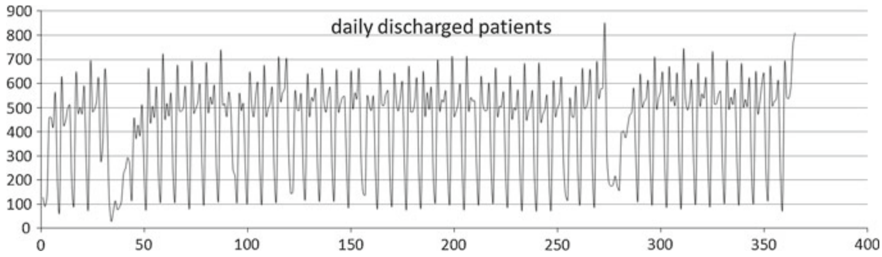

Fig. 2 Daily discharge patients in 2011

In Fig. 2, we can figure out that the sequence is a significant non-stationary, seasonal and cyclical fluctuation. Moreover, the random variable (daily discharge amount) in the sequence shows significant features in a year: (1) the first trough occurs in the first two weeks of February; (2) the second trough occurs in the first week of October. The two troughs respectively take place during the Spring Festival and National Day. In addition, it has significant weekly cyclical feature in the sequence. The cycle time of discharged patients' series is 7 days. That means the variable value of different points in the same week differs a lot. The huge difference between different points in the same week results from the difference of patient amount of outpatient, surgery, preoperative and admission in each day.

2. Input and Output Variables

According above data characteristics, we can conclude that there is a relationship existed in the same date in the different weeks, as to say, the patients time series have weekly autocorrelation. So we could use the discharged patients of last week to forecast the number of this week and produce forecasts for a weekly time series. In our forecasting model, one output variable is the number of discharge patients on Monday, and three input variables include the number of discharge patients on last Monday, last Saturday and last Sunday. The short-range and long-range dependence of discharged patients' series have been considered. Every time series has 155 samples, which can be seen in Fig. 3.

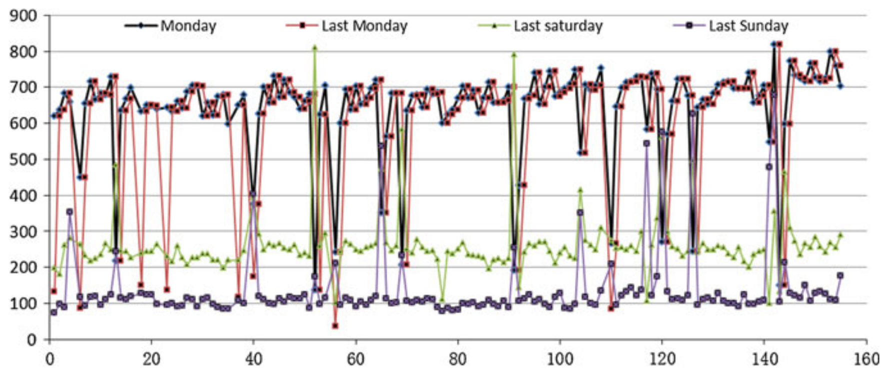

Fig. 3 Time series of input and output variables

3. Forecasting Results

We use above data in Fig. 3 to building PPCM. Through several optimization iterations, the model's parameters are achieved. Tow results calculated with PPCM model show in Figs. 4 and 5. Figure 4 shows the comparing results between actual values and simulation values. Figure 5 shows the percentage of residual error.

From the two figures, we can calculate some performance indexes in Table 1.

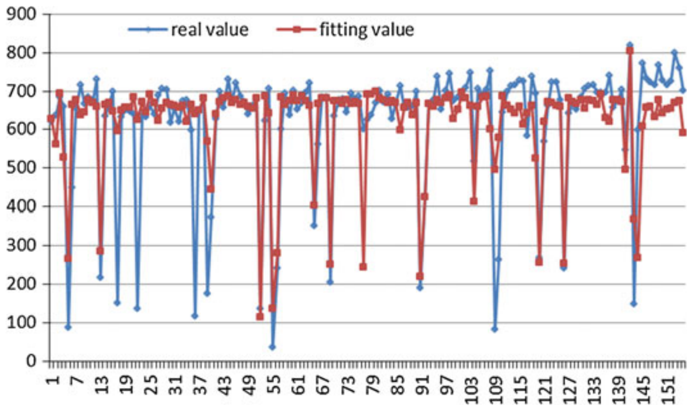

Fig. 4 Real values and simulated values

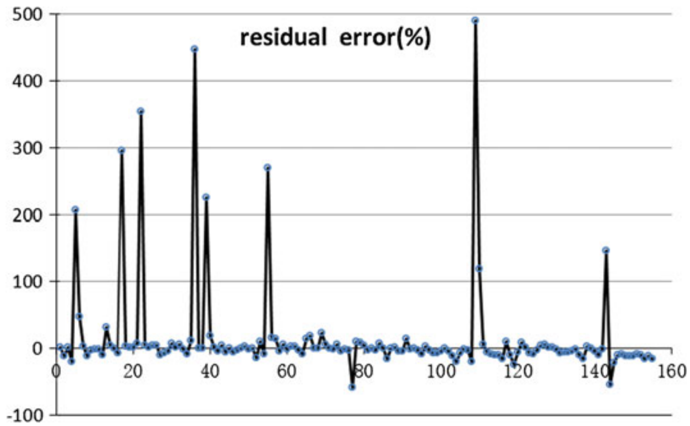

Fig. 5 The residual error (%) of PPCM

Table 1 The fitting performance of PPCM

The percentage of relative error	The Samples size	The percentage of all samples
More than 20 %	12	8 %

The results from Table 1 indicate that PPCM can get good fitting performance for 92 % samples. Furthermore, most of relative errors are less than 10 %, which means the mean numbers of absolute error for every day is less than 70 inpatients. PPCM for simulation discharged patients achieves a certain performance.

Once a step, for evaluating forecasting performance of this model, we give a benchmark that is consistent with the assumptions of commonly-used ARIMA model.

We build an auto-correlated time series models of daily discharged patients with ARIMA, which is a fractional ARIMA (F-ARIMA) model describing the short-range autocorrelation. The final ARIMA model is formed as Eq. (9), which is a seventh-order differential equation below.

$$\text{ARIMA}(1, 0, 1)(1, 0, 1)_7 : (1 - B^7)X(k) = \frac{1 - 0.75467B^7}{1 - 0.32432B}\varepsilon(k). \tag{9}$$

The relative errors of fitting results of the ARIMA model are figured in Fig. 6.

According to Fig. 6, the fitting performance indexes are presented in Table 2.

Comparing the results of Fig. 5 with Fig. 6, the maximum relative error of ARIMA is 900 %, which is larger than 500 % achieved by PPCM. Comparing the percentage of relative error more than 20 %, the number 12 % of ARIMA model in Table 2 is higher than the number 8 % of PPCM in Table 1. According to the above two indexes, the PPCM get the better performance than ARIMA.

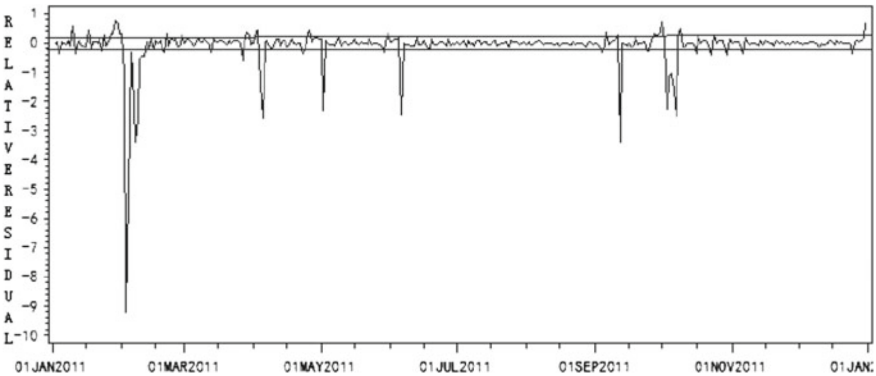

Fig. 6 The residual error (%) of ARIMA

Table 2 The fitting performance of ARIMA

The percentage of relative error	The samples size	The percentage of all samples
More than 20 %	45	12 %

6 Conclusions

On the one hand, a lot of pre-researches indicate that Projection pursuit method (PPM) is good method to dimension reduction of high dimensional small sample data sets; on the other hand, neural network has high nonlinear skills and strong self-learning function. In this paper, using the structure of neural network and combining GA optimization techniques, we compose a new model for multi-dimensional regression named PPCM. The new model is the extended application of projection pursuit theory combined with algorithm, learning strategy and structure. The PPCM's approximating function composed with Hermite spline is more flexible than the "S" shape function of BP neural network. The learning strategy of PPCM is different from projection pursuit regression totally as well. The residuals and additive strategies are used in the building process, which make the fitting performance of PPCM to be improved step by step. For two optimization methods, such as the least square procedure and genetic algorithm are used in the same model, PPCM would have much more adaptability to real data.

According to data's characters of discharged outpatients, the PPCM forecasting model of patients' numbers on Monday is proposed, which offers a new multiple forecast method to discharged outpatients flow. The forecasting results demonstrate that the new coupled model with projection pursuit regression and artificial neural network can be used to the simulation of real data. Another, the forecasting performance of some special samples such as maximum or minimum value is not good, so the prediction accuracy of PPCM still need to be improved in application.

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Impact of Faculty Demographic Characteristics on Educational Interaction via Social Media

Komal Mushtaq and Rana Rashid Rehman

Abstract In this hi-tech era, use of social media provides additional avenues and is a major contributor in all walks of life, hence it is effectually applicable in education sector. This study particularly addresses the use of social media for educational interaction. It explores the influence of demographic characteristics on the use of social media in faculty members. 354 members employed in federal chartered universities of Pakistan are selected on the basis of convenience sampling. Questionnaire was used for this data collection. In order to check the possible differences in the means of different demographic groups, this study applied Mann-Whitney Test and Kruskal-Wallis Test. The findings of the study are significant since they provide a better insight to the impact of demographic characteristics of faculty when it comes to use of social media. This study can find many utilities as it serve as a guideline for Higher Education Commission of Pakistan striving to establish digital universities. Results are helpful for Higher Education Institutions administration to modify the curriculum and study policies to improve quality and engagement of both faculty members and students in and outside universities.

Keywords Demographic characteristics · Educational interaction · Social media

1 Introduction

Higher education institutions (HEIs) play the role of leadership in development and sustainability of a nation. In developing countries these institutes are putting effort to move away from the academic notion of instruction to the training of high-level manpower for national development. Today 155 universities and degree awarding institutes are recognized by HEC in Pakistan (HEC, 2014). There are total 16 recognized public and private sector federal chartered HEIs. 4378 permanent faculty

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K. Mushtaq (✉) · R.R. Rehman
School of Management Sciences, Quaid-i-Azam University,
Islamabad 44000, Pakistan
e-mail: komal.sagittarian@gmail.com

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members are serving in these HEIs (HEC, 2008). Focal point of HEC is high learning of education, research, and development by e-universities in Pakistan. One possible reason for this focus can be the quantum leap in the development and exploitation of information technology by social media is changing the role of higher education institutes in the globalized world [29]. Likewise, sociability is natural in humans [8], therefore, the educational interaction between faculty and students is certain. For this purpose, social media by all means is the fastest medium of interaction. In addition, the rapid transition of industrial societies to information societies has led the individuals with diverse demographic characteristics in HEIs to utilize social media. This study is about the use of social media for educational interaction under the influence of demographic characteristics among the faculty members of HEIs located in twin cities of Pakistan.

Concept of social media evolved in 1971 with the introduction of E-mail [24] and has been researched from different perspectives [1, 7, 10, 13, 19, 21–23, 26]. However, little attention has been given to educational interaction by social media from the perspective of demographic characteristics [6]. No matter what is the utility objective behind educational interaction on social media, the demographic characteristics of faculty cannot be ignored. This study, therefore, aims at identifying impact of demographic characteristics in use of social media for educational interaction.

2 Literature Review

Using social media is among the most common activity and pedagogical strategy of today [9]. As social media begins to draw attention of academicians, researchers have begun to explore the characteristics of social media users. Yet, most studies have been focusing on specific social networking site and target mainly young users [2, 3, 11, 25, 28]. Not only young students but faculty have created social networking sites profiles to connect with their students in a more personable, informal and virtual space [20, 27]. Literature suggests, that gender [14–18], age [11, 14, 28, 31], job position [4, 14] and sector of employment [5, 12, 30] impact faculty social media usage.

Ul Haq and Jackson [15, 17] found that there is no significant difference in use of social media based on gender, whereas Barker et al. [3, 16, 18, 25] reported dissimilarity in use of social media. Hampton [14] reported that nearly twice as many men (63 %) as women (37 %) use LinkedIn, but all the other social networking platforms have significantly more female users than male users. Literature has consensus that teenagers or younger use social media the most. Social media loses its edge among adults [23]. As faculty members moves to higher job position their reluctance and disbelief in the use of technology increases [4]. Hampton [14] points out prominent generational differences in how faculty experience the effect of digital technologies in their professional lives. Fyfe et al. [5, 12, 30] reported public sector as a major producer and user of technological innovations.

Table 1 Hypotheses for study

	Hypotheses for study
Hypothesis 1 (H1)	There is significant differences in use of social media in faculty members based on gender
Hypothesis 2 (H2)	There is significant differences in use of social media in faculty members based on age
Hypothesis 3 (H3)	There is significant differences in use of social media in faculty members based on job position
Hypothesis 4 (H4)	There is significant differences in use of social media in faculty members based on sector of employment

In a nut shell, it is difficult to generalize the impact of demographic characteristics on use of social media by faculty members. Previous studies focus mainly on lone demographic characteristic and their findings are inconsistent. Moreover, these studies are mostly conducted in western countries. Developing countries have cultural, social, economic and other differences, making generalization of results difficult. This study, therefore, aims to fill the gap by considering impact of gender, age, designation and sector of employment of faculty members on use of social media in a developing country, Pakistan. For this purpose; this study attempts to formulate hypothetical link Table 1 for social media usage by consolidating all the demographic variables, identified as important in the discussed literature, to assess their impact on educational interaction.

3 Methodology

The purpose of conducting this study was to measure the impact of demographic characteristics, on the educational interaction via social media. Therefore, this study was conducted in higher education sector of Pakistan. 354 respondents are selected based on convenience basis. Data was collected using a questionnaire. The respondents of this study were limited to faculty members employed in the federal chartered universities of Pakistan. These federally chartered universities are 16 (13 public, 3 private) in number and are located in the twin cities (Rawalpindi and Islamabad) of Pakistan. The greater Islamabad-Rawalpindi metropolitan was selected as it has engrossed people from all over the country. Percentages and the frequencies of each characteristic is given in Table 2.

Above table suggests that sixty-five (65.3 %) percent of the respondents are male whereas 34.7 % are the female faculty members. Reason for smaller number of female as compared to male is that the female participation in work-force of Pakistan is very low. According to Pakistan Bureau of Statistics (2011) percentage of working women in Pakistan is only 24.4 %. World Development Report (2012) reveals a percentage of 28.

Table 2 Demographic characteristics of the respondents

	Characteristics	Frequency	Percentage
Gender	Male	231	65.3
	Female	123	34.7
	Total	354	100.0
Age	20–30 years	74	20.9
	31–40 years	145	40
	41–50 years	95	26.8
	51–above	40	11.3
	Total	354	100.0
Sector	Public	288	81.4
	Private	66	18.6
	Total	354	100.0
Designation	Lecturer	181	51.1
	Assistant Professor	104	29.4
	Associate Professor	44	12.4
	Professor	25	7.1
	Total	354	100.0

Sample size = 354

Respondent's data further identify that 20.9 % are in age bracket of 20–30 years, 40 % in bracket of 31–40 years, 26.8 % in bracket of 41–50 years whereas 11.3 % are 51 years old or above. In Pakistan HEIs employ fresh graduates, therefore fine percentage of faculty members lie in age bracket of 20–30 years. One possible reason for more number of faculty members in age bracket of 31–40 is a good position in higher education sector demands the individual to be highly educated and having some professional experience. 31–40 years is a practical age to get a higher degree along with some experience. Likewise, fair number of respondents lie in age bracket of 41–50. However, the number of respondents decreases with increase in age because in Pakistan retirement age is 60 years.

Data on the sector of employment suggest that 81.4 % of faculty members are serving in public and 18.6 % are associated with private HEIs. This huge difference is due to the fact that among 16 federal chartered HEIs 13 are public making larger part of sample, and only 3 are private therefore contribution in sample is smaller.

Furthermore, Table 2 shows that among respondents 51.1 % are serving as lectures, 29.4 % as assistant professor, 12.4 % as associate professors and 7.1 % as professors. Immense percentage of lecturers is possibly due to more number of available posts, which require individual with masters' degree having a few years or no experience. Competition and less number of posts that demand experienced higher degree holders are contributors to the fact that higher the designation lesser the employed individuals are.

To run the needed statistical tests, there is need to check the normality of data to spot the suitable statistical tools. Therefore, Shapiro-Wilk test is utilized to investigate

Table 3 Shapiro-Wilk test of normality based on dimensions of study variables

Variable	Shapiro-Wilk test	
	N	P
Educational interaction via social media	354	0.000

Sample size = 354

Table 4 Mann-Whitney test of social media usage based on gender differences

Variable	Gender	N	Mean	P
Educational interaction via social media	Male	231	182.36	0.220
	Female	123	168.37	

Significance level is at 0.05, sample size = 354

the normality of data as it is more suitable normality test for the sample size less than 2000. Results of the analysis show that at 95 % confidence interval the data is not normally distributed, as $p < 0.05$ (Table 3), therefore, to analyze the impact of gender and sector of employment on educational interaction by social media Mann-Whitney Test and to analyze the impact of age and job position Kurskull-Wallis Test is employed.

The demographic characteristic gender was tested for its impact on educational interaction via social by Mann-Whitney Test. Results of the analysis ($p > 0.05$) signify that there is no difference between male and female faculty members based on social media usage (Table 4). Therefore, it can be concluded that the propensity to interact on social media between both the categories of gender is approximately same. On the basis of the above statistics, the hypothesis 1: there is significant differences in use of social media in faculty members based on gender, has been rejected.

Potential differences in social media usage based on age group of faculty members Kruskal-Wallis test is used as shown in Table 5. Analysis shows that there are differences among different age group of faculty members ($p < 0.05$). Use of social media decreases with increase in age. Faculty members falling in age group 20–30 years use social media the most ($M = 238.92$, $p = 0.036$). On the basis of the above statistics, the hypothesis 2: there is significant differences in use of social media in faculty members based on age, has not been rejected.

Likewise, to analyze the potential differences based on job position of faculty members are calculated through Kruskal-Wallis test as shown in Table 6. Analysis

Table 5 Kruskal-Wallis test of social media usage based on age group

Variable	Age	N	Mean	P
Educational interaction via social media	20–30	74	238.92	0.036
	31–40	145	187.29	
	41–50	95	179.09	
	51–above	40	164.34	

Significance level is at 0.05, sample size = 354

Table 6 Kruskal-Wallis test of social media usage based on job position

Variable	Designation	N	Mean	P
Educational interaction via social media	Lecturer	181	218.91	0.021
	Assistant Professor	104	190.76	
	Associate Professor	44	167.89	
	Professor	25	157.76	

Significance level is at 0.05, sample size = 354

Table 7 Mann-Whitney test of social media usage based on university sector

Variable	University sector	N	Mean	P
Educational interaction via social media	Public	288	179.24	0.504
	Private	66	169.92	

Significance level is at 0.05, sample size = 354

shows that exist differences ($p < 0.05$) among different designations of faculty members based on social media usage. Faculty members working as lecturer use social media the most. Hence, the hypothesis 3: there is significant differences in use of social media in faculty members based on job position, has not been rejected.

At last, the potential differences based on sector of employment is analyzed through Mann-Whitney test as shown in Table 7. Statistical figures of the analysis denote social media usage is statistically insignificant ($p > 0.05$) between public and private sector faculty members. On the basis of the statistics, the hypothesis 4: there is significant differences in use of social media in faculty members based on sector of employment, has been rejected.

Following Table 8 shows the summary of the results obtained by the hypotheses testing for the study.

Table 8 Summary of results obtained

	Summary of results obtained	
Hypothesis 1 (H1)	There is significant differences in use of social media in faculty members based on gender	Rejected
Hypothesis 2 (H2)	There is significant differences in use of social media in faculty members based on age	Not rejected
Hypothesis 3 (H3)	There is significant differences in use of social media in faculty members based on job position	Not rejected
Hypothesis 4 (H4)	There is significant differences in use of social media in faculty members based on sector of employment	Rejected

4 Discussion and Conclusion

This study basically aimed at checking the demographic predictors of the educational interaction via social media. The predictor variables of this study (age, gender, job position and sector of employment) were analyzed to check their impact on social media usage of faculty. The results of this study signify that age and job position of faculty members has an impact on educational interaction via social media. The other demographic factors could not find an impact in predicting social media usage of faculty.

The results regarding gender are in line with previous studies [15]; Jackson [17] who report no significant difference in use of social media for educational interaction based on gender of an individual. This is most possibly because prevalence of gender inequality has been minimized in today's global world. Boys and girls, women and men are equally involved in the access and use of technology. Similarly, findings about age are consistent with the literature [14, 23] that display significant impact of age on educational interaction via social media. The reason being social media is the perfect tool for attracting the early adopters of technology. With the increase in age one moves to higher job level. Therefore, findings of Bennett [4], Hampton [14] are aligned with the results regarding job position as they indicated generational differences in use of social media. Social media as a teaching tool has a collaborative element. At lower level mostly young teachers are employed who are more interested in socialization, therefore they are more flexible and are frequent users of social media. Moreover, at lower levels faculty members are usually less experienced, therefore they need to interact more with students to settle all academic content not only in university but at home. This increases the need of more educational interaction for which social media is really a striking medium. However, results are not consistent with the literature [5, 12, 30]; who considered public sector as a major producer and user of technological innovations. One possible reason is limited literature highlighting difference between use of social media in public and private sector. Higher education sector is highly influenced by technology today and every institution either public or private is striving for digitalization, therefore, there exist no difference.

It is concluded that regardless of gender and sector of employment, faculty members falling in age bracket of 20–40 years, mostly serving at post of lecturer and assistant professor frequently make educational interactions with their students via social media. Educational interaction via social media is an efficient and business-like way for university campaigns, event updates, real-world way out to teachers' need to keep in close contact with students, overall quality of engagement, social support networks for once students arrive on campus, individualization of learning, comfort of exhibiting the content, virtual laboratories, increase in learners' technology proficiency and social skills.

5 Implications

Findings of the study will serve as a guideline for HEC Pakistan striving to establish e-universities by introduction of technology and popularizing the usage of digital gadgets. Moreover, for HEIs administration this study is helpful in modifying the curriculum and study policies. Developing countries are striving for improving the quality of education, an added advantage of this study, will be engagement of both faculty members and students not only within universities but wherever there is a need for educational interaction.

6 Limitations and Future Directions

This study has a few limitations; therefore, the findings need to be interpreted in view of that. Firstly, the data was collected only from the faculty members. Educational interaction, however, is a two way process including both faculty members and students therefore, studies focusing on characteristics of students influencing usage of social media can be conducted. Secondly, this study is limited to the Pakistani culture and considered most influencing demographic characteristics, therefore, the results cannot be generalized globally. Studies in other countries, may include moderating and mediating impact of characteristics, and can help get more wide-ranging and generalized impact.

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A Coupled Method of Meshfree Poly-Cell Galerkin and Finite Element for Elasticity Problems

Jie Ma and Kaiming He

Abstract This paper developed a new method named as MPG/FEM method which is constructed by coupling the meshfree poly-cell Galerkin method (MPG) with the finite element method (FEM) for the analysis of elasticity problems. The present MPG/FEM method synthesizes the advantages of both FEM and MPG. MPG/FEM method not only simplifies the implementation of essential boundary conditions like FEM, but also inherits good accuracy from MPG. The numerical tests in the present work demonstrate that the results obtained by MPG/FEM method show an excellent agreement with the theoretical results. The coupled method is very accurate and has a promising potential for the analyses of more complicated elasticity problems.

Keywords Coupled technology · Meshfree · Poly-cell local support · Finite element method · Elasticity problems

1 Introduction

The finite element method (FEM) has been widely applied to solve various types of problems in science and engineering in the past several decades [1]. However, due to its strong reliance on element mesh, it is always difficult (or even impossible) to simulate some problems such as large deformation problems with severe element distortions, crack growth problems with arbitrary and complex paths which do not coincide with original element interfaces, and the problems of breakage of material with large number of fragments [2]. In order to eliminate these shortcomings, the meshfree methods (MMs) have been developed and achieved remarkable progress in the recent years. They include the smoothed particle hydrodynamic method (SPH) [3, 4], the element-free Galerkin method (EFG) [5], the reproducing kernel particle method (RKPM) [6], the meshless local Petrov-Galerkin method (MLPG) [7, 8], etc.

J. Ma (✉) · K. He
Sichuan Institute of Building Research, Chengdu 610081, People's Republic of China
e-mail: wanfeng1004@126.com

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As elements are necessary in FEM, the integration cells based on background mesh are also required in EFG regardless of the actual geometrics. Compared with FEM, MMs have more difficulties in accurate integration, for the boundaries of integration domains do not align with shape function supports [9]. Then, MLPG is developed to waive the background cells [7], however, it resulted in an unsymmetrical stiffness matrix and obviously led to additional difficulties and extra expenses for analysis. The stabilized conforming nodal integration method is presented thereafter, but the nodal volume is not easy to evaluate [10], especially for 3D problems with complex geometries. To evaluate the volume of nodal support, the Voronoi diagram [11, 12] and other meshfree methods based on it [3, 13, 14] are adopted, nevertheless, the generation of Voronoi diagram is much more time-consuming and expensive than Delaunay triangulation which is widely used in standard FEM [15, 16].

The meshfree poly-cell Galerkin method (MPG) [17] employed the ploy-cell which is the local support domain surrounding the node and it can make sure of the alignment of integration domains with shape functions supports. Moreover, unlike the standard moving least-square approximation (MLS) applied in EFG and MLPG, an improved MLS is introduced in MPG which can avoid the frequent matrix inversion and improve the computation efficiency. However, like other MMs, the shape functions of MPG do not satisfy the Kronecker delta property, and the treatment of essential boundary conditions is not as straightforward as that in meshbased methods.

In order to tackle these problems, a coupled method has developed. The present work introduces a new simulation method called MPG/FEM method, it couples MPG with FEM to synthesize their advantages and overcome their shortcomings. In MPG/FEM method, the research domain is divided into two types of sub-domains: the first type of sub-domain which needs to impose essential boundary conditions is simulated by FEM, the other type of sub-domain is simulated by MPG, and these two parts are connected by transition domain which is the subdomain of the second sub-domain. The transition domain of MPG and FEM are discretized by interface elements, and a hybrid displacement approximation is defined to make sure that the shape functions of these interface elements can satisfy the delta Kronecker property.

This paper is organized as follows. Section 2 gives a brief description of MPG including the construction of poly-cell local support domain, MLS approximation and discrete equations for elasticity problems. Section 3 presents the coupled method of MPG and FEM and briefs the coupling technique. Section 4 gives two typical numerical examples of the present MPG/FEM method. Finally, some conclusions are drawn in Sect. 5.

2 Improved Poly-Cell Galerkin Method

In the construction of MPG trail function, the influenced domain is confirmed by poly-cell, and the moving least-squares approximation (MLS) method is widely used to construct shape functions.

2.1 Poly-Cell Support Construction

In the construction of MPG trial function, the influenced domain possessed by an interested node should be confirmed firstly. Unlike the traditional MMs, whose influenced domain is usually a circular domain centered by the interested node, the influenced domain of MPG is confirmed by poly-cell, as shown in Fig. 1. In the poly-cell local domain, a background mesh is firstly generated that may cover the whole research domain. The background mesh can be either Voronoi diagram or regular mesh [15], and the regular mesh is preferred in this paper. For an arbitrary node, its host cell needs to be found firstly, and then the local support domain can be obtained by extending the size of its host cell in four directions (x_+, x_-, y_+, y_-) [17]. The extending distance in direction x_+ of the given node can be expressed as: $d_{eI}^{x+} = n_e c_x$, where c_x is the size of host cell in the x direction, n_e is a constant integer ($n_e = 1$ in this work). The extending distances in other directions are obtained in the similar way.

After obtaining the local support, the weight function requires to be defined based on this poly-cell local domain. Suppose a node I has a local support shown in Fig. 2, then the weight function of node I is defined by $w_I(x, y) = f(x)g(y)$, in which

$$f(x) = \begin{cases} e^{-\beta\left[\frac{x-x_I}{0.5(x_I^{\max}-x_I^{\min})}\right]^2}, & \text{if } x_I^{\min} \le x \le x_I^{\max} \\ 0, & \text{else,} \end{cases} \tag{1}$$

$$g(y) = \begin{cases} e^{-\beta\left[\frac{y-y_I}{0.5(y_I^{\max}-y_I^{\min})}\right]^2}, & \text{if } y_I^{\min} \le y \le y_I^{\max} \\ 0, & \text{else,} \end{cases} \tag{2}$$

where β is a constant parameter, which will be studied in Sect. 4.

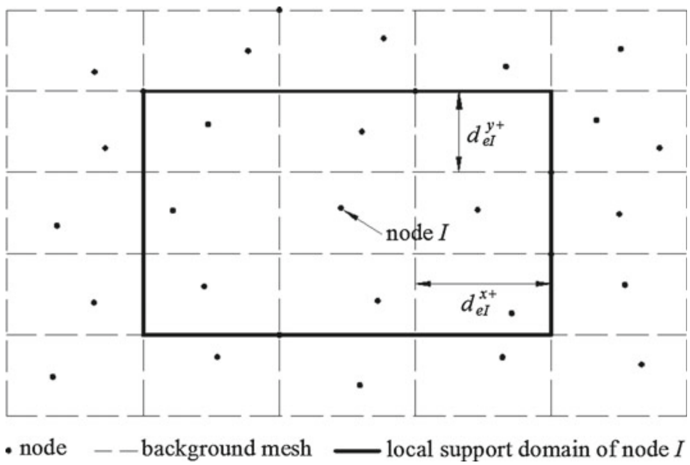


Fig. 1 Schematic of constructing poly-cell local support based on regular background mesh

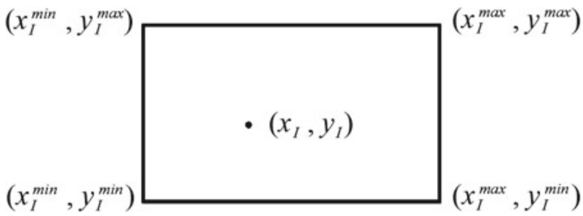


Fig. 2 A sampling local support of interested node I. *Note* This node may not be at the center of the support domain

2.2 Moving Least-Squares Approximation

Lancaster and Salkauskas [18] presented moving least-squares approximation (MLS), which is widely applied to form trial functions in MMs. Consider a field $u(x)$ defined in the 2D domain Ω with boundary Γ, which can be approximated in the following form:

$$u^h(x) = \sum_{i=1}^{m} p_i(x)a_i(x) = p^T(x)a(x), \tag{3}$$

$$p(x) = \left[p_1(x), p_2(x), \ldots, p_m(x)\right]^T, \tag{4}$$

$$a(x) = \left[a_1(x), a_2(x), \ldots, a_m(x)\right]^T, \tag{5}$$

where $p(x)$ is the vector of basis functions $p_i(x)$ built by the Pascal's triangles, $a(x)$ is the vector of unknown nodal parameter of the field $u(x)$, x is the space coordinates, and m is the number of basis functions.

To determine $a(x)$, a quadratic function $J(x)$ is constructed by the value of approximation function $u^h(x)$ and field function $u(x)$ at arbitrary node i:

$$\begin{aligned} J(x) &= \sum_{i=1}^{n} w_i(x)\left[u^h(x_i) - u(x_i)\right]^2 \\ &= \sum_{i=1}^{n} w_i(x)\left[\sum_{i=1}^{n} p_j(x_i)a_j(x_i) - u_i\right]^2, \end{aligned} \tag{6}$$

where n is the number of nodes inside and on the boundary line of the local support, and $w_i(x)$ is the value of the weight function. The partial derivative of $J(x)$ with respect to $a(x)$ leads to the following equation:

$$A(x)a(x) = B(x)u, \tag{7}$$

where the moment matrix A and basic matrix B are expressed by

$$A(x) = \sum_{i=1}^{n} w_i(x) p(x_i) p^T(x_i), \tag{8}$$

$$B(x) = \left[w_1(x)p(x_1), w_2(x)p(x_2), \ldots, w_n(x)p(x_n)\right], \tag{9}$$

$$u = (u_1, u_2, \ldots, u_n)^T. \tag{10}$$

Solving Eq. (7) yields:

$$a(x) = A^{-1}(x)B(x)u. \tag{11}$$

Substituting Eq. (11) back into Eq. (3) leads to:

$$u^h(x) = p^T(x)A^{-1}(x)B(x)u = N(x)u, \tag{12}$$

$$N(x) = p^T(x)A^{-1}(x)B(x), \tag{13}$$

where $N(x)$ is the vector of MLS shape functions.

In the improved MLS approximation, the Schmidt orthogonalizing formulas is imported to orthogonalize the vector of basis functions $r(x)$. Substituting $r(x)$ as $p(x)$ into equations of the standard MLS. A similar form of equations will be obtained as follows:

$$A(x) = \sum_{i=1}^{n} w_i(x) r(x_i) r^T(x_i), \tag{14}$$

$$B(x) = \left[w_1(x)r(x_1), w_2(x)r(x_2), \ldots, w_n(x)r(x_n)\right]. \tag{15}$$

Since the vector r is an orthonormalized vector, matrix A will be an identical matrix, and then the modified shape functions simplified as:

$$N(x) = r^T(x)B(x). \tag{16}$$

The advantage of using orthogonalized basis functions is that it not only reduces the computational cost, but also improves the accuracy of interpolation [19].

2.3 Discrete Equations

Consider a solid problem defined in domain Ω bounded by $\Gamma(\Gamma = \Gamma_t + \Gamma_u)$, the governing equations of the problems can be expressed as follows:

$$\nabla\sigma + b = 0 \ \ (\text{in} \ \ \Omega), \tag{17}$$

$$\sigma \times n = \bar{t} \quad (\text{on } \Gamma_t), \tag{18}$$

$$u = \bar{u} \quad (\text{on } \Gamma_u), \tag{19}$$

where ∇ is the divergence operator, $\sigma = [\sigma_x, \sigma_y, \sigma_{xy}]^T$ is the stress vector, $u = [u, v]^T$ is the displacement field, $b = [b_x, b_y]^T$ is the body force vector, $\bar{t}$ is the prescribed traction on natural boundary, $\bar{u}$ is the prescribed displacement on essential boundary, and n is the vector of unit outward normal at a point on the natural boundary.

Liu [20] presented the unconstrained Galerkin weak form for elasticity problems as Eq. (20).

$$\int_{\Omega} (L\delta u)^T DLud\Omega - \int_{\Omega} \delta u^T bd\Omega - \int_{\Gamma t} \delta u^T td\Gamma = 0, \tag{20}$$

where L is the differential operator.

In linear elasticity, the material matrix D for plane stress problem and plane strain problem are expressed respectively as Eqs. (21) and (22):

$$D = \frac{E}{1-v^2}\begin{bmatrix} 1 & v & 0 \\ v & 1 & 0 \\ 0 & 0 & \frac{1-v}{2} \end{bmatrix}, \tag{21}$$

$$D = \frac{E(1-v)}{(1+v)(1-2v)}\begin{bmatrix} 1 & \frac{v}{1-v} & 0 \\ \frac{v}{1-v} & 1 & 0 \\ 0 & 0 & \frac{1-2v}{2(1-v)} \end{bmatrix}, \tag{22}$$

where E is Young's modules and v is possion's ratio.

Like FEM, MPG uses the similar global weak form given in Eq. (20). Substituting the approximation equations into Galerkin weak form leads to $Ku = f$, where

$$K_{ij} = \int_{\Omega} B_i^T DB_j d\Omega, \tag{23}$$

$$f_i = \int_{\Gamma_t} N_i^T \bar{t} d\Gamma + \int_{\Omega} N_i^T bd\Omega, \tag{24}$$

$$B_i = \begin{bmatrix} \frac{\partial N_i}{\partial x} & 0 & \frac{\partial N_i}{\partial y} \\ 0 & \frac{\partial N_i}{\partial y} & \frac{\partial N_i}{\partial x} \end{bmatrix}. \tag{25}$$

3 Coupling of MPG and FEM

In order to couple MPG and FEM, the displacement compatibility and the force equilibrium conditions on interface boundary should be satisfied. The hybrid displacement approximation and hybrid shape functions are proposed in MPG/FEM method.

1. Transition Condition

Consider a 2D solid problem whose problem domain can be divided into two parts Ω_1 and Ω_2, and these two sub-domains are connected by the interface boundary Γ_I. FEM is used in Ω_1 and MPG is used in Ω_2 as shown in Fig. 3. In the coupling of MPG and FEM, the displacement compatibility and the force equilibrium conditions on Γ_I should be satisfied.

Thus, the nodal displacements $U_I^{(1)}$ and $U_I^{(2)}$ of node I on Γ_I for Ω_1 and Ω_2 should be equal.

$$U_I^{(1)} = U_I^{(2)} = U_I. \tag{26}$$

And the summation of the nodal forces $F_I^{(1)}$ and $F_I^{(2)}$ of node I on Γ_I for Ω_1 and Ω_2 should be zero.

$$F_I^{(1)} + F_I^{(2)} = 0. \tag{27}$$

In the coupled methods, it is ideal to satisfy the both two requirements. The displacement compatibility is more important and must be satisfied precisely, while the force equilibrium condition could be satisfied approximately by using the method of weighted residuals in some coupled methods [21].

2. Coupling Technique

Due to the shape functions of MPG lacking delta Kronecker property, it is impossible to couple MPG and FEM directly. So, the transition domain is introduced in MPG domain [21], in which the interface elements are discretized and the MLS shape functions are constructed near the interface boundary Γ_I. In these interface elements, a hybrid displacement approximation is defined to make sure that the MLS shape functions in the MPG domain along Γ_I can satisfy the delta Kronecker property. Figure 3 shows the transition domain Ω_I which is a layer of sub-domain

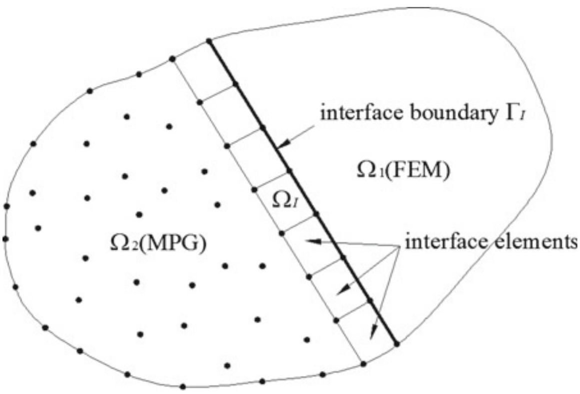


Fig. 3 Interface elements used in MPG/FEM method

along the interface boundary Γ_I within MPG domain Ω_2. The new displacement approximation in MPG domain Ω_2 can be rewritten as

$$u^h(x) = \sum_{i=1}^{n} \tilde{N}_i(x) u_i, \tag{28}$$

where the hybrid shape functions of the interface elements are defined as

$$\tilde{N}_i(x) = \begin{cases} [1 - R(x)] N_i(x) + R(x)\varphi(x), & x \in \Omega_I \\ N_i(x), & x \in \Omega_2 - \Omega_I, \end{cases} \tag{29}$$

where $\varphi(x)$ is the FEM shape functions of an interface element, $R(x)$ is a ramp function and it is performed as

$$R(x) = \sum_{j=1}^{k} \varphi(x), x \in \Gamma_I, \tag{30}$$

where k is the number of nodes located on the interface boundary Γ_I for an interface element. According to the property of FEM shape functions, $R(x)$ will be unity along Γ_I and vanish outside of the interface domain:

$$R(x) = \begin{cases} 1, & x \in \Gamma_I \\ 0, & \Omega_2 - \Omega_I. \end{cases} \tag{31}$$

Therefore, the modified interface shape functions can satisfy both FEM interpolation and MPG approximation, and it means that the coupling of MPG and FEM can satisfy displacement consistency and interpolate a linear field precisely.

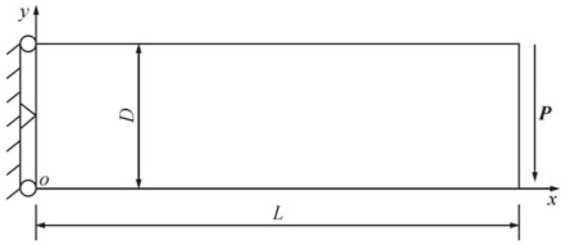
4 Numerical Examples

Two cases of 2D Elasticity problems have been studied in order to examine the properties of the presented MPG/FEM. The variable units used in this paper are based on international standard unit system unless specially denoted.

4.1 Cantilever Beam

A 2D cantilever beam with length L, height D and unit thickness is studied as a benchmark problem here. The beam is fixed at the left end and subjected to a parabolic traction P at the free end as shown in Fig. 4. Timoshenko and Goodier [22] calculated the theoretical solutions in stress for the plain strain case as follows.

Fig. 4 A 2D cantilever beam subjected to parabolic traction on the *right end*



$$\begin{cases} \sigma_{xx} = -\frac{P}{I}(L-x)(y-\frac{D}{2}) \\ \sigma_{yy} = 0 \\ \sigma_{xy} = -\frac{Py}{2I}(y-D), \end{cases} \tag{32}$$

where I is the moment of inertia of $D^3/12$.

The parameters in the computation are taken as: $L = 8$, $D = 1$, $P = -1$, $v = 0.25$, $E = 3.0 \times 10^7$, and the plane strain condition is assumed.

As shown in Fig. 5, the beam is divided into two parts. FEM using the four-node quadrilateral elements is used in the left part where the essential boundary condition is included, and MPG is used in the right part where the traction boundary condition is included. These two parts are connected by the transition region which is a sub-domain of MPG domain and discretized by 10 regularly distributed transition particles. Figure 6 illustrates the error of stress in x direction at the cross-section of $x = L/2$ with different value of β between calculated value and theoretical value. The figure shows the error is smaller with a larger value of β , and β is selected to be 0.8 as the optimal parameter.

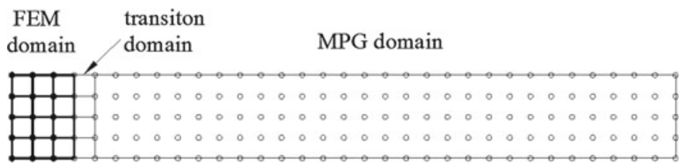
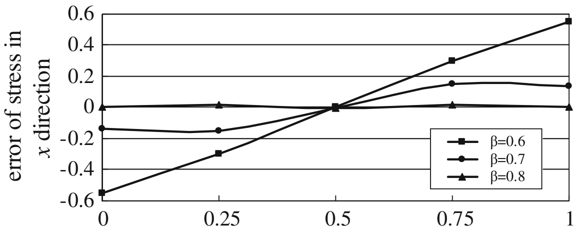


Fig. 5 Discretized model of the cantilever beam

Fig. 6 Comparison for error of stress in x direction at the cross-section of $x = L/2$ with different value of β



4.2 Hollow Cylinder Under Internal Pressure

A hollow cylinder with an internal radius a, an external radius b and unit thickness is considered as another typical problems to validate the MPG/FEM. As shown in Fig. 7, the uniform pressure p is applied to the inner surface ($r = a$), while the outer surface ($r = b$) is free of traction. Due to the symmetry of the problem, only one-quarter of the cylinder is modeled. Also, Young and Budynas [23] gave the theoretical solution.

$$\begin{cases} \sigma_r = \frac{a^2 p}{b^2 - a^2}(1 - \frac{b^2}{r^2}) \\ \sigma_\theta = \frac{a^2 p}{b^2 - a^2}(1 + \frac{b^2}{r^2}) \\ \sigma_{r\theta} = 0. \end{cases} \tag{33}$$

In the numerical computations, the following parameters are chosen: $a = 1$, $b = 5$, $p = 1$, and the plane stress conditions are assumed. The material used is linear elastic with Young's modules $E = 1 \times 10^3$ and $\nu = 0.25$ unless specially denoted.

As shown in Fig. 8, the hollow cylinder is also divided into several sub-domains. FEM is used in the sub-domain where the essential boundary condition is included, MPG is used in anther sub-domain, and these two sub-domains are connected by transition domain. Figure 9 contrasts the solution for stress in radial direction and circumferential direction between theoretical and calculated value by the coupled method with β equals 0.8, and they both show an excellent alignment between the theoretical results and numerical results.

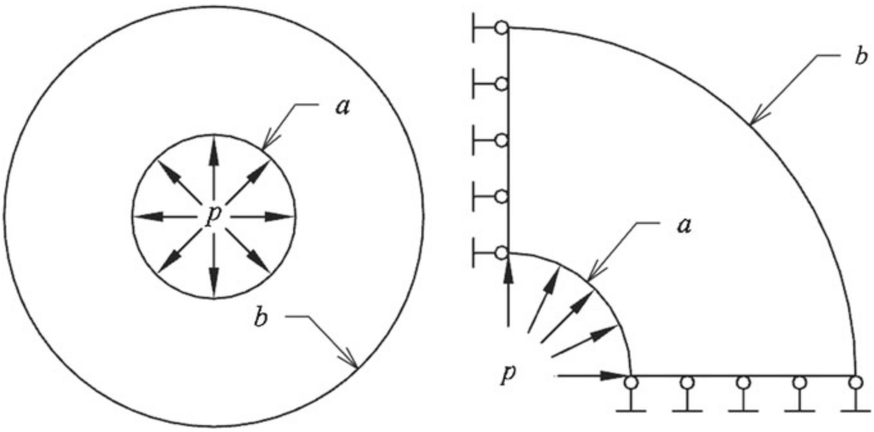


Fig. 7 A hollow cylinder subjected to internal pressure p and its quarter model

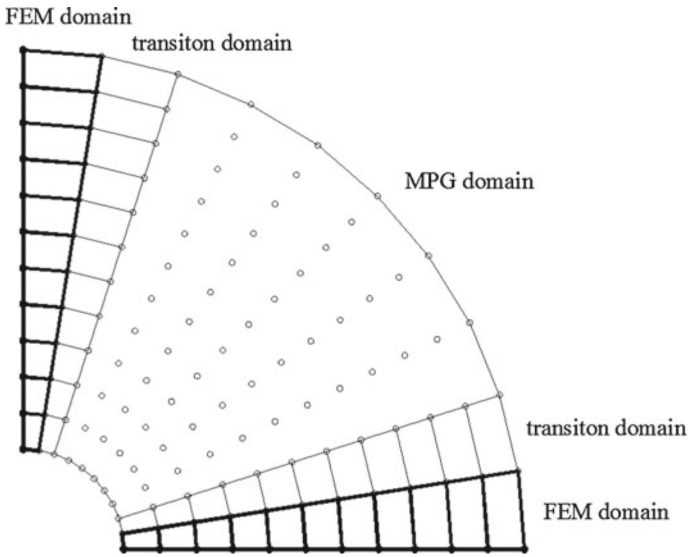


Fig. 8 Discretized model of the hollow cylinder

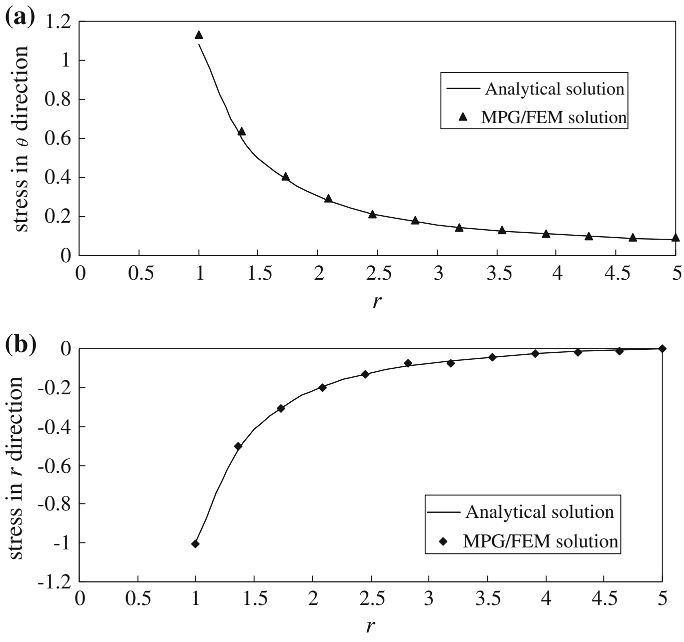


Fig. 9 Comparison of solutions for stress

4.3 Results and Analysis

Numerical examples have shown an excellent consistency between the theoretical and numerical results, and the following can be seen clearly:

(1) The improved poly-cell local support domain guarantees the alignment of integration domain and support of the shape functions, which can significantly improve the accuracy of numerical integration.
(2) Comparing with FEM, the MPG/FEM method is more flexible in dealing with the geometrical boundary, only the essential boundary which is limited in the studied boundary is simulated with the same way to FEM.
(3) Comparing with MPG, the shape functions of MPG/FEM method can satisfy the Kronecker delta property, so it is easier to impose essential boundary conditions.
(4) An excellent agreement has presented by comparing the solutions for stress between the theoretical and numerical results, and it shows the MPG/FEM method has a high precision in dealing with elasticity problems.

5 Conclusions

Formulations of a coupled method named as MPG/FEM method are presented in this paper. Numerical examples such as hollow cylinder under internal pressure, shows an excellent agreement between the theoretical and numerical results. The advantages of MPG/FEM are as follows:

(1) The poly-cell local support domain guarantees the alignment of integration domain and support of the shape functions, which can significantly improve the accuracy of numerical integration.
(2) Comparing with FEM, the MPG/FEM method is more flexible in dealing with the geometrical boundary, only the essential boundary which is limited in the studied boundary is simulated with the same way to FEM.
(3) Comparing with MPG, the shape functions of MPG/FEM method can satisfy the Kronecker delta property, so it is easier to impose essential boundary conditions.
(4) An excellent agreement has presented by comparing the solutions for stress between the theoretical and numerical results, and it shows the MPG/FEM method has a high precision in dealing with elasticity problems.

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The Concept and Typology of Ineffective Work Behavior: A Qualitative Analysis

Hao Zhou and Qian Ma

Abstract To understand work behavior from a wholly different perspective, this article referred to the concept of ineffective work behavior according to the outcome. Data was collected by interview, and analyzed by consensual qualitative research. We divided ineffective work behavior into five types: faulty work behavior, repetitive work behavior, perfunctory work behavior, acting work behavior and failed innovation behavior. Finally, we discussed the remedies for the ineffective work behavior, and proposed several future research orientations.

Keywords Ineffective work behavior · Work result · Qualitative research

1 Introduction

With the globalization of competition and the continuous change, instability of organizational environment, complexity of human relationships and differences of organizational individuals are increasingly apparent [6]. Katz proposed three kinds of behaviors that were vital for the organization, including behaviors employees must perform to join the organization and maintain membership in the organization, behaviors employees must act to fulfill the requirements of specific role and spontaneous behaviors outside the role [9]. Naturally, scholars had begun to explore the in-role behavior and extra-role behavior. And the division of these two behaviors is based on the role specification [8]. However, performing the in-role behavior conscientiously or taking the extra-role behavior actively is not a sufficient condition for the growth of organizational performance [1, 11]. So it is necessary to propose the concept of ineffective work behavior from the perspective of behavioral outcomes.

This study presented idle work as a trigger for ineffective work behavior. On the basis of summarizing relevant research on ineffective work behavior, we employed the method of consensual qualitative research [7]. Following the procedure

H. Zhou (✉) · Q. Ma
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zhouhao@scu.edu.cn

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of "domain-core idea-category", we conducted case analysis and cross case analysis to put forward the concept of ineffective work behavior. We also formed and explained the various categories of ineffective work behavior, and put forward the managerial strategies specifically. Our study makes two significant contributions to the literature. First, we analyzed the concepts and categories of ineffective work behavior to enrich the theories of employees' work behavior. Secondly, we provided remedies for managers to cope with employees' ineffective work behavior.

2 Literature Review

Previous research on ineffective work behavior can be divided into two categories. The first category focused on analyzing some variables that were related to the effectiveness of work behavior, and aimed to improve the effectiveness of work behavior by intervening. For example, Zhang et al. [16] integrated research on the relationships between work motivation and effective work behavior, and found that complex work behavior was more effective under autonomous motivation and mechanical work behavior was more effective under controlled motivation.

The second category focused on analyzing certain conditions under which work behavior became ineffective work behavior. For example, organizational citizenship behavior was believed to be beneficial for improving organizational effectiveness [2, 15]. Recently, more and more scholars had begun to question the effectiveness of organizational citizenship behavior. Impression management motive [10, 12], and the escalation of organizational citizenship behavior made employees no longer good soldiers but good actors [4]. In this situation, organizational citizenship behavior became ineffective work behavior.

In conclusion, the current studies on ineffective work behavior were scattered in different areas. What is ineffective work behavior? What factors constitute ineffective work behavior? How to avoid or reduce the ineffective work behavior for improving task performance? These are the questions this study hopes to answer.

3 Concept of Ineffective Work Behavior

The "ineffective" is interpreted as "invalid and no effect". Reflecting the effectiveness of resource allocation, efficiency was regarded as the ratio of input and output [5]. This interpretation provides an important criterion for judging the ineffective-outcomes. Work behavior referred to a series of stable behavioral responses, which employees used to adapt to the changing work environment and meet the needs of survival and development [14]. By completing tasks or realizing the accumulation of knowledge, ability and experience, these behavioral responses fulfill the needs of employees. Thus, the final state that work behavior should reach (or behavioral outcomes) includes two levels. The first level is to complete the tasks in the short term, in which "time" and "quality" are the measure standards. The second level is to realize the accumulation of knowledge, ability and experience in the long term.

Based on the short-term and long-term criteria, ineffective work behavior also can be divided into two types. One is unable to finish the tasks in short term, and without a long-term accumulation of knowledge, ability and experience, which can be named completely ineffective work behavior. The other is unable to finish the tasks in short term, but with the accumulation of knowledge, ability and experience, which can be named temporary ineffective work behavior.

There are three reasons for adopting the concept of ineffective work behavior rather than the concept of "sabotage" or "loaf". First, employees' sabotage or loaf is driven by subjective intention, while ineffective work behavior can be either intentional or unintentional [13]. Secondly, employees' sabotage or loaf is deviant behaviors in the work process that violate the organizational norms, but ineffective work behavior does not directly reject to the organizational norms [3]. Third, while sabotage or loaf is always negative for the organization, ineffective work behavior has a positive effect in some cases.

4 Methodology

1.Participants

Participants were all from different companies located in a central province of China. The specific personnel distribution was shown in the following Table 1.

2. Interviews

First, the interviewer encouraged participants to talk about their job contents and other work-related situations. By cultivating a relaxed atmosphere, the interviewer released the tension of participants and helped them to recall the usual work, which would be useful for answering subsequent questions. Then, the interviews were carried out around the themes like "list ineffective work behaviors in your work",

Table 1 Personnel distribution of participants

Types of organization	Junior staffs	Middle managers	Senior managers	Total	Percentage (%)
State-owned enterprises	5	7	1	13	35.14
Private enterprises	4	2	3	9	24.32
Government	6	2	/	8	21.62
Schools	2	1	/	3	8.11
Hospitals	2	2	/	4	10.81
Total	19	14	4	37	100
Percentage	51.35 %	37.84 %	10.81 %	100 %	

"list the reasons why ineffective work behaviors occurred in your work" and "list the standards you used to judge ineffective work behaviors". The interviewer interrupted the participants only when the participants' descriptions were not clear and definite. The interviews lasted 20–60 min unequally.

3. Transcription

After interviews, we transcribed interview recordings into texts. When having questions, we confirmed the information through telephone or return visit. The texts contained about 60,000 words in which personal information was removed.

4. Data Analysis

Consensual qualitative research was used for data analysis, and the detailed procedures were as follows. First, we divided all the information related to ineffective work behaviors into three domains: behavioral manifestations, behavioral causes and judgment criteria. Secondly, all the information in each case was classified into three domains we mentioned above and was analyzed to construct core ideas on the basis of remaining the main meaning. As a result, each case was divided into three parts. Then, we gathered and coded the core ideas of the same domain in the different cases. We analyzed and classified the core ideas in "behavioral manifestations", eventually forming the categories of ineffective work behavior. We analyzed and classified the core ideas in "judgment criteria", eventually forming the definition of ineffective work behavior. Finally, we conducted the stability analysis. Specifically, we analyzed 35 cases following the preceding steps and obtained the results. Next, we used another 2 cases to test the generalization of the results. According to the unchanged original results, data analysis of this study turned out to be stable.

5 Results

Our study collected 130 specific ineffective work behaviors through the interviews. We constructed core ideas of each work behavior on the basis of remaining the main meaning, and coded them into the domain "behavioral manifestations". Then, we classified these behaviors into different categories according to the meaning of each behavior. In this process, the discrepancy about classification was discussed with the team and a point of consensus was reached. Ultimately, five categories appeared. We named each category, including faulty work behavior, repetitive work behavior, perfunctory work behavior, acting work behavior and failed innovation behavior. The results were shown in Table 2.

Faulty work behavior refers to employees' work behavior that cannot finish the work tasks in terms of quality and time for the lack of attention and ability. In the work context, employees have to exhibit kinds of work behaviors to achieve the work targets. There is no doubt that employees must make physical and psychological efforts in this process. When they complete tasks successfully, the efforts and resources invested can be seemed to be effective and so as the employees' work behaviors. Otherwise, employees' work is ineffective. According to our data, there were some following reasons for this kind of behavior. Employees didn't forecast the work

Table 2 Five categories of ineffective work behavior

Category	Definition	Number of behaviors	Percentage (%)
Faulty work behavior	Employees' work behavior that cannot finish the work tasks in terms of quality and time for the lack of attention and ability	42	32.31
Repetitive work behavior	Employees' work behavior that is repetitive and unnecessary during the work process	29	22.31
Perfunctory work behavior	Employees' work behavior that is only a "form" and cannot maintain the quality of work for the reason of supervisory unscientific decisions and employees' limited resources	32	24.61
Acting work behavior	Employees' cheating work behavior that is used to make their compensation and bonus reasonable	14	10.77
Failed innovation behavior	Employees' innovative behavior that is unable to bring about actual effects for the organization because of individual and contextual factors	13	10.00
Total		130	100

conditions before performing a task, and the work conditions suddenly changed during the work. Employees didn't understand the work targets and requirements before performing a task. Employees didn't prepare a complete work plan to guide the work process. Employees lacked adequate knowledge, technology, motivation, energy and sense of responsibility, making errors and mistakes in the work. What's more, from the perspective of the team, once an employee made a mistake in the team work, this situation not only leaded to the employee's ineffective work behaviors, but also the team members' ineffective work behaviors. "In our gear processing workshop, if a worker made a mistake on the production line, the work others did before were all waste". Certainly, some participants focused that "I didn't think the mistakes I made in the work were detrimental, because I could draw lessons and avoid these kinds of mistakes next time at least". This means that when we summarize and analyze the main reasons of failures, we should also consider that errors in the work might be beneficial to the accumulation of experience, knowledge and ability.

Repetitive work behavior refers to employees' work behavior that is repetitive and unnecessary during the work process. In the work context, once an employee's work content is the same with other employees', or an employee have to repeat behaviors that are unnecessary for completing the work tasks, this employee may naturally define his or her work behaviors as ineffective work behaviors. "In our company, there was a production director and also a safety director. In fact, the work contents during these two jobs were highly overlapped. As a result, employees in these two positions might perform too many work behaviors that are repetitive". Actually, because of the repeated set of institutions and positions, repeated commands of multiple leaders, traditional work style and conservative work mentality, employees are more likely to repeat the same behaviors during the work process. However, this kind of repetition is needless for the increase of workers' knowledge and technology. "Since there was a large area of water at the gate of company, our leader ordered us to draw water. However, we finished this work the first day and there came the water the following day. As a result, we had to draw water day after day. If one of us had tried to find the source of water, we might not do so many repetitive work behaviors".

Perfunctory work behavior refers to employees' work behavior that is only a "form" and cannot maintain the quality of work for the reason of supervisory unscientific decisions and employees' limited resources. In the work context, one of the most important principles for employees is to obey the supervisors' orders. According to our data, when employees couldn't understand and even doubted supervisors' orders, or they lacked adequate resources to obey the orders, they were still willing to be compliant with other than rejected to the supervisors. As a result, their work behaviors became perfunctory and the work quality greatly reduced. "For some experienced teachers in our school, they already had detailed teaching plans. They just needed to modify the pre-existing teaching plans slightly to adapt to the new students. But in practice, these teachers had to prepare new teaching plans again and again to cope with the supervisors' inspection". In the interviews, most participants considered that this kind of work behavior "not only didn't bring about any benefits, but also disrupted the normal tasks". There were many reasons for employees to obey the supervisors' orders. For example, employees wanted to gain the respect of the supervisors through obeying the supervisors' orders. And some employees believed that being compliant with the supervisors was useful for their promotion. Under such a circumstance, employees' self-doubt gradually decreased and self-anesthesia emerged. This kind of behavior is greatly related to Confucianism-based Chinese culture. High power distance of Chinese employees urges themselves to be obedient to their supervisors unconditionally. And as a result, perfunctory work behavior generated.

Acting work behavior refers to employees' cheating work behavior that is used to make their compensation and bonus reasonable. This is a kind of impression management behavior, which employees use to impress others in the work context. Employees may get the rewards, respect and self-satisfaction to meet their own needs by exhibiting some work behaviors and making a good impression to others. However, if these behaviors are useless for the task accomplishment and ability development, they are ineffective. "Some employees didn't want to work. However, they were forced by supervisors' assessments and accompanying compensation. On balance, they just acted work behaviors without any substantive investment". This was a negative affective state for employees to work. On the contrary, some employees acted work behaviors to win supervisors' and co-workers' attention and recognition. Although these behaviors were also ineffective, employees' affective states were positive. In such a situation, employees were stimulated by positive impression management motives. For this reason, they are easier to be guided by the organizations to a high task performance direction. Furthermore, based on our data, acting work behaviors were inclined to become habitual behaviors. Once acting successfully, employees would devote themselves to keeping a good impression.

Failed innovation behavior refers to employees' innovative behavior that is unable to bring about actual effects for the organization because of individual and contextual factors. Employees have to take risks for putting forward and implementing new ideas about product, work technology, work procedures and so on. One of the most probable risks is that employees cannot obtain achievements after investing energy and resources. Considering that failed innovation behaviors cannot complete work tasks, they are treated as ineffective work behaviors. In face of innovation failures, employees will take two kinds of opposite actions to respond. One is a positive response and the other is a negative response. From the perspective of negative responses, part of employees may avoid innovative behaviors immediately, and the failed innovation behaviors they exhibited before become totally ineffective work behaviors. Conversely, other employees are more pleased to treat innovation failures as the accumulation of experience and knowledge, and the failed innovation behaviors they performed before are just temporary. Surprisingly, all the participants in our research tended to hold positive attitudes in terms of innovation failures and treat failures as a necessary phrase. Unlike four kinds of ineffective work behavior we mentioned above, failed innovation behavior is temporary ineffective work behavior. "Our company needed employees to provide more innovative services for the customers. For example, in addition to drugs, we could also provide drug management information systems for hospitals. However, we often encountered such a situation in which the drug management information system we created for a hospital didn't meet the hospital's demands. Although innovations during this process couldn't make a profit, we still regarded them as useful attempts". It is the existence of temporary failed innovation behaviors that makes the exploration of reasons leading to innovation failures more significant.

Table 3 summarize and distinguish five kinds of ineffective work behavior we analyzed above.

Table 3 Characters of five kinds of ineffective work behavior

Category	Whether work tasks were completed		Whether knowledge, ability and experience were accumulated
	In terms of quality	In terms of time	
Faulty work behavior	No	No	Uncertain
Repetitive work behavior	Yes	No	No
Perfunctory work behavior	No	Yes	No
Acting work behavior	No	No	No
Failed innovation behavior	No	No	Yes

6 Discussion

1. Remedies for Ineffective Work Behavior

The findings of this study also suggest a number of remedies for managers to cope with ineffective work behavior.

To reduce faulty work behavior, managers should strengthen the construction of responsibility systems and make sure that each work has been specially assigned. By guaranteeing that every employee in the workplace is responsible for the different aspects of work and implementing related regulation measures, managers can mobilize the enthusiasms of employees, urge them to make plans and help them to reduce work mistakes.

To reduce repetitive work behavior, managers should simplify the workflow and clear the division of responsibility among employees. On the one hand, by removing some unnecessary work links to simplify the workflow, managers can protect employees from repetitive but unnecessary work behaviors. On the other hand, definite division of responsibility can help employees to perform their own duties.

To reduce perfunctory work behavior, managers can improve the traditional ways of task assignment and allocate tasks combining with the actual situations of employees. When allocating tasks, managers need to evaluate whether these tasks are related, feasible and definite to the focal employee or department. By realizing the fit between tasks and employees, managers can prevent the perfunctory work behaviors effectively.

To reduce acting work behavior, manages can enhance the performance appraisal systems and compensation systems. Focused on task performance and regular performance assessments, managers can constrain employees' acting work behaviors, which are used to acquire compensation and rewards.

Managers should envisage the failed innovation behavior in the workplace. It means that managers should not blame or punish employees when facing innovation failures. By assessing employees' work objectively, creating a relaxed atmosphere and offering opportunities to employees, managers can promote the employees' accumulation of knowledge and experience.

2. Limitations and Future Directions

It should be noted that there were some limitations in this study. For example, participants in the interviews were all from the same region and most participants were working in the state-owned enterprises. These limitations weaken the generalizability of the results found in this study.

In the future research, the theory of ineffective work behavior should be further inspected and discussed. For example, ineffective work behavior may have both positive and negative effects, so the dynamic transformation from ineffective work behavior to effective work behavior should be valued.

Finally, ineffective work behavior of Chinese employees should be unique for the Chinese traditional culture and rapid economy development. Future research should examine ineffective work behavior in different cultural and organizational contexts.

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Research on Quality Evaluation of College Entrepreneurship Education Based on Extension Matter-Element Model

Xiaofeng Li and Suying Xiang

Abstract In order to cultivate students' innovative spirit and practical ability, more and more colleges and universities carry out innovation and entrepreneurship education. How to evaluate entrepreneurship education quality has long been plagued by colleges and universities education sector. Based on matter-element and extension set theories, this article established the multidimensional extension element model for evaluation of the quality of entrepreneurship education, and put forward the evaluation method of entrepreneurship education quality. The method not only describes the various factors that affect the quality of entrepreneurship education from the aspect of form, but also give s an accurate assessment of the entrepreneurship education quality from the essence. The theoretical analysis and practical results show the feasibility and effectiveness of the model, and provide a new approach for evaluation of the quality of College Students' entrepreneurship education.

Keywords Matter element model · Extension set · Entrepreneurship education · Quality assessment

1 Introduction

The innovation and entrepreneurship education in colleges and universities can not only deepen educational reform, but also cultivate students' innovative spirit and practical ability; to carry out entrepreneurship education has become a new trend of modern education and a major historic mission of Chinese colleges and universities in the 21st century [1]. At present, entrepreneurship education in universities of China is still in its infancy. Theory and practice of entrepreneurship education is still quite weak too [2]. How to establish a quality evaluate and control system combined with China's national conditions to ensure the orderly and healthy development of entrepreneurship education has a very important theoretical and practical value.

X. Li · S. Xiang (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: Xiangsuying@scu.edu.cn

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Currently the researchers have paid more attention to entrepreneurship education in colleges and universities and little attention is given to the quality evaluation of entrepreneurship education. How to measure the teaching quality of entrepreneurship education in colleges still does not have an industry generally accepted evaluation method [3, 4]. The extenics is an emerging discipline founded in 1980 by Chinese scholars Cai [5, 6], by the use of formal tools, from the perspective of qualitative and quantitative research to solve a number of factors under the regularity; it provides a new methodology system for people to understand and analysis of complex, real-world contradictions.

Based on matter-element and extension set theories, this article established the multidimensional extension element model for evaluation of the quality of entrepreneurship education, and the entrepreneurship education quality evaluation method. This method can not only from formally described the influence on college students' entrepreneurship education quality state of various factors, but also can essentially to the entrepreneurship teaching quality to give accurate qualitative and quantitative evaluation, which fully reflects the pros and cons of the college entrepreneurship education. In the end, an example is used to demonstrate the feasibility and effectiveness of the model, which has a strong practical value.

2 Matter-Element Model for Quality Evaluation of College Entrepreneurship Education

There are many factors that affect the quality of college entrepreneurship education, we can grasp the main characteristics—the factors index which accurately reflect the quality of entrepreneurship education, establish matter-element matrix of college entrepreneurship education quality, and thus to evaluate the quality of college entrepreneurship education. Below, first build college entrepreneurship education quality related factors index, then establish college entrepreneurship education quality assessment of classical domain matter-element model and the joint domain matter-element model.

2.1 Build the Evaluation Index System

College entrepreneurship education can train college students' entrepreneurial awareness, entrepreneurial thinking, entrepreneurial skills, and other entrepreneurial overall quality, and ultimately help students have a certain entrepreneurial ability. There are many factors that affect the quality of College Students' Entrepreneurship Education, including entrepreneurship education organization and leadership system, classroom teaching system, practice platform system and social support systems and so on.

Firstly, we divide the factors on the quality of College entrepreneurship education into three categories: innovative education, entrepreneurial practice and entrepreneurial environment, as the first-class indexes of quality evaluation of college entrepreneurship education. Then, according to comprehensive principle, concise scientific principle, coherent principle, workable principle, and with reference to relevant literature [7–9], combined with expert opinions to construct factor index of innovative education, entrepreneurial practice and entrepreneurial environment. The first-class index of innovative education includes 3 second-class indexes: entrepreneurship course (x_1), entrepreneurship teachers' level (x_2) and teaching method (x_3). The first-class index of entrepreneurial practice includes 2 second-class indexes: campus practice platform x_4, off-campus practice platform (x_5). The first-class index of entrepreneurial environment includes 3 second-class indexes: organizational leadership (x_6), financial support (x_7) and social collaboration (x_8). That is to say that the constructed College Entrepreneurship Education evaluation index system includes 3 first-class indexes, 8 second-class indexes.

2.2 Establish the Extension Matter-Element Model

Assume that there are m factors to constitute the college entrepreneurship education quality indicators, namely $x_1, x_2, \ldots, x_m$ (in this paper, $m = 8$). Based on these indexes, and with the expert or clustering analysis, the college entrepreneurship education quality is divided into f levels, described as qualitative and quantitative evaluation of the matter-element model (Called "classical domain matter-element matrix").

$$R_p = \begin{bmatrix} N_p & x_1 & V_{oj1} \\ & x_2 & V_{oj2} \\ & \vdots & \vdots \\ & x_m & V_{ojm} \end{bmatrix} = \begin{bmatrix} N_p & x_1 & \langle a_{oj1}, b_{oj1} \rangle \\ & x_2 & \langle a_{oj2}, b_{oj2} \rangle \\ & \vdots & \vdots \\ & x_m & \langle a_{ojm}, b_{ojm} \rangle \end{bmatrix}, \tag{1}$$

where N_{oj} represents college entrepreneurship education quality of the jth level; R_{oj} represents the matter-element model that college entrepreneurship education quality is at Level j, $V_{ojk} = \langle a_{ojk}, b_{ojk} \rangle$ represents the range of values of x_k at level j; $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$.

The range of index x_k values form the following matter-element model (Called "joint domain material matrix"):

$$R_p = \begin{bmatrix} N_p & x_1 & V_{p1} \\ & x_2 & V_{p2} \\ & \vdots & \vdots \\ & x_m & V_{pm} \end{bmatrix} = \begin{bmatrix} N_p & x_1 & \langle a_{p1}, b_{p1} \rangle \\ & x_2 & \langle a_{p2}, b_{p2} \rangle \\ & \vdots & \vdots \\ & x_m & \langle a_{pm}, b_{pm} \rangle \end{bmatrix}, \tag{2}$$

where R_p represents the college entrepreneurship education quality evaluation section of the domain of matter-element model; N_p represents the college entrepreneurship education quality of all grades; V_{pk}=$< apk, bpk >$ shows factor index x_k value of allowed range, $V_{ojk} \subset V_{pk}$, $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$.

2.3 Establish Matter-Element Matrix of the College Being Evaluated

According to the college entrepreneurship education quality evaluation indexes to evaluate the college, the data from the evaluation results form the following matter-element matrix:

$$R = \begin{bmatrix} N & x_1 & V_1 \\ & x_2 & V_2 \\ & \vdots & \vdots \\ & x_m & V_m \end{bmatrix}. \tag{3}$$

The N represents the assessment of entrepreneurship education quality of the college, indicates the assessed value of the kth factor to be evaluated college entrepreneurship education quality indicator x_k $(k = 1, 2, \ldots, m)$.

3 Extension Evaluation Method of Entrepreneurship Education Quality

After the matter-element model of entrepreneurship education quality evaluation is established, how to evaluate the level of entrepreneurship education quality of the college being evaluated? For this, we need to calculate the "approach degree" of matter element matrix of the college entrepreneurship education quality being evaluated and the classical domain matter-element matrix. In practice, based on the characteristics of the indexes, "approach degree" should be calculated by different calculation methods. In this paper, we use elementary dependent function of Extenics to calculate approach degree [10]. Let:

$$p(v_k, V_{ojk}) = \left|v_k - \tfrac{a_{ojk}+b_{ojk}}{2}\right| - \tfrac{1}{2}(b_{ojk} - a_{ojk}) \;\; (k = 1, 2, \ldots, m;\; j = 1, 2, \ldots, n),$$
$$p(v_k, V_{pk}) = \left|v_k - \tfrac{a_{pk}+b_{pk}}{2}\right| - \tfrac{1}{2}(b_{pk} - a_{pk}) \;\; (k = 1, 2, \ldots, m;\; j = 1, 2, \ldots, n),$$

denote the points v_k and range V_{oik}, V_{pk} "approach degree". For example, $p(v_k, V_{pk}) \geq 0$, that v_k is not in the range V_{pk} , $p(v_k, V_{pk}) \geq 0$, that v_k is within the range

v_{pk} and the different negative value indicates v_k within the interval V_{pk} different positions. Let:

$$K_j(v_k) = \frac{p(v_k, V_{ojk})}{p(v_k, V_{pk}) - p(v_k, V_{ojk})}, \quad j = 1, 2, \ldots, n; k = 1, 2, \ldots, m,$$

denotes the evaluation index x_k of the teacher's classroom teaching quality being evaluated about the correlation of level j. $K_i(v_k) \geq 0$ indicates v_k belongs to V_{ojk}, $K_i(v_k)$ greater, the more properties of v_k with V_{ojk}; $K_i(v_k) \leq 0$ indicates v_k does not belong to V_{ojk}, $K_i(v_k)$ smaller, the v_k is farther away from the range V_{ojk}.

According to the above formula, the correlation matrix between these evaluation indexes of the college entrepreneurship education quality being evaluated and the entrepreneurship education quality levels can be calculated, as $K = \lfloor K_j(v_k)_{m \times n} \rfloor$.

Through the aforementioned correlation matrix to calculate:

$$\max_{1 \leq j \leq n} K_j(v_k) = K_{io}(v_k) = K^*(v_k), \quad k = 1, 2, \ldots, m. \tag{4}$$

Then $K_{i_0}(v_k)$ describes the evaluation index x_k of the college entrepreneurship education quality being evaluated is at level i_o, by $K_{i_0}(v_k)$ can evaluate the grade of college entrepreneurship education quality.

If $w_k(\sum_{k=1}^{m} w_k = 1)$ is the weight coefficient of factor index x_k, the correlation between the college entrepreneurship education quality being evaluated and the jth level entrepreneurship education quality is:

$$K_j(R) = \sum_{k=1}^{m} w_k K_j(v_k). \tag{5}$$

The above formula comprehensively considered these factor indexes have different effects on college entrepreneurship education quality. Therefore, it has the strong scientific, pertinence and feasibility. Calculate:

$$K_{j0}(R) = \max_{1 \leq j \leq n} K_j(R). \tag{6}$$

Then the college entrepreneurship education quality being evaluated is at level j_0.

4 Empirical Study

We selected 3 colleges from western China. The 3 colleges are represented by T_1, T_2, and T_3, and use the model above to evaluate the three colleges' entrepreneurship education quality respectively.

The quality of entrepreneurship education is divided into five levels = {one, two, three, four, five} $\equiv$ {excellent, good, medium, qualified, unqualified}. When the entrepreneurship education quality factor indicator x_k (Sect. 3) is at level one, level two, level three, level four, level five, its assessed value is respectively v_1, v_2, v_3, v_4, v_5, where $v_1 \in (9, 10]$, $v_2 \in (8, 9]$, $v_3 \in (7, 8]$, $v_4 \in (6, 7]$, $v_5 \in [0, 6]$. Below, we first evaluate the quality of entrepreneurship education of college T_1.

4.1 Determine the Matter-Element Matrix

According to the range of values of college entrepreneurship education quality factors x_k $(k = 1, 2, \ldots, 8)$, we can get the classical domain matter-element matrix of college entrepreneurship education quality as follows:

$$R_{01} = \begin{bmatrix} N_{01} & x_1 & \langle 9, 10\rangle \\ & x_2 & \langle 9, 10\rangle \\ & \vdots & \vdots \\ & x_9 & \langle 9, 10\rangle \end{bmatrix}, R_{02} = \begin{bmatrix} N_{02} & x_1 & \langle 8, 10\rangle \\ & x_2 & \langle 8, 10\rangle \\ & \vdots & \vdots \\ & x_9 & \langle 8, 10\rangle \end{bmatrix}, R_{03} = \begin{bmatrix} N_{03} & x_1 & \langle 7, 8\rangle \\ & x_2 & \langle 7, 8\rangle \\ & \vdots & \vdots \\ & x_9 & \langle 7, 8\rangle \end{bmatrix},$$
$$R_{04} = \begin{bmatrix} N_{04} & x_1 & \langle 6, 7\rangle \\ & x_2 & \langle 6, 7\rangle \\ & \vdots & \vdots \\ & x_9 & \langle 6, 7\rangle \end{bmatrix}, \quad R_{05} = \begin{bmatrix} N_{05} & x_1 & \langle 0, 6\rangle \\ & x_2 & \langle 0, 6\rangle \\ & \vdots & \vdots \\ & x_9 & \langle 0, 6\rangle \end{bmatrix}. \tag{7}$$

Comprehensive the allowed value range of college entrepreneurship education quality of the factors index, form the joint domain matter-element matrix as follows:

$$R_p = \begin{bmatrix} N_p & x_1 & \langle 0, 10\rangle \\ & x_2 & \langle 0, 10\rangle \\ & \vdots & \vdots \\ & x_9 & \langle 0, 10\rangle \end{bmatrix}. \tag{8}$$

4.2 Determine Matter-Element Matrix of the College Being Evaluated

The assessed values of indexes of the college T_1 entrepreneurship education quality are determined by the following methods: first, determine the evaluators of entrepreneurship education quality. The evaluators are composed of 7 entrepreneurship education experts. Then, the evaluators assess the factor index $x_k (k = 1, 2, \ldots, 8)$ by following this process.

If one evaluator think the factor index x_k as "unqualified", the index value is $u_1 (u_1 \in [0, 6])$; if the factor index x_k is the "qualified", the index value is $u_2 (u_2 \in (6, 7])$; by the analogy, if think factor index x_k for "excellent", the index value is $u_5 (u_5 \in (9, 10])$.

According to the above method, these factor index $x_k (k = 1, 2, \ldots, 8)$ are assessed by all the evaluators. And then compute the mean of every index. Thus the material element matrix of the college entrepreneurship education quality being evaluated is achieved as following.

$$R = \begin{bmatrix} N & x_1 & 8.92 \\ & x_2 & 8.37 \\ & x_3 & 8.25 \\ & x_4 & 9.12 \\ & x_5 & 8.53 \\ & x_6 & 9.15 \\ & x_7 & 7.89 \\ & x_8 & 8.01 \end{bmatrix}. \tag{9}$$

4.3 Evaluate the College Entrepreneurship Education Quality

In order to evaluate the entrepreneurship education quality of the college T_1, we should first find the correlation matrix between these evaluation indexes of college entrepreneurship education and the different levels of entrepreneurship education quality; then by the correlation matrix to calculate the correlation degree; at last determine the quality grade of entrepreneurship education of college T_1 by the correlation degree.

1. Calculating correlation matrix

Calculate the correlation matrix $K = \left[K_j(v_k)_{11\times 5}\right]$ between these indexes of entrepreneurship education quality of college T_1 and the levels of entrepreneurship education quality, the results are as follows:

$$K = \left[K_j(v_k)_{8\times 5}\right] = \begin{bmatrix} -0.0690 & 0.0800 & -0.4600 & -0.6400 & -0.7300 \\ -0.2788 & 0.2937 & -0.1850 & -0.4567 & -0.5925 \\ -0.3000 & 0.1677 & -0.1250 & -0.4167 & -0.5625 \\ 0.1579 & -0.1200 & -0.5600 & -0.7067 & -0.7800 \\ -0.2423 & 0.4700 & -0.2650 & -0.5100 & -0.6325 \\ 0.2143 & -0.1500 & -0.5750 & -0.7167 & -0.7875 \\ -0.3447 & -0.0495 & 0.0550 & -0.2967 & -0.4725 \\ -0.3322 & 0.0051 & -0.0050 & -0.3367 & -0.5025 \end{bmatrix}. \tag{10}$$

2. Calculating teaching quality correlation calculation

According to the expert research and AHP method [11], we can determine the weight coefficient $w_k (k = 1, 2, \ldots, 8)$ of the various factors of the entrepreneurship education quality indicators x_k as follows:

$$W = (w_1, w_2, \ldots, w_8) = (0.223,0.112,0.075,0.093,0.105,0.224,0.097,0.071).$$

Then, the correlation between the entrepreneurship education quality of college T_1 and the jth level entrepreneurship education quality is:

$$K_j(R) = \sum_{k=1}^{11} w_k K_j(v_k), (j = 1, 2, 3, 4, 5). \tag{11}$$

Putting college entrepreneurship education quality factor index weights coefficient and the correlation matrix of the data into the above equation, we can get the following results:

$$K_j(R) = \sum_{k=1}^{8} w_k K_j(v_k) = (-0.0889, 0.0634, -0.3364, -0.5576, -0.6682).$$

That is: $K_1(R) = -0.0889$, $K_2(R) = 0.0634$, $K_3(R) = -0.3364$, $K_4(R) = -0.5576$, $K_5(R) = -0.6682$. Then: $K_{j_0}(R) = \max_{1 \le j \le 5} K_j(R) = K_4(R) = 0.0634$.

Therefore, the quality of entrepreneurship education of college T_1 is level two. That is, the entrepreneurship education quality of college T_1 is good.

Similarly, we use the above method to evaluate the quality of entrepreneurship education of college T_2 and college T_3 (Due to space limitations, the calculation process is omitted), get the entrepreneurship education quality of college T_2 and college T_3, which are medium and unqualified, namely the entrepreneurship education quality of college T_2 is medium, the entrepreneurship education quality of college T_3 is unqualified.

These are consistent with the actual situation of the three colleges' entrepreneurship education quality. The college T_1 focuses on students' entrepreneurship education and innovates in the ways of colleges' entrepreneurship education so that creates a good atmosphere for college students. Even though the college T_2 focuses on students' entrepreneurship education too, but it only opens some related entrepreneurship courses, does not build a corresponding entrepreneurship platform for the college students, so that the students have low enthusiasm in entrepreneurship. The college T_3 does not pay much attention to entrepreneurship education and the entrepreneurship education system is imperfect, so that the entrepreneurship environment is poor.

5 Conclusion

In this paper, based on matter-element and extension set theory, the multidimensional extension matter-element model and extension evaluation method are established. The research shows that the method not only can describe the states of the various factors of college entrepreneurship education but also can evaluate entrepreneurship education quality in Colleges and universities accurately. Therefore, the model is scientific and effective, it has considerable practical value.

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Design and Implementation of Multidimensional Earthquake Marking System

Jinjiang Yan, Haoliang Jiang, Yongzhong Cheng and Deshan Liu

Abstract Marking key target areas of damage to minimize casualties and property losses is an important part of the relief work after an earthquake. This paper analyses the design and implementation of a targeting system that compiles a multidimensional geographic scene using ArcGIS and OpenGL technology. The system can not only display the damage situation by the rapid assessment of the multidimensional geographic scene, but also accurately mark target areas in accordance with the three-level marking principles concerning importance and potential danger to civilians. In addition, this system can effectively plan and provide instruction for the proper rescue procedure regarding a specific target area.

Keywords Earthquake · Marking system · Multidimensional scene · ArcGIS · OpenGL

1 Introduction

Qing [5] considered earthquakes a threat to civilian life as well as social and economic stability. As one part of the earthquake relief work system, marking key target areas aims to rapidly obtain the spatial distribution of the damage situation and identify key targets for rescue.

Fei [3] identified the Geographic Information System (GIS) as an effective tool to manage spatial information and accurately query, retrieve, and calculate statistically significant details regarding geographic data. The development of 3D scene rendering technology provides a new method of marking key areas for disaster relief in an

J. Yan · H. Jiang
Business School, Sichuan University, Chengdu 610064, People's Republic of China

Y. Cheng (✉)
West China Hospital, Sichuan University, Chengdu 610041, People's Republic of China
e-mail: eeecheng@163.com

D. Liu
Beijing Jiesitu Information Technology Co. Ltd., Beijing 100028, People's Republic of China

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earthquake site. In a 3D scene, Over et al. [4] considered that marking earthquake information can more intuitively reflect the site condition and more effectively provide help for the earthquake rescue command. After years of development, ArcGIS, the development platform of GIS, is now outstanding in the 2D GIS field, but Zhang [10] thought that this high-performing platform should gain prominence in the 3D GIS field. Xiao et al. [9] said that OpenGL can provide a variety of API and more free space for application developers in the rendering and flight simulation of the 3D scene.

This paper designs and implements a targeting system that compiles a multidimensional geographic scene based on both ArcGIS and OpenGL technology, by first developing the system in a 2D geographic scene with ArcGIS Engine 9.2 and C# before displaying the earthquake site in a 3D geographic scene using OpenGL and Visual C++. This system is intuitive in responding to site conditions and effective in providing ancillary support for emergency rescue work by recording earthquake information under the 3D geographic scene.

2 Development Platform

1. ArcGIS Engine 9.2

Devasto et al. [2] said that the ArcGIS Engine, developed by ESRI, is a complete and embeddable GIS component library for custom applications. Using ArcGIS Engine, developers can not only integrate function of ArcGIS to some application software, but also provide customized GIS applications for users. Arnab et al. [1] stated that ArcGIS Engine 9.2, based on the core component library of ArcObjects, has more than 3000 objects, which can be invoked by developers to manage layers, render maps, interact with spatial database interfaces, output graphics, and display marks of GIS application. By combining with many popular development tools, ArcGIS can be embedded into a development environment including C++, the programming language supporting COM (such as Delphi), NET, Java etc.

2. OpenGL

Richard et al. [7] introduced Open Graphics Library (OpenGL) as a widely used 2D/3D graphic-rendering API that crosses programming language and platform. It has spawned thousands of excellent applications, on various computer platforms and devices, including hundreds of different functions which programmers can call to set objects and operations to make interactive 3D applications. In the fields of CAD, content creation, entertainment, manufacturing, virtual reality and so on, Reina et al. [6] said that OpenGL helps programmers realize the development of graphics processing software with high performance and visual expression in PC, workstations, super computers, and other hardware devices.

3. Microsoft Visual Studio 2005

Skibo et al. [8] identified Microsoft Visual Studio 2005 (VS 2005) as a Microsoft development kit featuring many tools needed for software design such as UML tools, code management tools, integrated development environment (IDE) etc. The code written with this program can apply to all platforms supported by Microsoft including Microsoft Windows, Windows Mobile, Windows CE, NET Framework, NET Compact Framework, and Microsoft Silverlight.

3 Analysis of Importance and Danger Level of Seismic Target

Using information from the Earthquake Emergency Database, this paper further analyses the levels of importance and danger concerning a seismic key target.

3.1 Hospital

The importance of hospitals is mainly determined by the hospital's rating (R) the number of personnel within the hospital (N), the number of beds (B), the number of emergency vehicles (P), and the volume of plasma inventory (A), among other aspects. These factors are combined in the following equation to determine a hospital's importance.

$$\mu = R^{*}\lambda R + N^{*}\lambda N + B^{*}\lambda A + P^{*}\lambda P. \quad (1)$$

In the above equation, λ represents the weighted influence of each factor, and μ is the importance index of the hospital ranging from 0 to 1. $0 \leq \mu < 0.45$ means "general", $0.45 \leq \mu < 0.80$ means "important", and $0.80 \leq \mu \leq 1.0$ means "very important".

3.2 Reservoir

The classification of the danger posed by reservoir dams mainly considers the damage state (D), the terrain (T), the reservoir capacity (C), the earthquake magnitude (M), the season (S) and other aspects.

$$R = D^{*}\delta d + T^{*}\delta a + M^{*}\delta m + S^{*}\delta m. \quad (2)$$

In the equation, R is the danger index of dams, and δ is the weight of each influential factor. The influential factors and weights are shown in Tables 1, 2, 3, 4 and 5. R ranges from 0 to 1, $0 \leq \mu < 0.25$ means "no danger", $0.25 \leq \mu < 0.5$, means "danger" and $0.5 \leq \mu \leq 1.0$ means "high danger".

Table 1 Influential factors and weight of the damage state of dam

Damage state or mean damage index	Factor	Weight
Slight damage	0.1	
Moderate damage	0.5	0.5
Serious damage	1	

Table 2 Influential factors and weight of the terrain

Slope of terrain	Factor	Weight
$<10°$	0.3	
10–30°	0.5	0.2
$>30°$	0.9	

Table 3 Influential factors and weight of the capacity

Capacity	Factor	Weight
<0.01 billion m^3	0.1	0.2
0.01–0.1 billion m^3	0.3	
0.11 billion m^3	0.5	
>1 billion m^3	0.9	

Table 4 Influential factors and weight of the earthquake magnitude

Earthquake magnitude	Factor	Weight
<7.4	0	0.1
>7.5	1	

Table 5 Influential factors and weight of the season

Season	Factor	Weight
Not rainy season	0	0.1
Rainy season	1	

3.3 School

Schools are where people are heavily concentrated. Using state of damage as basic data, Table 6 shows the classification of the levels of danger posed by school buildings at different levels of damage.

Table 6 Level of the danger of schools

Damage state (Mean damage index)	Level
Slight damage [0, 0.3)	Not dangerous
Moderate damage [0.30, 0.5)	Dangerous
Serious damage [0.50, 1)	Very dangerous

3.4 Power Facilities

In this paper, the classification of the importance of power facilities is specific to power dispatch centers and substations. Factors to consider include the rank of power facility (R), the invalid index of earthquake damage (I), and the facility's sphere of jurisdiction (S).

$$\varphi = R^{*}\lambda R + I^{*}\lambda I + S^{*}\lambda S. \tag{3}$$

In the equation, φ is the importance index of power facilities ranging from 0 to 1, and λ is the weighted importance of each factor. $0 \leq \varphi < 0.5$ means "general", $0.5 \leq \varphi < 0.8$ means "important", and $0.8 \leq \varphi \leq 1$ means "very important". The importance of power facilities, in relation to the power levels of their substations and capacity of their power plants, are shown in Table 7.

In Eq. (3), the invalid index of earthquake damage uses the method of expert advice to research the seismic fragility of facilities and functions of power systems. The relationship between the loss rate of power system facilities and the intensity of the earthquake, obtained by a logistic function, is shown in Table 8.

The method evaluating the importance of the above key targets is obtained, for the most part, on AHP scores. For example, the annual average power generation, the capacity of power plants, the level of voltage and other elements of power facilities can be used as the main evaluation index. However, when referring to the hydraulic engineering, power engineering, medical health, and other important determinants, it is necessary to consult experts in these fields to confirm the factors and their weights.

Table 7 Level of power facilities

Level of power facilities	Level of power substations	Capacity of power plants
General	<110 KV	<12 MW
Important	110–220 KV	12–300 MW
Very important	>330 KV	>300 MW

Table 8 Relationship between the loss rate of facilities and functions of power system and the intensity of earthquake

Intensity	VI	VII	VIII	IX	X	XI	XII
Facilities main	4.56	9.06	18.56	35.67	52.85	72.09	85.22
Loss rate part	2.52	7.71	18.24	37.54	54.37	78.52	90.55
P (%) serve	3.12	8.95	19.68	35.52	53.17	75.55	88.22
Functions main	4.92	9.92	19.72	37.94	62.00	78.08	89.40
Loss rate part	3.30	7.61	17.02	37.00	61.60	80.15	91.39
P (%) serve	3.32	10.62	22.39	41.69	60.62	81.60	91.90

4 System Design

4.1 Design of Function Module

The 2D GIS geographic scene function is based on a desktop application and includes the ability to file operations, display views, mark important targets, demonstrate emergency rescue plans, export 3D files in the function implementation, and operate on a human-computer interaction design.

The 3D GIS geographic scene function includes basic terrain generation, DEM data consolidation, 3D visualization of the sky and bodies of water, pinpointing of the sun or other lighting, 3D scene map operations, 3D model library management and addition of 3D objects, flight and roaming, the ability to save a 3D geographic scene, and the function of setting effects on a 3D geographic scene.

The multidimensional geographic scene-switching module mainly includes the functions of loading a 2D or 3D geographic scene and the ability for users to freely switch between them.

4.2 Style Design of Symbols

This paper uses a combination of shape and color to express the design of key target marks and GIS symbols: shape represents the target's level of damage and color represents its importance or danger. Regarding shapes, the square frame represents the level of damage and the circular frame represents importance designated for the dams of reservoirs and the schools. "W", "C" and other special letters represent

Table 9 Level of danger

Level	Symbol	Color
Not dangerous	W C	green
Dangerous	W C	yellow
Very dangerous	W C	red

Table 10 Level of danger

Level	Symbol	Color
Not dangerous	M E I	Green
Dangerous	M E I	Yellow
Very dangerous	M E I	Red

uses of the buildings and the color of the borders represents the level of danger. For example, “W” with green square frame represents a dam which is not dangerous. The detailed classification of danger is shown in Table 9.

The classification of importance is suitable for hospitals, power facilities and communication facilities. “M”, “E”, “I” and other letters represent uses of the buildings, and the color of the borders represents their levels of importance. For example, “M” with green borders means the importance of this particular hospital is general. The detailed classification of importance is shown in Table 10.

4.3 Spatial Data

1. Main element

The geographical information of this system is classified into basic geographic data, common data, and professional data. The basic geographic data is based on the geographic information data of 1:250,000, including: control points, residential area, industrial facilities, frontier, traffic, water, topography, vegetation, cities, and other basic information. The common data is the geographic data which is associated with social activities and the national economy other than the basic geographic data, such as hospitals, schools, water plants, sewage disposal works, and gas pipelines. The professional data is that which is related to the objects of earthquake, including, but not limited to, geological structure, active area of earthquake,and networks of monitoring station. The emphasis of this research is marking key targets in the disaster area under the multidimensional geographical scene where basic data and the operational data are separated. The system can be applied to all earthquake emergency rescue units and the spatial element information can be used to display the geographical background of the disaster area. There is no limitation to the scale of the data, and all related user data can be configured in practice. The data of the city or town units can be configured according to the actual situation.

2. Graphic symbol

The symbols of geographic information in this system are designed according to current national standards and those belonging to the same class should maintain consistency in the visual effect according to the principles of intuition, aesthetics, and convenience. After creating a map, users can judge whether these graphic symbols are consistent with these principles and belong in the same class.

5 Realization of the System Functions

5.1 2D Geographic Scene Map

The interface of the 2D geographic scene uses multiple document interfaces (MDI) to gather various operations into different view panels according to different functions. Users can present the functions which need high-frequency operations on a human-computer interface through interactive operations. The benefit of this design is the convenience afforded by displaying important functions and hiding the rest when the displaying space is too small. In addition, all windows have the "DOCK" function, allowing them to dock at the edge of the main interface. The 2D geographic scene interface is shown in Fig. 1.

5.2 Function of the 3D Scene

1. Basic Landform Formation

The software adopts LOD algorithm and creates the basic terrain from the DEM file according to the terrain and implementation of DEM data modeling. The 3D scene texture on surface topography can post the map details, choose a texture image, and perform map operations. Using remote sensing images to create surface texture, terrain generation and texture processing is a quick and interactive process.

2. The 3D Visualization of the Sky

The sky texture configuration achieved through 3D effects using the CSkyBox class is shown in Fig. 2.

3. The Position of Sun/light and Sea/river

The sun/light effect is created by setting position of the light source and by using lens flare effect of two parts. Glare effect is realized by the CLens class.

Optional marine texture can also be provided. According to the definition and 3D connectivity, the system can realize the ocean's distributed generation. Elevation

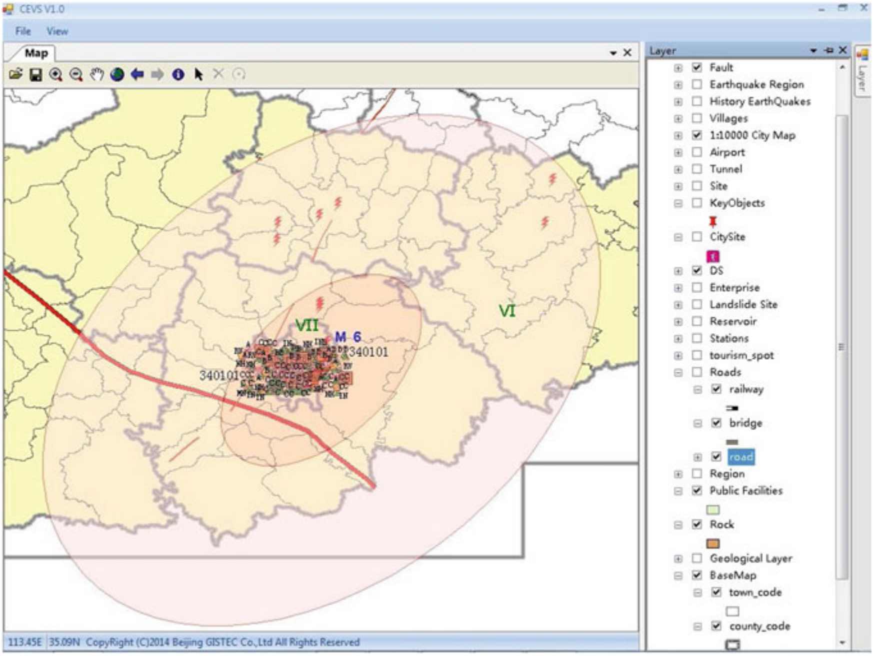

Fig. 1 Geographic scene map

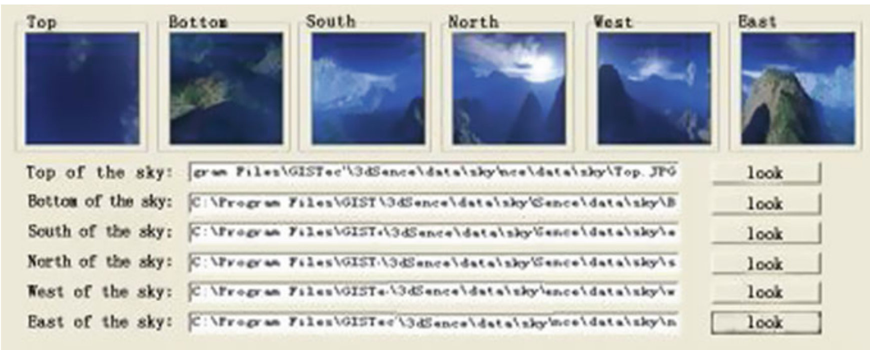

Fig. 2 The sky box set

settings can be configured through interactive settings or configuration files. In addition, the position of the sun can be defined, showing the effect of light and shadow in a 3D scene.

5.3 Marking Key Targets

On the map, users can add interactive marks on key targets and draw planar trend arrows, among other marking functions, by the operations of the mouse. When adding marks to the map, it is necessary to coordinate with a specific point diagram panel, text mark panel, and planar mark panel to select specific symbols to add. Marking is executed in the MouseDown event of the map.

1. Marks of 2D animation

The capability to display text annotations can be activated by opening the text mark library Dock window display. Click on the "labels" submenu, and select the text annotation panel. The "display surface icon note style library" function can display the planar dimension style library through the Dock window. The "surface labeled" sub menu and planar dimension style library panel are shown in Fig. 3 and Fig. 4 respectively.

2. Marking Key Targets

Marking key targets can be realized by the bulletin board technology in a 3D geographic scene. This is accomplished by keeping the model in a vertical state, perpendicular to the ground, and facing the observer, while the terrain is being changed and rotated. The key targets of this system include dams, schools, electric facilities, hospitals, and other locations. For a large scene, there are so many targets that this

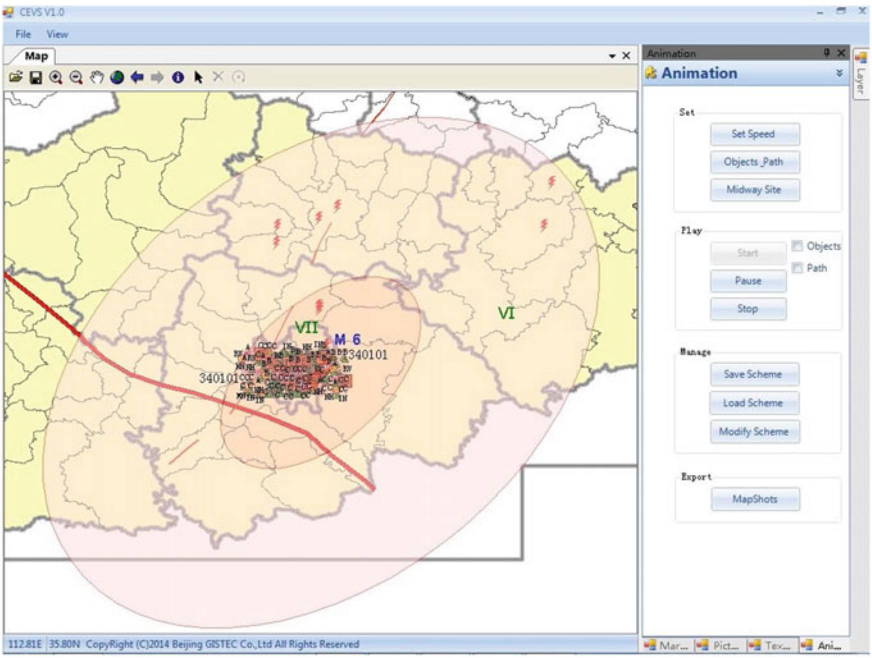

Fig. 3 Marks of 2D animation

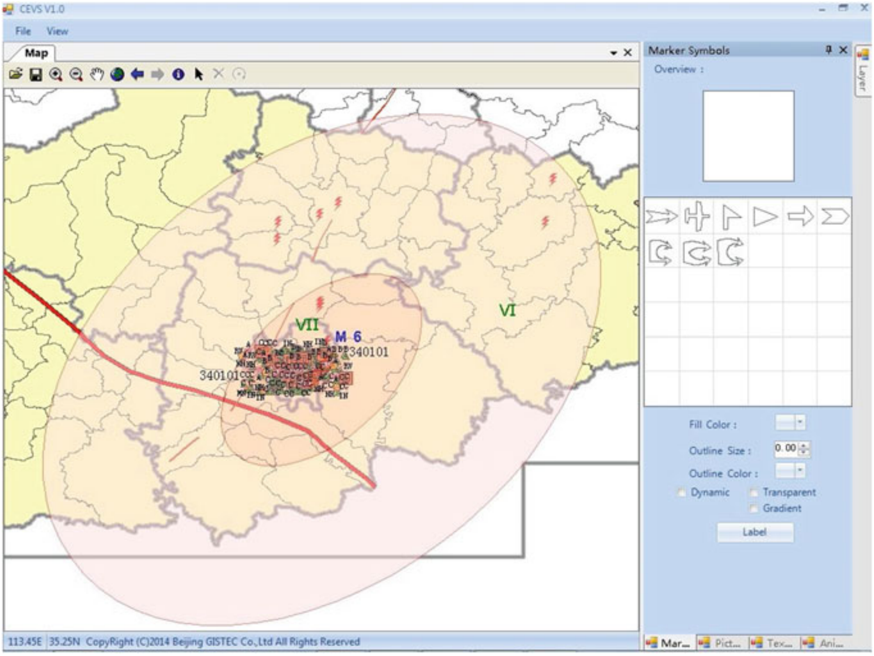

Fig. 4 Text mark font panel

system imports them in large quantities from files. Users can choose appropriate symbols to add into a 3D scene according to symbol type, spatial location, level of danger posed, importance, etc. Marking Key Targets is shown in Fig. 5.

5.4 The Animation Deduction of Emergency Rescue Program

1. Emergency Rescue Plan of Action Choreography

The system can carry out many layout designs of emergency rescue plans in response various relief forces, evacuation needs, procession route and speed, while expediting the intermediate tasks that require processing content. The specific implementation steps are as follows:

Step 1. Add a point target representing all types of disaster relief efforts to map with a symbol.

Step 2. Select "set travel speed"and set the dialog team speed.

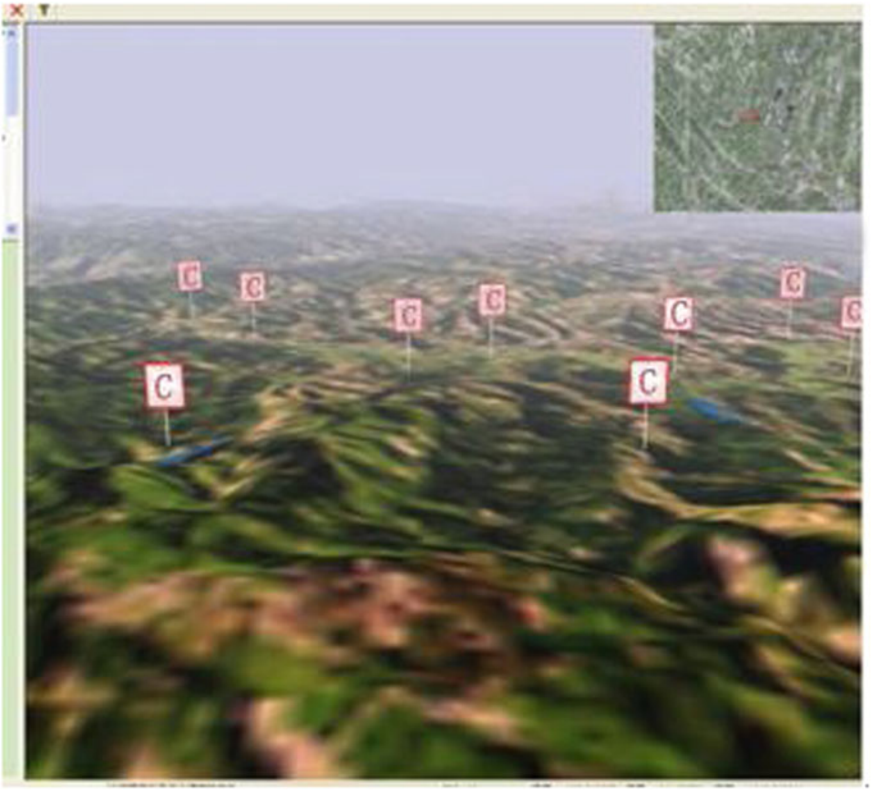

Fig. 5 Marking key targets

Step 3. Click “select target and route”, click on the map panel and select target. Then use the mouse to draw target route with a line.
Step 4. After a target route has been set, a midway point can be set for an additional course of action. Click “select the midway point”, and then click on the route to set the midway point and input text to mark the half-way point. To avoid mistaking the midway point as a separate route, set the midway point only to the last target.
2. Animation Deduction of Emergency Rescue Program

The animation deduction of an emergency rescue plan can be done after completing the arrangement scheme. The animation can be altered in various ways, including moving the course of action according to the setting speed, extending the target along the line, and extending the target route. The animation deduction effect is shown in Fig. 6.

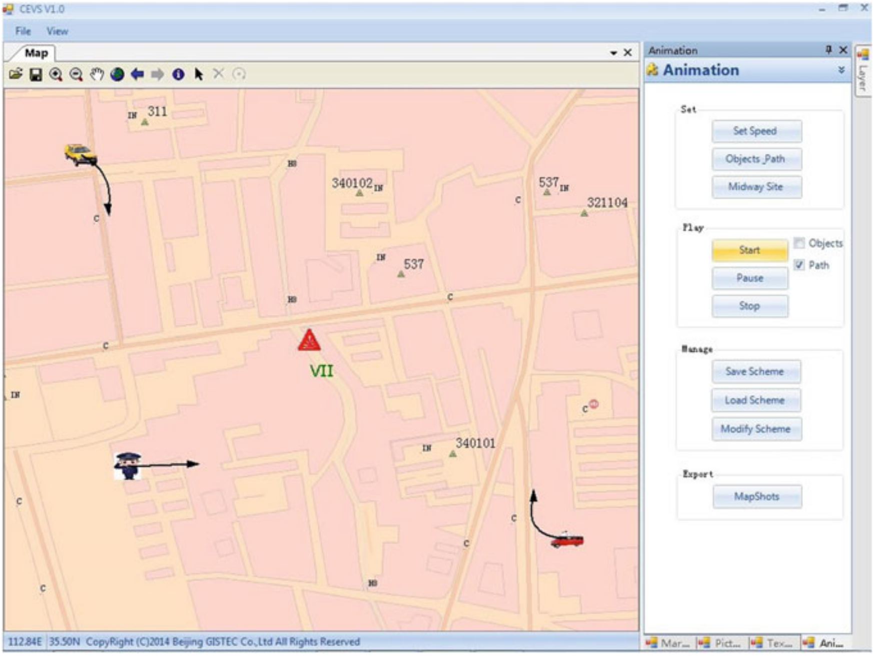

Fig. 6 The animation deduction of emergency rescue program

6 Conclusions

Through design and implementation of a multidimensional earthquake marking system by combining the GIS development platform and the 3D display software, preliminary studies may be carried out concerning the effects of applying geographic marks with 3D display technology to direct earthquake emergency rescue. This system achieves more stable 2D symbol markings by making full use of support from ArcGIS for the secondary development, taking advantage large-scale outdoor rendering of the 3D geographic scene by the OpenGL technology, and in order to reach relatively quicker display performance within a range of hardware conditions comparable to what is of current use.

This study promotes the development of earthquake emergency command and use of multidimensional display technology in earthquake disasters, further increases the visibility of earthquake emergency command system, and provides an intuitive command platform for the earthquake emergency rescue work. Adding the concepts of the map mark and posture of the operational command to the earthquake emergency commanding system strengthens its usefulness and improves the effectiveness of earthquake prevention and disaster reduction.

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Collaborations Within and Across Regions in Technology Commercialization in China

Xiaoping Li and Qi Zhang

Abstract This study is motivated by the observation of asymmetry in studies on collaboration, as little attention has been given to downstream joint commercialization activities, such as licensing activities for both the licensee and licensor. To address this imbalance, this paper investigates such collaboration from a regional perspective by identifying two types of collaboration, i.e., within and across provinces, in technological commercialization. China's licensing data was employed in the analyses. Our results indicate that China has witnessed a dramatic growth in both types of collaboration, particularly since 2007, and that the geographical variations among the provinces of China engaged in these two types of collaboration has declined in recent years. China has also experienced a dramatic structural reconstruction in within- and cross-province collaboration. Meanwhile, it must be noted that Chinese provinces illustrate different strengths in fostering boundary-bounded collaboration and cross-province collaboration. Further empirical work confirmed this observation and found that provincial populations, according to their per capita GDP and the length of the relationship, have a positive effect on these two types of collaboration. FDI and R&D investment exert positive influences on cross-province collaboration and within-province collaboration, respectively.

Keywords Commercialization-oriented collaboration · Cross-border collaboration · Patent licensing · Geographical variation · FDI · R&D investment

X. Li (✉) · Q. Zhang (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 739278537@qq.com

Q. Zhang (✉)
West China School of Public Health, Sichuan University,
Chengdu 610064, People's Republic of China

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1 Introduction

There is wide recognition that technological commercialization, rather than technological generation, is the driving force for regional and national economic development albeit technological production is the prerequisite for later commercialization [6, 33, 41]. Technologies, which include millions of registered patents in patent offices across the globe, are not directly linked to regional and national economic growth or to enhancing international competency [4]. Thus, the question of how to find, acquire, and monetize external technology has become an increasingly prominent and important issue for firms, regions, and countries. Currently, we are witnessing an innovation paradigm shift from closed to external collaborations in an increasingly well-distributed knowledge landscape both within and outside a county [17]. As Chesbrough noted, the key problem regarding innovation today is not to store more patents on a shelf but to identify an appropriate way to commercialize the existing technology. This author cites, for example, that in the United States, only 7 % of patents were successfully commercialized.

However, in bibliometric and innovation literature, studies regarding collaborations in technology commercialization are rare, though bibliometric scholars have paid sufficient attention to the collaborations in knowledge production, which are generally measured as co-inventions or as coauthored in publications [1, 7, 23, 29, 32, 35, 36, 43, 48]. We do not deny the important role of knowledge/technological production, but we do emphasize in this study the collaboration involved in the technology commercialization stage. Herein, the term commercialization-oriented collaboration means that the technology producer and the potential technology user collaborate to create and produce new products or advanced services [6]. Extant innovation literature has suggested various collaborative schemes in this context, such as technology licensing, technology buying as well as joint ventures that target the commercialization of a particular technology [5, 27, 44, 45].

In this study, we provide information on collaboration during the technological commercialization phase at the regional level by considering patent licensing as the collaborative channel. Patent licensing means that the patent holder allows another entity to make use of the patent holder's patents under certain conditions, such as the payment of money to compensate the patent holder for research and development (R&D) investments needed to generate the patent [3, 34]. Patent licensing has become an important and visible way to collaboratively commercialize external technology [9, 15, 18, 31].

Collaboration in innovation and technology have been widely recognized as a geographically bounded phenomenon [12, 14, 20, 24, 40]. That is, geographical proximity enables collaborations, and the geographical distance affects the degree of success of the collaboration. In essence, geographical distance itself neither fosters nor discourages collaboration, particularly with the rapid development of transportation and communication technology, but the institutional difference behind the geographical distance may discourage the collaboration [11]. Consistent with this discourse, we set the research at the regional level as many scholars believe that the region is an appropriate unit of analysis for innovation-oriented collaborations [28, 37].

To be specific, this study uses certain provinces in China as the analysis unit to examine the collaborative patterns and dynamic changes in technology commercialization within and across provinces. Furthermore, we investigate determinants of the likelihood of within- and cross-province collaboration. In the next section, we introduce the methodology used in this study. In Sect. 3, we examine the patterns and dynamics of within- and cross-province technology commercialization-oriented collaborations. The measures and empirical models used for our analysis of the likelihood for such collaborations in China are presented in Sect. 4. Finally, a brief discussion of the findings drawn from this study is presented in Sect. 5.

2 Methodology

This study uses a Chinese licensing dataset, a unique and valuable dataset, to illustrate the patterns and dynamics of within- and across-region collaboration in technological commercialization and to identify the precise location of collaboration. In previous studies, similar datasets have been employed in bibliometric and innovation management and in international business research [25, 42, 46]. The Chinese licensing dataset is published by the Chinese authority, the State Intellectual Property Office (SIPO), which includes all patent licensing activities in China since 2000. A record in this dataset contains the specific identity of the licensor, licensee, licensed patents, contracting date, and contract type (e.g., general licensing, exclusive licensing). To the best of our knowledge, this is the most complete dataset pertaining to technology licensing in the world. In Western countries, technology licensing is a private business activity, and as such, it is generally not available for public access (a few exceptional studies use data from some consulting companies [26, 27]). In China, however, licensors are required by law to register their patent licensing activities in the SIPO or its branches located in provinces and large cities within three months after the signing of the licensing contracting.

Through the names of the licensors and licensees, we are further able to identify the locations of the licensing activities. In the current study, because we are interested in the domestic collaborations in technology commercialization, licensing activities involving foreign partners are excluded. We assign all relevant licensing activities to their respective Chinese provinces according to the locations of the licensor and licensee. In this way, we know the number of licensed patents that occurred within (licensor and licensee co-locate in one province) and across provinces (licensor and licensee locate in different provinces) at the aggregate level. In total, there were 72,177 patents that were licensed during the period 2000–2012. Among those, 44,321 were licensed within the provinces, and 27,856 were licensed across provinces, including inward and outward licensing.

3 The Patterns of within- and Cross-region Collaborations in China

The uniqueness of the Chinese licensing dataset provides information about the locations of each of the partners, thus allowing us to determine if the collaboration was within or across provinces. As a result, we investigated the geographical distributions of the collaboration and the evolving process of within- and cross-province collaborations in technology commercialization.

An overview of the distribution of licensed patents, both within- province and cross-province, between 2000 and 2012 is presented in Table 1. From Table 1, it can be noted that during the past 13 years, there was a huge surge of collaborations in technological commercialization, from the lowest in 2005 with 24 licensed patents to the summit in 2011 with 24,650. That translates to 1027 times more licensed patents in 2011 than in 2005. During these six years, the annual growth rate averaged 56.55 %. However, we found that, since 2006, collaborations began to increase rapidly. In 2006, there were only 56 licensed patents, 1.19 times that of 2000. The number jumped to 15,941 in 2012.

Whether the collaborations occurred within or across provinces is shown in Table 1, and it is also clear, based on the results depicted in the table, that both types of collaborations experienced rapid growth, with average annual growth rates of 52.84 and 65.06 %, respectively. During the period 2007–2012, the growth was much more evident than it was in the first 7 years (2000–2007). However, from a structural perspective, the collaborations within province have dominated the collaborations in the past 13 years, see Fig. 1. With a few exceptions (2002, 2006, 2007), collaborations within province exceeded those for across provinces. In recent years,

Table 1 An overview of the distribution of licensed patents, 2000–2012

Year	Total	Within	Across
2000	47	37	10
2001	62	44	18
2002	93	35	58
2003	29	19	10
2004	153	125	28
2005	24	16	8
2006	56	10	46
2007	227	99	128
2008	1910	1096	814
2009	19,174	11,460	7714
2010	9811	6124	3687
2011	24,650	16,064	8586
2012	15,941	9192	6749

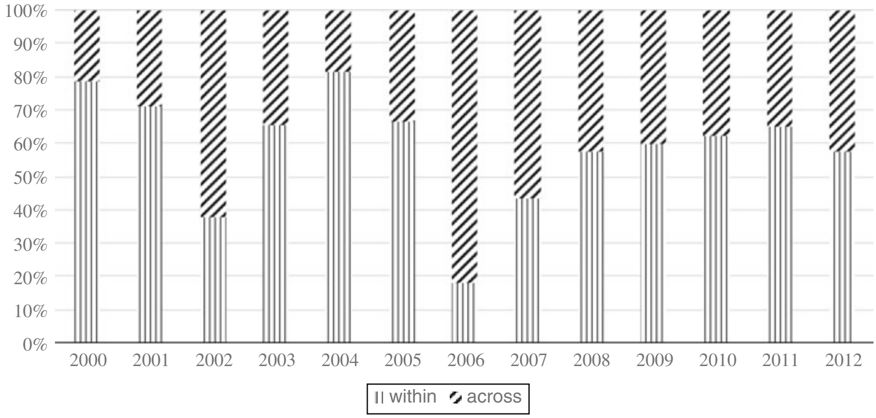

Fig. 1 The structural changes of within- and cross-province collaborations

the structure has remained stable as collaborations within province have accounted for approximately 60 % of all collaborations.

Table 2 exhibits the geographical variations of collaborations in terms of within- and across provinces. It further shows that there are huge variations among provinces regardless of whether the collaborations are within or across provinces. For instance, in 2004, the mean for licensed patents within province was 4.17, while the standard deviation was extremely high at 22.26, and the relevant coefficient of variation was

Table 2 Geographical variations of collaborations

Year	Within			Across		
	Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation
2000	1.23	3.73	3.03	0.33	0.80	2.43
2001	1.47	6.37	4.33	0.60	1.25	2.08
2002	1.17	3.00	2.56	1.93	3.30	1.71
2003	0.63	2.58	4.10	0.33	0.61	1.84
2004	4.17	22.26	5.34	0.93	1.60	1.72
2005	0.53	2.92	5.51	0.27	0.91	3.36
2006	0.33	1.16	3.50	1.53	5.45	3.56
2007	3.3	10.42	3.16	4.27	9.43	2.21
2008	36.53	90.04	2.46	27.13	42.42	1.56
2009	382	679.50	1.78	257.13	264.06	1.03
2010	204.13	441.27	2.16	122.90	132.54	1.08
2011	535.47	990.24	1.85	286.20	272.64	0.95
2012	306.40	413.84	1.35	224.97	202.39	0.90

5.34. Similarly, in 2006, for cross-province collaborations, the mean was only 1.53, but the standard deviation reached 5.45, and the coefficient of variation was 3.56. However, the research indicates the variations became smaller beginning in 2006, a decreasing trend that was continued for both types of collaborations. That suggests that more provinces became actively involved in collaborations in technology commercialization, on one hand, while on the other hand, there was a rapid growth in collaborations among the inactive provinces in the prior period. The latter points to a structural dynamic change for active provinces in the past 13 years, more specifically, in the past 7 years.

To further illustrate the structural dynamic change we list the top five most active provinces in the years 2000, 2003, 2006 and 2012, see Table 3. As shown in Table 3, in 2000, the most active top five most active provinces regarding within province collaborations were Shandong, Zhejiang, Beijing, Guangdong, and Hebei, while in 2006, Guangdong, Zhejiang, and Shanghai were the most active. Moving forward to 2012, however, we find that Heilongjiang recorded the most within-province collaborations. Similarly, with respect to cross-province collaborations in technology commercialization, we also observe a dynamic change in the top five most active provinces. For example, in 2000, Beijing and Heilongjiang were the top two most active provinces in cross-province collaborations, while in 2003, they were not even among the top five. In 2012, Guangdong, Jiangsu, Beijing, Shanghai, and Zhejiang rank as the top five most active provinces with respect to cross-province collaborations.

Meanwhile, the cumulative proportions in Table 3 show the extent of the changes corresponding to the dynamic entity change in the collaborations. Except for 2003 and 2006, in general, both types of collaborations are relatively well-distributed. For example, in 2000, the five top most active provinces accounted for 97 and 90 % of the within and cross-province collaborations, respectively, and they declined to 60 and 40 %, respectively, in 2012. In addition, there is not always an overlap between the top five most active provinces for the within- and cross-province collaborations. For example, in 2012, the top most active provinces in collaborations within province were Heilongjiang, Guangdong, Zhejiang, Jiangsu, and Hebei; however, the most active provinces in cross-province collaborations, were Guangdong, Jiangsu, Beijing, Shanghai, and Zhejiang. This suggests that a province may be good at internal collaborations but not necessarily as strong when negotiating collaborations with other provinces. Thus, understanding the various mechanisms that stimulate collaborations within and across provinces deserves more attention, a topic that will be addressed later in the paper.

Table 3 Top five most active provinces in collaborations

2000				2003			
Within	Cumulative proportion (%)	Across	Cumulative proportion (%)	Within	Cumulative proportion (%)	Across	Cumulative proportion (%)
Shandong	51	Beijing	30	Beijing	68	Guangdong	22
Zhejiang	67	Heilongjiang	60	Guangdong	100	Shanxi	44
Beijing	81	Hebei	70	NA		Guangxi	55
Guangdong	94	Jiangsu	80	NA		Hebei	66
Hebei	97	Shanghai	90	NA		Jiangsu	77
2006				2012			
Within	Cumulative proportion (%)	Across	Cumulative proportion (%)	Within	Cumulative proportion (%)	Across	Cumulative proportion (%)
Guangdong	50	Guangdong	50	Heilongjiang	15	Guangdong	11
Zhejiang	90	Zhejiang	93	Guangdong	29	Jiangsu	22
Shanghai	100	Jiangxi	95	Zhejiang	43	Beijing	30
NA		Shanghai	97	Jiangsu	56	Shanghai	37
NA		Tianjin	100	Hebei	60	Zhejiang	44

4 Determinants of Within- and Cross-province Collaborations

According to the findings discussed in the previous section, Chinese provinces demonstrate various capabilities in fostering boundary-bounded collaborations and cross-province collaborations in technological commercialization. In this section, we conduct an investigation of the determinants of within- and cross-province collaborations with an aim to determining potential factors or mechanisms that influence the possibility of collaboration occurring within and across provinces. We predict that there are different factors that explain the likelihood of collaboration within a province and across provinces, though we are unable to find prior studies that conducted thorough and holistic research to guide us in identifying potential determinants. Therefore, based on a careful synthesis of prior studies on regional innovation systems, bibliometrics, and innovation management literature, we propose the following factors:

1. Population in province

   Previous studies have suggested that population is associated with the demand for innovation [13]. Accordingly, population may enable or encourage the demands for diverse technology, new products and/or updated services, thus stimulating collaborations for technology commercialization within and across provinces.

2. Provincial investments in R&D

   R&D investment is the most popular indicator for inquiries in innovation in extant literature [19]. With respect to this study, strong R&D investment in a province may indicate that a province is actively involved in innovation activities. With regard to cross-region collaborations, a strong R&D investment may indicate a strong absorptive capacity for technology from other provinces [10].

3. Per capita GDP

   This is a widely used indicator to reflect the knowledge stock in a region or country, and as a result, it has a positive influence on innovative activities including technology generation and application [16]. Thus we propose that per capita GDP has an effect on both within- and cross-province collaboration for technological commercialization.

4. Foreign direct investment (FDI)

   FDI has been widely used in literature to measure the openness of a region toward participating in the global economy [38, 47]. In this study, we use FDI as an indicator to show a province's openness to technological collaborations. Thus, we propose that FDI has a positive effect on cross-province collaborations in technology commercialization.

5. Domestic trade

   Similar to FDI, this indicator is used to measure a province's external connections with other provinces. A province that engages in active domestic trade may also be willing to engage in collaboration within- and across provinces. In this study, domestic trade is measured by the total amount of inward and outward flows of domestic trade.

6. Industrial output

This variable is used to measure a province's industrial structure. A province that has a high industrial output may have a higher demand for technology from both within and from outside the province than provinces with lower industrial output values.

7. Index year variables

Since 2006, the Chinese government has highlighted the strategic importance of "indigenous innovation" (zizhuchuangxin), which puts a premium on developing a self-sustaining innovation system by using domestic technology, indicating a new era for innovation and technological collaboration.

Thus, we use an Index year to measure the change in external institutional development. Before 2007 it was coded as 0, otherwise 1. Finally, due to the disparity among Chinese provinces in economic and technological development [39], we also controlled regional differences by using three separate indexes, one for the eastern region, one for the middle region and one for the western region. The east region was omitted as the reference group.

All of these measures are drawn from the China Statistical Database (2000–2012), and all the measured indicators are transferred to the value measured by 1999 prices based on the retail price index published by the China Statistics Bureau. The FDI is measured in US dollars. Although the transformation may not be accurate, we believe that the data after transformation should be better than the original values based on individual year prices. In addition, to alleviate the potential endogeneity problem, we follow the traditional means to lag all explanatories by one year [2]. It is noted that we do not use other methods such as SSLS, 3SLS or GMM due to the constraint that we are not able to find an appropriate instrumental variable in this study. In the end, to lessen the non-linear effect, all explanatory variables (except dummies) are taken in the logarithmic form.

5 Results

The descriptive statistics and correlations between the variables are presented in Table 3. As shown in Table 3, the selected explanatories have a higher correlation with our dependent variables, indicating they might be appropriate for explaining the variations among provinces with regard to collaborations in technology commercialization. Meanwhile, we also observed that some variables are highly correlated, such as domestic trade and FDI. The correlation is high enough to suspect that there could be a multicollinearity problem. However, robustness tests indicate that the results are consistent and unaffected by the correlations among the variables as the maximum estimated variance inflation factor is 4.37, which is below the recommended level of 10 [8].

Given that both dependent variables take a count value (i.e., number of licensed patents within and across provinces) and the data structure is strongly balanced, we employ the generalized estimating equations (GEE) regression model, which is well

Table 4 Descriptive statistics

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7
1. Within province	113.6	407.9	0	4814							
2. Across province	71.43	163.3	0	1033	0.80						
3. Population	8.13	0.77	6.23	9.26	0.19	0.19					
4. FDI	6.95	1.80	1.52	10.38	0.35	0.46	0.46				
5. R	D	12.92	1.55	9.02	16.18	0.40	0.54	0.54	0.83		
6. Domestic trade	26.56	3.45	18.22	35.46	0.42	0.53	0.42	0.87	0.86		
7. Industrial output	7.69	1.15	4.55	10.18	0.39	0.50	0.70	0.83	0.91	0.85	
8. Per capita GDP	9.58	0.75	7.81	11.35	0.38	0.56	−0.04	0.72	0.74	0.79	0.67

Note dummy variables were not shown in this table

known in extant literature [22]. This method accounts for autocorrelation owing to repeated yearly measurements of the same province by estimating the correlation structure of the error terms [30]. Additionally, to account for any over dispersion in the data, we report all results with standard errors. Table 4 presents the regression results based on the GEE method.

As we predicted, population, per capita GDP and the sample year have positive effects on within- and cross-province collaboration with respect to technology commercialization. That is, both within- and cross-province collaborations between innovators are more likely to occur in highly populated provinces. Likewise, the higher the per capita GDP of a province, the greater the propensity for within- and cross-province collaboration in joint technological commercialization. In addition, according to the results it seems that from the beginning of 2006 Chinese provinces started to increase their interest in increasing their collaborative efforts in technology both within and across provinces. The collaboration is the result of a Chinese indigenous innovation strategy supported by a web of policies including those that promote technological collaboration among science, industry and province [21]. No differences among China's eastern, middle or western regions were found pertaining to technological collaboration in our empirical studies. This finding is similar to the regions' domestic trade and industrial outputs.

Interestingly, it has been determined that there are different mechanisms for nurturing technological collaboration within and across provinces. In Table 3, we can see that FDI has a positive effect at the 1 % level of significance on cross-province collaboration rather than on within-province collaboration. That is, a province that has more connections with foreign investors will have more collaboration with other provinces in China. It can be concluded that the greater the economic openness for foreigner partners is, the higher is the technology openness for domestic partners will be. However, this effect does not account for technological collaboration within

Table 5 Analysis results

	(1)	(2)
Variables	Within province	Across province
Constant	−35.92*** (7.570)	−29.74*** (7.253)
Population	1.514** (0.677)	1.464** (0.644)
FDI	0.0083 (0.151)	0.350*** (0.110)
R&D	0.453* (0.261)	−0.091 (0.169)
Domestic trade	0.134 (0.091)	−0.104 (0.134)
Industrial output	−0.112 (0.535)	−0.715 (0.547)
Per capita GDP	1.515* (0.782)	2.583*** (0.575)
Year dummy	3.242*** (0.266)	3.431*** (0.212)
West	0.181 (0.498)	0.509 (0.441)
Middle	0.112 (0.512)	0.097 (0.423)
Observations	390	390
deviance	670.6	526.7
Df	9	9

Note Standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

a provinces boundary. Rather, provincial R&D investments exert a positive effect on provincially bounded technological collaboration but not for cross-province collaboration. This is in contrast to our prediction that strong R&D investment would foster both internal and external collaboration due to the discourse of absorptive capacity (Table 5).

6 Conclusion and Discussions

Complementing the extant bibliometrics literature as well as innovation management literature, which is informed on collaboration in knowledge production activities that are generally measured by co-patenting and/or co-authoring, this study investigated the downstream collaboration in technological commercialization activities. Based on a regional perspective and using a valuable dataset with information on Chinese patent licensing activities where the licensor and the licensee collaborate to commercialize existing technology, this paper specifically examined the patterns and dynamics of collaboration within and across provinces. The results indicate that both types of collaboration in technological commercialization have experienced dramatic growth in the past 13 years, more particularly since 2006. Concerning the relationship between collaboration within and across boundaries, except for a few years, boundary-bounded collaborations dominated collaborative activities in China as they accounted for approximately 60 % of all collaborations; these statistics have remained stable.

Furthermore, it has been found that there are huge variations among the provinces regarding both within- and cross-province collaborations. However, this geographical variation has significantly decreased recently due to the dramatic restructuring of provinces that are active in this type of commercialization of technological collaborative activities whether they be within a province or across provinces. More importantly, we observed that provinces are not always active in both types of collaboration, but rather that for most Chinese provinces, they are either active in collaboration within a province's boundaries or across a province's boundaries. Few provinces could demonstrate strength in both internal and external collaborations with respect to technological commercialization. This forced us to further investigate factors fostering or prohibiting collaboration within and across provinces.

Based on a panel dataset of 30 provinces with over 13 years of data and on the results of the GEE regression method, we find that provincial population, per capita GDP in the focal province, and short duration (only since 2007) has a positive effect for within- and cross-province collaborations. While FDI and R&D investments play different roles in promoting collaboration, the former appears to be effective for across provinces collaborations, while the latter influences internal collaborations within a province's boundaries. Taken together, while it appears that there are factors that effectively nurture both types of collaboration, simultaneously there are also factors that have varying effects on fostering different types of collaboration. Accordingly, we conclude that there are different mechanisms for promoting different types of collaborations when a province is seeking to commercialize existing technology.

Our findings may suggest that the Chinese indigenous strategy appears to have achieved great influence. For example, we observed there was a significantly large increase before and after 2006 in terms of the absolute number of collaborations and with respect to a declining variation of collaboration among provinces. Furthermore, empirical results prove that these findings are significant at the 1 % level. In 2006, China issued its Long-Term Planning and Formulation of Science and Technology proposal. The goal of this plan is for China to become an innovative country by 2020. China's government, including all central sectors and local governments, promulgated a considerable number of policies to support this ambitious strategy. The key issue in these policies is to shift China's economic track from being resource intensive and energy based to being domestic-generated and innovation based. Thus, policies and institutions promote internal and external collaboration and technological exchanges among sectors and provinces [21]. To link our results strictly to China's indigenous innovation strategy is beyond the scope of this study, but we believe it remains an important topic for future studies.

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Construction and Validation of the Integration Model of Planned Behavior Theory and Health Belief Model

Xinyan Guo

Abstract Used the Method of questionnaire survey, mathematic statistic and structural equation model, establish the integration model of planned behavior theory and health belief model based on the 343 samples data at baseline surveys on community-based intervention trial in Urban Resident, and validated this model on follow-up surveys. Then, the intervention method was provided based on the explanatory of the integrationmodel. The research results show below: (a) the influence factors of urban residents' exercising behavior are multidimensional, including 9 factors: behavioral attitude, subjective norm, perceived behavioral control, perceived susceptibility, perceived severity, perceived benefits, perceived barriers, behavioral cues and behavioral intention. (b) An integrated model is constructed to best explain functions of urban individuals' physical activity and correlation factors. (c) Individuals at different stages show different psychological cognitive state and behavior intention level who confront different problems and barriers. Comparison and analysis on behavior characteristics of different exercising stages at intervention group and control group show that stage-matched intervention is economical and efficient.

Keywords Exercise behaviour · Attitude · Belief · Cognition · Health intervention

1 Introduction

With the development of society, people pay much more attention to living environment, living styles and the consequent changes of morbidity and mortality rates. Researches on health management and promotion show a close relationship between residents' living style and physical health. General public are aware of the hazards that not enough or too less exercises bring about to the individual physical health.

X. Guo (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: sindystory@163.com

X. Guo
Chengdu Sport University, Chengdu 610041, People's Republic of China

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It is easy to take exercises but hard to persist. In Japan, less than 30 % of Japanese do frequent (usually one year or more) and regular (30 min per time, twice a week) physical exercises. A survey in Australia showed that 53 % of the adults didn't take regular exercises with their sitting time being 4.7 hours per day or more [1]. High income countries like U.S. and U.K. showed the same results. According to the survey, in U.K., only 39 % male and 29 % female adults were doing exercises regularly, moreover, the participation rate declined with the change of age, work and family [2–4]. Domestic researches show that a lot of residents are aware of the profits of exercises, but many of them haven't built clear exercise consciousness and voluntary exercise habits, which have certain influences on the promotion of their health quality. In fact, studies and discussions on how to encourage regular physical exercises to the utmost extent has lasted dozens of years. Public medical institutions and the world health organization have already launched public health campaigns and taken intervention measures to deal with the problem of lacking physical exercises. In other words, the key value that physical exercise behavior holds to the national and public health, society and the country as well, is under estimated. Launching campaigns only to promote the benefits of exercises to the public is not enough to change people's behavior in doing exercises. Therefore, challenging the public health problem of physical exercise deficiency, designing and framing workable behavior intervention methods are key issues to be resolved.

In order to improve the limitations of the study of existing behavior theory, many researchers begin to find the better way, for example to explore the possibilities of various combination of theory and the integration of various theories to construct the more comprehensive theory system, such as scholar Poss [5] had proposed a comprehensive application of the health belief model and the theory of reasoned action interpretation of tuberculosis screening behavior, and this kind of practice in the research of physical exercise behavior is also began to try [6, 7].

Theory of Planned Behavior is generated in Ajzen [8] was revised based on the Theory of Reasoned Action. Based on the internal mechanism of this theory, the behavior attitude, subjective norm, and behavioral control has the function of predicting the behavior intention, while at the same time, behavior intention and behavior control and the occurrence directly affect the behavior. The health belief model was born in twentieth Century 50 times, is first used in a theoretical model to explain and predict individual health behavior, the model proposed by Rosenstock and by Becker and Maiman [9] to be revised. This theory interprets and explains the health behavior change from the angle of psychology, emphasizes the use of individual beliefs and attitudes to explain and predict various health behavior, the core part includes four closely related beliefs and behavior change: disease perceived susceptibility, disease perceived severity, perceived benefits and perceived barriers, in addition to besides, the model also takes into account the lead up to the final impetus to change the behavior of the individual, namely "behavioral cues". Because perceived benefits in health belief theory and the behavior faith in theory of planned behavior have similarity, and the concept of self-efficacy and sense of control is the cross concept, two theoretical models have cross on theory, so two kinds of models are combined used, from the comprehensive discussion of individual motivation and social psychological perspective of individual sports fitness behavior.

A few researchers conducted a preliminary integration of the two kinds of theory, but there is no related research to study the behavior of physical exercise, especially in the exercise behavior of follow-up survey. Therefore, in this study, the theory of planned behavior and health belief theory were integrated, and to verify and modify the integrated model on the basis of survey data.

2 Methods

1. Participants

Participants were four hundred and fifty urban residents who were randomly selected from the north and south in China. Participants who did not complete data were excluded, so there are 343 samples at baseline, the people completed a self-administered questionnaire during specially arranged times in groups of 20–50 as part of a research participation requirement. The samples were randomly divided into two groups: the intervention group and the control group, the intervention group 165, 178 in the control group (two subject's differences in exercise behavior results and behavior characteristic variables were not statistically significant, $P < 0.05$). Adults aged 18 or older, and the mean age of the sample was 42.5 years ($SD = 3.2$), 52.9 % were female. Their occupations are full-time workers 51.2 %, part-time worker 9.7 %, retired persons 10.1 %, housewives 13.8 %, students 4.7 %, and others 10.5 %.

2. Instruments

Relative documentations on current physical exercise and behavior intervention are summarized and reviewed to find defects and flaws in the previous studies. Research scales are designed to define conceptual model and theoretical hypothesis. The baseline test was in progress in 2014 March, after six months of behavior intervention, the tracking test was constructed in 2014 September, and all tests were completed to 2014 October.

A self-designed questionnaire was formed on the combination of the theory of planned behavior and health belief model, the questionnaire contain 4 items of personal basic information (including gender, age, occupation, education etc.), perceived susceptibility, perceived severity, perceived barriers, perceived benefits, behavioral cues, behavioral attitude, subjective norm, perceived behavioral control, behavioral intention and behavior, a total of 33 items. Scale by Li Kete five point scale scoring methods: among them, perceived barriers project assigned the remaining items reverse, positive score, namely "strongly disagree" for 1 points, "disagree" for 2 points, "not sure" for 3 points, "agreed" for 4 points, "strongly agree" for 5 points.

3. Development and Test of Scale

First of all, amount the sum score of the subjects according to the sequence from low to high, before scoring 27 % as high achievers, after scoring 27 % for the low group, differences in each item on the two group analysis by independent sample t test, and adjust and modify the scale based on the t test results which did not reach

Table 1 Each item discrimination test table of the exercise behavior integration scale

Item	T	P	Item	T	P	Item	T	P
q1	−11.058	0.000**	q12	−7.021	0.000**	q23	−4.256	0.000**
q2	−7.802	0.000**	q13	−4.974	0.000**	q24	−8.260	0.000**
q3	−6.151	0.000**	q14	−4.455	0.000**	q25	−11.352	0.000**
q4	−6.668	0.000**	q15	−9.477	0.000**	q26	−8.613	0.000**
q5	−5.598	0.000**	q16	−4.151	0.000**	q27	−6.101	0.000**
q6	−4.460	0.000**	q17	−4.375	0.000**	q28	−9.921	0.000**
q7	−4.705	0.000**	q18	−5.761	0.000**	q29	−3.099	0.002**
q8	−9.695	0.000**	q19	−7.635	0.000**	q30	−5.133	0.000**
q9	−11.933	0.000**	q20	−7.738	0.000**	q31	−5.210	0.000**
q10	−3.331	0.002**	q21	−9.124	0.000**	q32	−3.310	0.002**
q11	−5.480	0.000**	q22	−3.333	0.002**	q33	−9.125	0.000**

*the difference is significant at 0.05 level. ** the difference is significant at 0.01 level

the significant level ($P > 0.05$) [10], to modify the scale two times based on the results of analysis, and the terms of measurement tools with good discrimination can identify different behavior characteristics of sports fitness' (as shown by Table 1).

At the same time, use the factor analysis method to test the structure validity of the scale, and to test internal reliability using Cronbach alpha coefficient. The results showed in Table 2. Part of the investigation object in Chengdu City Community (36 residents) was re-test, to verify the external reliability of research scale, time interval of 4 weeks, using the same scale to test. The result show that Pearson correlation coefficient of the scale was 0.89 ($P < 0.01$). The research results show that, the scale has good validity and reliability.

4. Data Analysis

First of all, using baseline data to construct integrated model then explore the relationship between each variable using the tracking data after the intervention.

Table 2 Analysis results of reliability and validity of the scale

Component	Number of items	Cronbach alpha	Cumulative of variance (%)
Behavioral attitude (BA)	3	0.859	13.970
Behavioral cues (BC)	8	0.811	11.991
Perceived benefits (PBE)	5	0.883	9.159
Perceived severity (PSE)	3	0.782	6.407
Perceived barriers (PBA)	4	0.890	6.125
Subjective norm (SN)	2	0.761	5.348
Perceived susceptibility (PSU)	2	0.762	5.123
Perceived behavioral control (PBC)	2	0.795	4.912
Behavioral intention (BI)	2	0.816	4.774
Behavior	2	0.830	3.940
Total	33	0.865	71.749

The Epi-Data software to establish database, and application of Check module for detecting logic error, at the same time, using the regression analysis method to eliminate the influence of gender, age, education level, occupation and other individual factors on the variable, use AMOS 7.0 software to build a structure model of path analysis, and the model was tested and modified.

3 Model Construction

3.1 Establishment of Initial Model

The basic model was constructed based on the baseline data, among them, perceived susceptibility, perceived severity have the impact on behavioral benefits and behavioral attitude; perceived susceptibility, perceived severity, perceived benefits

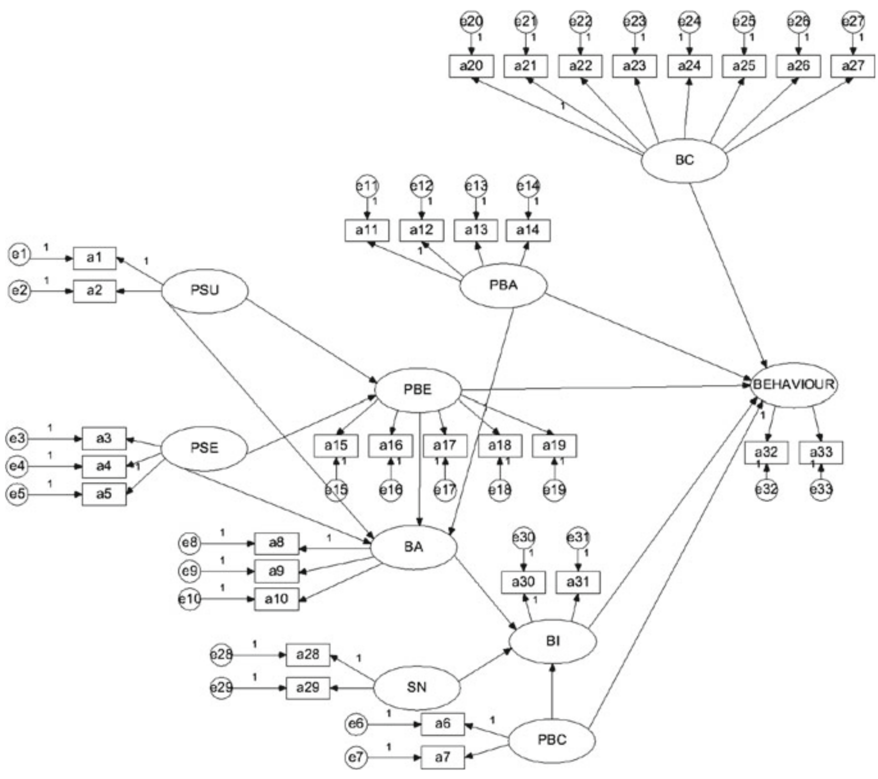

Fig. 1 The integrated theory hypothesis model of behaviour of urban residents $a_i\,(i = 1, 2, \ldots, 33)$ for the observed variables for each latent variable in the graph, $e_i\,(i = 1, 2, \ldots, 33)$ as the residuals of the observed variables

Table 3 Each path coefficient estimation results of the integrated model

	Nun standardized path coefficient estimation	P	Standardized path coefficient estimation
PBE<—PSU	0.196	***	0.189
PBE<—PSE	0.179	***	0.162
BA<—PSU	0.187	***	0.171
BA<—-PSE	0.180	***	0.165
BA<—PBE	0.259	***	0.245
BA<—PBA	0.206	***	0.183
BI<—BA	0.264	***	0.260
BI<—SN	0.179	***	0.162
BI<—PBC	0.333	***	0.301
Behaviour<—BC	0.207	***	0.184
Behaviour<—PBA	0.192	***	0.180
Behaviour<—PBE	0.230	***	0.196
Behaviour<—BI	0.346	***	0.317
Behaviour<—PBC	0.262	***	0.223

and perceived barriers have the impact on behavioral attitude; behavioral attitude, subjective norm and perceived behavioral control have the impact on behavioral intention; behavioral intention, perceived benefits, perceived barriers and behavioral cues have the impact on behavior. The initial model was showed in Fig. 1.

The model fitting effect display that the results of significance test parameters significantly (specific data as shown in Table 3), but $\chi^2/df = 3.256$, $GFI = 0.865$, $RMR = 0.05$, $NFI = 0.91$, It said that it is the general effect about basic model fitting, we should give further verification and correction.

3.2 The Verification of the Model

Two models were constructed in the intervention group and control group using tracking data, and based on the model test index feedback adjustment and test of the model (Fig. 2), the results showed a good fitting effect. The total effect of external variable impacted on inner variable in Table 4.

The model considers the direct effect of external variable on inner variables and the total effect, perceived subjective control and behavior intention are important factors to influence behavior, perceived benefits on action role to behavior is mainly manifested in the direct effect in the intervention group. On the contrary, there is indirect effect through perceived barriers in the control group.

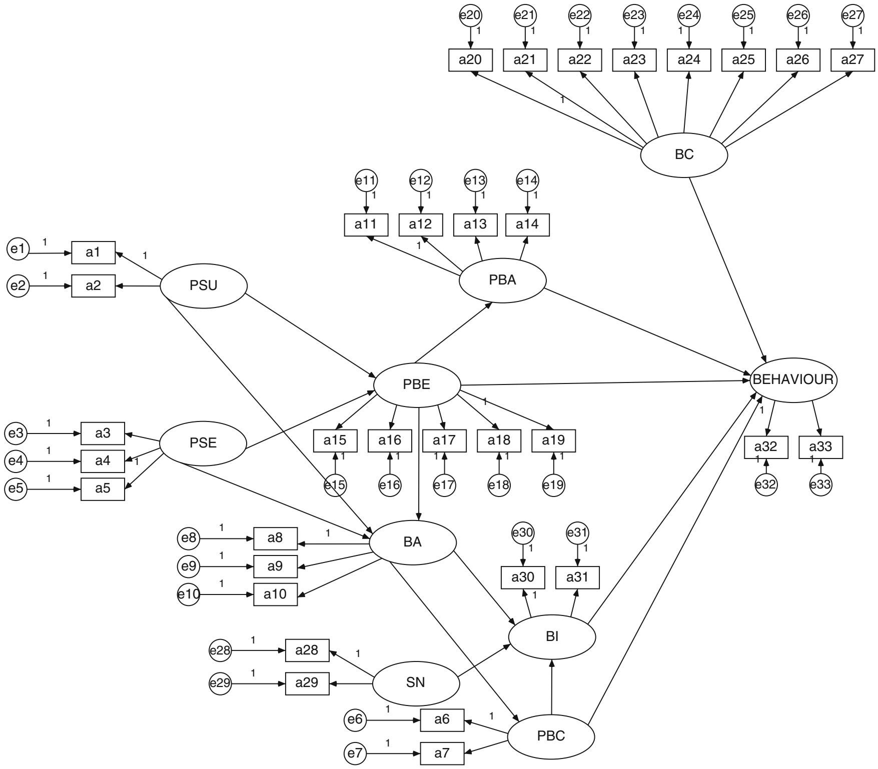

Fig. 2 The adjusted model of behaviour of urban residents $a_i (i = 1, 2, \ldots, 33)$ for the observed variables for each latent variable in the graph, $e_i (i = 1, 2, \ldots, 33)$ as the residuals of the observed variables

Table 4 The total effect between model variables (tracking data)

		PBE	PBA	BA	BI	Behaviour
Control group	PSU	0.180	0.047	0.214	0.055	0.021
	PSE	0.173	0.045	0.217	0.055	0.021
	PBE	–	0.260	0.058	0.015	0.050
	PBA	–	–	0.222	0.056	0.192
	BA	–	–	–	0.255	0.056
	PBC	–	–	–	0.301	0.598
	SN	–	–	–	0.162	0.035
	BI	–	–	–	–	0.219
	BC	–	–	–	–	0.079

(continued)

Table 4 (continued)

		PBE	BA	PBC	BI	Behaviour
Intervention group	PSU	0.188	0.224	0.153	0.098	0.112
	PSE	0.169	0.187	0.127	0.082	0.099
	PBE	–	0.264	0.180	0.116	0.269
	BA	–	–	0.681	0.439	0.383
	PBC	–	–	–	0.244	0.468
	SN	–	–	–	0.158	0.024
	BI	–	–	–	–	0.151
	BC	–	–	–	–	0.076
	PBA	–	–	–	–	0.063

4 Conclusion

The influence factors of urban residents' exercising behavior are multidimensional, including 9 factors: behavioral attitude, subjective norm, perceived behavioral control, perceived susceptibility, perceived severity, perceived benefits, perceived barriers, behavioral cues and behavioral intention. Perceived susceptibility and perceived severity of physical exercise have effects on perceived benefits and behavior attitude: perceived susceptibility, perceived severity, behavior barriers and perceived benefits have a positive impact on behavior attitude; perceived benefits have a negative role in behavior barriers but positive in behavior attitude; behavior attitude, subjective norm and perceived behavioral control function positively to behavior intention and behavior attitude does positive role to perceived behavioral control at the same time; behavior intention, perceived behavioral control, perceived benefits, barriers and cues exerts positive effects on behavior itself.

Based on the survey results, in the baseline data, the majority of urban residents are aware of the benefits from physical exercise, but they are not necessarily involved in the fitness. In other words, the promoting effect which perceived benefits impacted on behavior intention is still to be strengthened. For there are more worried about, such as ways of physical exercises and strength, physical training environment, time cost, etc. In addition, although the residents hold a positive attitude for physical exercise benefits, but due to the limited understanding of their own physical condition and the relevant authority on argument, there is no clear subjective feeling for the contrast effect not to participate in fitness activities, and actively participate in fitness activities. But the intervention group was improved in these aspects.

Previous similar research, such as a few researchers began to try to combine two or three kinds of theory to construct a comprehensive theory of exercise behavior, and carry out some preliminary empirical. Jackson and Aike [7] and Courneya and Bobick [6] in the study of exercise behavior change, assuming that form 10 cognitive process exercise behavior of college students will have an impact on the behavior of change, in this process, the components in the theory of planned behavior (behavior attitude, subjective norm, perceived subjective control and behavior intention) will play the role of regulating the intermediary. But more and more researchers have realized that the limitation of existing theories in exercise behavior today, to explore the possibility of multiple theories combined with the integration of core components and various theoretical construct more comprehensive theory system has gradually become the new trend of the future development of theories of exercise behavior. The research on the construction of the theory of planned behavior and health belief model integration model also has some attempts in other behavioral studies, but the differences between the different behaviors greatly, influence factors of the intensity of the effects are not the same.

The validation study was constructed by baseline data and tracing data, integrated model can explain the individual to participate in exercise behavior and the effect of the related factors. The integrated model points out the importance of health intervention for residents' exercise behavior. From innovation diffusion perspective, exercise behavior belongs to preventive innovation, perceived benefits are important factors to help overcome perceived barriers and promote behavior occurrence, in the previous related research, also verify the correlation both [11]. Therefore, should give publicity and introduce the lack of sports and physical exercise and the hidden trouble of "sub health" relationship to the residents, appropriate fitness guidance at the same time, in order to eliminate the concerns of residents physical exercise behavior, improve the subjective sense of control and promote exercise behavior. In addition, except by increasing the degree of understanding of exercise behavior knowledge, also can be increased through behavioral cues to enhance the behavior identity so as to promote the behavior, such as, the doctor's advice, friends or family experience. At the same time, behavioral cues itself also has a positive role in promoting the behavior.

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Study on Owner's Incentives to Supervisor Under a Ternary Structure

Lei Zhao and Sheng Zhong

Abstract In order to resolve owner's insufficient incentives to supervisor arising out of information asymmetry, this paper adopts principal-agent theory and constructs a ternary structure consisting of owner, contractor, and supervisor. On the condition of information verifiability and partial information verifiability, two owner-supervisor moral hazard models under the influence of contractor are constructed respectively to facilitate quantitative study on project management. Results show in the bill of quotation mode, partial verifiable information can make the owner grant more incentives to the supervisor and that the working capability of the contractor can exert positive influences on these incentives while the capability of the supervisor would negatively affect incentives.

Keywords Ternary structure · Owner · Supervisor · Moral hazard · Incentives

1 Introduction

As the pillar industry of the national economy, construction industry has become increasingly prominent in terms of status and function [17]. The soaring growth of China's urbanization indicates that a broader market for the construction industry is about to come. Considering its prominence in national economy, the sound development of the construction industry is of great significance. However, currently it is still troubled by problems, such as disordered management system, payment default, low profit for contracting companies, weak corporate competitiveness, and poor construction quality.

L. Zhao
College of Environment and Civil Construction, Chengdu University of Technology, Chengdu 610065, People's Republic of China

S. Zhong (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: szhong666@163.com

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In order to prevent the occurrence of the previous mentioned vicious incidents and ensure the sound development of the construction industry, China has been trying to learn from western countries and has formulated a set of policies and measures accordingly. Since the adoption of the supervision system in 1988, the construction industry has made continuous improvements in law, regulation, and structure. Now four basic systems have taken shape in China's project management industry: project legal person system, bidding system, project supervision system, and contract management system. Correspondingly, the construction market has converted from the previous dual structure to a ternary structure: owner, contractor,and supervisor [15]. It has been proven that these systems are playing vital roles in ensuring project quality and schedule as well as in improving construction performance.

However, engineering project management still faces many challenges in China. For example, information asymmetry in project construction between owner and contractor could lead to typical moral hazards as it is a prevalent act for contractors to conceal their effort information. In practice, contractor can not only conceal its effort information but also can hold back the project quality as private information due to owner's non-professional background (here project quality can be broadly defined as the final outcome of project construction, such as project quality, project deadline, project cost, and project safety). In order to effectively obtain information about project quality, an owner needs to engage a supervisor in project construction, who can get relevant information in a more effective way in virtue of its professional background. As contractor differs from supervisor in nature, an owner would adopt different incentive approaches for them.

Studies on owner's incentives to contractors are plentiful, with some from the empirical perspective [3, 14] and others from the perspective of risk [2, 8]. In methodology, most studies are carried out under the framework of one principal and one agent while major theories used include game theory [11, 16] and incentive theory [5, 19]. In these researches, comparative studies are made under the framework of one-to-one gaming in both complete information situation and asymmetrical information situation. In addition, a few studies considered owner, contractor, and supervisor at the same time and set up a ternary structure [7]. But these studies only adopted a simple matrix gaming model, ignoring information asymmetry.

On the other hand, the uncertainty of project construction would bring an inconclusive result to project quality even if the contractor makes great efforts. Similarly, it would also be dubious for the owner to get correct information of project quality, however hard the owner tries. These uncertainties make project quality into partially verifiable information. In this instance, what changes would occur in owner's incentives to contractors and supervisor?

Partially verifiable information was firstly proposed by Grossman [6]. He thinks chances are that true quality might not be revealed when a product is being examined. Information like product quality which possibly can be verified is then termed as partially verifiable information. Green & Laffont [10] holds that in a traditional principal-agent model with adverse selection, the agent always makes choices in accordance with the contract designed by the principal and never lies. However, sometimes agents lie and the literature presents the Stackelberg model for the situation where the agent possibly lies to some extent and the principal conducts auditing based on probability. In that literature, partially verifiable information denotes agent information that the principal tries to verify based on probability. Most scholars [1, 4, 9] adhere to the definition of partially verifiable information by Green & Laffont, and some studies [12, 18] also try to discuss partially verifiable information in moral hazard model.

On the condition of partial verifiability, literatures [13] mainly discussed owner's incentive to contractor in the ternary structure of owner-contractor-supervisor. This paper, in contrast, is mainly concerned with owner's incentive to supervisor in such a ternary structure. First of all, a moral hazard model on the condition of verifiable information is established as the basis, and then a more practical moral hazard model on the condition of partial verifiability is set up. After calculation and comparison between these two conditions, this paper presents the changes to the optimal payment in these two scenarios and analyzes how different conditions could influence the optimal payment.

2 Assumptions

On the premise that the contract amount for a bid has been decided [13], this paper considers a principal-agent model composed by an owner and a supervisor who can choose his effort level. In this model, the owner serves as the principal while the supervisor serves as the agent.

Gaming sequences for owner and supervisor is as follows:

(1) The owner provides the contract;
(2) The supervisor dejects or accepts the contract;
(3) The supervisor decides to make efforts or not;
(4) The supervisor starts to work;
(5) The supervisor sends reports to the owner;
(6) The contract is implemented.

Assumption 1: As a principle the owner's risks are neutral, while as the agent the contractor needs to avoid risks. The meaningful effort of the agent has two possible values, which can be standardized into zero effort level and positive effort level.

Assumption 2: Contractor's construction process entails random factors, and the effort level would influence project quality. Only two options are available for random quality level: high quality and low quality. If the contractor makes efforts, there is probability that high quality may be achieved, that is $pr(q = \overline{q}|e_1 = 1) \geq 1/2$. Such a probability in effect reflects the working capability of the contractor. If the contractor doesn't make any efforts, it is definitely sure that the project would be of low quality, that is $pr(q = \overline{q}|e_1 = 0) = 0$, $pr(q = \underline{q}|e_1 = 0) = 1$.

Assumption 3: Randomness also exists in supervisor's monitoring process, and his effort level would affect the accuracy of the report. In the report project quality is either high or low. If the project is of low quality and the supervisor makes strenuous efforts, the low quality would be observed at a certain probability. Correspondingly, low project quality would be reflected in the report, that is $pr(s = \underline{s}|e_1 = 1, q = \underline{q}) \geq 1/2$. Such a probability can also be viewed as a reflection of the supervisor's working capability. To facilitate the study, we simplify the variables. When the project is of high quality, a hard-working supervisor is not able to find any quality problems, so he would definitely submit a report to demonstrate the high quality of the project, that is $pr(s = \overline{s}|e_2 = 1, q = \overline{q}) = 1$. In contrast, when the supervisor doesn't make any effort, he would submit a report of high project quality for the sake of liability exemption regardless of the project's real quality, then $pr(s = \overline{s}|e_2 = 0, q = \overline{q}) = pr(s = \overline{s}|e_2 = 0, q = \underline{q}) = 1$.

Assumption 4: An owner would make payment to his contractor in terms of the contract and the report submitted by the supervisor. Specially, if the report from the supervisor shows that the project is of high quality, then the contractor would get the high transfer payment as stated in the contract; otherwise, the contractor would be properly punished and get the low transfer payment as set in the contract. The contractor can choose to appeal after knowing the report result submitted to the owner by the contractor. At that time, we suppose that the owner could bring in an external indifferent institution to fully justify the properness of the supervisor's report. If the supervisor submits a false report, then it would be fined to prevent the occurrence of situations where the supervisor maliciously submits reports stating the project's low quality in order to get incentives.

3 Model

Discussions will be carried out in two different sections. The first scenario, which is based on the condition of verifiable information, is a standard moral hazard model; while the second includes analysis on the condition of partial verifiable information. In comparison with the first model, here the influence of contractor's capability on the revenue and utility of the owner and the supervisor is taken into consideration.

3.1 The Model with Verifiable Project Quality

As incentives make it an inevitable choice for the supervisor to make efforts in his work, the owner's revenue would be discussed in two scenarios below.

(1) If the contractor completes the project at high quality, then the supervisor would surely observe the real state of the project quality and submit a report $\bar{s}$. In this case, the owner's revenue is $\bar{Q}$ and the payment to the supervisor is $\bar{t}$.
(2) If the contractor doesn't complete the project at high quality, then the supervisor would surely observe the real state of the project quality and submit a report $\underline{s}$. In this case, the owner's revenue is $\underline{Q}$ and the payment to the supervisor is $\underline{t}$.

Probabilities for each scenario are π_1 and $1-\pi_1$ respectively.

Therefore, the final revenue of the owner is: $V=\pi_1(\bar{Q}-\underline{t})+(1-\pi_1)(-\bar{t})$.

Similarly, supervisor's revenue would also be discussed in two scenarios, and the final revenue when the supervisor makes efforts is: $U=\pi_1\underline{t}+(1-\pi_1)\bar{t}-\varphi_2$.

The following plan is established:

$$\max_{\{(\bar{t},\underline{t})\}} \pi_1(\bar{Q}-\underline{t})+(1-\pi_1)(\underline{Q}-\bar{t})$$

$$s.t.\ \ \pi_1+(1-\pi_1)\bar{t}-\varphi_2\geq 0, \tag{1}$$

$$\pi_1\underline{t}+(1-\pi_1)\bar{t}-\varphi_2\geq \underline{t}, \tag{2}$$

$$\underline{t}\geq\varphi_2. \tag{3}$$

Equation (1) is participation constraint, and it is possible for the supervisor to accept the owner's contract only when the supervisor's expected revenue is larger than 0 after his efforts; Eq. (2) is incentive constraint, and the fact that more efforts would result in more effectiveness would elicit more efforts out of the supervisor. Equation (3) is limited liability constraint.

It is easy to see that due to Eq. (3), when Eq. (2) is satisfied, Eq. (1) must be satisfied. So the participation constraint doesn't work.

Let λ_1 and λ_2 be the Lagrangian multipliers in Eq. (2) and Eq. (3) respectively. After $\bar{t}$ and $\underline{t}$ are optimized, we can get the following first order condition:

$$-(1-\pi_1)+\lambda_2(1-\pi_1)=0, \tag{4}$$

$$-\pi_1-\lambda_1(1-\pi_1)+\lambda_2=0. \tag{5}$$

It can be get: $\lambda_1=\lambda_2=1$.

Therefore, the corresponding constraint Eq. (2) and Eq. (3) are both compact. We can calculate the values of $\bar{t}^1$ and $\underline{t}^1$ through the compactness of these tow formulas:

$$\bar{t}^1=\frac{\varphi_2}{1-\pi_1}+\varphi_2,\ \ \underline{t}^1=\varphi_2. \tag{6}$$

The superscript 1 indicates the optimal result in plan P3.1 and the same below.

At this time, the owner's expected utility is:

$$V^1=\pi_1\bar{Q}+(1-\pi_1)\underline{Q}-2\varphi_2. \tag{7}$$

3.2 The Model with Partially Verifiable Project Quality

In this case, the owner cannot get a global picture of the project quality by the observation of the supervisor, and the supervisor can only observe some quality information at certain probability.

In this case, neither the supervisor's efforts can be directly observed by the owner and the supervisor, nor can the supervisor be forced to make efforts. Nevertheless, the owner could make the supervisor contribute his efforts by offering incentives. As the incentives make it an inevitable choice for the supervisor to make efforts in his work, the owner's revenue would be discussed in three scenarios. Probabilities for each scenario are π_1, $(1-\pi_1)\pi_2$ and $(1-\pi_1)(1-\pi_2)$ respectively.

Therefore, the final revenue of the owner is: $V = \pi_1(\bar{Q}-\underline{t}) + (1-\pi_1)\pi_2(\underline{Q}-\bar{t}) + (1-\pi_1)(1-\pi_2)(\underline{Q}-\underline{t})$.

Similarly, the supervisor's revenue would also be discussed in three scenarios, and the final revenue when the supervisor makes efforts is: $U_1 = \pi_1\underline{t} + (1-\pi_1)\pi_2\bar{t} + (1-\pi_1)(1-\pi_2) - \varphi_2$.

The following plan is established:

$$\max_{\{(\bar{t},\underline{t})\}} \pi_1(\bar{Q}-\underline{t}) + (1-\pi_1)\pi_2(\underline{Q}-\bar{t}) + (1-\pi_1)(1-\pi_2)(\underline{Q}-\underline{t})$$

$$s.t.\ \ \pi_1\underline{t} + (1-\pi_1)\pi_2\bar{t} + (1-\pi_1)(1-\pi_2)\underline{t} - \varphi_2 \geq \underline{t}, \tag{8}$$

$$\pi_1\underline{t} + (1-\pi_1)\pi_2\bar{t} + (1-\pi_1)(1-\pi_2)\underline{t} - \varphi_2 \geq 0, \tag{9}$$

$$\underline{t} \geq \varphi_2. \tag{10}$$

Equation (9) is participation constraint, and it is possible for the supervisor to accept the owner's contract only when the supervisor's expected revenue is larger than 0 after his efforts; Eq. (8) is incentive constraint, and the fact that more efforts would result in more effectiveness would elicit more efforts out of the supervisor. Equation (10) is limited liability constraint.

It is easy to see that due to Eq. (10), when Eq. (8) is satisfied, Eq. (9) must be satisfied. So the participation constraint doesn't work.

Let μ_1 and μ_2 be the Lagrangian multipliers in Eqs. (8) and (10) respectively. After $\bar{t}$ and $\underline{t}$ are optimized, we can get the following first order condition:

$$-(1-\pi_1)\pi_2 + \mu_1(1-\pi_1)\pi_2 = 0, \tag{11}$$

$$-[1-(1-\pi_1)\pi_2] - \mu_1(1-\pi_1)\pi_2 + \mu_2 = 0. \tag{12}$$

It can be get: $\mu_1 = \mu_2 = 1$.

Therefore, the corresponding constraint Eqs. (8) and (1) are both compact. We can calculate the values of $\bar{t}^2$ and $\underline{t}^2$ through the compactness of these tow formulas:

$$\bar{t}^2 = \frac{\varphi_2}{(1-\pi_1)\pi_2} + \varphi_2,\ \ \underline{t}^2 = \varphi_2. \tag{13}$$

The superscript 2 indicates the optimal result in plan P3.2 and the same below. At this time, the owner's utility is: $V^2 = \pi_1\bar{Q} + (1-\pi_1) - 2\varphi_2$.

4 Model Analysis and Comparison

Firstly, it can be observed from the model of verifiable information that the owner will make his transfer payment decisions according to the project quality report submitted by the supervisor as the effort level of the supervisor is invisible to the owner. At this time, the constraint of limited liability would exclude the possibility for the owner to punish the supervisor. Hence the only solution to simulate the supervisor is to improve incentives. Observation into Eq. (7) reveals that compared with the complete information scenario, supervisor would rake in more profits in cases of informational asymmetry. As a result, the owner would lower his revenue expectation and the information rent paid by the owner to the supervisor to remedy the informational asymmetry is φ_2.

Proposition 1 *On the condition of verifiable information, the supervisor will not obtain the complete security that he would usually get when complete information is available. As the owner can’t punish the supervisor, in order to motivate him more incentives would be granted when the supervisor reports low project quality. The incentives would be* $\frac{\varphi_2}{1-\pi_1}$*. The owner lowers his revenue expectation because of these incentives.*

By comparing the models on verifiable conditions and partially verifiable conditions, we can find that the supervisor would get the same basic transfer payments (low transfer payments)łthe supervisor’s effort costłon these two conditions due to the protection of limited liability. It can be sensed from Eqs. (6) and (13) that partially verifiable information would render it less likely for the supervisor to find low project quality and thus report it to the owner. To keep the incentive level intact, the supervisor would get more incentives on this condition. From Eqs. (7) and (6) it can be found that the final revenue expectations for the owner and the supervisor are the same as the expectations when information is verifiable, that is $V^1 = V^2$.

Proposition 2 *On both verifiable and partially verifiable conditions, when the supervisor reports high project quality, the owner would grant him the same transfer payment* φ_2*; however, when he reports low project quality, he would be granted more incentives from the owner on partially verifiable conditions with the incentive value at* $\frac{\varphi_2}{(1-\pi_1)\pi_2}$*. As the supervisor is risk-neutral, revenue expectations for the supervisor and the owner won’t change on these two conditions.*

On the condition of partial verifiability, it is evident from Eq. (13) that larger π_1 value would incur greater incentives for supervisor’s reporting low project quality; and larger π_2 value means less incentives for the supervisor. In fact, partially verifiable conditions in this model would turn into verifiable conditions when $\pi_1 = 1$.

Proposition 3 *Incentives for the supervisor for reporting low project quality are negatively correlated to the supervisor’s working capability and positively correlated to the contractor’s working capability.*

This conclusion also conforms to the truth. The lower the supervisor's working capability or the higher the contractor's working capability, the less likely it is for the supervisor to detect low project quality. To stimulate the supervisor to work harder, the owner needs to increase its incentives. However, as the supervisor is risk-neutral, the increased incentives wouldn't lift the owner's costs.

5 Conclusion

In this paper, a principal-agent relation between owner and supervisor is discussed, in which the contractor's influence is considered. Through the construction of relevant moral hazard models, an analysis regarding the choice of optimal incentive strategy for the supervisor is presented on the conditions of verifiable information and partially verifiable information respectively, and then comparative studies on the optimal results on these two conditions are carried out. The emergence of supervisor may make a project's quality information no longer totally verifiable. Randomness increases in the supervisor's correct acquisition of project quality information would make it a necessity to grant more incentives to the supervisor. In addition, the respective working capability of the contractor and the supervisor can exert positive and negative influences on these incentives. Unlike what has been mentioned in literature [13], the growth in incentives will not affect the revenue expectations of the owner and the supervisor due to the supervisor's risk-neutral nature. Such results can serve as theoretical guide to studies on owner's incentives to the supervisor.

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An Optimal Control Model for Biogas Investment Problem Under Fuzzy Environment

Yanfei Deng

Abstract To improve the biogas energy development structure, this paper studies the multi objective dynamic programming in its investment system. Limited resource has bandaged the ideal of investors. Variety of stages in the systems and in object function us state diversion, stage decision and overall decision constitute optimization problem. This paper applied multi-objects fuzzy optimization dynamic-state scheme model to establish the math-model of having disagreement of amount, and the resource allocation problem not only having quantum object but also having qualitative object. The decision makers need to make a decision assigning the different area condition and resource to invest different scales of biogas projects under exploring constraint. Due to the lack of historical data, some coefficients are considered as fuzzy numbers according to experts advices. Therefore, a multi-objective dynamic optimization model with possibilities constraints under the fuzzy environment is developed to control the pollution and realize the economic growth. Finally, a practical case is proposed to show the efficiency of the proposed model and algorithm. A bi-level biogas investment planning multiple objective multistage programming model is constructed.

Keywords Fuzzy optimization · Dynamic programming · Uncertain programming · Biogas investment

1 Background

The use of biogas for energy production has progressively increased in recent years, due to an increasing interest both in agricultural and energy policies of many industrialized countries [5]. The energy project planning problem has long been recognized

Y. Deng (✉)
School of Management, Southwest University for Nationalities, Chengdu 610064, People's Republic of China
e-mail: dengyanfei921@163.com

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as a critical optimization problem. In this study, a optimal programming model with fuzzy random variables is developed for tackling a regional biogas project investment problem to achieve energy efficiency gains and improve the quality of the environment worldwide.

In energy, as in other economic fields in China, this is one of the controversies between the local and central governments, which makes it difficult to implement economic reforms [3, 4, 8]. Thus, a bi-level optimal control model to biogas investment problem has been built in this paper.

The bi-level programming model takes the optimal total benefit of the society and the optimal economic benefit of each subarea as the upper and lower targets, respectively [7]. In contrast to previous studies, the balance of the satisfactory degree between the upper and lower decision makers is considered in the bi-level optimization for ensuring the equity of the biogas project investment allocation [1, 2, 6].

2 Assumptions and Notations

Before developing the optimization model, some assumptions should be introduced. Full benefits represent the economic benefits of new projects and renovation projects. Non-full benefits represent the economic benefits of the old projects without renovation.

The national funding amount is different for full benefits project and non-full benefits project; Since the government endows the different subsidies to biogas projects, we assume that every project has its own tax rate and the tax is in proportion to the turnover of all the products; The raw materials described in this paper are also assumed to be co-digested in order to obtain the pre-set biogas yield or to fulfill the conditions set by the design of the system.

The following symbols are used in the paper.

Indices

i : Index of biogas project type, where $i = 1, 2, \ldots, N$;
j : Index of region, where $j = 1, 2, \ldots, M$;
k : Index of stages for the biogas investment planning and Management, where $j = 1, 2, \ldots, T$;

Certain parameters

$M(t)$: The investments from the central government in stage t;
$E_{ij}(t)$: The input-output ratio of i biogas project at j region in stage t;

$I_j^{\min}(t), I_j^{\max}(t)$: Minimal and maximal satisfaction limitations of the investments of region j in stage t;
A_0, A_{T+1} : Initial and terminal available investment of biogas project for the central government at the beginning and at the end of the decision making stages;
s_{ij}^0, s_{ij}^{T+1} : Initial and terminal the capacity scale of i biogas project in region j at the beginning and end of the decision making stages;
C_{ij} : The cost of each unit biogas project capacity of i biogas project at j region;
$N_{ij}(t)$: Capacity of each unit investment of i biogas project at j region in stage t;

$W_{ij}(t)$: The scrapped project of ip biogas project at j region in stage t;
δ : The discount rate of investments for biogas project;
φ_i : The ideal proportion of the biogas project structural for i biogas project

Decision and State variables

$y_j(t)$: The total investment of biogas project at j region in stage t, determined by the upper level decision maker;
$x_{ij}(t)$: The regional investment of i biogas project at j region in stage t, determined by the lower level decision maker;
$A(t)$: Available investment of biogas project for the central government in stage t;
$S_{ij}(t)$: The capacity scale of i biogas project at j region in t period

2.1 Model Formulation

The entire model is composed of the lower and upper level objectives, constraints, and state transit equations.

1. Decision Making Level for the Regional Manager of the Subarea.

When the mathematical description for the lower level is obtained, it is easier to determine the mathematical description for the upper level [7].

Regional economic benefit: Biogas from AD will not only improve the energy balance of a country but also make an important contribution to the preservation of the natural resources and to environmental protection. The production and utilization of biogas from AD has the potential to comply with all three targets at the same time. The ultimate goal of the government is to maximize the total economic benefit of the three projects in a whole period. The total economic benefit is calculated as the sum of full benefits and non-full benefits. Full benefits represent the economic benefits of new projects and renovation projects. Non-full benefits represent the economic benefits of the old projects without renovation. The farmers get also a new and important social function as energy providers and waste treatment operators. Thus the regional economic utility function can be expressed as:

$$RE(x_{ij}(t)) = \sum_{i=1}^{N}\sum_{t=1}^{T}[E_{ij}(t) \times x_{ij}(t) \times (1-\delta)^t - S_{ij}(t) \times C_{ij}]. \tag{1}$$

The regional manager also wants to maximize each subarea's economic utility as shown below:

$$\max_{\boldsymbol{x}}\{RE(x_{ij}(t))\}. \tag{2}$$

State transit of capacity scale: Based on the above statement, the origin and distribution of constructive capital are the motivation for the state transition of biogas system for different scales projects.

The origin of constructive capital consists of two parts: capital of state support and the income of projects in $k-1$ year. While treating agricultural waste, produced biogas can be used for household cooking, heating and warming, food and fruit preservation for small rural biogas digesters. The distribution of constructive capital including two parts: construction cost of the new biogas project and maintenance cost of the renovation biogas project. Each state can transfer to the neighboring state through the occurrence of arrival event or service event. The above state transition has two characteristics: (1) the one is that each state may be transferred to the rest either state; (2) the other is the number of all possible states is finite. So then the state transit equation for the lower level is:

$$S_{ij}(t+1) = S_{ij}(t) + N_{ij}(t) \times x_{ij}(t) \times (1-\delta)^t - W_{ij}(t). \tag{3}$$

Initial and terminal conditions of capacity scale: The initial and terminal conditions describe the capacity scale level at the beginning and at the end of the whole decision making procedure:

$$S_{ij}(1) = s_{ij}^0 \quad \text{and} \quad S_{ij}(T+1) \geqslant s_{ij}^{T+1}. \tag{4}$$

Constraints on aggregate investment: The sum of the volume of the regional investments of i biogas project cannot exceed the allocation investment of the central government:

$$\sum_{i=1}^{N} x_{ij}(t) \leq y_j(t). \tag{5}$$

Constraints on fund of investment to region: There are also nonnegative constraints on the decision variable $x_{ij}(t)$ because the investment of i biogas project in subarea j in stage t cannot be nonnegative:

$$x_{ij}(t) \geq 0. \tag{6}$$

2. Decision Making Level for the Central Government

After giving the mathematical description for the lower-level, the objective function and constraints for the upper level can then be determined. To fulfill the key investment of biogas allocation principles (i.e., satisfaction, efficiency, and economic benefit), the objective functions consider each subarea's satisfaction degree, the degree of development of biogas project and the balance development of type biogas project.

Investment satisfaction degree: The upper objective functions define the social satisfaction degree of the biogas project for the investment allocation, so the central government needs to create a plan to effectively allocate the investment to the subareas to maximize the minimal social satisfaction degree in each subarea. The social satisfaction degree for each subarea is defined by the function:

$$g_{jt}(y_j(t)) = \begin{cases} 0, & y_j(t) \leq I_j^{\min}(t) \\ \frac{y_j(t) - I_j^{\min}(t)}{I_j^{\max}(t) - I_j^{\min}(t)}, & I_j^{\min}(t) < y_j(t) < I_j^{\max}(t) \\ 1, & y_j(t) \geq I_j^{\max}(t). \end{cases} \tag{7}$$

The function of investment satisfaction degree assumes that for each subarea there is a basic (minimal) volume of investment fund allocated and maximal fund utilizing. That is, if the investment allocation volume is less than $I_j^{\min}(t)$, the satisfaction degree for that subarea is reduced to zero (0). However, if the water allocation volume increases to be more than $I_j^{\max}(t)$, the satisfaction degree of that subarea cannot increase to more than one (1). As a result, the objective function for the satisfaction degree is to maximize the minimal satisfaction degree:

$$\max_{\boldsymbol{y}} \min_{j,k} \{g_{jt}(y_{ij}(t))\}. \tag{8}$$

Development degree of biogas project: To guarantee investment of biogas project allocation efficiency in the upper level, the central government wants to maximize the development level of the each biogas project for the whole districts:

$$\max_{\boldsymbol{x}} \{DD(x_{ij}(t))\}, \tag{9}$$

where the development level of biogas project is defined as:

$$DD(x_{ij}(t)) = \sum_{i=1}^{N} \sum_{j=1}^{M} \sum_{k=1}^{T} E_{ij}(t) \times x_{ij}(t). \tag{10}$$

Sustainable development of biogas project: The vitality of the development of biogas project compatible with nature requires the sustainable development that protects and enhances natural resource quantities through improvements in management practices, efficiency and changes in development structure of biogas project. The development scale of the biogas project is consisted of the output amount of every subarea. That means there usually exists a proportional relation between the amount of investment for the different type of biogas project. Therefore, the total amount of investment of biogas project can obtained according to the allocated funds to every industry in the subarea. To achieve the development of biogas vitality, the central government usually expects to approximate the ideal proportion of the investment structure of the biogas project. Thus, the following objective function can be obtained,

$$SD(x_{ij}(t)) = \sum_{i=1}^{N} \left(\frac{\sum_{j=1}^{M} \sum_{t=1}^{T} x_{ij}(t) \times (1-\delta)^t}{\sum_{i=1}^{N} \sum_{j=1}^{M} \sum_{t=1}^{T} x_{ij}(t) \times (1-\delta)^t} - \varphi_i \right)^2 . \tag{11}$$

This objective also means that central government expects the minimal deviation from the realistic fund allocation structure of the biogas project to the ideal one under the subareas' responses to the allocated fund, namely:

$$\min_{\boldsymbol{x}} \{SD(x_{ij}(t))\}. \tag{12}$$

State transit of total investment: For the upper level decision maker, the total available fund is considered a state variable. Multistage decision making is actually a discrete dynamic process. The fund is the allocated to the subareas to develop biogas project, so the state transit equation for the upper level is as below:

$$A(t+1) = A(t) - \sum_{j=1}^{M} y_j(t) + M(t). \tag{13}$$

Initial and terminal conditions for total investment: The initial and terminal condition describe the investment at the beginning and at the end of the complete decision making process as shown below:

$$A(1) = A_0 \quad \text{and} \quad A(T+1) \geqslant A_{T+1}. \tag{14}$$

Constraints on fund of investment to biogas project: There are also nonnegative constraints on the decision variable $y_j(t)$ because the investment at subarea j in stage t cannot be nonnegative:

$$y_j(t) \geq 0. \tag{15}$$

2.2 Biogas Project Investment Equilibrium Model

The central government has to allocate the funds to n subareas. To meet the three type biogas project demands, the n regional authority seek adequate investment planning to maximize their economic benefit in accordance with the central government funds allocation decisions. As an upper level decision maker, the central government also considers equity, sustainability and efficiency in the n subareas when making the fund allocation decisions to develop biogas project. Therefore, there is an interactive relationship between the central and regional government. This relationship can be described as a multi-objective Stackelberg-Nash problem. The objective functions for the two level decision makers, as shown in Eqs. (8), (9) and (12), reflect the multiple goals and decision conflicts between the central and regional government. Therefore, by integrating the constraints and objective functions, the investment equilibrium model for optimizing the bi-level multiple objective investment of biogas project can be formulated as below:

$$
\begin{array}{l}
\max\limits_{\boldsymbol{y}} \min\limits_{j,k}\{g_{jt}(y_j(t))\} \\
\max\limits_{\boldsymbol{x}}\{DD(x_{ij}(t))\} \\
\min\limits_{\boldsymbol{x}}\{SD(x_{ij}(t))\} \\
\left\{\begin{array}{l}
A(t+1) = A(t) - \sum_{j=1}^{M} y_j(t) + M(t) \\
A(1) = A_0 \\
A(T+1) \geqslant A_{T+1} \\
y_j(t) \geq 0 \\
\left\{\begin{array}{l}
\max\limits_{\boldsymbol{x}}\{RE(x_{ij}(t))\} \\
s.t. \left\{\begin{array}{l}
S_{ij}(t+1) = S_{ij}(t) + N_{ij}(t) \times x_{ij}(t) \times (1-\delta)^t - W_{ij}(t) \\
S_{ij}(1) = s_{ij}^0 \\
S_{ij}(T+1) \geqslant s_{ij}^{T+1} \\
\sum_{i=1}^{N} x_{ij}(t) \leq y_j(t) \\
x_{ij}(t) \geq 0.
\end{array}\right.
\end{array}\right.
\end{array}\right.
\end{array}
\tag{16}
$$

3 Conclusion

This paper applied optimal control model to biogas investment problem under fuzzy environment to establish the math-model of having disagreement of amount, and the resource allocation problem not only having quantum object but also having qualitative object. The decision makers need to make a decision assigning the different area condition and resource to invest different scales of biogas projects under exploring constraint. Thus, it is essential to ensure that financing to mitigate and adapt to climate change responds to national needs and priorities and that national and international activities are linked and do not contradict each other.

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Analysis of the Operation Mechanism of Local Governments' Information Publicity Based on System Dynamics

Xiaoyan Li and Xiangling Guan

Abstract The publicity of local government information is an important aspect of the government livelihood construction. Using the principle of system dynamics, we have determined the system boundary, the main elements, dynamic and obstructive elements, and we divided the process into three subsystems. Therefore we analyzed the causality between the main elements and the force which exists in the mechanism of publicity of local government information. The information disclosure mechanism of local government can achieve a normal operation by the linkages between these three subsystems, mutual promotion and mutual restraint.

Keywords Information disclosure · Operation mechanism · System dynamics

1 Introduction

The information government agencies published involves the vital interests of citizens, legal persons or other organizations. Promoting the information disclosure of government is not only one of the content of the construction of the people's livelihood which government focused on but also the key to create a service-oriented government. The information publicity of Chinese local government has been running for many years, but there are still some issues such as information interoperability is not strong, means backward and so on. "2013 Chinese provincial fiscal transparency report" shows that the fiscal transparency of 31 provinces were average 23.14 points, 25.33 points and 31.4 points from 2011 to 2013. The degree of Chinese fiscal information disclosure is significantly lower, and there is a big gap from the expectations of the population [12]. The operation of government's information disclosure is a complex system, the running status of the disclosure of government information is

X. Li (✉) · X. Guan
School of Humanities and Social Sciences, Nanjing University of Science and Technology, Nanjing 210094, People's Republic of China
e-mail: 442354503@qq.com

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the key to influence the process, so the study of its dynamic mechanism is a good entry point to study the publicity of government information [11].

2 The Research Review and Theoretical Basis

2.1 The Research Review

The study of local government information publicity system mainly includes the following several aspects: (1) Study on the subject of a system. Zhuge [14] analyzed the different attitude of government, media and citizens' attitude towards information disclosure in the public crisis, and he thought that transfer way, models of information disclosure depends on the game of the three parties. Similarly, Niu [6] concerned the self-interest of managers and put forward that it is necessary for government departments who had specific information resources to improve the service efficiency of information institutions of government and further improve the management of government information resources. Form the angle of journalism, Chen [1] treated the broadcast of government news as a regular way to report the condition, how work processes, to the people, so that it's qualified with the function to deal with public relations. Yi [10] held that the government agencies should give a "prior notice" to the third person concerned with some information, and considered the scope of information disclosure from the prospective of information disclosure system. (2) Study on the operation process of information disclosure. Zhu [13] has studied the government information disclosure platform, including the traditional way to disclose and online media. Shao [7] has introduced, according to customer relationship management, personal service for information disclosure, technical support based on the application of information, new service system for the government information disclosure. Jiang [3] has analyzed the main factors, from the point of the Game between the power and resistance for disclosing information, restricting and promoting the government information disclosure, and then gotten the conclusion the power and the resistance comes from different subjects. Li [4] analyzed the dynamic mechanism of governments' information disclosure in public crisis and she thought that the driving force consisted of gravity, pressure and thrust. (3) Study on the value orientation or the target elements of information disclosure. It means the value target and code of conduct which government would choose and flow in the information disclosure. Chen [2] has constructed multilayer value orientation model for the information disclosure of food and drug safety, and discussed the principles or values of particular industry government disclosure information.

The research shows that: (1) The information disclosure of governments involves many subject-government, citizen, medias and the game of the three parties; (2) There is force between mechanisms such as gravity, pressure and thrust that may restrict or promote the operation of information disclosure; (3) There is a correlation between subjects' behavior and force in the mechanism of information disclosure. In addition, there are some factors such as economy, culture and others also affect the operation of the information disclosure mechanism. The above study viewed those different elements of information disclosure mechanism as study objects, and they didn't completely research the running status of the information disclosure mechanism and causal relationship exists between the various links under the condition of different subject and force balanced each other from a systematic angel.

2.2 Theoretical Basis

The codes and means of information disclosure are dynamic complex and nonlinear due to the influence of different factors [8]. Because of the different roles and responsibilities of different participators in the information disclosure process, thus creating a different feedback paths and subsystems, with interdependence between the various constituent elements of the subsystem. We can't fully understand the process of operation if we analyze the mechanism and mechanisms of local governments' information disclosure just relying on our intuition and experience due to the non-synchronization between transmission way and the results in information disclosure.

System Dynamics gradually explored the shape-changed causality by researching the closing interdependencies between system behavior and the internal mechanism. We used SD to analyze the operation of local governments' information publicity because of these flowing reasons: (1) Local governments' information disclosure is a complex information system that involves many participants. There may be different results according to different codes or means when subjects participate in information disclosure. (2) The results of information disclosure have a causal feedback relationship and paths. Their structures are complex because of the interlocking relationship. (3) The information disclosure and subjects' responses are lagging and the jet lag was depended on breadth, depth and ways of information disclosure. (4) We could explain why the subjects' behaviors and ideology generated such as whether the public are satisfactory by understanding the structural reasons behind the mechanisms and modes of information disclosure.

System dynamics can fully considered the process of local governments' information disclosure and the hidden reasons behind the behavior. It is able to describe the dynamic changing reasons and results so that it can provide reliable reference and basis for operation mechanisms of.

3 System Dynamics Analysis Process of Local Governments' Information Disclosure

First, we should ensure the system boundaries and analyze the target elements, subjects' elements and influence factors when we use system boundaries to study the operation and development mechanism of local governments' information disclosure. Next, we should analyze the causal relationship of elements between the subsystems which conducted in the information process. Finally, we should put forward an operation system of information disclosure and operation model of each subsystem.

3.1 Determine of System Boundaries

A complete local government's information disclosure system is a complex social system which includes not only the construction of basic system and information dissemination process systems, process system of citizens' receiving information, and including social monitoring and information feedback system. Citizens' right to know the information and formulating systems of related information disclosure are not included within the boundaries of the system.

3.2 Element Analysis of Multiple Subjects

The process of the governments' information publicity is the process of game between multiple interest subjects, interests being redistributed between different subjects again and ultimately achieving a balance. This balance would be constantly redistributed and reach a new balance again with the change of social politics, economic environment and the growth- decline between the subjects' force. Subjects of local governments' information disclosure include subject of right and obligation. The essence of information disclosure is the sharing and transfer of interests between both parties [9].

Right subject of governments' information disclosure refers to the person or organization which has the right to obtain or apply for obtaining the governments' information. Personal refers to the residents. The organization refers to a public organization. The tissue-type public of governments' information disclosure mainly includes corporate and government itself.

The obligation subject of local governments' information disclosure refers to the people who have the obligation to disclose governments' information. It contains administrative authorities. Some scholars believe that some enterprises, institutions, social organizations also hold some public information, so the research subject is defined as a broad government. The news media is not only the right subject but also the obligation subject. The media as an addresser of governments' information was supervised by government and the public.

3.3 Influence Factors

According to the points of system, information disclosure of local government is a manifestation of a new model of governance. The honest and transparent government is motive power. The process of information disclosure was affected by many external forces due to the game about interest between right subject and obligation subject in information disclosure. There are not only driving force from the government and the external environment but also resistance from IT or the distribution of benefits of different groups.

(1) Propulsion of local governments' information disclosure

The information disclosure of local government was affected by different subjects and external environment. Internal factors from the rights and obligations of subjects are the following:

a. Requirement of transforming government's functions

New public management requires that government provides public services with a new model and public goods and services were evaluated by public. Government has to provide more sharing public services and change the inherent resources to social public resources. Information disclosure of government was reflected through making the internal resource shared and socialized. All these are the original propulsion of information disclosure.

b. Requirement of public authority and political democratization

Public authority requested the government to safeguard the fundamental interests of citizens and reflect its fundamental will when implementing affairs. It is the fundamental motion which can push the information disclosure of government. Political democratization is requirement of transition from control to participation and it is the intrinsic motivation of information disclosure.

The complexity of the external economic environment and the social environment as exogenous variables of system has strong driving effect on the operation of the whole system. These factors are the following:

• IT is the basic guarantee

E-government established online bridges for government to communicate with other subjects, improved the improve the transparency of government information dissemination exchange and eliminated the channels blocked of communication between government and the public, the media thus avoiding public rights being private and other issues and promoting information disclosure.

• Economic development is an indirect driver of information disclosure

Market mechanisms require transparent information of different subjects when providing product. Government Information plays a leading role on the different economic behavior. Product provided by the government related to some decision information. Requests the government information transparent and improve information availability is conducive to economic development. The development of economic globalization requires the means of intervention of economic supervision subject transparent and the government information disclosure is conducive to lower transaction costs.

(2) Obstacle of local governments' information disclosure

Internal and external dual power can promote information disclosure of increasingly sophisticated, but the information disclosure will touch the interests of all parties. The shift in power of interests of both sides is bound to hinder the realization of the breadth and depth of information disclosure when they are in the game.

a. Scale and management of information disclosure are not normal.

The content and scope of information disclosure formulated the exception principle. Government always tends to the principle of confidentiality, fearing the large -scale disclosure will also increase supervision of public so that reduced the discretionary power of government. The resistance was largely from government itself in addition to the legislative resistance. In addition, lack of strict management standards makes the efforts and depth of information disclosure has a lot of randomness. Since the government holds more than 80 % of the information, basic arrangement and collection of information is not critical and is not shared, resulting in information disclosure is not enough.

b. Hypothesis of economic man and powers of rent-seeking.

Government is a special interest group and it would expand powers constantly for the pursuit of maximizing the Department and personal interests. The assumption that a government is economic person will lead to the expansion of government self-interest, thus forming a government of asymmetric information and public information barriers. On the one hand, the government kept a secret in order to avoiding blame, which affects the efforts of information disclosure; on the other hand, the government's management made asymmetric information barriers for increasing management rent, resulting in the power of rent-seeking behavior and had an effect on the breadth and depth of information disclosure.

4 SD Model for Operation and Development of Local Government Information Disclosure

Government, to achieve the information disclosure and construct the government information platform, information preparation and other aspects of activities, through certain means of communication, form a local government-centric information system platform for building and dissemination subsystem; government information disclosure is for service public, then depending on the degree of satisfaction and response to public as standard, open government information to build up the subsystem; Information disclosure is to service the public, and then quality and legality of services subject to the oversight of higher levels of government and the news media, the formation of supervisory control systems information disclosure. In addition to the main part of monitoring mechanism, news media is also charged with a number of information endorsements, refinement and complementary role. Specific three system operation and development SD model as follows:

The transfer process of SD model for local government information disclosure includes the construction of information system infrastructure, the establishment of information preparation systems and the system of transfer information, at the core and important position in the government information disclosure. In the subsystem that the infrastructure of government information being built and delivered, increase in government's investment on constructing information → increase the completeness of repository construction → strengthen the capacity of transferring government information → increase the breadth and depth of information → increase public satisfaction → increase government performance → the government increased investment in infrastructure of information disclosure.

On the other hand, the complete government's preparation system → strengthening the construction of the network organization → online forums frequency increased, the increase in the exchange of information → strengthen in the breadth and depth of information; the completeness → providing training → improving public awareness of information disclosure → enhance the acknowledge of related disclosure and privacy protection, improve of government staff's ability to disclose information → improve of public satisfaction. In such a system, the information disclosure completes the collection, sorting and delivery process. From this system, the government is a body of information collection and transmission, the government increasing investment in related information, making repository complete, holding related training activities and creating networking organizations and the clearing house, which will help to improve the transmission of information disclosure, information depth, strengthen communication, channels increased, improving delivery time and quality of information.

In the public feedback subsystem of information disclosure, making the scope, content and channels of the public receiving information a starting point, the more breadth, depth, and channel → the more economic benefits deriving from the information public have access to → public satisfaction increase → improve the public participation' strengthen the government's ability to interact with public → increase the benefit of government investment → increase the government's performance → improve the investment. In this subsystem, it, with the exception of large-scale government information disclosure → the public received information with little breadth and depth → lower public satisfaction. This is a negative feedback system. It is in this system, the realization of the public can effectively receive government information, and realize the information interaction between government and citizens and feedback.

Local governments' information disclosure must be supervised by various subjects such as superior or subordinate government, news media and the public. Different subjects would concern and supervise different content of information disclosure. It contains three feedback subsystems. First, the system of public feedback about supervision on information: public question after receiving information → collecting related information/appealing for data → government relief → the credibility of the government to reduce → the public satisfaction to reduce → the supervision of the superior or subordinate governments to increase → the related document published to increase → the enhancement of supervision. Second, superior or subordinate government collects related information /data → the supervision of the superior or subordinate governments to increase → the quality of governments' information disclosure enhanced → increase in the credibility of the government → the enhancement of public satisfaction. Third, the increase of public appeal → increase in the News media's attention to information disclosure → collecting related information or data → increase of the press conference → the credibility of the government to improve → the public satisfaction to increase. The supervision system composed of the three causal feedback systems.

In the above three subsystems, the construction of information system infrastructure, the establishment of information preparation systems and the system of transfer information are the center and connection of this system. These three systems are the relationship of mutual coordination, balance and restriction. The more complete the systems of basic structure and transferring process is, the better quality, quantity, accesses of public acceptance of information, thus the operation of supervision mechanism would lower the time and cost. Similarly, running in a good condition of supervision subsystems could play a security role in the process of information disclosure and the mechanism of public acceptance of information (Fig. 1).

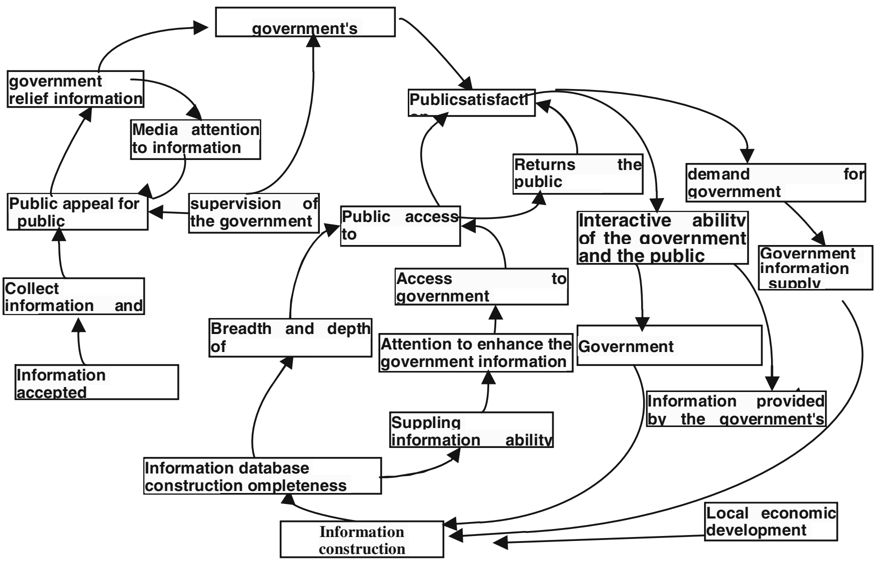

Fig. 1 The operation of the local government information disclosure mechanism

5 Conclusion

By using theories of system dynamics, this article analyzed operation mechanisms of information disclosure from two aspects: target elements and interaction of different subjects. Mechanism models of information disclosure were constituted by propulsion, hindrance and the game between every subject. They include three interrelated subsystems: constructing the infrastructure of information system, establishing the system of information preparation and the process of information transmission system; subsystem of the public's feedback about information disclosure; subsystem of subjects' supervision on local governments' information disclosure. There is a dynamic relationship of checks and balances between the three systems. By using the analysis results of local governments' information disclosure, we can solve following problem:

(1) Treat the information disclosure of government dynamically. System Dynamics can handle the complex identifying system which is nonlinear and of multiple feedback. It chooses a comprehensive perspective and considers various parallel elements in the information disclosure of government. It analyzed those complex problems of process when achieving the information disclosure by illustration. These three subsystems are interrelated and mutually conditioned. In the long run, we should dynamically analyze the mechanisms of governments' information disclosure when researching the problem of information disclosure.

(2) Be able to simulate the running operation of local governments' information disclosure under the condition of the related data collection is not complete. There are qualitative indicators and variables in the simulation system, so we may encounter some problems such as insufficient data or data are difficult to quantify in modeling. Although it is difficult to estimate the parameter because of the lack of data, we can still calculate and analyze under the help of causal relationship between the elements in the system dynamics, limited data and specific structure if the parameter falls within the tolerances so that solving the tendency of operation or behavior model in information disclosure.

(3) Provide theoretical reference for researching the operation mechanisms of local governments' information disclosure. With the help of the theory of system dynamics, we analyzed the target elements and the relationship between different subjects, the factors of propulsion and resistance, revealed the casual feedback relationship between factors and providing theoretical guide for promoting the operation of whole information disclosure. System dynamics finally solved the problem about the dynamic simulation of information disclosure of operation mechanisms, so we can make the assumption about the system minimized. At the same time, it provided a kind of "policy laboratory" for local governments' information disclosure and we can test the current status of operation mechanism, decision and results of policy by simulating. It can make the current system improving and perfect by the redesign of system [5].

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An Empirical Study of Relationship Between Executive Compensation and Performances of Chinese Listed Company—Based on Simultaneous Equations Model

Lixia Yu, Lu Wang and Min Shang

Abstract As a potentially important internal incentive, the executive compensation has gradually become a research focus. Based on simultaneous equations model and principal component analysis, this paper studies the relationship between executive compensation and corporate performance. Using comprehensive financial and accounting data on China's manufacturing listed companies from 2009 to 2012, we find that the improved corporate performance can advance executive compensation. At the same time, we also find executive compensation has positive feedback effect to company performance. The paper also sees that the company's equity incentive has the potency to improve the effectiveness of the performance. This result offers insights to shareholders focused on enhancing the design of internal corporate governance mechanism.

Keywords Simultaneous equations model · Principal component analysis · Executive compensation · Corporate performance

1 Introduction

According to the modern agency theory, with the separation of ownership and executive, the objective conflict between corporate executive and shareholders intensifies. To reduce such conflict, shareholders through the remuneration incentive mechanism allow the executive to have some residual claim, so that makes their goals consistent. Meanwhile, in the condition of trust-agent theory, due to the information asymmetry, the managers have the motivation to pursuing their own interests. To reduce agency cost and maximize wealth, the shareholders tend to through the company performance to determine the executives pay, trying to motivate managers to act in the best interest of shareholders.

L. Yu (✉) · L. Wang · M. Shang
Business School, Sichuan Normal University, Chengdu 610101, People's Republic of China
e-mail: ylx6209@163.com

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However, a survey shows that under the influence of the 2008 international financial crisis, the overall profits of China's quoted companies generally decline, while the payment of the executives continues to rise. It had aroused strong opposition among the investors. By comparing the 431 quoted companies in 2007 and 2008, the data shows that the profits of quoted companies decrease by 26.2 billion Yuan in total, while the executives pay increase by 200 million Yuan [1] . This is aroused the public question the relationship between the executive compensation and company performance. What is the interaction between the two things? The paper will discuss this question by establishing simultaneous equations and get some new discoveries.

We will test the interaction between the executives compensation and company performance by establishing simultaneous equations. To avoid the limitation of single variables, we will get the overall performance index through the analysis of the principal components of the four variables. However, there are still some limitations in the paper, mainly reflected in the following aspects: (1) The analysis of the incentive theory for executive compensation is not thorough. Besides the low level of domestic executives pay and the different pay in each period also caused diverse results. (2) The data is limited to the industrial quoted companies from 2009 to 2012, and the influence of industries and some non-financial factors are not considered. (3) Because the performance indicators are too much to listed, the paper only use four indicators to reflect the company performance, so it may not completely represent the true performance of the company.

2 Literature Review

2.1 The Incentive Effects of Executive Compensation

As for the study of executive incentive and compensation, the overseas scholars involve in the field earlier. With the change of the external environment, the conclusion also changes. Taussings and Baker [2] are the earliest scholars to study enterprise salary, finding little correlation of executive compensation with performances. By analyzing external determinants of enterprise CEO compensation, Finkelstein and Hambrick [3] found that different remuneration packages have different effects on CEO's behavior, and ultimately affect the company's overall performance. Jensen and Murphy [4] found that if the CEO compensation increase or decrease by every $3.25, then the shareholder's wealth will increase or decrease by every $1000. Accordingly, compensation and shareholder's wealth are positively correlated. Mehran [5] found that executive compensation incentive became a driving force for improving corporate performances. With the development of theories and methods, studies from abroad tend to believe that executive compensation has a significant effect on corporate performance. By analyzing the relationship between compensation quantity and corporate performance in three incentive schemes, Li et al. [6] found that the increasing in executive compensation can significantly improve the corporate performance. Generally speaking, with time goes on, an increasing number of scholars believe that the incentive for executive compensation works indeed.

2.2 The Impact of Corporate Performance on Executive Compensation

Theoretically, attaching executive compensation to corporate performance can reduce the probability of Agency's conflict, and positive relationship exists. Many scholars attempted to use various analytical methods to test this theory, but conclusion varied. By using Black-Scholes model to analyze the relationship between the CEO's compensation and the share value in stock market of 478 large U.S companies, Hall [7] found that the value of the company increased by every 10 %, management salaries and bonuses would increase by 2.4 %. Lai [8] who concentrated on the impact of incentive mechanism and governance structure on company's compensation, found that the executive compensation was positively related to accounting performance significantly but irrelevant to market performance, thus he believed that quoted companies inclined to regard accounting performance as incentive assessment indicator. Mao and Zhang [9] tested the relation between Executive compensation and corporate performance in domestic quoted companies through ownership structure indicators, finding that the positive relationship between executive compensation and corporate performance existed, and the executives increased their salaries through the improvement of corporate performance. In turn, the increase in salaries impels them to work harder to improve corporate performance.

3 Theoretical Analysis and Hypotheses

The aim of incentive mechanism is to make executives act in the best interest of shareholders and to improve efficiency, which is also the cornerstone of incentive mechanism. In order to improve their income and appreciate the compensation given by principal, managers work harder. Meanwhile,they consider more for the shareholders when they behave, which will undisputedly reduce the agency cost and improve corporate performance. According to the above, we can propose hypothesis.
Hypothesis 1. (H1) Executive compensation incentive indeed has a positive effect on corporate performance in the domestic quoted companies, that is, with the increase in salary, the corporate performance gradually increases.

According to principal-agent theory, the separation of ownership and management forces companies to hire more external managers. Due to there is a serious information asymmetry between the principal (shareholders) and their proxies (managers), and that managers have a practical "control" and lack the necessary binding mechanism. Then, these make the managers tend to have the on-the-job consumption motives or do not work hard to shirk their responsibilities. In order to reduce the agent cost of information asymmetry and the risk of moral hazard, stockholders will sign the contract for pay-performance with the managers before their entry. Under the contract, corporate performance is directly related to the interests of executive by linking executive compensation and corporate performance. Thus, in order to maximize their individual interests, the managers must work hard to improve the performance of the company. It can be concluded from the above theory that it exist significant positive relationship between executive compensation and corporate performance. Therefore, we propose the following hypothesis.

Hypothesis 2. (H2) Executive compensation is affected by the performance of the company, that is, the executive compensation increase with the increase of the performance of the company.

However, in reality, the relationship between management compensation and performance of quoted companies in China seems generally weak. According to the survey, because of the effection of the global financial crisis in 2008, profits of quoted companies in China generally declined, but executives' payment did not fall but rise. Comparing the data in the year of 2007 and 2008 of 431 quoted companies, we found that total profits of quoted companies had fallen by 26.2 billion Yuan, while the executive pay had increased by 200 million Yuan [1]. Based on this, we propose the alternative hypothesis.

Hypothesis 3. (H3) Executive compensation and corporate performance are not related.

4 Study Design

4.1 Sample Selection and Data Sources

All samples are derived from CSMAR database system and the data analysis is completed by SPSS17.0 and EXCEL. According to the research, we collected annual data of Manufacturing quoted Companies in Shen & Hu A-share Stock Market between 2009 and 2012 as sample. In order to ensure the effectiveness of research sample, we sifted:

(1) Rejected a Stock quoted companies which issue B stock or H stock simultaneously;
(2) Rejected ST or *ST quoted companies which have poor performance;
(3) Rejected the quoted companies which don't disclose detailed data or have incomplete data;
(4) Rejected the quoted companies which executive couldn't be paid;
(5) Rejected the quoted companies which Tobin's Q value is more than 2.

Based on the above principles, we get the effective samples: 1144 samples of 2012, 895 samples of 2011, 430 samples of 2010, and 487 samples of 2009.

4.2 Selection of Variable

1. Compensation index

This paper selects the cash compensation that the executive got to measure their incentive compensation index, and choose the average figure of the top three compensation of executive as the executive compensation index. In order to eliminate the influence of scale, we choose Natural Logarithm, denoted by AP.

2. Corporate performance index

Agency theory put emphasis on using multiple indicators to exclude the deviation from Single indicator, to reduce the agency's opportunity cost and to eliminate conflicts. In order to work better, this paper select ROANPMROTA and Tobin's Q (market performance indicator). Meanwhile, after the analysis of factors, we select the common factor to reflect corporate performance and use it to comprehensively evaluate and analysis samples' performance.

3. Control variables

In order to reflect the relation between executive compensation and corporate performance better, and avoid the phenomenon of spurious regression, the paper adds corporate size, GRO, LEV and MSR in Empirical model.

As is shown by Table 1.

Table 1 Variable name, symbol and definition

Variable name	Symbol	Variable definition
Performance variable		
Corporate performance	ROTA	ROTA = (total profit + financial costs)/total assets at the year end
	NPM	NPM = net profit/operate income
	ROA	ROA = net profit /balance of total assets
	TQ	Tobin's Q = (circulating shares market value + non-circulation Shares market value + book value of liabilities)/total assets at the year end, net assets replaced by non-circulation shares market value to calculate
Compensation variable Executive compensation	AP	LN (the top three compensation of director, supervisor and executive sum/3)
Control variables		
Corporate size	SIZE	LN(total assets at the year end)
Corporate growth	GRO	(Main business income at the end of the year − Main business income at the end of last year)/Main business income at the end of last year
Financial leverage	LEV	Liabilities/Total assets
Managerial ownership	MSR	The sum of percentage of shareholdings in the top three of all senior executive(director, supervisor and senior executive)

4.3 Factor Analysis to Obtain Comprehensive Performance Indicators

1. Test Factor Analysis

According to Table 2, there are relationships between the four indicators. It's suitable for Principal Component Analysis to extract common factor. Specifically, return on total assets and total assets net margin correlation coefficient reached 0.967, ROE and total assets Net profit margin of the correlation coefficient is 0.305. It shows that single indicator can't comprehensive reflect corporate performance. Therefore, we need to use factor analysis to conclude comprehensive performance indicators. In addition, according to Table 3, KMO value is 0.542, and the more the figures are closer to 1, the better for the analysis results. Bartlett test can indicates that each index isn't identity Matrix and passes 1 % significance level by factor analysis.

2. Factor analysis

We commonly use Kaiser Test in factor analysis, and extract the main ingredient which eigenvalues are greater than 1. Table 4 shows that former 2 factor eigenvalues are greater than1. After factor rotation, cumulative variance has little change and don't affect the results of original variables. Therefore, we selected the first factor and the second factor to represent the information that contained in the four performance indicators. And Table 5 shows that the first principal component has a larger load coefficient to ROTA, ROA and ROE, noted as F1 and the second component has a lager load coefficient to Tobin's Q, noted as F2.

Table 2 Performance indicator correlation matrix

	Return on total assets ratio	Tobin's Q	ROA	ROE
Return on total assets ratio	1			
Tobin's Q	0.103	1		
ROA	0.967	0.09	1	
ROE	0.293	−0.073	0.305	1

Table 3 KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.542
Bartlett's test of sphericity	Approximate chi-square	9722.79
	Df	6
	Sig.	0

Table 4 The total variance explained

Component	Initial eigen values			Extraction sums of squared loading			Rotation sums of squared loading		
	Total	Variance(%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	2.141	53.517	53.517	2.141	53.517	53.517	2.124	53.109	53.109
2	1.000	25.012	78.529	1.000	25.012	78.529	1.017	25.421	78.529
3	0.826	20.648	99.177						
4	0.033	0.823	100						

Table 5 Rotated factor loading matrix and ingredients score coefficient matrix[a]

Variables	Rotated factor loading matrix		Ingredients score coefficient matrix	
	1	2	1	2
Tobin's Q	0.129	0.970	−0.056	0.970
ROTA	0.963	0.015	0.445	0.069
ROA	0.964	−0.015	0.449	0.039
ROE	0.516	−0.244	0.269	−0.213

[a]Extract method: principal component analysis

Table 5 shows:

$$F1 = -0.056TQ + 0.445\text{ROTA} + 0.449ROA + 0.269ROE,$$
$$F2 = 0.970TQ + 0.069\text{ROTA} + 0.039ROA - 0.213ROE.$$

According to the models above, $F = (53.109F1 + 25.421F2)/78.529$.

4.4 Model Construction

1. Simultaneous equation

$$F = \alpha_0 + \alpha_1 AP + \alpha_2 MSR + \alpha_3\text{SIZE} + \alpha_4 GRO + \alpha_5 LEV + \varepsilon_1, \quad (1)$$
$$AP = \beta_0 + \beta_1 F + \beta_2 MSR + \beta_3\text{SIZE} + \beta_4 GRO + \beta_5 LEV + \varepsilon_2. \quad (2)$$

Model (1) is used to verify the effectiveness of executive incentive compensation. Model (2) is to judge whether the executive compensation is decided by performance.
2. Simultaneous equations test

This paper use Hausman test method to examine the relation between corporate performance and executive compensation. The model is as follows:

$$AP_i = a_0 + a_1 F + a_2 MSR + a_3\text{SIZE} + a_4 GRO + a_5 LEV + \varepsilon_3, \quad (3)$$
$$F = b_0 + b_1\varepsilon + b_2 AP_i. \quad (4)$$

Table 6 shows, the coefficient of ε is −2.507, the T-value is −3.994. Both of them pass significant test of 1 % leverage. Therefore, there is a simultaneous equation between executive compensation and corporate performance.

Table 6 Simultaneous equations test

Variables	Parameter coefficient	T-value	P
C	−32.713***	−4.544	0
AP_i	2.507***	4.459	0
E	−2.507***	−3.994	0.001
Adj-R^2	0.046		
F	9.945		

***The corresponding variable parameters significantly correlated on level 1 %

5 Empirical Results

5.1 Descriptive Statistics

Table 7 provides the variables' descriptive statistics of sample companies. It shows that the sample companies' performance (F) is 0.504, median is 0.506 and indicates that the sample's overall profitability is good. Executive compensation (AP) minimum is 9.338, maximum is 15.865, standard deviation is 0.924, indicating that there is a big difference between the executive compensation. The maximum of executive shareholding ratio (MSR) is 97.3 %, the minimum value is 0, the median is 1 %, average is 16.7 %. It shows that the executives which hold no stock or lower stock ownership in sample company exists wildly, and it has a limited equity incentive. At the same time, sample company's executives also have large differences in shareholding.

Other control variables-company size (SIZE), growth (GRO) and financial leverage (LEV)- differ largely, indicating that the company size, growth and the degree of financial risk are different, and it helps to control the impact on each variables of the sample companies.

Table 7 Descriptive statistics of variables

	F	AP	MSR	SIZE	GRO	LEV
Average	0.504	12.791	0.167	21.657	0.655	0.419
Median	0.506	12.824	0.001	21.512	0.108	0.417
Standard deviation	0.166	0.924	0.25	1.204	14.294	0.235
Minimum	−1.679	9.338	0	18.76	−0.967	0
Maxima	3.226	15.865	0.973	26.487	665.54	2.373

5.2 Regression Analysis

According to the regression results of simultaneous equations in Table 8, we know that the correlation coefficient between executive compensation (AP) and firm performance (F) is 0.012 and there are 10 % passed the test about level of significance. It shows that the executive compensation of sample companies produce incentives to improve the company performance. Thus, the hypothesis 1 is verified. Meanwhile, we also find that the relationship is not particularly significant. It proves that the company performance is not the only factor to determine the executive compensation. With the increase in executives' power; compensation may not meet the growing "appetite". The correlation coefficient between the performance of the company (F) and executive compensation (AP) is 0.356, significantly correlated at the 1 % level, and salary increases with the improvement of the performance of the company. This conclusion confirms the hypothesis 2. The empirical results show that the pay-performance under the contract, executive compensation is indeed linked to the corporate performance in sample companies'. In order to maximize their own interests, executives must strive to improve business performance and to achieve the final goal through this way.

In addition, in the incentive compensation equation, we can find that there is a significant positive correlation between executive shareholding ratio (MSR) and company performance (F). This suggests that when the company executive enjoys the right of residual claim, they will tend to be consistent with the interests of shareholders. The more the executive hold shares, the larger the correlation is. They will regard enterprise as a community of interests, and strive to improve the company's operating performance. And in the compensation criterion equation, executive shareholding ratio (MSR) and executive compensation (AP) were positively related, but not significantly, probably in Chinese enterprises, executive stock ownership is not

Table 8 Simultaneous equations of regression analysis

Incentive compensation equation				Compensation criterion equation			
Variable	Parameter estimation	T-values	VIF	Variable	Parameter estimation	T-values	VIF
Constant	1.054***	16.073		Constant	7.146	20.165	
AP	0.012*	1.502	1.1	AP	0.356***	3.502	1.048
MSR	0.120***	7.89	1.284	MSR	0.133	1.563	1.31
SIZE	0.031***	10.378	1.392	SIZE	0.267***	16.777	1.317
GRO	0	−1.105	1.005	GRO	−0.003**	−2.404	1.003
LEV	−0.014	−0.94	1.43	LEV	−0.786***	−9.669	1.386
Adj-R^2		0.05		Adj-R^2		0.309	
F		30.942		F		61.447	

* The corresponding variable parameters significantly correlated on level 10 %
** The corresponding variable parameters significantly correlated on level 5 %
*** The corresponding variable parameters significantly correlated on level 1 %

widespread. In addition, when executives hold stocks, it might exclude executive who owned equity in order to avoid suspicion at the pay-setting.

Meanwhile, when the variance inflation factor is greater than 10, we usually think that a serious multicollinearity exists between variables. However, the simultaneous equation model of multiple linear diagnosis result shows that the maximum value of the equation inflation factor (VIF) is 1.43, which is far less than 10, so there is no multicollinearity between the model variables.

6 Conclusions

According to a empirical study about relationship between Executive Compensation and Performances, the present paper can draw third important contributions: First, in China, the "pay-performance incentive" mechanism has been established, but compensation incentive and restriction mechanism is not perfect. This paper argues that Incentive compensation cannot make the senior executive interest be achieved. The incentive compensation can't control moral hazard and adverse selection problems that caused by Incentive invalid. These situations moved in a vicious cycle. Second, the improved performance of the company can advance executive compensation. At the same time, we find Executive compensation has positive feedback effect to company performance.Third, the company's equity incentive has the potency to improve the effectiveness of the performance.

The empirical results show that the companies need to establish the evaluation standards that can truly reflect the overall performance. Through the combined accounting performance indicator and corporate market performance indicator, the pay-performance incentive mechanism will play an effectively role to solve incentive incompatibility problems which caused by agency problems. Simultaneously, because of a lower proportion of managerial ownership it can't effectively solve the problem of moral hazard and adverse selection between executive and shareholders. If companies can moderately increase the proportion of managerial ownership and elaborate the influence of Equity incentive effectively, then the company can complementarily be promoted from cash compensation incentive and Equity incentive. These will change the structure of the unitary executive compensation, so potential effectiveness exits.

Overall, according to endogenous perspective, analyze the relationship between executive compensation and corporate performance is a beneficial supplement based on existing research. The study results suggest that there is not a completely symmetrical affection between executive compensation and corporate performance. However, China and the west has a completely different institutional background. Therefore, to better understand the causes and consequences of symmetrical affection between executive compensation and corporate performance, future studies should focus on the unique China's characteristics of the institutional environment, such as equity structure.

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Analyzing and Forecasting Crude Oil Price Based on Stochastic Process Model

Jiancheng Hu

Abstract The dynamic behavior of crude oil prices has become a hot issue in recent years because the increased oil prices worldwide are having a great impact on all economic activities. This paper aims to select the continuous- time stochastic model to describe and forecast the world crude oil price. The Maximum Likelihood Estimation method is implemented to fit the parameters of continuous-time stochastic processes. The result of unit root test shows that time series of the crude oil price is a stationary series. And the simulation of continuous-time stochastic processes and the mean error between the simulated prices and the market ones shows that the Geometric Brownian Motion is a very effective model for the world crude oil price.

Keywords Stochastic process · Crude oil price · MLE · Euler-maruyama method

1 Introduction

Oil is one of the most important energy resources in the world and is indispensable foundation for economic and social development. To some extent, energy has significant effects on global economic activities. Over the past few years, the oil market is not steady, and is known for wide price swings. The rise or the decline of crude oil prices has a direct influence on the economies of various states and on the more general international economy. Long term high oil prices on developing countries, such as China and India, the impact is more obvious than in developed countries, not only increased the economic operation cost, but also increases the burden on foreign oil imports. Low oil prices may result in economic recession and political instability in oil-exporting countries. Recent research has provided evidence that crude oil prices were supported by positive economic data from the United States and China [7, 11].

J. Hu (✉)
College of Applied Mathematics, Chengdu University of Information Technology, Chengdu 610064, People's Republic of China
e-mail: jianchenghu@163.com

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Oil is one of the largest commodity markets in the world and it has evolved from trading the crude oil into a sophisticated financial market. There have been extensive studies on analysis and forecasting of crude oil price. The early real options literature assumed that there is a single source of uncertainty related to the prices of commodities [1, 5]. Most of the models try to analysis the price volatility assumes that the price follows a stochastic processes that evolve over time [2, 12, 14].

A stochastic volatility model in continuous times was first introduced by Hull and White [10]. Gibson and Schwartz [8] accepted the nonstationarity hypothesis for the crude oil price and used the Geometric Brownian Motion to evaluate oil-linked assets. The GBM approach to oil price modeling is based on an analogy with the behavior of prices of stocks in the capital markets. The price process assumes that expected prices grow exponentially at a constant rate over time and the variance of the prices grows with proportion to time. Pindyck [16] presented that a mean-reverting stochastic process can be applied for the oil price model. The unit root tests are applied by Postali and Pichetti [17] to the oil price series reject the unit root for long samples. In recent years, much of the literature assumes the market price of crude oil follows a continuous stochastic process that assumes smooth changes, such as two factor models [3, 4, 19], stochastic time effective modes [13, 18], etc.

2 Unit Root Tests

The daily data of West Texas Intermediate (WTI) crude oil spot price (in US dollars per barrel), which is treated as the benchmark crude oil price for international oil markets, are used in our analysis. The data on Fig. 1 consist of daily closing prices over the period from January 02, 1986 to December 11, 2013 and contains 7054 observations for WTI crude oil markets. They are obtained from U.S. energy information administration.

We examine the mean reversion of the crude oil price. Econometric analysis is performed by using unit-root tests: Augmented Dickey, Fuller test (hereafter, ADF),

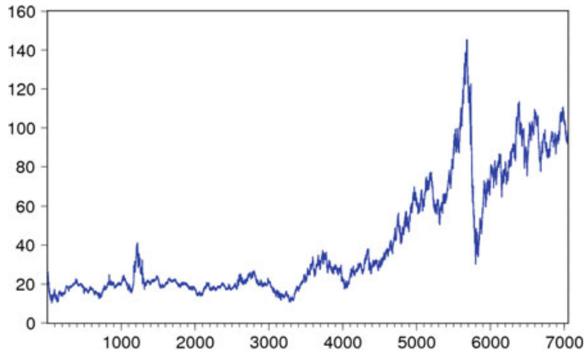

Fig. 1 Crude oil daily spot prices over the period from Jan 02, 1986 to Dec 11, 2013

Table 1 Results of ADF and PP test for the crude oil price series

Test type	Bandwidth	The test statistic	Critical value at risk level 1 %	Critical value at risk level 5 %	Critical value at risk level 10 %	P value
ADF with intercept	5	−0.8911	−3.4311	−2.8618	−2.5669	0.7917
ADF with intercept and trend	5	−2.9018	−3.9593	−3.4104	−3.127	0.1619
PP with intercept	17	−0.9378	−3.431	−2.8618	−2.5669	0.7767
PP with intercept and trend	15	−2.9492	−3.9593	−3.4104	−3.127	0.147

Phillips and Perron test (hereafter, PP) whose null hypotheses are non-stationary [6, 15]. The results of unit root tests without breaks are shown in Table 1.

As can be seen in above table, for the crude oil price series, the ADF test statistic with intercept and without the time trend is greater than the critical values at the 1, 5 and 10 % risk levels, so we accept the unit root null hypothesis. For different given bandwidth, the PP test also accepts the non-stationary hypothesis at the 1, 5 and 10 % risk levels.

3 Crude Oil Stochastic Price Models

The Weiner process is a continuous-time stochastic process and satisfies

$$E(W(t) = 0, E(W(t)^2)) = t, \quad \forall t \geq 0, \tag{1}$$

$$E(W(s)W(t)) = t \wedge s = \min\{s, t\} = t, \quad t \geq 0, \quad s \geq 0, \tag{2}$$

for $s, t > 0$, the Wiener increments $W(t) - W(s)$ is independent Gaussian process with mean 0 and variance $|t - s|$ for any $0 \leq s \leq t$. Brownian motion is the most common example of a Wiener process. Let $X(t)$ be the price of oil at time t and let $dX(t)$ be the infinitesimal change in $X(t)$ over the infinitesimal interval of time dt. The changes in price of oil $X(t)$ involve a deterministic factor which is a function of time and a stochastic factor which depends upon a random variable.

Geometric Brownian Motion is the simplest and probably most popular specification in financial models. The venerable Black-Scholes option-pricing model assumes the underlying state variable follows GBM. By virtue of Ito Lemma, Geometric Brownian Motion (GBM) real process for price of crude oil has the form:

$$dX(t) = \mu X(t)dt + \sigma X(t)dW(t), \tag{3}$$

where μ is the expected price appreciation (also μ is called the drift coefficient), σ is the implied volatility (also σ is called the diffusion coefficient) and $dW(t)$ is a Wiener increment.

Under GBM the time- exchange rate evolves according to:

$$X(t) = X(0)exp\left(\left(\mu - \frac{1}{2}\sigma^2\right)\tau + \sigma W(t)\right). \tag{4}$$

Let $\tau > 0$ denote the interval between observations. Then the τ period logarithmic return:

$$\ln\left(\frac{X(t+\tau)}{X(t)}\right) \equiv R(\tau) = \big(\mu - \frac{1}{2}\sigma^2\big)\tau + \sigma(W(t+\tau) - W(t)). \tag{5}$$

4 Estimation of the Crude Oil Price Process

The Maximum likelihood estimating (MLE) method relies on maximizing the density function. The density functions of the GBM is respectively:

$$p(x) = \frac{1}{\sigma x\sqrt{2\pi\Delta t}}exp\left[-\frac{\log(x/x_0) - (\mu - \sigma^2/2)\Delta t]^2}{2\sigma^2\Delta t}\right]. \tag{6}$$

Observed at discrete equally interval times $t_0, t_1, \ldots, t_N$, then

$$\ln X_i = \ln X_{i-1} + \left(\mu - \frac{1}{2}\right)\sigma t + \sigma\sqrt{\Delta t\varepsilon_i}, \tag{7}$$

where $\Delta t = t_i - t_{i-1}$ and ε_i are independently and identically distribution from the standard normal distribution. Then the likelihood function of return data $R_i = \ln(X_i/X_{i-1}), i = 1, 2, \ldots, N$ is:

$$l(\mu, \sigma) = \frac{1}{\sqrt{2\pi\Delta t}}\prod_{i=1}^{N}\frac{1}{\sigma}exp\left(-\frac{[\log(x/x_0) - (\mu - \sigma^2/2)\Delta t]^2}{2\sigma^2\Delta t}\right). \tag{8}$$

Maximizing log-likelihood function with respect to and gives the following MLEs:

$$\hat{\sigma^2} = \frac{1}{N\Delta t}\sum_{i=1}^{N}(R_i - \bar{R})^2, \quad \hat{\mu} = \frac{1}{\Delta t}\bar{R} + \frac{1}{2}\hat{\sigma}^2, \tag{9}$$

where $\bar{R} = \frac{1}{N}\sum\limits_{i=1}^{N} R_i$.

Table 2 Parameter estimates of price models

Models	GBM	
Parameters	μ	σ
Values	0.020124	0.070257
Maximum log-likelihood	1.87	

We estimate the parameters by maximizing the log-likelihood function. The estimation results are illustrated in Table 2.

5 Numerical Simulation of Crude Oil Price

Given a discretion of the time interval $[0, T]$, let $\Delta t = T/N$ for a given positive integer N, $t_n = n\Delta t$, $X_n = X(t_n)$ and $W_n = W(t_n)$. The independent increment $\Delta W_n = W_{n+1} - W_n \sim N(0, \Delta t)$. In this paper we will discuss the Euler-Maruyama (EM) [9] method for Eq. (3). The Euler-Maruyama methods take the form:

$$X_{n+1} = X_n + \mu X_n \Delta t + \sigma X_n (W_{n+1} - W_n), \quad n = 1, 2, \ldots, N-1. \tag{10}$$

The sample path simulated by the Geometric Brownian Motion follows the historical crude oil price curve, shown by Fig. 2.

In order to compare the stochastic processes in this study among themselves, we also define the mean error (ME) between the simulated prices and the market ones:

$$\mathrm{ME} = \frac{\sum_{i=1}^{N} |p_i^s - p_i|}{N}, \tag{11}$$

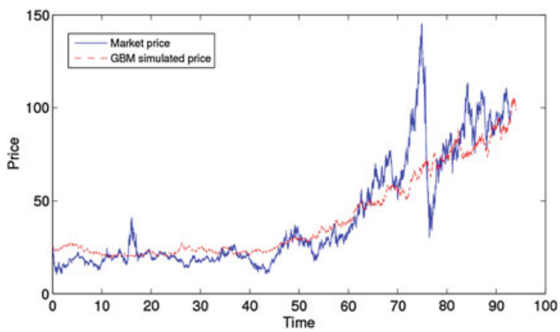

Fig. 2 Crude oil price simulation of GBM

where p_i^s are the simulated prices, p_i are the market prices and N is the number of observations. To reach a high level of accuracy, a large number of simulations following the Monte-Carlo procedure along 1000 discretized Brownian paths are carried out. We find that ME $= 42.4219$.

6 Conclusions

The purpose of this paper is to determine the continuous-time stochastic processes for the crude oil price. The daily crude oil prices are used over the period from January 02, 1986 to December 11, 2013, which obtained from U.S. energy information administration. Firstly, unit root tests are carried out. Secondly, the Geometric Brownian Motion model is presented to simulate the continuous-time stochastic crude oil price, and the parameter estimation of Geometric Brownian motion is implemented through the MLE procedures. Finally, the mean error between the simulation price and the market ones is calculated.

Crude oil price in the long term is generally determined by the trend, which changes continuously and stays around the long term mean. The sharp downs or ups in crude oil prices are detonated by unpredictable and significant events, the impact of which may endure for several years. Otherwise, the small fluctuations in the short term are mainly driven by market activities or some small events which do not have a serious influence on oil markets. Predicting daily data of WTI crude oil spot price based on its market characteristics, GBM model is considered. The numerical simulation shows that the Geometric Brownian Motion is a very effective stochastic process to model the world crude oil price.

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A Bi-Level Waste Load Allocation Model Based on Water Function Zoning for Sichuan-Neijiang

Shuhua Hou, Xiaoling Song and Liming Yao

Abstract Water pollution is becoming very serious currently, and has been a major bottleneck in China's economic and social sustainable development. Because rivers has no clear division of functions and protection requirements early, there has been no clear goals of water conservation, which has affected the overall water resources management and protection work carried out. So it is urgent for local basin management committee to reasonably allocate waste based on the water function zoning. In this paper, we focus on water function zoning waste load allocations, and develops equilibrium strategies to balance the needs of both the first level and the second level water function zoning. In order to solve the problem between the two level function zoning, a bi-level optimization model is proposed to minimize water pollution. Finally, a practical case from Neijiang segment of Tuojiang, a typical developing city with typical water function zoning, is given to demonstrate the effectiveness of the proposed model. Some operational policies are developed to assist decision-makers cope with pollution limitation for water function zoning.

Keywords Waste load allocation · Water function zoning · Bi-level model

1 Introduction

With the rapidly population growth and economic development, the associated activities often disturb the water system equilibrium through the discharge of a great deal of wastewater into the river basin. So rivers have become the main recipients and conduits of wastewater and river pollution has become one of the most serious water pollution problems of the present day all over the world [1]. Water quality in most Chinese rivers and groundwater sources is poor and declining, owing to industrial and municipal wastewater discharges [2]. Water pollution

S. Hou · X. Song · L. Yao (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: lmyao@scu.edu.cn

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allocation with rapid socio-economic development in the Tuojiang river Basin, has been attracted increasing attention from both the public and the regional government. Previously, a number of optimization techniques have been developed to deal with deteriorating water systems in the economic-environmental management of sustainable development. With the conception and growth in popularity of a number of optimization techniques, the problem of optimal waste load allocation (WLA) has been formulated and solved using a variety of mathematical techniques [3]. Since pollutant total amount control was introduced in China in the 1980s, many researches have focused on water environmental capacity, the allocation of pollutant load, and the pollution discharge right trading, of which the allocation of water pollution load is the core as well as difficult point in total amount control system of water pollutants discharge [4]. There are a series of objects for water waste load allocation, including water basin, the water function zoning, administrative units, sewage outlets and pollutant discharging points. However, few of optimization models established from different water function zoning. In this research, we focus on the waste load allocation for water function zoning.

In Neiajiang there are one first level water functional areas and four second level water function zoning. This situation may be modeled as a bi-level decision-making optimization problem, which is based on a static Stackelberg game with leader-follower strategy [5]. The upper-level decision-maker (leader) is Neijiang development and utilization zone committee and the lower-level decision-makers (followers) is the authority of subareas.

The remainder of this paper is organized as follows. Section 2 mainly describes the problem of Neijiang segment, Tuojiang river. The mathematical formulation for the bi-level waste load allocation model is presented in Sect. 3. Finally, conclusions are given in Sect. 4.

2 Problem Description

Tuojiang with 629 km long is one of the four tributaries of the Yangtze River located in eastern Sichuan Province, flows through the cities of Neijiang. Located in the downstream of Tuojiang River Basin, the segment of Neijiang longs 303 km and accounts for 60.4 % of Tuojiang river trunk stream, most of it belongs to the middle stream of Tuojiang river. In recent years, Water pollution problems in the Neijiang have generally become worse as a result of rapid population growth, industrial development and urbanization. Water quality in rivers has deteriorated due to direct discharges of untreated domestic and industrial wastewater. Not only the serious water pollution, as well as the water quality deterioration has made the water problems worse and hindered the social and economic development in this area. Increasing pollution loads necessitates the incorporation of water quality issues in water waste load allocation.

Since the ability of river to clean itself due to its assimilative capacity makes necessary determination of waste water treatment levels for the management committee and each subarea. As shown in Fig. 1, the first level water functional areas for Neijiang

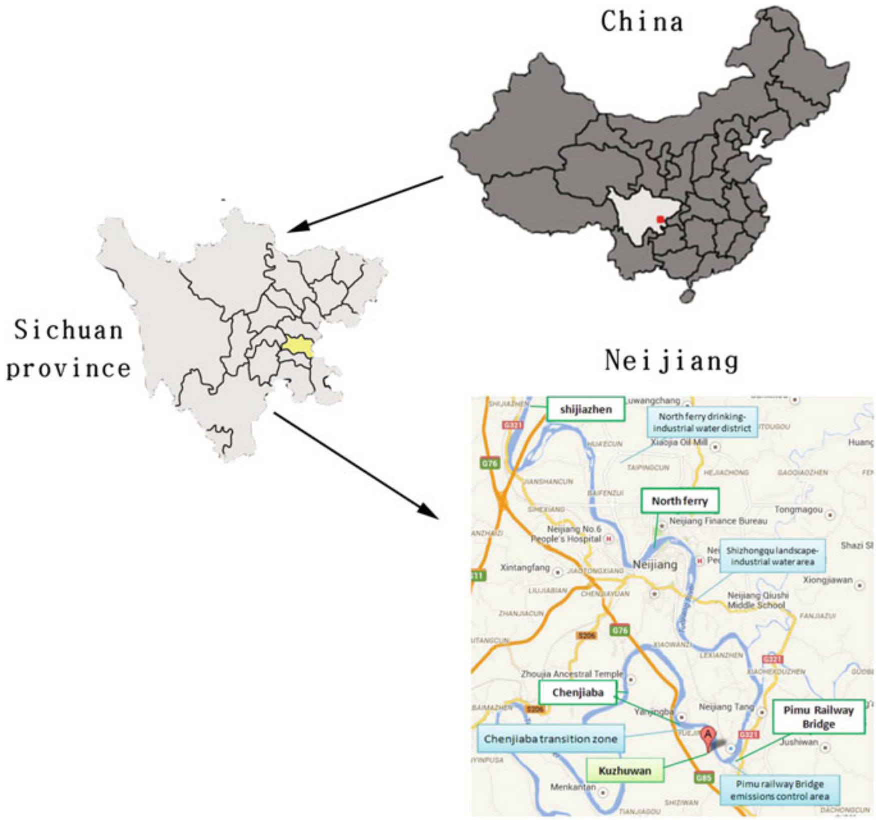

Fig. 1 The distribution of the four two level water function zoning

segment is the Neijiang water development and utilization zone. Based on the development and utilization of district, we have 4 second level water function areas.

Among them, the North ferry drinking-industrial water area and Shizhogqu landscape-industrial water area are concentrated industrial water district. The main source of pollution is factory wastewater discharge, and water pollution seriously restricting the economic development of the region. In the case of emissions strictly controlled, how to pursue maximum economic benefit is that we need to solve. However, Pimu emissions control area is relatively the concentrated sewage outfall area of life wastewater. Sewage and waste it accepted has no significant impact on the water environment and the local economic development. Chenjiaba transition zone is designated to allow the smooth transition for different quality requirements between the adjacent area. There is no economic target for the two area, the regional authority of Pimu emissions control area and the Chenjiaba transition zone just need control sewage discharge that is to pursuit the greatest environmental benefits. According to the country water function area standard requirements, the local government determine the river basin's decomposition goal of water function zone to amount to mark targets, determine the total water pollutant emission limits in 2015.

Since water is an essential resource for all life on the planet, water scarcity means that water resource allocation is a global concern. In order to improve the water quality and ecological environment, the total pollutant load must be controlled. Based on the response relationship between the pollutant load and water quality, the total maximum allowable pollutant load was calculated and allocated to the each subarea. Further, as the distribution of water resources is spatially uneven, there is often a trade-off in a river basin between the regional authority and the subarea water managers. A Stackelberg-Nash equilibrium exists between the basin management committee and the subarea water manager for the wastewater load allocation with different contaminant carrying capacity levels. The waste load equilibrium allocation model is considered suitable for tackling the waste load allocation problem in Neijiang segment of Tuojiang river basin. Total distribution of pollutants is the core of the total pollutant control and the basis for the implementation of emissions trading. This waste load allocation has a two-level structure; the management committee is the decision maker for the initial allocation level, and the regional authority of each second level water function area is the decision maker for the secondary allocation level. Considering the above, the problem should be regarded as a bi-level optimization model.

China's current total allocation is mainly implemented proportional allocation way, the total allocation does not reflect a fair, efficient and viable distribution. The problem of designing a based emission factor can be viewed as a hierarchical process where the management committee of Neijiang determines the total pollutant emission and the subarea authorities decides on the volume of waste load to be withdrawn to minimize pollutant emission. The regional basin management committee allocates the water rights to the subareas, and after obtaining these initial rights, each subarea makes waste load allocation decisions based on waste use volume allocation with the aim of promoting equitable cooperation in the Neijiang segment of Tuojiang river basin. The basin management committee of Neijiang must project waste generation and plan for adequate treatment and disposal capacity in their region. More specially, once the regional basin management committee determines the waste allocation schedule, it sends this information down to the lower levels. The lower levels then process the waste allocation structure and pass results back up to the basin management committee as optimal treatment levels.

As shown in Fig. 2, the basin management committee of Neijiang has minimum environment Gini coefficient as its most important goal. On the lower level, under the conditions of total amount constraint, maximizing enterprises' economic efficiency. The North ferry drinking-industrial water area and Shizhongqu landscape-industrial water area consider economic profit as their goal and consider minimizing emissions to maximizing enterprises economic efficiency. The Pimu emissions control area and the Chenjiaba transition zone aim to achieve water quality standard to minimizing emissions.

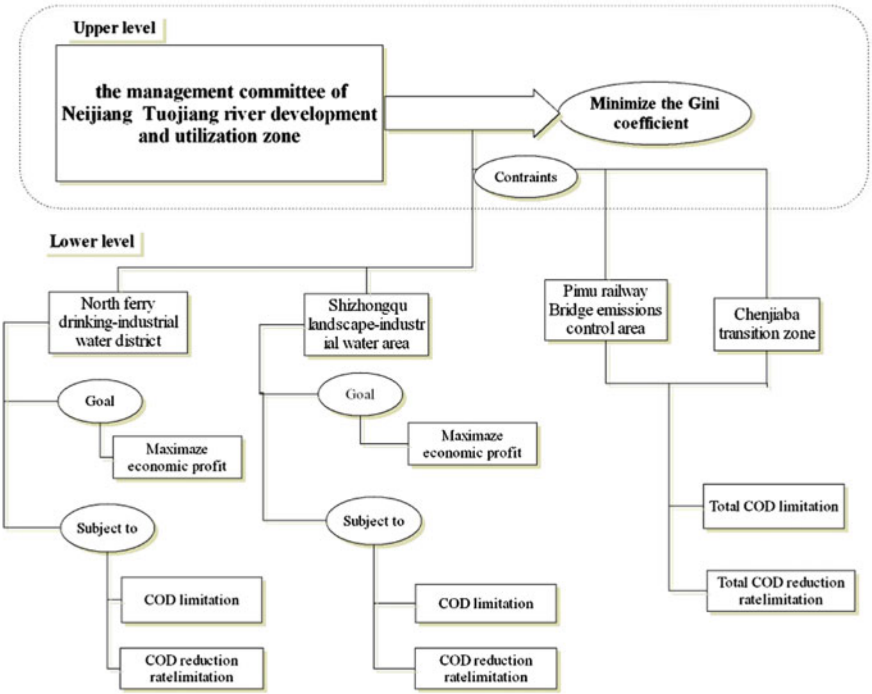

Fig. 2 The bi-level model for the wastewater allocation in Neijiang Tuojiang river

3 Mathematical Model

3.1 Assumptions and Notations

Assumptions:

In reference to the Surface Water Environmental Quality Standard of the Peoples' Republic of China (GB 3838-2002) and the embodiments of key watersheds water pollution prevention plan (2011–2015) for Neijiang City.

- Since the two pollutants chemical oxygen demand (COD) and ammoniacal nitrogen ($NH_3 - N$) react the same degree of water pollution, we just consider chemical oxygen demand (COD) in the bi-level single objective based on waste load allocation.
- All subareas are located in the same river basin, and all industrial pollution emissions flow into this river basin.
- There are certain limitations of the environment capability.

Notations:

The following symbols are used in this paper.

G_k: the indicator's Gini coefficient, which are the GDP, population and waste water discharged quantities,

Y_{ik}: Cumulative percentage of the kth evaluation index for Gini coefficient in the ith subarea,

X_i: accumulative percentage of waste COD for Gini coefficient in the ith subarea,

E_i: the amount of economic scale in the ith second level water function zone,

G_i: the amount of GDP in the ith second level water function zone,

P_i: the amount of total household population in the ith second level water function zone,

W_i: the amount of waste water discharged in the ith second water function zone,

$W_{-\text{limit}}$: the total amount of allowable waste water discharge in the Neijiang segment,

$W^i_{-\text{limit}}$: the amount of allowable waste water discharge in the ith two level water function,

R: the COD reduction rate of the designed target along the Neijiang segment,

$G_{0(k)}$: the Gini coefficient for the kth index with status value,

F_i: the volume of economic scale in the ith two level water function,

D_0: the total amount of COD emission in the Neijiang segment now,

D_{0i}: the amount of actual COD emission in the ith second level water function zone,

r_{i0}: the lower bound of the COD reduction rate in the ith second level water function zone,

r_{i1}: the upper bound of the COD reduction rate in the ith second level water function zone,

α^j: Average economic benefit coefficients per unit the discharge of COD of jth water user,

β^j: Average COD discharge coefficients per unit the waste water of jth water user.

Decision variable:

D_i: the amount of COD allocation in the ith second level water function zone,

d^{ij}: the amount of COD allocation to jth water user in the ith second level water function zone.

3.2 In the Upper Level, the Environment Gini Coefficient (EGC) Method

In the upper level for the Neijiang water development and utilization zone, the environmental Gini coefficient (EGC) [6] analysis method is applied to set up an appropriate optimal allocation model. The objective function is to minimize the sum of every control indicator of Gini coefficient. The decision variable is the amount of COD distribution in every subarea. Multi-constrained single-objective linear programming method can be used to strike the optimal solution.

The upper level's goal is to minimize the environment Gini coefficient

$$\min EGC = \sum_{k=1}^{3} G_k(D_i), \tag{1}$$

where

$$G_k = 1 - \sum_{i=1}^{4}(Y_{ik} - Y_{i-1,k}) \times (X_i + X_{i-1}), Y_{i1} = Y_{i-1,1} + \frac{E_i}{\sum_{i=1}^{4} E_i}, \ Y_{01} = 0,$$

where the volume of the economic scale is equivalent to $E_i = \sum_{j=i}^{i+1} \alpha^j \times d^{ij}$, for $i = 1, 2$, and $E_3 = G_3$, $E_4 = G_4$.

$$Y_{i2} = Y_{i-1,1} + \frac{P_i}{\sum_{i=1}^{4} P_i}, \ \ Y_{02} = 0, Y_{i3} = Y_{i-1,1} + \frac{D_i}{\sum_{i=1}^{4} D_i}, \ \ Y_{03} = 0,$$

where the total amount of the waste water discharged in ith subarea is equivalent to $W_i = \sum_{j=i}^{i+1} \beta^j \times d^{ij}$, for $i = 1, 2$, and when $i = 3, 4$, the amount of waste water discharged is equal to the actual quantity:

$$X_i = X_{i-1} + \frac{D_i}{\sum_{i=1}^{4} D_i}, X_0 = 0.$$

The total amount of waste (COD) sewage cannot exceed the reduction target of the region:

$$\sum_{i=1}^{4} D_i \le (1 - R) \times D_0. \tag{2}$$

The environment Gini coefficient of every control indicates equal or less to status value:

$$G_k \le G_{0(k)}. \tag{3}$$

The total amount of waste water discharged in the Neijiang segment of Tuojiang river cannot exceed the carrying capacity of the river basin.

$$\sum_{j=1}^{2} \beta^j \times d^{1j} + \sum_{j=2}^{3} \beta^j \times d^{2j} + W_3 + W_4 \leq W_{-\text{limit}}. \tag{4}$$

The constraints about the Pimu emissions control area and Chenjiaba transition zone:

Unlike the first two area, we regard the emissions target of the Pimu emissions control area and Chenjiaba transition zone as the constraints of the upper level.

The constraint of reduction rate upper and lower limit for waste (COD) emission.

$$r_{i0} \leq \frac{D_{0i} - D_i}{D_{0i}} \leq r_{i1}. \tag{5}$$

For drinking-industrial water function and industrial-landscape water, there are different need of reduced rate.

$$\frac{D_{0i} - D_i}{D_{0i}} \geq r_{i0}, \; i = 1, 2. \tag{6}$$

3.3 In the Lower-Level

In the lower level, we chooses maximum profit as the objective function and tries to use minimal environmental costs to get maximize economic development. And the decision variables are the amount of COD allocation. The main sources of pollutants in the region for landscape and industrial water discharge, so we optimize the amount of each users' allocation with these constraints such as total amount of COD target, the total amount of wastewater.

The objective functions to be optimized consider both the economic and environmental factors. The lower level aim to maximize economic profits.

$$\max F_i = \sum_{j=i}^{i+1} \alpha^j \times d^{ij}. \tag{7}$$

The amount of waste (COD) into the river equal or less to the total designed target of the water function.

$$\sum_{j=1}^{2} d^{ij} \leq D_i. \tag{8}$$

The amount of waste water sewage equal or less to the total designed target of the water function.

$$\sum_{j=i}^{i+1} \beta^j \times d^{ij} \leq W^i_{-\text{limit}}. \tag{9}$$

In short, the total optimization model for Neijiang segment, Tuojiang river waste allocation is summarized as follows.

$$\min EGC = \sum_{k=1}^{3} G_k(D_i)$$

$$\text{s.t.} \begin{cases} \sum\limits_{i=1}^{4} D_i \leq (1-R) \times D_0 \\ G_K \leq G_{0(k)} \\ r_{i0} \leq \frac{D_{0i}-D_i}{D_{0i}} \leq r_{i1}, \ i = 3, 4 \\ \frac{D_{0i}-D_i}{D_{0i}} \geq r_{i0}, \ i = 1, 2 \\ \begin{cases} \max F_1 = \sum\limits_{j=i}^{i+1} \alpha^j \times d^{ij} \\ \text{s.t.} \begin{cases} \sum\limits_{j=i}^{i+1} d^{ij} \leq D_i \\ \sum\limits_{j=i}^{i+1} \beta^j \times d^{ij} \leq W^i_{-\text{limit}}. \end{cases} \end{cases} \end{cases} \tag{10}$$

4 Case Study

4.1 Basic Condition

The Neijiang segment of Tuojiang river is divided into 4 two level water function areas to which the total waste control permit is distributed. This research demonstrates how the discharge permits of 2010 are distributed to each district using the EGC method in the upper level. In 2010, the COD discharged with wastewater was 4732.5 tons in Neijiang water development and utilization zone. According to the "Focus on water pollution prevention plan" of the Twelfth five-year plan. By 2015, all the city's major water pollutant emissions of chemical oxygen (COD) demand control of 5.1544 million tons, reducing 11 % (including industrial and domestic chemical oxygen demand reduction of 11.64 %) than in 2010; The data for COD discharge and environmental capacity come from Neijiang government while the date for GDP, population and wastewater discharged into river come from National Bureau of Statistics of Sichuan (2011).

In the lower level, Tuojiang flows through the Shizhongqu and Dongxing District of Neijiang City, which shijiazhen section is located at the Shizhongqu, the three other section are located in Dongxing district of Neijiang City. So we taking the geography division and representatives of river length, roughly estimated GDP and population of each subarea. Besides, according to the Statistics of Sichuan in nearly three years, we estimates the average economic benefit coefficients per unit the discharge of COD based on the total amount of the gross industrial production and COD discharge of industrial in 2010 of Neijiang.

4.2 The Results

First, calculate EGC based on COD discharges of the districts in 2010, The result is shown in Table 1.

Second, optimize the EGC for each criterion with constrains. Given that the total reduction rate of waste discharge is $r = 11.0\,\%$, after the discussion with local EPBs from each district, the upper limit and lower limit of waste discharge reduction rate for Pimu emissions control area and Chenjiaba transition zone is 0 and 20 %. Besides, for the North ferry drinking-industrial water area and the Shizhongqu landscape-industrial water area, there is just lower limit of 13.98 and 13.15 % for each other. The optimization result and finial waste discharge permit allocation are shown, respectively, in Table 2.

Table 1 Calculation of water COD discharge Gini coefficient based on GDP

Water function areas	GDP (million RMB)	Population (thousand)	Wastewater (thousand m^3)	COD (t/year)	Cumulative[a]	
					GDP	COD[b]
North ferry drinking industrial water district	12684.50	531	4328	615.5	49.90 %	13.01 %
Shizhongqu landscape industrial water area	9169.567	635.76	22740	4007	85.97 %	97.68 %
Pimu railway bridge emission control area	764.13	52.98	420	60	88.98 %	98.94 %
Chenjiaba transition zone	2801.812	194.26	72	50	100.00 %	100.00 %
Total	25420.01	1414.1	27560			

[a]Cumulative percentage
[b]COD discharge

Table 2 Environment Gini coefficient

Criteria	GDP	Population	Wastewater	Total
Before optimization	0.257	0.106	0.031	0.394
After optimization	0.134	0	0	0.134
Difference	0.123	0.106	0.031	0.26

We can see the environment Gini coefficient before optimization and after, the result show that the Gini coefficient for every indicator shrink obviously. After optimization, we get that $D_1 = 120.8$, $D_2 = 0$, $D_3 = 48$, $D_4 = 49$ for the upper level, and $d^{11} = 0$, $d^{12} = 120.8$, $d^{22} = 0$, $d^{23} = 0$ for the lower level. We can see the history and current optimal condition, the value of the optimal objective function of environment Gini coefficient is 0.134, lower than before by 0.26.

5 Conclusion and Proposal

The situation of water quality and pollution in Neijiang is not optimistic now. In this study, a wastewater load allocation (WLA) model was developed for regional wastewater load allocation planning design among different water function zone in the same river basin. The wastewater load allocation is determined by the river basin management committee and the management committee allocates the waste load rights to the subareas. And it is necessary to establish restrict pollutant system for water function zone and take measures from the following aspects.

- *Taking strictly management for water functional areas*: Governments at all levels should take the limitation of the amount of sewage as an important basis for the work of pollution prevention and pollution reduction and strictly control the total amount of sewage into the river. Finally, carrying water function zones compliance assessment, and implementing the limit control targets of total amount of emissions.
- *Strengthening the sewage outfall into the river management*: It is most need to get the administrative department' agreement to set a new outfall. For emissions exceed the total amount of water function zones where approval of new water intake and emission outfall is strictly limited.
- *Ensuring the industrial enterprises discharge standards*: The local government should take actions to adjust the industrial structure, establish reasonable industrial layout and implement emissions trading system to Control the industrial pollution.
- *Installing pollution automatic monitoring system in the key industrial pollution watershed and implementing environmental supervisor system.*
- *Strengthening the protection of water resources*: Implementing water protection projects and building water resources protection project with the river basin as a unit so that achieve clean water into rivers.

- *Actively promoting clean production and recycling economy*: The local committee should effectively combine the functional services and functional areas of water management constraints to achieve controllable social cycle of water, thus contributing to the development and protection of the coordination equilibrium. Besides, strengthen water conservation work in the whole society, and actively carry water resource utilization, improve water reuse and utilization.

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Part II
Logistics Engineering

Supply Chain Coordination with Group Buying Through Buyback Contract

Yanni Ping, Wenjing Shen and Benjamin Lev

Abstract Under group buying strategy, a retailer offers buyers price discount based on buyers' aggregate purchase quantity. This paper studies the supply chain coordination issue with a supplier and a retailer that uses group buying mechanism when selling to customers. We demonstrate that a buyback contract can coordinate the supply chain under group buying, and how its contract terms critically depend on the quantity threshold above which group buying deal is activated.

Keywords Group buying · Buyback contract · Supply chain coordination

1 Introduction

Group buying (GB) is a distinctive selling strategy where quantity discount are offered based on buyers' aggregated purchasing quantity. As the price decreases with the total quantity, buyers enjoy positive externality that allows them to obtain lower prices than they otherwise would be able to obtain individually [1].

Group buying is widely used for both business-to-business (B2B) and business-toconsumer (B2C) transactions. In a B2B context, co-operatives of independent grocers, convenience stores, or retail hardware stores have long existed in the United States as well as in Europe [1]. Most of the research work on B2B group buying is focused on the benefit buyers receive in reduced acquisition cost or enhanced bargaining power. B2C group buying first emerged as a new selling strategy in the late 1990s, which is also known as "social discounting" or "collective buying". Sellers usually offer group buying through third-party platform firms. Most of the representative groupbuying websites that became popular in the late 1990s, including Mercata, Mobshop, and Letsbuyit, either ceased operating or changed their business models a few years later [2]. Interestingly, despite the failure of these pioneering group-buying sites, a decade later another generation of social buying websites like

Y. Ping (✉) · W. Shen · B. Lev
Business School, Drexel University, Philadelphia 19104, USA
e-mail: yp86@drexel.edu

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Groupon.com and LivingSocial.com emerged. Led by the market leader, Groupon, these newcomers typically offer 'a deal a day' tailored to each local market. The market enthusiasm for online group buying peaked when Groupon declined a $6 billion offer from Google [3].

Many different forms of group buying exist. For instance, group-buying auction (GBA) allows the price of the deal to change dynamically. With GBA, the seller announces the price scheme and a closing date before the sale begins. The sale's status–the current number of bidders and the imputed prices–is updated dynamically and displayed on the Web. Based on the number of participating customers at the end of the selling period, all winning customers receive the same closing price, no matter what price they originally signed up for. Another relatively new form of group buying, prepaid discount vouchers, was first offered in 2008 by Groupon. It gives consumers large discounts when they prepay for the participating firms' goods and services. It soon expanded the diversity of group buying products to restaurants, skydiving and museum visits. Although new selling forms continue to emerge, the most common form of group buying strategy remains to be fixed pricing mechanism (FPM), where group-buying customers receive products at a fixed discount price only if the pre-specified deal threshold is reached. We adopt FPM as the group buying mechanism in this paper.

The majority of the group-buying research restricts attention to the interaction between retailer and customers. To the best our knowledge, there has been little research that takes the supply chain perspective and studies the coordination between supplier and retailer. In view of this gap in the literature, this paper studies the supply chain performance with group buying through a buyback contract. Our model builds on the classic newsvendor formulation. In our setup, the retailer faces a random aggregate demand and makes decision of the stocking quantity, assuming price is an exogenous parameter. The retailer adopts group buying strategy by pre-specifying a threshold. If the number of customers reaches this threshold, then all of the buyers receive a fixed price discount. Otherwise the product is sold at regular price. We demonstrate that a buyback contract coordinates a supply chain with group buying and it is dependent on the value of exogenous parameters including prices and demand distribution.

The remainder of this paper is organized as follows: Sect. 2 provides a review of the existing literature on B2C group buying mechanism along with a review of buyback contract. Section 3 outlines our model and discuss the supply chain optimal decisions. Section 4 studies how buyback contract coordinates the supply chain with group buying. The last section provides some potential research extensions on group buying through buyback contact and a conclusion of this paper.

2 Studies on B2C Group Buying Mechanism

Most existing research on B2C group buying focused on the increased purchasing power of buying groups. For example, Che and Gale [4] examine how an organized "buyer alliance" can use its power to influence the design of health insurance plans offered to its members. Chen and Li [5] explore whether buying groups, such as buying clubs for goods or utilities, should commit to exclusive purchase in the presence of competing sellers and how such commitment influences competition.

There has been a growing number of theoretical literature on group buying as a selling strategy in recent years. Most of the studies examine the effectiveness of group buying auction in comparison with traditional fixed pricing mechanism. Anand and Aron [6] is believed to be the first analytical model of group buying. They demonstrate that under demand uncertainty, group buying mechanism outperforms posted pricing under demand heterogeneity and production postponement in combination with scale economies. Based on their model, Chen and Chen [7] studied the groupbuying auction considering the risk seeking seller and different demand regimes. They analyze the sellers' optimal price curve of the GBA in the uniform unit cost case and in some supply chain coordination contracts. They found that the best discount rate is zero, which implies that the optimal group-buying auction is equivalent to the optimal fixed pricing mechanism. They also compared the GBA with the FPM in two special cases, the economies of scale and risk-seeking seller, and found that (1) when economies of scale are considered, the GBA outperforms the FPM; (2) when the seller is risk-seeking, the GBA also outperforms the FPM. As voucher discount emerged as a new form of group buying, Edelman and Jaffe [8] formulated a model to explore how offer details interact with characteristics of the consumer population to shape the profitability of voucher discounts. Their results illustrate that offering vouchers tends to be more profitable for firms which are patient or relatively unknown, and for firms with low marginal costs.

Besides the study on the profitability and effectiveness of group buying, in recent years, many researchers put more focus on the study of consumer behavior and other interesting effects appeared in the group buying processes. Their findings bring more insights to better understand customer behavior and better design group buying mechanisms. For example, Wu et al. [9] empirically identified two types of threshold-induced effects in online group-buying diffusion: a surge of new sign-ups around the time when the thresholds of group-buying deals are reached, and a stronger positive relation between the number of new sign-ups and the cumulative number of sign-ups before the thresholds are reached than afterwards. They found that the first type of threshold effects is significant in all product categories and in all markets, while the second type of threshold effects varies across product categories and markets. Their research offers useful insights to the threshold-induced behavior in the online group buying context, at the same time calls for extended research to enrich the understanding of this issue. In another study, Hu and Shi [3] studied the design of group-buying mechanisms in a two-period game. A firm can adopt either a sequential mechanism where the firm discloses to second-period arrivals the number of sign-ups accumulated in the first period, or a simultaneous mechanism where the firm does not post the number of first-period sign-ups and hence each cohort of consumers faces uncertainty about another cohort's size and valuations when making sign-up decisions. Their analysis shows that the deal's success rate is always higher under the sequential mechanism, since sequential mechanism eliminates the uncertainty and increases the ex ante expected sign-up rates of the second cohort of consumers.

This results also offer a potential explanation for why firms such as Groupon display the updated number of sign-ups along with the minimum number required to unlock the deals.

A growing number of literature integrates consumer social interactions into designing the group buying mechanism. Jing and Xie [10] argued that Group buying allows a seller to gain from facilitating consumer social interaction, i.e., group discount can motivate the more informed customers to acquire those less informed customers through sharing his knowledge and experiences about the product. They formulated a static model for such an information-sharing effect and compared group buying with other selling strategies. Following this study, Liang and Ma [11] incorporated the information and demand dynamics into their model to study information sharing in group buying in a dynamic framework.

The aforementioned group buying literature has been focused on understanding consumer behavior and analyzing a retailer's best strategy. There has been little work that investigates the supply chain coordination issue when a retailer adopts group buying mechanism. Supply chain coordination without group buying has been extensively studied in the operations literature. Pasternack [12] was the first to identify that buyback contracts coordinate the fixed-price newsvendor. With that contract, the supplier charges a wholesale price ω_b per unit and pays the retailer b per unit for unsold products. Cachon [13] provided an extensive survey on other contracts for supply chain coordination. An important implicit assumption of implementing buy back contract is that the supplier is able to verify the number of unsold units and the cost of such monitoring does not negate the benefits created by the contract. Our study contributes to the literature by unifying group buying and supply chain coordination issue into a single framework.

3 Model and Supply Chain Optimal Decisions

Consider a supply chain with two entities, a supplier and a retailer. The supplier's production cost is c per unit; the retailer has a per unit salvage value s and loss of goodwill l. All of the three parameters are exogenously specified. The product is regularly sold at price p_1. The retailer sells to the customers through a group buying mechanism. With a pre-specified quantity threshold q, the retailer is committed to offer a lower price $p_2 < p_1$ to all customers if demand exceeds q.

Customer demand is random. Typically demand randomness can be modeled in either an additive or a multiplicative fashion. In this paper we choose to model the demand in additive form, as it is easy to analyze and is commonly used in the literature, although the analysis can be easily carried over for multiplicative demand. Assume at the regular price p_1 consumer demand $D_1(p_1, \varepsilon) = a - bp_1 + \varepsilon$. If the lower price p_2 is charged consumer demand becomes $D_2(p_2, \varepsilon) = a' - bp_2 + \varepsilon$. Notice that a' can be equal to, larger or smaller than a. If $a' < a$, it indicates that only a fraction of customers have access to group buying offer. If $a' > a$, it indicates on the other hand that group buying can increase the market base through advertising. Under group buying mechanism, if the group buying demand D_2 does not exceed the threshold q, then the group buying deal is not activated. Price p_1 will be charged and demand is D_1. Otherwise price is p_2 and demand is D_2. Note that the prices p_1 and p_2 and the group buying threshold q are all exogenously specified. ε is a random variable defined on $(-\infty, +\infty)$ with expectation $E[\varepsilon] = 0$. We let $F(\cdot)$ and $f(\cdot)$ represent the cumulative distribution function and probability density function of ε. Denote the expected demand $\bar{D}_1 = a - bp_1$, $\bar{D}_2 = a' - bp_2$. So D_1 and D_2 can be expressed as $D_1 = \bar{D}_1 + \varepsilon$ and $D_2 = \bar{D}_2 + \varepsilon$. We also assume $\bar{D}_1 < \bar{D}_2$, capturing the fact that group buying increases total expected demand.

The expected profit of the centralized supply chain is:

$$E\pi_c(Q) = E(\pi_c(Q)|D_2 < q) + E(\pi_c(Q)|D_2 > q),$$

where

$$\begin{aligned}
&E(\pi_c(Q)|D_2 < q) \\
&\quad = E_{D_2}\left[p_1 E\min(D_1, Q) + sE(Q - D_1)^+ - lE(D_1 - Q)^+ - cQ\right] \\
&\quad = \int_0^q \left[p_1 Q - (p_1 - s)E(Q - D_1)^+ - lE(D_1 - Q)^+ - cQ\right] dF(D_2) \\
&\quad = \int_0^q \left[(p_1 + l)Q - l\bar{D}_1 - (p_1 - s + l)E(Q - D_1)^+ - cQ\right] dF(D_2) \qquad (1) \\
&\quad = \int_{-\infty}^{q - \bar{D}_2} \left[(p_1 + l)Q - l\bar{D}_1 - (p_1 - s + l)E(Q - \bar{D}_1 - \varepsilon)^+ - cQ\right] dF(\varepsilon).
\end{aligned}$$

Therefore:

$$\begin{aligned}
E\pi_c(Q) = &\int_{-\infty}^{q - \bar{D}_2} \left[(p_1 + l)Q - l\bar{D}_1 - (p_1 - s + l)E(Q - \bar{D}_1 - \varepsilon)^+\right] dF(\varepsilon) \\
&+ \int_{q - \bar{D}_2}^{\infty} \left[(p_2 + l)Q - l\bar{D}_2 - (p_2 - s + l)E(Q - \bar{D}_2 - \varepsilon)^+\right] dF(\varepsilon) \\
&- cQ. \qquad (2)
\end{aligned}$$

Taking the first derivative with respect to Q:

$$\frac{\partial E\pi_c(Q)}{\partial Q}$$
$$= \begin{cases} \text{if } Q < q - \bar{D}_2 + \bar{D}_1: & (p_1 + l)F(q - \bar{D}_2) + (p_2 + l)\bar{F}(q - \bar{D}_2) \\ & -(p_1 - s + l)F(Q - \bar{D}_1) - c \\ \text{if } q - \bar{D}_2 + \bar{D}_1 < Q < q: & (p_1 + l)F(q - \bar{D}_2) + (p_2 + l)\bar{F}(q - \bar{D}_2) \\ & -(p_1 - s + l)F(q - \bar{D}_2) - c \\ \text{if } q < Q: & (p_1 + l)F(q - \bar{D}_2) + (p_2 + l)\bar{F}(q - \bar{D}_2) \\ & -(p_1 - s + l)F(q - \bar{D}_2) \\ & -(p_2 - s + l)\left[F(Q - \bar{D}_2) - (q - \bar{D}_2)\right] - c. \end{cases} \tag{3}$$

Since $\frac{\partial E\pi_c(Q)}{\partial Q}$ is nonincreasing and continuous in Q, we can conclude that $E\pi_c(Q)$ is concave in Q. Noticing that $\frac{\partial E\pi_c(Q)}{\partial Q}$ is constant if $q - \bar{D}_2 + \bar{D}_1 < Q < q$ since all the parameters appear in that expression are pre-specified, we let $u = (p_1 + l)F(q - \bar{D}_2) + (p_2 + l)\bar{F}(q - \bar{D}_2) - (p_1 - s + l)F(q - \bar{D}_2) - c = (p_2 + l - c) - (p_2 + l - s)F(q - D_2)$. Denote $\bar{q}^C = \bar{D}_2 + F^{-1}(\frac{p_2+l-c}{p_2+l-s})$, then $u > 0$ is equivalent to $q < \bar{q}^C$. In the theorem below we derive the expression for the supply chain optimal quantity Q_0^* based on the value of u.

Theorem 1 *The supply chain optimal order quantity under group buying is:*

$$Q_0^* = \begin{cases} \textit{any value} \in \left[q - \bar{D}_2 + \bar{D}_1, q\right], & \textit{if } q = \bar{q}^C \\ \bar{q}^C, & \textit{if } q < \bar{q}^C \\ \bar{D}_1 + F^{-1}\left[\frac{p_2+l-c-(p_2-p_1)F(q-\bar{D}_2)}{p_1+l-s}\right], & \textit{if } q > \bar{q}^C. \end{cases} \tag{4}$$

All the proofs are provided in the Appendix.

Theorem 1 indicates that there are three possible scenarios for the supply chain optimal quantity decision, depending on the group buying threshold q. Note that $\bar{q}^C$ is in fact the newsvendor quantity if demand is always D_2. Intuitively, when the group buying threshold is small enough ($q < \bar{q}^C$), group buying deal is expected to be activated with almost certainty, therefore it is optimal to ignore the possibility of doing regular sale and simply order the newsvendor quantity $\bar{q}^C$. On the other hand, if the group buying threshold is large enough ($q > \bar{q}^C$), then it is likely that group buying demand cannot exceed the threshold, in which case the retailer should order the expected regular demand ($\bar{D}_1$) plus some safety inventory:

$$\left(F^{-1}\left[\frac{p_2 + l - c - (p_2 - p_1)F(q - \bar{D}_2)}{p_1 + l - s}\right]\right).$$

Interestingly, he should order a little more than the newsvendor quantity when demand is always D_1, due to the possibility of activating group buying deal and thus facing a larger demand. If q is exactly equal to $\bar{q}^C$ then a variety of order quantities can be optimal.

4 Supply Chain Coordination

When the supplier and retailer are two separate entities, they make decisions on their own interests. In this section we explore whether there exists a buyback contract such that the retailer continues to make the supply chain optimal decision even though she maximizes her own profit. With the buyback contract, supplier charges a wholesale price ω_b, and buys back any unsold inventory at a price b. The retailer still adopts group buying strategy, where price p_2 is offered if demand D_2 exceeds the threshold q, and p_1 is offered otherwise.

Analogous to the centralized supply chain, with the supplier offering a buyback contract, the first order condition for the retailer's profit can be easily obtained by substituting the production cost c and salvage price s in Eq. (3) with the wholesale price ω_b and buyback price b respectively. Thus in the decentralized system with buyback contract, the first order condtion with respect to the retailers optimal purchase quantity becomes:

$$\frac{\partial E\pi_R(Q,b,\omega_b)}{\partial Q} = \begin{cases} \text{if } Q < q - \bar{D}_2 + \bar{D}_1: & (p_1+l)F(q-\bar{D}_2) \\ & +(p_2+l)\bar{F}(q-\bar{D}_2) \\ & -(p_1-b+l)F(Q-\bar{D}_1) - \omega_b \\ \text{if } q - \bar{D}_2 + \bar{D}_1 < Q < q: & (p_1+l)F(q-\bar{D}_2) \\ & +(p_2+l)\bar{F}(q-\bar{D}_2) \\ & -(p_1-b+l)F(q-\bar{D}_2) - \omega_b \\ \text{if } q < Q: & (p_1+l)F(q-\bar{D}_2)+ \\ & (p_2+l)\bar{F}(q-\bar{D}_2) \\ & -(p_1-b+l)F(q-\bar{D}_2) \\ & -(p_2-b+l)\left[F(Q-\bar{D}_2)\right. \\ & \left.-F(q-\bar{D}_2)\right] - \omega_b. \end{cases} \tag{5}$$

It is natural to assume that $b \geq s$ since otherwise the retailer will not return the unsold products to the supplier. In order to derive the supplier's optimal order quantity Q_R^* in the decentralized supply chain, we let $v = (p_1+l)F(q-\bar{D}_2) + (p_2+l)\bar{F}(q-\bar{D}_2) - (p_1-b+l)F(q-\bar{D}_2) - \omega_b$, which is the second expression in Eq. (5). Also denote $\bar{q}^R = \bar{D}_2 + F^{-1}(\frac{p_2+l-\omega_b}{p_2+l-b})$, then $v > 0$ is equivalent to $q < \bar{q}^R$.

Note that $\bar{q}^R$ depends on the contract terms ω_b and b. The optimal order quantity under the buyback contract is:

$$Q_R^* = \begin{cases} \text{any value } \in \left[q - \bar{D}_2 + \bar{D}_1, q\right], & \text{if } q = \bar{q}^R \\ \bar{q}^R, & \text{if } q < \bar{q}^R \\ \bar{D}_1 + F^{-1}\left[\frac{p_2 + l - \omega_b - (p_2 - p_1)F(q - \bar{D}_2)}{p_1 + l - b}\right], & \text{if } q > \bar{q}^R. \end{cases} \tag{6}$$

We now identify the coordinating buyback contract b, ω_b based on different values of q.

Theorem 2 *If $q = \bar{q}^C$, any buyback contract b, ω_b that satisfies*

$$\omega_b = (b - s)F(q - \bar{D}_2) + c, \tag{7}$$

coordinates the supply chain.

Theorem 3 *If $q < \bar{q}^C$, the following buyback contract coordinates the supply chain:*

$$\omega_b = p_2 + l - \left(\frac{p_2 + l - c}{p_2 + l - s}\right)(p_2 + l - b), \tag{8}$$

with $Q_R^* = Q_0^* = \bar{q}^C$.

Theorem 4 *If $q > \bar{q}^C$, the following buyback contract coordinates the supply chain:*

$$\omega_b = \left[p_1 + l - \frac{p_1 + l - b}{p_1 + l - s}(p_1 + l - c)\right] - \frac{b - s}{p_1 + l - s}(p_1 - p_2)\bar{F}(q - \bar{D}_2), \tag{9}$$

and $Q_R^* = Q_0^* = \bar{D}_1 + F^{-1}\left[\frac{p_2 + l - c - (p_1 - p_2)F(q - \bar{D}_2)}{p_1 + l - s}\right]$ is optimal for the retailer.

Theorem 2, 3 and 4 suggest that the supply chain coordination contracts take different forms when the group buying threshold falls into different ranges. When the threshold q is exactly equal to the critical threshold $\bar{q}^C$, the contract has a very simple form, and it is particularly interesting to observe that ($\omega_b = c, b = 0$) is also one possible contract. In other words, a simple wholesale-only contract is already sufficient to induce the retailer to order the supply chain optimal quantity. When the group buying threshold is small enough, the retailer expects to sell to group buying demand D_2, therefore the coordination contract takes the form as in the classic coordination literature [13]. If the group buying threshold is large enough, the contract has a complicated form depending on demand distribution, however, it can be observed that the first term in Eq. (9) is the coordinating wholesale price if demand is always D_1. Group buying, therefore, forces the supplier to lower his wholesale price in order to coordinate the supply chain, and he needs to lower more if the group buying discount is large, or if the group buying threshold is small.

5 Conclusions

Group buying mechanism has been widely studied in both business-to-business B2B and B2C contexts. While there has been little research studying its effect to the performance of supply chain under a contract, our study attempts to fill this gap by formulating a fixed-price newsvendor type model incorporating group buying selling and buyback contract. We identified the buyback contract $\{b, \omega_b\}$ under group buying setting that coordinates the supply chain and it is dependent on the value of exogenous parameters including the normal selling price p_1, group buying price p_2, group buying quantity threshold q, as well as the random demand distribution.

Our work can be extended in several dimensions. We model demand randomness in an additive fashion, so a potential future extension is to examine the coordination contracts using multiplicative form. Additionally, we assume implicitly that the randomness in D_1 and D_2 are identical. While in reality it may be highly correlated but not necessarily identical. Therefore this research can also be extended to identify the coordinating contract assuming different distributions for regular and group buying demand. We believe these extensions would lead to more insights in supply chain management under a new selling strategy of group buying.

Appendix

Proof of Theorem 1:

1. If $u = 0$: Since $\frac{\partial E\pi_c(Q)}{\partial Q}$ is contineous and nonincreasing in Q, Q_0^* can be any value within $\left[q - \bar{D}_2 + \bar{D}_1, q\right]$.
2. If $u > 0$: Q_O^* will be achieved within $(q, +\infty)$. Go back to Eq. (3), the optimal Q satisfies $(p_1+l)F(q-\bar{D}_2)+(p_2+l)\bar{F}(q-\bar{D}_2)-(p_1-s+l)F(q-\bar{D}_2)-(p_2-s+l)\left[F(Q-\bar{D}_2)-F(q-\bar{D}_2)\right]-c=0$. So $Q_0^* = \bar{D}_2 + F^{-1}\left(\frac{p_2+l-c}{p_2+l-s}\right)$. Since $\frac{\partial E\pi_c(Q)}{\partial Q}$ is contineous and nonincreasing in Q, $u > 0$ ensures Q_O^* in this case belongs to $(q, +\infty)$.
3. If $u < 0$: then Q_O^* will be achieved within $(0, q-\bar{D}_2+\bar{D}_1)$. According to Eq. (3), the optimal Q satisfies $(p_1+l)F(q-\bar{D}_2)+(p_2+l)\bar{F}(q-\bar{D}_2)-(p_1-s+l)F(Q-\bar{D}_1)-c=0$. So

$$Q_0^* = \bar{D}_1 + F^{-1}\left[\frac{p_2+l-c-(p_2-p_1)F(q-\bar{D}_2)}{p_1+l-s}\right].$$

Proof of Theorem 2:

$u = 0$ implies that $Q_0^* \in \left[q - \bar{D}_2 + \bar{D}_1, q\right]$. To enable $Q_R^* = Q_0^*$ and thus achieve supply chain coordination, v must also be zero. So $(p_1+l-s)F(q-\bar{D}_2)+c = (p_1+l-b)F(q-\bar{D}_2)+\omega_b$. Then we derive the expression of ω_b with respect to b as $\omega_b = (b-s)F(q-\bar{D}_2)+c$.

Proof of Theorem 3:

$u > 0$ implies that

$$Q_0^* = \bar{D}_2 + F^{-1}\left(\frac{p_2 + l - c}{p_2 + l - s}\right).$$

To enable $Q_R^* = Q_0^*$ and thus find a coordinating buyback contract $\{b, \omega_b\}$, we must ensure $v > 0$ at the same time. Then

$$Q_R^* = \bar{D}_2 + F^{-1}\left(\frac{p_2 + l - \omega_b}{p_2 + l - b}\right).$$

Let $Q_R^* = Q_0^*$ and it gives the result shown in Eq. (8). Substitute ω_b into the expression for v. Since $v > 0$, it implies $(p_2 + l - b)\left[\frac{p_2+l-c}{p_2+l-s} - F(q - \bar{D}_2)\right] > 0$. Given the buyback price b must be less than the retailer's selling price p_2, the second term $\left[\frac{p_2+l-c}{p_2+l-s} - F(q - \bar{D}_2)\right] > 0$ should be positive.

Proof of Theorem 4:

$u < 0$ implies that

$$Q_0^* = \bar{D}_1 + F^{-1}\left[\frac{p_2 + l - c - (p_2 - p_1)F(q - \bar{D}_2)}{p_1 + l - s}\right].$$

Similarly, to find a coordinating buyback contract $\{b, \omega_b\}$, we must ensure v also to be negative. Then

$$Q_R^* = \bar{D}_1 + F^{-1}\left[\frac{p_2 + l - \omega_b - (p_2 - p_1)F(q - \bar{D}_2)}{p_1 + l - b}\right].$$

Equalizing the expression for Q_0^* and Q_R^* gives the coordinating buyback contract:

$$\begin{aligned}\omega_b &= p_2 + l - (p_2 - p_1)F(q - \bar{D}_2) \\ &\quad - \frac{p_1 + l - b}{p_1 + l - s}\left[p_2 + l - c - (p_2 - p_1)F(q - \bar{D}_2)\right] \\ &= \left[p_1 + l - \frac{p_1 + l - b}{p_1 + l - s}(p_1 + l - c)\right] - \frac{b - s}{p_1 + l - c}(p_1 - p_2)\bar{F}(q - \bar{D}_2).\end{aligned} \tag{10}$$

Substitute ω_b into the expression for v as before. Since $v < 0$, it implies $(p_1 + l - b)\left[p_2 + l - c - (p_2 - p_1)F(q - \bar{D}_2)\right] < 0$. Given the buyback price b must be less than the retailer's selling price p_1, the second term $[p_2 + l - c - (p_2 - p_1)$ $F(q - \bar{D}_2)]$ must be negative.

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Economic Viability Study for Offshore Wind Turbines Maintenance Management

E. Segura Asensio, J.M. Pinar Pérez and F.P. García Márquez

Abstract Nowadays, there is a growing interest in the development of offshore wind farms due to the increasing size and capacity of wind turbines, improvement of wind resources, social acceptance, noise reduction, depletion of onshore locations with great wind resources, etc. However, the operation and maintenance (O&M) costs are too high to make offshore wind turbines economically viable. The use of condition monitoring systems (CMS) appears as a solution to minimize O&M costs and increase the reliability of offshore wind farms. The quantification of the economic benefits of CMS is a non-trivial problem. In this work is presented a novel maintenance management research based of an economic study of the Life Cycle Cost (LCC) of CMS for offshore wind turbines. The model includes the costs of investment and O&M of the CMS and costs for reduction of O&M and energy losses of the wind turbine generates by the implementation of CMS. These costs are related with a reliability analysis of a real case study. The application of the economic model on a real case study assuming different scenarios enables the analysis of the economic benefits to use CMS in offshore wind turbines.

Keywords Life cycle costs · Condition monitoring systems · Wind energy · Offshore wind turbines

1 Introduction

Owing to climate change is a reality, the European Union target for 2020 is to reach that the 20 % of the total energy consumption will be generated by renewable energies [3]. Wind energy represents an essential technology of the electricity production sector and has enjoyed a growing interest in recent years [4]. Offshore wind projects

E. Segura Asensio · F.P. García Márquez (✉)
Ingenium Research Group, University of Castilla-La Mancha, Albacete, Spain
e-mail: FaustoPedro.Garcia@uclm.es

J.M. Pinar Pérez
CUNEF-Ingenium Research Group, Serrano Anguita 8, 28009 Madrid, Spain

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have been part of this expansion due to the increase in size and capacity of wind turbines, better wind resources than onshore, depletion of ground locations with great wind resources, higher social acceptance and noise reduction. However, the operational and maintenance costs are too high to make offshore wind turbines economically viable [16]. The energy research Centre of the Netherlands (ECN) revealed an estimation of these costs for offshore wind farms is in the order of 30–35 % of the cost of electricity (distributed in 25–30 % in preventive maintenance and 65–75 % in corrective maintenance) [14].

The use of CMS is needed to improve the availability, reliability, safety and maintenance costs of offshore wind farms. The main reasons for the implementation of CMS are the following [5, 8]:

- Higher power installed and, therefore, higher wind turbine investments. Higher wind turbines fail more frequently.
- Reduction of corrective maintenance costs.
- Increasing reliability, decreasing downtime.
- Offshore installations with difficult access to carry out maintenance tasks.
- Requirements from insurance companies in the EU countries to regularly realize replacement and repair operations in offshore wind farms.
- High interest of specialized companies which supply advanced CMS.

In the scientific literature can be found different techniques used in wind turbines such as acoustic emission [15], ultrasonic systems [6], oil analysis [17] or strain measurements [12], among others. However, the quantification of the economic benefits of CMS is a problem non-trivial. In [13] is studied the cost benefits on a CMS for onshore wind turbines and a relationship between gearbox maintenance costs and CMS efficiency is found. In [9] is provided an economic justification of CMS regarding to operational parameters for a wind farm showing that the accurate diagnosis of CMS in the interval 60–80 % makes them cost-effective. In [1] is demonstrated the effectiveness of the online monitoring system for wind turbines using an economic model. In [10] is developed and analysis with different strategies where the use of CMS improves maintenance planning in offshore and onshore wind farms.

In this research is presented a novel maintenance management research based of an economic study of the Life Cycle Cost (LCC) of CMS for offshore wind turbines. The model includes, on the one hand, the costs of investment and O&M of the CMS and on the other hand, costs for reduction of O&M and energy losses of the wind turbine generates by the implementation of CMS. These last costs are related with the failure rate and downtime, respectively, from a reliability analysis of a real case study. The net present value (NPV) is used in the economic model including different NPV factors in the interval between 1 and 10 %. The application of the economic model on a real offshore wind farm is developed, assuming different scenarios including different percentages of energy losses and different percentages of preventive and corrective maintenance tasks. In addition, the problem is raised in two different approaches: initial investment provided by the company and initial investment supported by a bank loan with an interest rate of 6 %. This study will give us a map of the different solutions varying the variables considered.

The work is structured as follows: Sect. 2 explains the theoretical foundations of the maintenance management research based of the LCC of CMS for offshore wind turbines presented in this work. In Sect. 3 is presented the application of the maintenance management model on the real data reported from Egmon aan Zee wind farm in the Netherlands. Finally, Sect. 4 illustrates conclusions of the work.

2 Model Definition

The research presented in this work studies the feasibility of CMS for offshore wind turbines through a Life Cycle Cost (LCC) using different annual rates of return. The main objective of the study is to illustrate that the use of CMS are highly profitable in offshore wind turbines. The LCC model proposed for the CMS of offshore wind turbines presents a similar structure than the model used in [7], applied to railway industry. The definition of the LCC takes into consideration the following assumptions: (a) Property tax, value added tax, etc., and general inflation are constant and included within the annual discount rate (defined as k); and (b) Cash required for investment is provided by the company (rather than being borrowed) so the equity rate is 1. Then, the LCC is based on the following expression:

$$\mathbf{Y} = \sum_{i=1}^{n} \mathbf{y}_i = \lambda \sum_{i=1}^{n} \mathbf{a}_i \cdot \mathbf{c}_i^T,$$

where $\mathbf{Y}$ is the total cost, $\mathbf{Y}$=[$Y_1, \cdots, Y_t, \cdots, Y_T$], Y_t denotes the cumulative cost in year t, the subscript T is the total number of years, Y_t indicates the cost of breakdown in category i, and λ expresses the net present value factor vector defined by the following expression:

$$\lambda = \sum_{t=1}^{T} \frac{1}{(1+k)^{t-1}} = 1 + \frac{1}{k}[1 - (1+k)^{1-T}],$$

being T the total number of years of the study (10 years) and k the factor of the NPV. In the case study considered in this work, it is selected $n = 5$ (CMS investment: $i = 1$; CMS operation: $i = 2$; CMS maintenance: $i = 3$ and; maintenance reductions by CMS: $i = 4$ and; energy production and energy losses by CMS $i = 5$). Now, if the term a_{ij} indicates the number of times that the unit cost c_{ij} is incurred, the matrix A and C can be described as $A = [a_1, \ldots, a_5]$, and $C = [c_1, \ldots, c_5]$, where a_i and c_i are one dimensional arrays of length 4, i.e., $a_i = [a_{i1}, \ldots, a_{i4}]$ and

$c_i = [c_{i1}, \ldots, c_{i4}]$. The base year has been set 0. Therefore, the values that compose the matrices A and C are the following:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \\ a_{51} & a_{52} & a_{53} & a_{54} \end{bmatrix}, C = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \\ c_{51} & c_{52} & c_{53} & c_{54} \end{bmatrix}.$$

The detailed description of the different costs that compose the matrixes A and C are developed next.

(1) CMS Investment Costs

The CMS investment cost c_1 is related to the costs of capital. These costs are represented by the general investment costs of CMS, and the costs of the different parts of the CMS installed in the wind turbine (tower, nacelle and blades). The elements of c_1 are therefore described in Table 1.

On the other hand, the number of times incurred in these costs are: $a_{11} = a_{12} = a_{13} = a_{14} = 1$.

Table 1 CMS investment costs

	Definition	This term includes the cost of
c_{11}	General CMS investment costs	Capital, installation (operator, technical and diver salaries), regulatory Approval, initial testing, software, power, communications and the transport costs (boat)
c_{12}	Tower CMS investment costs	Data acquisition system (hardware, data transmission and software), Installation costs (operator, technical and diver salaries), the acquisition of the different sensors necessary to monitor the tower of the wind turbine, the initial testing and the transport costs (boat)
c_{13}	Nacelle CMS investment costs	Data acquisition system (hardware, data transmission and software), Installation costs (operator, technical and diver salaries), the acquisition of the different sensors necessary to monitor the nacelle of the wind turbine, the initial testing and the transport costs (boat)
c_{14}	Blades CMS investment costs	Data acquisition system (hardware, data transmission and software), Installation costs (operator, technical and diver salaries), the acquisition of the different sensors necessary to monitor the blades of the wind turbine, the initial testing and the transport costs (boat)

Table 2 CMS operation costs

	Definition	This term includes the cost of:
c_{21}	General CMS Operation costs	Data acquisition and transmission, software, testing, power consume and human resources (operator and technical salaries)

(2) CMS Operation Costs

The CMS operation cost c_2 is the cost incurred by the technical operation process in a period of time. The most significant costs incurred in this term are in Table 2.

Operation costs are performed monthly, therefore, $a_{21} = a_{22} = a_{23} = a_{24} = 12$. Finally, $c_{22} = c_{23} = c_{24} = 0$.

(3) CMS Maintenance Costs

The CMS maintenance costs c_3 are the cost for CMS maintenance management processes. The most significant costs incurred in this term are in Table 3.

Maintenance costs are carried out once a year, therefore, $a_{31} = 1$. Finally, $c_{32} = c_{33} = c_{34} = 0$ and $a_{32} = a_{33} = a_{34} = 1$.

(4) Maintenance Reduction Costs by CMS

This costs represents the difference between total maintenance costs with and without CMS. The computation of these costs includes the assumption that preventive and inspection costs are reduced in 75 % with CMS and corrective maintenance costs are reduced in 40 % using CMS. The failure rates of the different components of the wind turbine from the case study have been used to calculate these costs. The elements of c_4 are therefore described in Table 4.

The number of times that these cost are incurred are: $a_{41} = a_{42} = a_{43} = a_{44} = 1$.

(5) Energy Production and Energy Losses by CMS

The cost due to energy production losses is represented by the cost difference of production losses with and without CMS. The downtime of the different components

Table 3 CMS maintenance costs

	Definition	This term includes
c_{31}	General CMS maintenance costs	Corrective and preventive CMS maintenance costs

Table 4 Maintenance reduction costs by CMS

	Definition	This term includes:
c_{41}	General maintenance reduction costs	Preventive costs (helicopter rand barge costs, operator, technical and diver salaries, cleaning costs, etc.) and corrective costs (other failures, see failures rates in Fig. 1)
c_{42}	Tower maintenance reduction costs	Preventive costs (base inspection, tower inspection and alignment of the turbine costs, technical and operator salaries and cleaning costs, etc.) and corrective costs (base repair without dismantling, base replacement, base transport (boat), base repair, technical installer and technical operator salaries, etc.)
c_{43}	Nacelle maintenance reduction costs	This term is included the preventive and corrective maintenance costs of the elements that compose the nacelle of the wind turbine
c_{44}	Blades maintenance reduction costs	Preventive and corrective maintenance reduction costs of the blades

Table 5 Assumptions for the LCC calculation

	Assumptions
Assumptions hours by year	8760
Wind turbine eficiency (%)	0.6
Electricity price (€/kWh)	0.083
Failures reduction by CMS (%)	0.4

of the wind turbine from the case study have been used to calculate these costs. The main assumptions used in the computation of the energy production and energy losses employing CMS are resumed in Table 5.

The values of c_5 are defined as the electricity price (0.083 €/kWh) [2] and the elements of a_5 are defined as the difference of power loss (kWh) between the different elements with and without CMS.

3 Case Study

The data used for the evaluation of the proposed maintenance management approach are the annual operations reports from Egmond aan Zee wind farm in Netherlands [11]. It was the first large offshore wind farm installed in the Dutch coast (in the North Sea). It comprises 36 Vestas V90-3 MW turbines producing 108 MW and is located 10–18 km from the coast covering around 27 km^2. The data is available for 2007–2009 and illustrates the failures and the hours lost related with the different components of the wind turbines installed. This data information is depicted in Fig. 1.

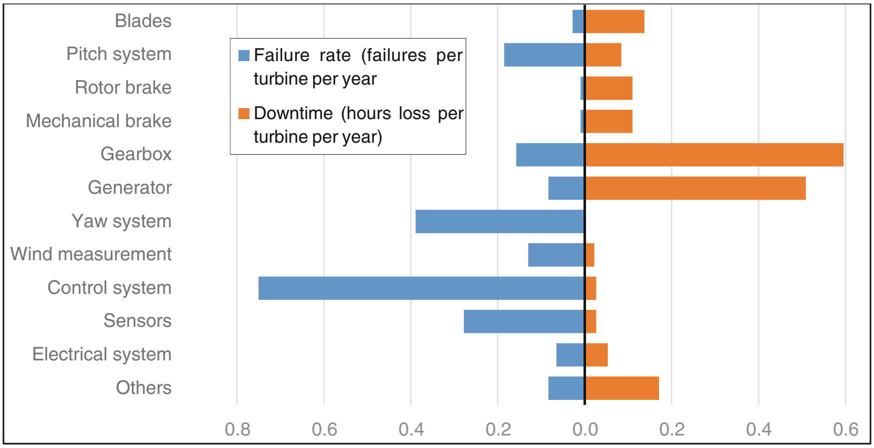

Fig. 1 Failure rates and downtime associated for 2007–2009 in Egmond aan Zee wind farm

In the application of the LCC described in the previous section to the case study the values that compose the matrices are the following:

$$A = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 12 & 12 & 12 & 12 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 132.2 & 0 & 1048 & 160 \end{bmatrix}, C = \begin{bmatrix} -19133.3 & -100970.6 & -74434.2 & -83285.3 \\ -4877.8 & 0 & 0 & 0 \\ -8333.3 & 0 & 0 & 0 \\ 37250 & 19500 & 83140.7 & 4672.2 \\ 0.083 & 0.083 & 0.083 & 0.083 \end{bmatrix}.$$

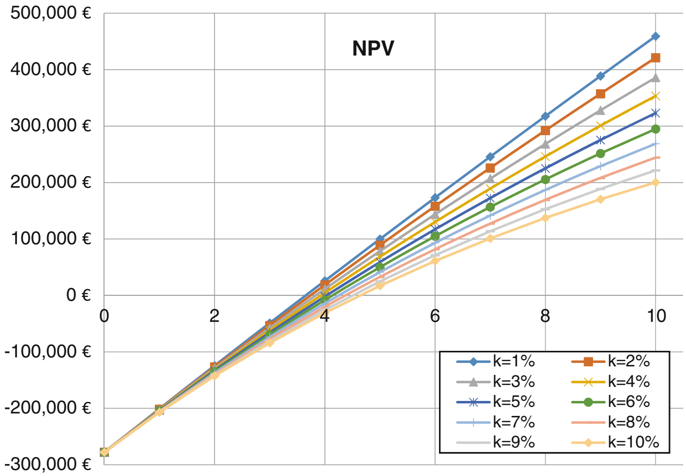

Fig. 2 NPV results for different values of rate of return and for different years of operation in Vestas V90

Figure 2 displays the NPV values for ten years operation considering 40 % of reduction of failures by using CMS. This figure illustrates different curves depending on the annual rate of return k. It is observed that the initial CMS costs are recovered for all the values of k in the 3rd year of operation. There are energy production benefits from the 4th year of operation making the use of CMS profitable. Additionally, it is shown that the lower is the rate of return k greater is the benefit obtained.

An extension of the LCC proposed above is the assumption that the investment costs for CMS are supported by a bank loan with an interest rate of 6 % and 10 years. The study includes the NPV results for values of rate of return between 1 and 10 %. Figure 3 shows that the benefits caused by the use of CMS start appearing between the 3rd and the 4th year of operation for all the values of rate of return. Similarly than in the previous study, the lower is the rate of return k greater is the benefit obtained.

Finally, a study of the NPV results has been carried out under the assumption of variations on the electricity price. Figure 4 shows the NPV results in the 10th year of operation for values of rate of return between 1 and 10 %. The graph shows that CMS

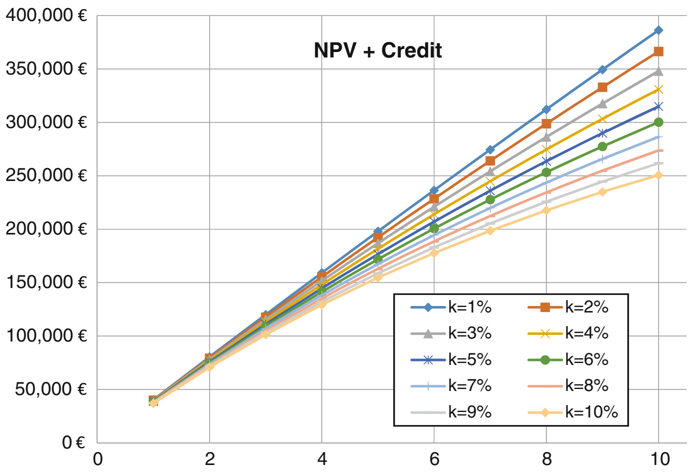

Fig. 3 Investment costs supported by a bank loan—NPV results for different values of rate of return and for different years of operation in Vestas V90

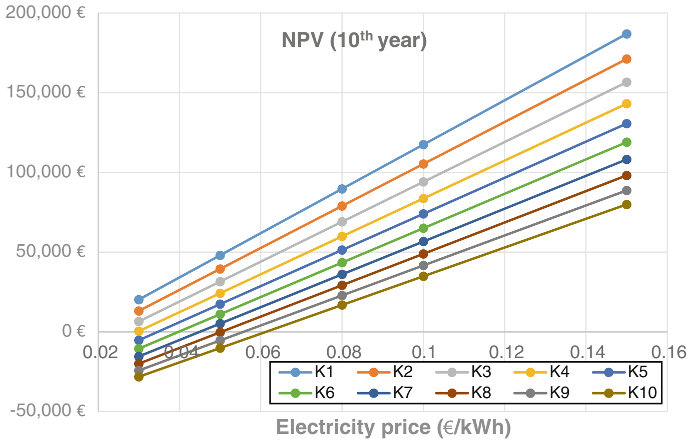

Fig. 4 NPV results for different values of rate of return and for different years of operation in Vestas V90 assuming changes in the electricity price

are profitable in most cases. Additionally, benefits are always obtained for values of rate of return between 1 and 4 %. For high values of k and small values of electricity price gives the use of CMS not profitable.

4 Conclusions

A CMS for offshore wind turbines is proposed in this work to reduce operation and maintenance costs. The use of CMS has been demonstrated to be an effective solution to avoid large failures and/or downtimes. The economic study of the LCC of CMS for offshore wind turbines reveals the effectiveness of the CMS itself, economic benefits of CMS and the sensitivity to O&M costs under different scenarios: (a) initial investment provided by the company; (b) initial investment supported by a bank loan with an interest rate of 6 %; and (c) variations in the electricity price. The following conclusions were achieved: (1) the results for case (a) shows that the return of the initial CMS investment cost is in the 3rd year and small values of rate of return caused higher CMS benefits; (2) similar results are obtained when the initial investment of CMS is supported by a bank loan (case (b)); and (3) The electricity price highly influences in the benefits obtained using CMS.

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A Multi-Objective Optimization Model for the Purchasing and Inventory in a Three-Echelon Construction Supply Chain

Qiurui Liu and Zhexiong Tao

Abstract Material purchasing and supply is a great insurance to the continuity of the construction process. In this paper, a multi-objective purchasing model is presented for the purchasing and inventory in the perspective of each construction partner in a construction supply chain. The model aims to reduce the purchasing and supply cost as well as the lead time in a construction supply chain. Purchasing quantity and lead time are both considered as controllable decision variables in this model.

Keywords Decision making model · Purchasing · Multi-objective optimization · Construction supply chain

1 Introduction

An appropriate procurement system are fundamental to the success of a construction project. Many procurement research for the construction project have been developed to reach more efficient purchasing decisions, such as supplier selection [8, 18], e-procurement [10], fuzzy inference system [3] and so on. Nowadays, there is a trend to analysis the construction procurement with project logistics. Caron et al. [2] integrated the procurement with construction processes. Said and El-Rayes [19] presented an optimization planning model for materials procurement and storage of the construction logistics. Moreover, there are also critical principles for the decision making of procurement in construction project [10]. Except for the practical procurement method used in the construction industry [21], adequate consideration of unique characteristics and conditions of a project [7, 11] is needed. Usually, the material supply process involves complex factors, such as inventory level, time uncertainty, price uncertainty, etc.

Q. Liu (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: qiurui.liu@hotmail.com

Q. Liu · Z. Tao
Faculty of Management, Mcgill University, Montreal H3A 1G5, Canada

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Lead time is an important element in any inventory management system [17]. Service level and business competitiveness can be shown to possibly be influenced directly or indirectly via lead-time and/or ordering cost control [4]. In a practical construction supply chain, lead time is a random variable due to the uncertain of the order preparation, order transit, supplier lead time, delivery time, and setup time. Some research has discussed the variable lead time in the general inventory model [1, 12–14]. Pan and Yang [17] investigated an integrated inventory model with controllable lead time for the implementation of just-in-time (JIT) production. Ouyang et al. [15] presented a single-vendor single-buyer integrated production inventory models assuming that lead time demand is stochastic. A JIT was extended with quality improvement and lead time reduction [16]. By shortening the lead time, we can lower the safety stock, improve customer service level, and increase the competition ability [12]. However, there has few work concerning the lead time reduction in the integration of the procurement and construction supply chain. Therefore, this paper tried to build the gap between the general inventory model and the construction supply chain optimization considering the lead time uncertainty.

The reminder of this paper is organized as follows. Section 2 shows the modeling of a three-echelon construction supply chain; The last part is an example and a suitable outcomes that truly reflects construction practice. Readers can refer the following content to learn more details.

2 Modelling

Nowadays, large volume of building material inventory system is usually subpackaged to a third-party inventory contractor by the construction owner. In this case, there is an inventory contractor between the supplier and the general contractor in a construction supply chain. The owner pay for the inventory management for the inventory contractor. And there do not exists the transfer price of the material between the owner and the inventory contractor. Thus, a construction supply chain can not be treated and represented by a generalized supply chain. The biggest issue for the material purchasing and inventory of a construction supply chain is how to use optimization model to reduce each cost and ensure the whole supply efficiency. One way to increase the supply efficiency is to control the lead time. Therefore, we tried to determine the optimal lead time and purchasing quality in a construction supply chain in this paper.

1. Assumption

(1) Information is shared on the construction supply chain;
(2) No shortage is allowed;
(3) Inventory level decreases linearly;
(4) The construction progress rate is definite;
(5) Materials are delivered to the inventory contractor in compliance with the construction sequence;

(6) Duration of the construction process T is divided into planning periods with duration τ.

2. Notation

The following notations are used in the formulation of the model.

Sets and Subscripts

i : index of a component of lead time L, $i = 0, 1, 2, \cdots, n$;
j : index of a component of lead time L, $j = 0, 1, 2, \cdots, n$

Decision Variable

Q : order quantity;
L : lead-time, L_0 is the safety lead time;
r : re-order point;

Certain Parameters

T : duration period;
A : fixed preparation cost for supplier;
B : fixed set-up cost for each procurement;
D : demand in duration T;
X : extra costs incurred by the supplier when shortened lead time is requested;
Y : inventory contract fee given by construction owner to inventory contractor;
p : purchasing price in the contract;
S : safety stock;
h : unit holding cost;
m : production profit margin rate;
n : number of independent components of lead time L;
β : construction progress rate;
c_i : the unit crashing cost;
a_i : minimum duration of ith component of lead time L;
b_i : maximum duration of ith component of lead time L;
τ : length of a planning period.

2.1 Objectives

1. Supplier cost

Lead time can be decomposed into independent components that have a different crashing cost for reduced lead time [9]. The lead time crashing cost can be expressed as:

$$c_i\left(\sum_{i=1}^{n} b_i - \sum_{j=1}^{i-1}(b_j - a_j) - L\right) + \sum_{j=1}^{i-1} c_j(b_j - a_j), \tag{1}$$

where $\sum_{i=1}^{n} a_i < L < \sum_{i=1}^{n} b_i$, n is the number of independent components of lead time L, c_i is the unit crashing cost. The components of lead time are crashed one at a time starting from the first component because it has the minimum unit crashing cost, and then the second component, and so on.

The number of order is $\frac{D}{Q}$. The cost for the supplier contractor includes preparation cost (i.e. A), production cost (i.e. $(1-m)pQ$) and lead time cost.

$$\min f_1 = \frac{D}{Q}(A + (1-m)pQ) + \frac{D}{Q}\left[\left(\sum_{j=1}^{n} b_j - \sum_{j=1}^{i-1}(b_j - a_j) - L\right)c_i + \sum_{j=1}^{i-1}(b_j - a_j)c_j\right]. \tag{2}$$

2. Inventory contractor cost

The inventory contractor focus on how to minimize the holding cost. It is assumed that the inventory is at the safety level S at the beginning. The demand for the material is constant. Then, the inventory level at the end of a period is $S + Q - \frac{D}{T}$ respectively. As we assumed that the inventory level decreases linearly, the average inventory level can be explained as $S + \frac{Q}{2} - \frac{D}{2T}$. Then, the holding cost can be expressed as:

$$\min f_2 = \left(S + \frac{Q}{2} - \frac{D}{2T}\right)\frac{D}{Q}h. \tag{3}$$

3. Owner cost

In a construction supply chain, the construction owner needs to pay for the purchasing cost, lead time reward to the supplier and inventory contract fee (i.e. Y). The extra costs (i.e. X) incurred by the supplier will be fully transferred to the owner if shortened lead time is requested. The purchasing cost includes fixed order cost (i.e. B) and variable cost (i.e. Qp). Thus, the construction owner cost can be expressed as following:

$$\min f_3 = (B + Qp)\frac{D}{Q} + X + Y. \tag{4}$$

The average demand per unit time on the owner is $\frac{D}{T}$. Then, the expected demand during the lead time can be explained as $\frac{D}{T}L$. The safety stock is S. Then, the reorder point r can be stated as following equation:

$$r = \frac{D}{T}L + S. \tag{5}$$

2.2 Constraints

1. Safety lead time

If the construction progress rate is a regular trend, there exists an approximate relationship between the safety lead time and safety stock [2]. Each delivery of materials to the site was translated into an equivalent amount of man hours of construction. The value of these man hours earned during a τ is β. As safety stock is S and p is the price (i.e. p can be treated as unit value of material), so pS determines the value of the materials safety stock. Then, the approximate relationship for safety lead time L_0 can be developed as following:

$$L_0 = \frac{pS}{\beta}\tau, \tag{6}$$

where τ is the length of the planning period.

Though the decision maker need to reduce the lead time, there is still an limitation for the lead time L which should be above the safety lead time. So,

$$L_0 \geq L. \tag{7}$$

Besides, as a_i and b_i is the minimum and maximum duration of ith component respectively, the duration of L must in a range of:

$$\sum_{i=1}^{n} a_i < L < \sum_{i=1}^{n} b_i. \tag{8}$$

2. Purchasing quantity limitation
   Usually, there is a minimum order quantity, which can be stated as follows,

$$Q^{\min} \leq Q. \tag{9}$$

2.3 Formulation Model

In order to increase the efficiency of the construction supply chain, objectives function of supplier, inventory contractor and construction owner were established by considering economic cost (i.e. the objective Eqs. (2), (3) and (4)). To ensure continuous construction process, safety lead time was fulfilled in Eq. (7). In reality, there also exist other resource constraints, such as purchasing quantity limitation (i.e. Eq. (9)). From the above statement, we can then formulate the optimization decision model.

$$\min f_1 = \frac{D}{Q}(A + (1-m)pQ) + \frac{D}{Q}\left[\left(\sum_{j=1}^{n} b_j - \sum_{j=1}^{i-1}(b_j - a_j) - L\right)c_i + \sum_{j=1}^{i-1}(b_j - a_j)c_j\right]$$

$$\min f_2 = (S + \frac{Q}{2} - \frac{D}{2T})\frac{D}{Q}h$$

$$\min f_3 = (B + Qp)\frac{D}{Q} + X + Y$$

$$\text{s.t.} \begin{cases} \frac{pS}{\beta}\tau \geq L \\ \sum_{i=1}^{n} a_i < L < \sum_{i=1}^{n} b_i \\ Q^{\min} \leq Q \\ r = \frac{D}{T}L + S. \end{cases}$$

where $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, i-1$.

PSO (Particle Swarm Optimization) is a population-based evolutionary computation technique which has found applications in a lot of areas. It have been utilized to solve multi-objective optimization problems using efficiently PSO [20]. The PSO algorithm has few parameters to adjust and is simple in concept, easy to implement and computational efficient. In this paper, PSO algorithm is used to find the optimal order quantity, reorder point and lead time simultaneously.

3 Numerical Example

In order to illustrate the proposed model, we used the data of a construction supply chain as a numerical example. The data of this numerical example is shown in Table 1. The lead time has three components with data shown in Table 2 [14, 16, 17].

Under the same set of parameters, the results of 10 runs of the PSO algorithm were shown in Table 3. From Table 3, we can see the optimal solution Q is around 40 t and the lead time is in a range of 21∼23 days. The optimal solution purchasing quantity Q is 39.8842 t. The optimal lead time L is 21 days. The reorder point is 58.3261 t. The cost of the supplier f_1 is \$27980. The holding cost of the inventory contractor f_2 is \$5930.2. The purchasing cost of the owner f_3 is \$34327. At this solution, the minimized total cost is \$68237.

Table 1 Parameters in the numerical example

Parameters	Value	Parameters	Value
A (\$)	100	m \$/t	8 %
B (\$)	200	n	3
Y (\$)	5000	T (month)	12
S (t)	30	τ (month)	1
h (\$/t/month)	10	β (day)	60
D (t)	480	p (\$/t)	54

Table 2 Lead time data

Parameters	$i = 1$	$i = 2$	$i = 3$
c_i ($/day)	0.1	1.2	5
a_i (day)	6	6	9
b_i (day)	20	20	16

Table 3 Results

Replication	Q	L	r	f_1	f_2	f_3	Total cost
1	39.6591	21.0253	58.0338	27986	5950.3	34341	68277.3
2	39.8164	22.3068	59.7424	28067	5936.2	34331	68335
3	39.446	21.5215	58.6953	28047	5969.4	34354	68370
4	39.8109	22.7746	60.3661	28103	5936.7	34331	68372
5	39.3957	21.3191	58.4255	28037	5974	34357	68367
6	39.9129	23.2185	60.9581	28126	5927.7	34325	68379
7	39.8842	21.2446	58.3261	27980	5930.2	34327	68237
8	39.4648	21.0795	58.106	28011	5967.7	34353	68331
9	39.6895	21.3655	58.4873	28009	5947.5	34339	68295
10	39.4837	21.1159	58.1546	28012	5966	34351	68329

To see the agent fee reduction and extra cost effect, we also checked the results of the numerical example when agent fee (i.e. Y) changes. Obviously, extra cost X and agent fee Y has liner cumulative relationship in the cost function of the owner. Then, we found out that for any given agent fee Y or extra cost paid by the owner to the supplier X, the optimal purchasing amount Q keeps the same. And the cost of the supplier and the inventory contractor changes very slightly. So, the agent fee and the extra cost has little effect on the purchasing plan.

In the proposed construction supply chain, the supplier and the owner cooperate with each other. So, the same purchasing quantity Q, the reorder point r and lead time are taken as decision variables simultaneously. To check the effect of the lead time reduction, the model was solved under the same purchasing quantity (Q = 39.6895 t). Comparing the results shown in Table 4, we see that the savings of cost of the supplier and the total cost of the CSC are achieved from the efforts of leat time reduction. Therefore, this kind of cooperation can improve the supply efficiency significantly.

Table 4 Lead time effect

Replication	1	2	3	4	5
L	21.0376	21.0709	21.4176	21.451	21.831
f_1	27984	27987	28013	28016	28045
CSC total cost	68270	68273	68299	68302	68331
Replication	6	7	8	9	10
L	22.2372	23.0171	23.0814	23.9694	24.2802
f_1	28076	28135	28140	28208	28231
CSC total cost	68362	68421	68426	68494	68518

4 Conclusion

The objective is to minimise the total cost of each construction parter. The models are developed with production cost, ordering cost, holding, agent cost and lead time crashing costs. The results reveal that the cost of the supplier, the inventory contractor and the owner were reduced in this case. Moreover, we examine the performance of agent fee of the inventory contractor against the total purchasing cost. While, it turns out the agent fee and the extra cost transferred to the owner because of shortened lead time has no significant effect on the purchasing plan. Investigation of the dynamic and uncertainties in the CSC is one aspect of the future research. For example, there are some kind of distribution of price and demand. There also exists stock out and backorder. Each of these areas is the future research topic and is worthy of attention.

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Integrated Distribution-Transportation Planning for the Raw Material Supply Chain Management

Siwei Zhao and Zongmin Li

Abstract In this paper, we study an integrated distribution-transportation problem for raw material in supply chain management. A bi-level model is proposed for dealing with this distribution-transportation planning problem. In this hierarchical system, the leader is the retailer who wants to maximize total profit and decides the selection for supply location. The follower is the distributor, who responses to these information and will decide the quantities of the raw material. Then, a bi-level decision procedure based genetic algorithm is employed to handle the bi-level model. A case will be presented to prove the effectiveness of the proposed model and algorithm.

Keywords Supply chain management · Distribution-transportation · Bi-level modeling · Genetic algorithm

1 Introduction

A supply chain (SC), is an integrated manufacturing process, beginning with raw materials collected by the distributors, and ending up with the sale of productions to customers. Traditionally, planning, production, transportation, distribution and market along the SC are independently operated. However, each participant has his own benefit and objective which may interact with others'. Therefore, there is a need for a system that these organizations can be integrated together. Supply chain management (SCM), involving planning, production, transportation and distribution, provided a method through which such integration can be reached and a way to enhance industrial chain [8]. For years, tremendous papers have studied many aspects of the SCM problems, such as home electronic, mechanical engineering and automobile industry [6, 12, 14].

S. Zhao · Z. Li (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: lizongmin@scu.edu.cn

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Some SCM problems consist of complicated structure and system, which is made up by different organizes [1, 3, 5]. Fernandes [3] considered a multi-entity, multi-product, multi-echelon and multi-transport downstream petroleum SCM with resource quantities, supply sources and demand requirements. Ang et al. [1] proposed a game model of multi-leader and one-follower in SCM where n suppliers compete to provide the single products for the one manufacturer. In this paper, we study an integrated distribution-transportation (DT) planning for the raw material SC coordination. A bi-model with multiple decision-makers for an integrated DT planning is developed to describe the relationship between the decision-maker of upper level (the retailer) and the decision-maker of lower level (the distributor), both of whom can optimize their objectives by taking each other's actions into consideration.

The bi-level model increases difficulties and complication to solve it. Lot of studies have proved that genetic algorithm (GA) is superior to other algorithms for solving bi-level problems, including a population-wide search, a continuous balance between convergence and diversity, and the principle of building-block combination [13]. The advantage of GA is that there is no need for more specific information about the problem space [9]. GA has been used to solve the SCM problems [2, 4, 11]. In addition, to handle the bi-level model, we apply the bi-level decision procedure. Therefore, a bi-level decision procedure based genetic algorithm (bpGA) is proposed to deal with the bi-level model.

The paper is organized as follows. In Sect. 2, we make a detailed key problem statement about the DP problem considering the characters and relationships between participants in the system. In Sect. 3, the global model is given, which is made up by the retailer sub-model and the distributor sub-model. In Sect. 4, to solve the bi-level DP planning, we put forward a bpGA to improve the performance of the basic GA. In Sect. 5, a case study is presented. The results and discussion is presented in Sect. 6. Finally, some concludes are outlined in Sect. 7.

2 Key Problem Statement

The SCM problem in this paper involves two participants, the retailer and the distributor, covering raw materials market. Complicated relationships exist between the retailer and the distributor that they are interacting with each other. For the practical operation in SCM, the retailer's main work is to purchase raw materials from the distributor and sell them to consumers. To satisfy demand of consumers and own interests, he must make an effective decision about choosing the supply locations and offering raw material quantitative constraint for the distributor. Apparently, his decisions will influence the global SCM. Then, in accordance with information conveyed from the retailer, the distributor would confirm his objective and take action under restriction of the retailer. His plan is to provide enough raw materials to the retailer and minimize his total cost. In response, the distributor presents his solution to the retailer and they would update and improve their targets to reach a satisfactory solution ceaselessly. A bi-level model is established for a problem which consists

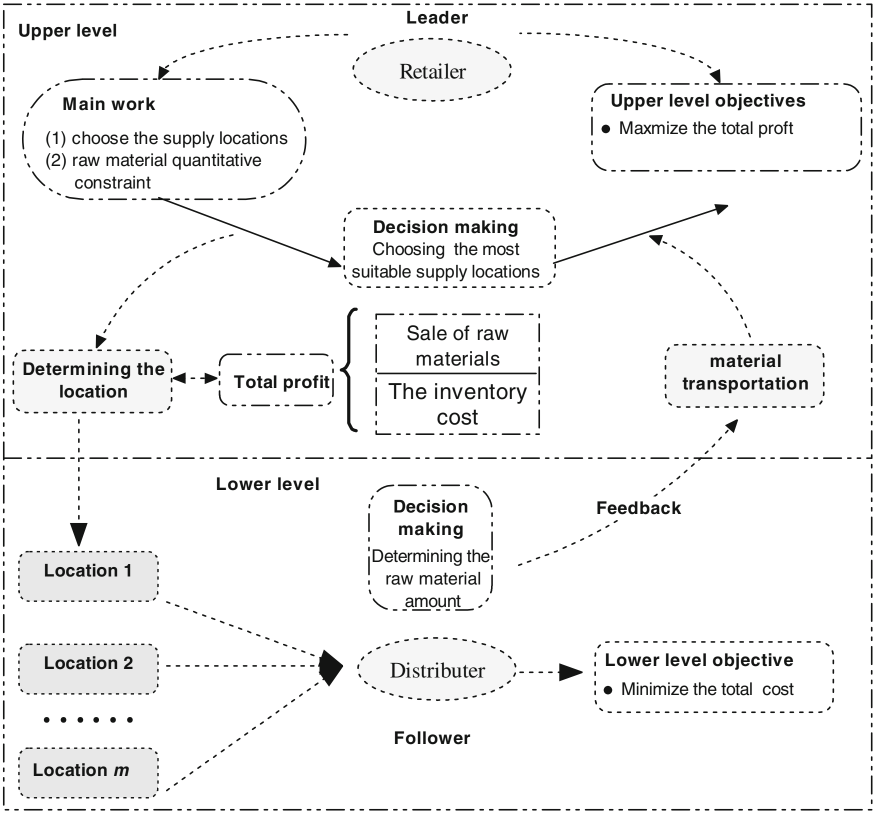

Fig. 1 The abstract structure of the bi-level model

of two or more decision makers, who independently optimize their own goals, but are affected by the decision made by the other under a hierarchical structure [10]. Therefore, based on description above, the two decision makers can be seen to have a bi-level relationship, while the retailer is the leader and the distributor is the follower. The bi-level model is shown in Fig. 1.

3 Model

In this section, a bi-level model is constructed. The mathematical description of the model, is given as follows.

1. Assumptions:

(1) All the possible locations for different materials can be identified.

(2) The marginal revenue and transportation costs of the same materials at different locations are different.

(3) All the resource demands for each kind of materials during can be satisfied.

2. Notations:

Indices:

i : raw materials index, $i \in \{1, 2, \cdots, N\}$

j : supply location index, $j \in \{1, 2, \cdots, M\}$

Decision variables:

x_j : 0-1 matrix variable, 1 denotes that supply location j is selected by the retailer, otherwise takes 0

y_{ij} : the quantity of raw material i offered by the distributor at the supply location j

Objective function:

$P(x_j, y_{ij})$: the total profit function for the retailer

$C(x_j, y_{ij})$: the total cost function for the distributor

Certain parameters:

R_{ij} : the marginal revenue unit of raw material i from location j

C_j : the inventory cost at the supply location j

C_j^o : the operating cost at supply location j

C_{ij}^t : the transportation cost unit of material i from the supply location j

$A_i^{\min}$: the lower bound for the amount y_{ij} of purchased material i

$A_i^{\max}$: the upper bound for the amount y_{ij} of purchased material i

V_i : the volume unit for material i

$V_{\max}$: the maximum storage capacity limitation for the storehouse of the retailer

C_b : the budget cap for operating cost

3. Optimization Model for the Retailer

According to requirement of consumers, the retailer must deal with n kinds of raw materials. He concerns about total profits, which mainly come from the sale of raw materials $\sum_{i=1}^{n} R_{ij} y_{ij}$. The retailer purchases raw materials from the distributor who collects them from m supply locations and transports them from the supply locations to the retailer's market. As the leader, the retailer has the right to choose the supply location for purchase raw materials because he determines the inventory cost $C_j x_j$ [7]. If he intends to purchase the raw material from location j, then x_j takes 1, otherwise takes 0. There is an agreement between two decision makers that transportation costs are paid by the distributor and the inventory costs are usually paid the retailer. In general, inventory costs denote $\sum_{j=1}^{m} C_j x_j$. Therefore, total profit objective function is as follow

$$\max P(x_j, y_{ij}) = \sum_{i=1}^{n} \sum_{j=1}^{m} R_{ij} y_{ij} - \sum_{j=1}^{m} C_j x_j, \tag{1}$$

where R_{ij} is the marginal revenue unit of raw material i, C_j is the inventory cost at the supply location j.

Next, some constraints are required. First, for the retailer storehouse, there exists the maximum storage capacity limitation $V_{\max}$. The volume unit for material i is defined as V_i. The total volume of material should be less than or equal to maximum storehouse space. Thus, the storage constraint for storage is:

$$\sum_{i=1}^{n}\sum_{j=1}^{n} V_i y_{ij} \leq V_{\max}. \tag{2}$$

Then, it is the logic constraint, which ensures that the distributor can only collect the raw materials from the supply location selected by the retailer, $y_{ij} \leq Mx_j$, where M is a very large number.

The modeling can thus be formulated as the following mathematical programming problem:

$$\begin{cases} \max P(x_j, y_{ij}) = \sum\limits_{i=1}^{n}\sum\limits_{j=1}^{m} R_{ij} y_{ij} - \sum\limits_{j=1}^{m} C_j x_j \\ s.t. \begin{cases} \sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} V_i y_{ij} \leq V_{\max} \\ y_{ij} \leq Mx_j \\ x_j \in \{0, 1\}. \end{cases} \end{cases} \tag{3}$$

4. Optimization Model for the distributor
As is depicted above, the retailer purchases raw materials from the distributor. In this model, the distributor's goal is to minimize the total cost, which consists of operating costs at supply locations and transportation costs. The operating costs are $\sum_{j=1}^{m} C_j^o$. The transportation costs are $\sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij}^t y_{ij}$. Therefore, the total cost function is:

$$\min C(x_j, y_{ij}) = \sum_{j=1}^{m} C_j^o x_j + \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij}^t y_{ij}, \tag{4}$$

where C_{ij}^t is the transportation cost unit of material i from the supply location j.

For the amount $\sum_{j=1}^{m} y_{ij}$ of offered material i, there is an interval constraint offered by the retailer. Namely, taking into account the volume of inventories, the $\sum_{j=1}^{m} y_{ij}$ has a lower bound $A_i^{\min}$ and a upper bound $A_i^{\max}$, respectively. The amount constraint is expressed as:

$$A_i^{\min} \leq \sum_{j=1}^{m} y_{ij} \leq A_i^{\max}. \tag{5}$$

Moreover, there is a constraint on financial resources of the distributor for operating costs at the supply locations, and it is expressed as:

$$\sum_{j=1}^{m} C_j^o x_j \leq C_b, \tag{6}$$

where C_b is the budget cap for operating cost.

Operation of the distributor can thus be formulated as the following mathematical programming problem:

$$\begin{cases} \min C(x_j, y_{ij}) = \sum\limits_{j=1}^{m} C_j^o x_j + \sum\limits_{i=1}^{n} \sum\limits_{j=1}^{m} C_{ij}^t y_{ij} \\ s.t. \begin{cases} A_i^{\min} \leq \sum\limits_{j=1}^{m} y_{ij} \leq A_i^{\max} \\ \sum\limits_{j=1}^{m} C_j^o x_j \leq C_b. \end{cases} \end{cases} \tag{7}$$

5. The Global Modeling

In this model, two decision makers are under constraints while seeking to achieve their objectives, the retailer is under constraints of storage volume and logic. The distributor must meet the constraint for raw material amount and financial budget. In summary, the global modeling is as follows:

$$\begin{cases} \max P(x_j, y_{ij}) = \sum\limits_{i=1}^{n} \sum\limits_{j=1}^{m} R_{ij} y_{ij} - \sum\limits_{j=1}^{m} C_j x_j \\ s.t. \begin{cases} \sum\limits_{i=1}^{n} \sum\limits_{j=1}^{m} V_i y_{ij} \leq V_{\max} \\ y_{ij} \leq M x_j \\ x_j \in \{0, 1\} \\ \min C(x_j, y_{ij}) = \sum\limits_{j=1}^{m} C_j^o x_j + \sum\limits_{i=1}^{n} \sum\limits_{j=1}^{m} C_{ij}^t y_{ij} \\ s.t. \begin{cases} A_i^{\min} \leq \sum\limits_{j=1}^{m} y_{ij} \leq A_i^{\max} \\ \sum\limits_{j=1}^{m} C_j^o x_j \leq C_b. \end{cases} \end{cases} \end{cases} \tag{8}$$

4 Bi-Level Decision Procedure Based Genetic Algorithm

In this section, we proposed the bpGA to deal with the bi-level model.

1. Bi-level Decision Procedure
Based on the structure of the bi-level modeling, we apply bi-level decision procedure (BP) to cope with it. The elementary theory of BP is that the leader pursues his objective, who needs the follower to give him an optimal solution in isolation. Then follower's decisions are changed yielding to global benefits. The processing is repeated until a satisfactory solution is obtained. In this paper, the leader is the retailer and the follower is the distributor.

2. Hybrid Particle Representation
In this paper a hybrid particle representation which is combined by ordinal encoding in the lower level and 0-1 representation is used in upper level programming. In ordinal encoding, for example, $x_1 \in \{15, 16, 17, \ldots, 35\}, x_2 \in \{100, 105, 110, \ldots, 200\}$, $x_3 \in \{200, 210, 220, \ldots, 450\}$, $x_4 \in \{3, 4, 5, \ldots, 20\}$, then population size of x_1, x_2, x_3, x_4 is 21, 21, 26, 18. If we define $\{x_1, x_2, x_3, x_4\} = \{15, 110, 220, 9\}$. Thus, the corresponding chromosome is $\{1, 3, 4, 7\}$.

3. Partially Mapped Crossover
The theory of partially mapped crossover (PMX) [9] is that two crossover sites are stochastically produced while the offspring directly inherits the element between two locations of one parent. An element in one parent holds the position which is arranged to map the element between the two points in the other parent. Then the remainders are inherited from the other parent. As the transfer of elements from one parent in the sequence crossover 1 to offspring maintains sequence, adjacency and locations for the segment.

4. Reversal Sequence Mutation
The reversal sequence mutation is applied in this GA as a mutation operator. In this processing, the whole order is conversed. For example, through the operation, a chromosome (3, 4, 5, 6, 7) will become (7, 6, 5, 4, 3).

5. Roulette Wheel Selection
Wheel selection as a selection approach is employed in this paper. It is one of proportional selection approaches. The basic theory on it is to determine selection or survival probability for each chromosome proportional to the fitness value. Then a model of roulette wheel can be made showing these probabilities.

6. Overall Procedure of the bpGA
To deal with the bi-level model, the bpGA is applied to look for the solution to the upper level. At the beginning of the algorithm, some feasible solutions (particles: x_j) for the upper level decision variables satisfying the constraints of upper level modeling are generated. Then the solutions are set into the lower-level model. The bpGA is used to find the optimal solution (y_{ij}) to the lower-level model. Both the solutions to the upper level and the lower level make up of the final feasible solutions ($\{x_j, y_{ij}\}$) of the global model. Then the new solutions are generated through an update of the particles. The overall procedure of the algorithm is presented in Fig. 2.

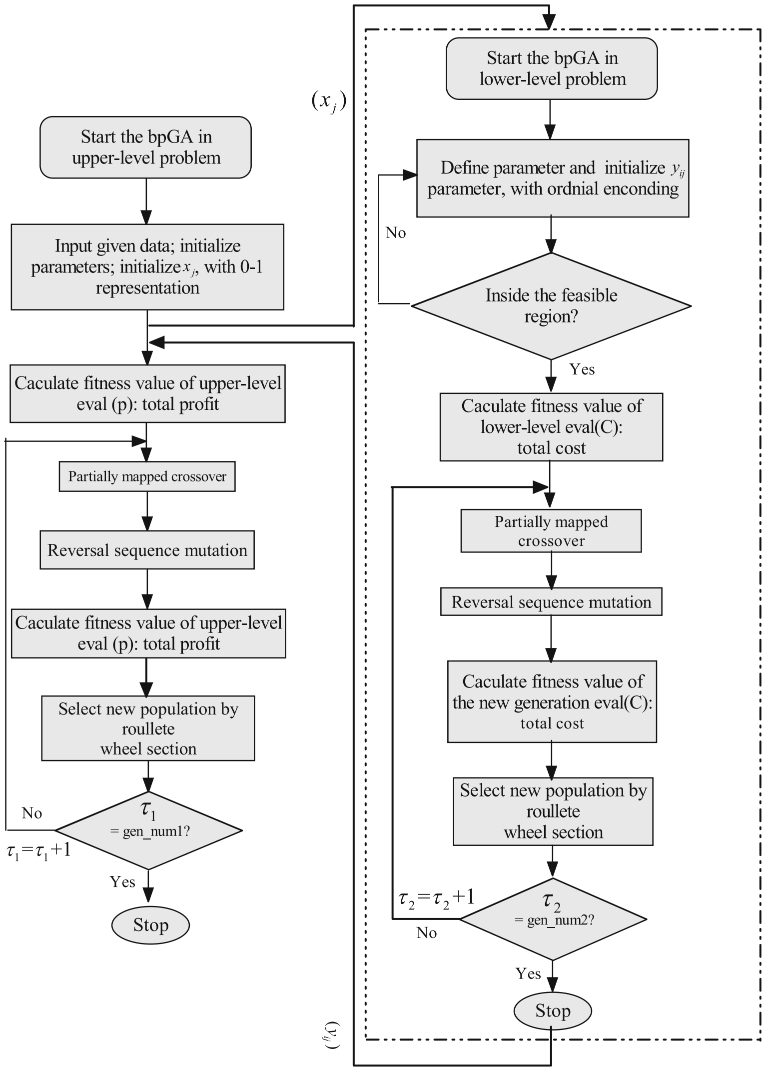

Fig. 2 The overall procedure of the bpGA

5 Case Study

Above model and algorithm are applied to a case to test its feasibility in this section. We assume that the retailer requires to buy 5 raw materials and they are allocated on 4 different supply locations. The marginal revenue unit R_{ij} of raw material i from location j are shown in Table 1, the inventory cost C_j at the supply location j and the operating cost C_j^o at supply location j are presented in Table 2. Table 3 gives the

Table 1 The marginal revenue unit R_{ij} (unit: CNY/kg)

	Raw material				
Supply location	1	2	3	4	5
1	103	102	95	117	97
2	86	96	113	84	99
3	98	106	121	95	87
4	99	110	94	108	103

Table 2 The inventory cost and the operating cost (unit: 100 CNY)

Supply location	1	2	3	4
The inventory costs	2385	1964	2014	1876
The operating costs	1874	2281	1989	2041

Table 3 The transportation cost unit C_{ij}^{t} (unit: CNY/kg)

	Raw material				
Supply location	1	2	3	4	5
1	23	18	25	17	19
2	26	16	21	19	22
3	18	23	15	14	31
4	27	30	17	13	22

Table 4 The lower, upper bound for material purchase amount (unit: kg) and the volume unit (unit: cm^3/kg)

	Raw material				
Purchase amount	1	2	3	4	5
The lower bound	5000	6000	5600	4500	3900
The upper bound	2200	3600	3400	2100	1800
The volume unit for material	5000	3200	5000	4000	2400

transportation cost unit of material i from the supply location j. The lower, upper bound for material i purchase amount and the volume unit for material i are given in Table 4. The storage constraint is 95 m^3, the financial constraint C_b is 6.3×10^5CNY.

Table 5 The feasible solution

x_j	y_{ij}				
1	2000	1500	1800	2000	1000
0	–	–	–	–	–
1	1000	1500	2000	1200	800
1	1500	2500	1500	1000	1500

6 Results and Discussion

By using the MATLAB to run proposed algorithm, we get a feasible solution for this case study. After running 200 generations, the feasible solution is shown in Table 5. The the total profit for the retailer is 23.0×10^6 CNY, the total cost for the distributor is 1.07×10^6 CNY. Then we compare the PMX and the sublist crossover. Both of two crossover methods in this case have obtained satisfactory solutions. However, the PMX runs convergent faster, and gets the satisfactory solution more quickly and runs more stable.

7 Conclusion

In this paper, a bi-level model is developed for dealing with integrated DT planning for SCM. The bi-level model aims to obtain the satisfactory purchase plan for the retailer and the satisfactory sale plan for the distributor. In our model, the retailer is the leader trying to maximize the total profits by deciding supply locations and purchase quantity constraints while the distributor as the follower aims at the total cost minimization by determining the operating costs for selected supply locations and the transportation cost. Then we propose the bi-level decision procedure based genetic algorithm (bpGA) to handle this problem. Compared with the plain GA, the bpGA offers a designed method to convert the complicated bi-level structure into simple structure. At last, we apply the proposed model and method to a case study. In this case study, we test our method and acquire a satisfactory solution, which proves the advisability and efficiency of the optimization method. In addition, we compare the partially mapped crossover (PMX) and the sublist crossover, showing the advantages of using PMX.

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The Vehicle Routing Optimization with Uncertain Demands and Traveling Time

Fang Yan, Manjing Xu and Haiyan Yu

Abstract This paper studies the vehicle routing optimization problem with uncertain demands and traveling time. Here two objectives are considered: (1) minimize the total cost of all vehicles, and (2) maximize the average service level for all customers. Based on the assumptions, a mathematical model is set up and then a particle swarm optimization algorithm is proposed to solve the model.

Keywords Vehicle routing optimization · Uncertain demands and traveling time · Particle swarm optimization

1 Introduction

Vehicle routing problem (VRP) is a combinatorial optimization seeking to service a number of customers with a fleet of vehicles. Since VRP was proposed by Dantzig [1], it has attracted more attentions of the scholars and was widely researched.

According to the different requirements of the customers, VRP could be different types. For example, if there are more than one vehicle type providing service, then the problem could be multi-type vehicle routing problem. Beside, if the customers have requirements for the service time, then the problem could be the vehicle routing problem with service time windows. Further more, if the service time window cannot (can) be violated, then the problem could be the vehicle routing problem with hard (soft) time windows. This paper studies the vehicle routing problems with soft time windows (VRPSTW).

F. Yan (✉) · H. Yu
School of Management, Chongqing Jiaotong University, Chongqing 40074, People's Reoublic of China
e-mail: yanfang@cqjtu.edu.cn

M. Xu
College of Information and Business, Zhongyuan University of Technology, Zhengzhou 450007, People's Reoublic of China

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In fact, some uncertain information which could affect the decisions for VRPSTW. There are many research have noticed this problem and studied it from different views. Bertsima [2] surveyed those developments, including the uncertain natural stochastic and dynamic variations of VRP, with an emphasis on the insights gained and on the algorithms proposed. In previous research, customer demands and traveling time usually were treated as the uncertain information. The research adopted different approaches to describe these uncertain information, including stochastic theory and fuzzy theory. Sungur [3] introduced a robust optimization approach to solve the VRP with stochastic demand, Laporte [4] proposed an integer L-shaped algorithm for the capacitated vehicle routing problem with stochastic demands, Novoa [5] established a approximate dynamic programming for the VRP with random demands. There also exist much research which studying the VRP with stochastic demands, such as [6–9]. There research believed that the demands in VRP should be considered as random variables. While, some other research believed that the uncertain demands should be considered as fuzzy variables, such as [10–13]. All of these research treated the demands as an interval and adopted the fuzzy theory to handle them. Based on the pervious research, recently some research proposed that the demands could be the complex uncertain information which has stochastic and fuzzy traits at the same time. For instance, both Xu [14] and Dey [15] handled the demands as fuzzy random variables because they believed that the demands could be involved with subjective and objective uncertainties simultaneously. Another important uncertain information existing in VRP is the time variable. Li [16] considered the traveling time and service time in VRP as stochastic, and Nahum [17] proposed a model for stochastic time-dependent vehicle-routing problem. Other research, including [18, 19], also proposed the variable of time (i.e., traveling time, service time) as random variables. While, there were some research handling the time as fuzzy variables, for example, Zheng [13] treated traveling time as fuzzy numbers and some researched the VRP with the fuzzy time windows [20]. So it can be found that the time could involve stochastic and fuzzy traits as the same time.

VRP is a classical NP-hard problem [21]. Recently, various approaches were proposed to deal with it, including the heuristic methods [22–24], evolutionary algorithm [25–27], tuba search algorithm [28, 29] and so on. This papre will adopt particle swarm optimization (PSO) to deal with the target problem.

The rest of this paper will be organized as following structure. In Sect. 2, a presentation of the target problem will be given, and in Sect. 3, the model will be established based on the assumptions. Then, the approach method will be proposed in order to solve the problem in Sect. 4 and at last a conclusion will be given.

2 Problem Statement

As mentioned in Sect. 1, the customer demands and traveling time are usually uncertain in VRP. In fact, these uncertain information are complex, which have the stochastic and fuzzy features at the same time. Usually the stochastic theory could describe the objective uncertainties, and the fuzzy theory could describe the subjective uncertainties. Most of the previous research focused on either or stochastic feature or fuzzy feature, but it is believed that these uncertain information should be considered in the fuzzy random environment, which could properly handle with the complex uncertainties. For example, the traveling time could be affected by the weather, traffic conditions and so on, which are stochastic events. On the other hand, it may be different from various drivers on the same path, which reflects its subjective feature. So suppose the traveling time on a certain path could be described as "if it is rainy (the probability is 0.3), then the traveling time may be about 10 h, but if it is sunny (the probability is 0.7), then it may takes about 8 h". Now this uncertain information could be translated as a fuzzy random variable, i.e.,

$$\tilde{\bar{\xi}} = \begin{cases} [9\ 10\ 11]\,, & \text{with probability } 0.3 \\ [7\ 8\ 9]\,, & \text{with probability } 0.7. \end{cases} \tag{1}$$

Similar cases appear in customer demands. So we will adopt the fuzzy random variables to describe the customer demands and traveling time in VRP.

Besides, the soft time window is considered in our research. There is a close relationship between the delivery time (arriving time) and the customer satisfaction level. Hence, we use the fuzzy number to describe this relationship between them. For example, if the customer hopes the service could start at $[12:00\ 12:30]$, and no earlier than $11:00$ and no latter than $13:00$, then the customer satisfaction level could be described by a fuzzy number with the following membership function:

$$\mu(t) = \begin{cases} 0 & t < 11 \\ L(t-11) & 11 \le t < 12 \\ 1 & 12 \le t < 12.5 \\ R\left(\frac{t-12.5}{0.5}\right) & 12.5 \le t < 13 \\ 0 & t \ge 13, \end{cases} \tag{2}$$

which is, if the service starts between $12:00$ and $12:30$, then the customer could be satisfied and the satisfaction level is 1; if the service starts between $11:00$ and $12:00$ or between $12:30$ and $13:00$, then the customer may be not satisfied and the satisfaction level could be less than 1 and more than 0; But if the service starts earlier than $11:00$ or latter than $13:00$, then the customer could be angry and the satisfaction level is 0.

2.1 Modelling

Based on above problem presentation, the mathematical model will be established in this section. Firstly, let us give the basic assumptions for the modelling.

(1) There is only one vehicle type and the capacity of each vehicle are known.
(2) The route of each vehicle starts and finishes at the supplier or the distribution center.
(3) Each customer is served by a single vehicle.
(4) The traveling time and customer demands are fuzzy random variables.

Then the model will be given as following based on above assumptions.

$$\begin{cases} \min \sum\limits_{k\in K}\sum\limits_{i\in N+(0)}\sum\limits_{j\in N+(n+1)} c_{ij}x_{ijk} \\ \max \frac{1}{n}\sum\limits_{i\in N} L_i(t_i) \\ s.t. \begin{cases} \sum\limits_{j\in N} x_{0jk}=1,\ \sum\limits_{i\in N} x_{i,n+1,k}=1,\ \forall k\in K \\ \sum\limits_{i\in N+(0)-(j)} x_{ijk}-\sum\limits_{i\in N+(n+1)-(j)} x_{jik}=0,\ \forall j\in N,\ \forall k\in K \\ \sum\limits_{k\in K}\sum\limits_{j\in N+(n+1)-(j)} x_{ijk}=1,\ \ \forall i\in N \\ \sum\limits_{i\in N}\tilde{\bar{d}}_i\sum\limits_{j\in N+(n+1)-(j)} x_{ijk}\le C_k,\ \forall k\in K \\ t_j\ge \max\{EET_j,(t_i+s_i+\tilde{\bar{t}}_{ij})x_{ijk}\},\ \forall j\in N, i\in N+(0),\forall k\in K \\ t_j\le ELT_j,\ \ \forall j\in N \\ x_{ijk}\in\{0,1\}, \end{cases} \end{cases} \tag{3}$$

where c_{ij} denotes the cost of traveling from nodes i to j, x_{ijk} denotes whether vehicle k travel from customer i to customer j: if $x_{ijk}=1$, then vehicle k travel from customer i to customer j; else, $x_{ijk}=0$. K and N are the vehicles set and customers set, respectively. The node 0 is the start node and the node $n+1$ is the end node. $L_i(t_i)$ denotes the satisfactory level of customer i, n is the total number of customers. $\tilde{\bar{d}}_i$ denotes the demand of customer i, which is fuzzy random variable, and C_k denotes the capacity of vehicle k. EET and ELT are the earliest and latest service time that a customer can endure. t_i denotes the time of a vehicle starts service for customer i, s_i denotes the service duration time of customer i, and $\tilde{\bar{t}}_{ij}$ denotes the travel time from customer i to customer j, which are fuzzy random variables. The model (3) tries to find out the satisfactory solution which could minimize the total cost and meanwhile maximize the average service level for customers. The constrains ensure all vehicle could not overload and the service time could be accepted by each customer. Besides, the route continuity is considered by the constrains too.

Actually, when the model involves in uncertain variables it is hard to get the accurate solutions. So we have to chose the proper approach to deal with these uncertain variables in order to find out the satisfactory solutions for the decision makers. Usually, if the decision makers want to get the expected solutions, then the expected operators will be adopted. Besides, if the decision maker want to get satisfactory solutions with a certain chance, then the CCP will be chosen. Here, we suppose the decision maker tries to get satisfactory solutions with a certain chance so that use CCP to deal with above model as following.

$$\begin{cases} \min \sum\limits_{k\in K}\sum\limits_{i\in N+(0)}\sum\limits_{j\in N+(n+1)} c_{ij}x_{ijk} \\ \max \frac{1}{n}\sum\limits_{i\in N} L_i(t_i) \\ s.t. \begin{cases} \sum\limits_{j\in N} x_{0jk}=1,\ \sum\limits_{i\in N} x_{i,n+1,k}=1,\ \forall k\in K, \\ \sum\limits_{i\in N+(0)-(j)} x_{ijk} - \sum\limits_{i\in N+(n+1)-(j)} x_{jik}=0,\ \forall j\in N,\ \forall k\in K \\ \sum\limits_{k\in K}\sum\limits_{j\in N+(n+1)-(j)} x_{ijk}=1,\ \forall i\in N \\ Ch\left\{\sum\limits_{i\in N}\tilde{\bar{d}}_i \sum\limits_{j\in N+(n+1)-(j)} x_{ijk}\le C_k\right\}\ge\gamma_1,\ \forall k\in K \\ t_j\ge EET_j\ \forall j\in N, i\in N+(0), \forall k\in K \\ Ch\left\{t_j\ge (t_i+s_i+\tilde{\bar{t}}_{ij})x_{ijk}\right\}\ge\gamma_2,\ \forall j\in N, i\in N+(0), \forall k\in K \\ t_j\le ELT_j,\ \forall j\in N \\ x_{ijk}\in\{0,1\}, \end{cases} \end{cases} \tag{4}$$

where $Ch\{\cdot\}$ means the chance of the fuzzy random event. So the model 4 means the to find out the satisfactory solutions when the uncertain constrains are satisfied with a chance which is no lower than the required level (i.e., γ_1 and γ_2). Now the model could be solved according to Liu [30].

3 Solution Approach

Particle swarm optimization (PSO) as an evolutionary algorithm was first proposed in [31], which imitates the animal social behavior of birds, and it has become one of the most useful and efficient techniques. While, one problem in using PSO to solve the VRP is that the particles in a swarm tend to cluster quickly toward the global best particle and the swarm is frequently trapped in a local optimum and no longer moves. Many studies have concentrated on solving such problems and proposed some methods, such as generating the new particle randomly, or crossovering the particles between different swarms, or updating the velocity and position to move away from the worst particle.

This paper will adopt GLNPSO to solve the Model (4) in order to reduce the possibility of swarm trapping in local optimum. GLNPSO which was first proposed by [32], the component for social learning behavior includes not only the global best but also the local best and near neighbor best. The local best particle is the best one among several adjacent particles. The near neighbor best is a social learning behavior concept proposed by [33], which is determined by fitness-distance-ratio (FDR).

$$FDR = \frac{\text{Fitness}(P_l) - \text{Fitness}(P_o)}{|p_{ld} - p_{od}|}, \tag{5}$$

where P_l and P_o are the vector positions of the lth particle and oth ($o = 1, \cdots, L$ and $o \neq l$) particle.

The procedure of the GLNPSO can be stated as follows.

Step 1. Initialize the particle swarm;
Step 2. Update the particles positions and velocities
Step 2.1. For $l = 1, \cdots, L$ (L is the population size), decode each particle to a vehicle route. Calculate the fitness value for each particle and set the position of the lth particle as its personal best. Choose the best one of these personal best positions as global best position;
Step 2.2. Update pbest: for $l = 1, \cdots, L$, if Fitness(P_l) < Fitness(P_l^{pbset}), $P_l^{\text{pbest}} = P_l$, where P_l^{pbest} is the vector personal best position of the lth particle;
Step 2.3. Update gbest: for $l = 1, \cdots, L$, if Fitness(P_l) < Fitness(P^{gbset}), $P^{\text{gbest}} = P_l$, where P^{gbest} is the vector global best position;
Step 2.4. Update lbest: for $l = 1, \cdots, L$, among all pbest from M neighbors of the lth particle, set the personal best which obtains the least fitness value to be P_l^{lbest}, where P_l^{lbest} is the vector local best position of the lth particle;
Step 2.5. Generate nbest: for $l = 1, \cdots, L$, $o = 1, \cdots, L$ and $d = 1, \cdots, D$ (D is the size of dimension), find the p_{od} which has the maximum FDR, and set p_{od} as p_{ld}^{nbest};
Step 2.6. Update the velocity and the position of each lth particle:

$$
\begin{aligned}
&w(\tau) = w(T) + \frac{\tau - T}{1 - T}[w(1) - w(T)],\\
&v_{ld}(\tau+1) = w(\tau)v_{ld}(\tau) + c_p r_1[p_{ld}^{\text{best}}(\tau) - p_{ld}(\tau)] + c_g r_2[p_{gd}^{\text{best}}(\tau) - p_{ld}(\tau)]\\
&\qquad\qquad + c_l r_3[p_{ld}^{\text{lbest}}(\tau) - p_{ld}(\tau)] + c_n r_4[p_{ld}^{\text{nbest}}(\tau) - p_{ld}(\tau)],\\
&p_{ld}(\tau+1) = p_{ld}(\tau) + v_{ld}(\tau+1),
\end{aligned}
\tag{6}
$$

where T is the total iteration number, c_l and c_n are the global and near neighbor best position acceleration constant, respectively. $p_{ld}^{\text{lbest}}(\tau)$ and $p_{ld}^{\text{nbest}}(\tau)$ are the local and near neighbor best position of the lth particle at the dth dimension in the τth iteration, respectively. r_3 and r_4 are uniform random numbers in the interval [0, 1].
Step 2.7. Check the position value of each particle. If $p_{ld} > P^{\max}$, then $p_{ld} = P^{\max}$; else if $p_{ld} < P^{\min}$, then $p_{ld} = P^{\min}$, where $P^{\max}$ and $P^{\min}$ are the maximum and minimum position value respectively.
Step 3. Based on vehicle vector, group the ranking vector and number that in one group, the smallest one is numbered 1, the second smallest one is numbered 2 and so on. Replace the ranking vector by using these new numbers.
Step 4. If the stopping criterion is met, stop; otherwise, $\tau = \tau + 1$ and return to Step 2.

4 Conclusion

This paper studied the vehicle routing optimization problem with uncertain demands and traveling time. The problem is a N-P hard problem and an improved particle swarm optimization was proposed to solve it. This paper considered the demands and traveling time as fuzzy random variables, which could be more closer to the reality of applications. Hence, this model as well as the algorithm could be useful both for the shipper and the carriers.

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Study on Supplier Selection of Manufacturing in Lean Closed-Loop Supply Chain

Yueyu Li and Shujie Dong

Abstract In lean closed-loop supply chain, suppliers are required to make a rapid response for the changing market, at the same time, the capability of resource recycling is also important. So supplier selection is critical for manufacturing enterprises based on lean closed-loop supply chain. This paper builds a manufacturing supplier evaluation model in lean closed-loop supply chain. Weight is given to indicator by entropy-weighing method, and it makes the comprehensive evaluation and sorting for supplier using the gray relational analysis method, and a new decision program is presented. Finally an example was shown and validation was proved in selection of suppliers. According to the variation of individual indicators, calculate the criteria weighting coefficients by quoting from the information entropy to reflect the utility value of the data itself. It can avoid the formation of redistribution deviation which is affected easily by personal subjective factor.

Keywords Lean closed-loop supply chain · Supplier selection · Gray relational analysis method · Entropy method

1 Introduction

With the development of economic globalization, the competition among enterprises is increasing, and personalized demands are more and more popular. On one hand, enterprises take the low volume-high variety way to satisfy the demand of the changing market [11]. On the other hand, they control the suppliers cost not only for the supply chain management, but also maximizing profit. While the process of industrialization accelerates gradually, the demand of diversified and individualized consumer makes the life cycle of product get shorter, as a result, a lot of products are wasting. Based on these two aspects of background, this paper combines lean logistics and closed-loop supply chain, then, proposes a model-lean closed-loop sup-

Y. Li · S. Dong (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: dongshujie@stu.scu.edu.cn

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ply chain. Lean supply chain is to eliminate waste and reduce costs. The purpose of closed-loop supply chain (CLSC) is to close the flow of materials processing, reduce wasting and pollution, and turn them into reusing resources [11]. Lean closed-loop supply chain is to combine the core idea of lean logistics and closed-loop supply chain. It is required that not only be low cost and high efficiency, but also be green. So there will be a lot of factors can affect companies' ability to choose the right supplier [3].

Supplier selection is the process of finding the suitable suppliers who can provide the buyer with the right quality products and services at the right price, in the right quantities and at the right time [8]. A lot of researches have been carried out on the evaluation of manufacturing suppliers in the domestic and foreign. Existing researches in the field of supplier selection can be divided into two major categories: those focusing on the evaluation criteria of different supply chain and second those aiming to select the better supplier by different model and method. Abdollahi [1] presented a framework for supplier selection based on product-related and organization-related characteristics of the suppliers to be more competitive in the market and flexible to overcome probable changes in demands, supplies etc. Lin [7] proposed a multiple comparisons with the best method based on the yield index to compare the quality of suppliers. Pokharel and Mutha [9] focused on all aspects of reverse logistics from networking and inventory analysis, collection of used products, determining the pricing, use, resale, and remanufacturing. Amin [2] presented supplier selection is a multi-criteria decision making problem which consists of both qualitative and quantitative factors.

In the supplier selection arena, there are numerous researches that use different method to solve the problem. Rezaei [10] investigated supplier selection in the airline retail industry, and a fuzzy analytic hierarchy process (AHP) is used, in which suppliers are evaluated against the main criteria and sub-criteria. Juniora [5] presented a comparative analysis between fuzzy AHP and fuzzy TOPSIS methods in the context of supplier selection decision making. Tadic [6] proposed a novel hybrid fuzzy MCDM model for solving complex problems which combines DEMATEL, ANP and VIKOR. Golmohammadi and Mellat-Parast [4] took the two stage method with the combination of fuzzy matching and grey correlation degree analysis to select the supplier and analyses the example of automotive industry with the method.

Evaluating and selecting suppliers are essential tasks in managing supply chains. Although numerous criteria are being used for the selection of suitable supplier in lean logic and CLSC, selection of the critical factors in conformance to the specification of the lean closed-loop supply chain is less investigated. This paper is an attempt to provide a model to help manufacturer choose the best supplier in lean closed-loop supply chain.

The rest of this paper is organized as follows. Section 2 describes the system of supplier evaluation criteria and the figure of the relationship of the criteria is given. The supplier evaluation model with gray relational analysis method and entropy method are presented in Sect. 3. After that our case study will be proposed in Sect. 4 and the result of the evaluation will be discussed as well. Some concluding remarks are provided in Sect. 5.

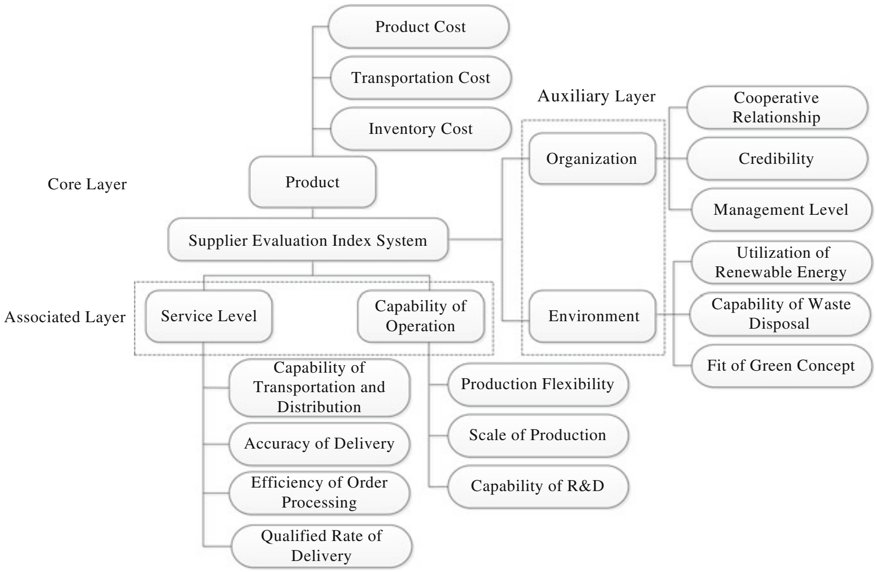

Fig. 1 The system of supplier evaluation criteria

2 The System of Supplier Evaluation Criteria

On one hand, in lean closed-loop supply chain, the evaluation criteria of supplier should meet the requirement of the lean supply chain to cut down the cost and enhance the benefit: On the other hand, it needs waste recycling links to make the process not do harm to the environment. Manufacturing companies can accurately choose the best supplier through supplier evaluation system which should follow the design principles of applicability, rationality, mutual independence, comparability and meet the characteristics of lean closed-loop supply chain.

Based on the existing research of criteria system in the literature and combined with requirements of lean closed-loop supply chain to suppliers, the paper builds a three-level criteria system which evaluates the indicators of suppliers from the viewpoint of organizational factors, product factors, service factors, environmental factors. The system is shown in Fig. 1.

3 The Supplier Evaluation Model

This paper builds the suppliers evaluation model by using gray relational analysis method and entropy method. The biggest advantage of entropy method is that it is based on the size of criteria information to determine the weights, which can avoid the influence of subjective factors and draw the objective weight value. The main calculation method and steps are as follows.

Step 1. Normalize the criteria coefficient
Assuming that the criteria of each supplier composing the matrix is $D = (a_{ij})_{m\times n}$. Product cost, transport cost and inventory cost are cost type criteria, the formula is:

$$x_{ij} = \frac{\max a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}} \quad (i = 1, 2 \ldots, m, j = 1, 2, \ldots n).$$

The others are effective type, the formula is

$$x_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}} \quad (i = 1, 2, \ldots, m, j = 1, 2, \ldots, n).$$

Step 2. Calculate the gray correlation coefficient of criteria
Assuming that the optimal solution of criteria value is $x_j^* = \max(x_{ij})$ $(j = 1, 2, \ldots, n)$, find the optimal solution which composes the reference sequence $x_{0j} = \{x_j^* | j = 1, 2, \ldots, n\}$. Take the criteria value of the ith supplier as a comparison sequence $x_{ij} = \{x_j^* | i = 1, 2, \ldots, m\}$. The correlation coefficient of x_0 and x_i under jth criteria is $\delta_i(j)$.

$$\delta_i(j) = \frac{\min\limits_i \min\limits_j |x_0(j) - x_i(j)| + \rho \max\limits_i \max\limits_j |x_0(j) - x_i(j)|}{|x_0(j) - x_i(j)| + \rho \max\limits_i \max\limits_j |x_0(j) - x_i(j)|}$$
$$(i = 1, 2, \ldots, m, j = 1, 2, \ldots, n). \tag{1}$$

In these formulas, $\min_i \min_j |x_0(j) - x_i(j)|$ and $\max_i \max_j |x_0(j) - x_i(j)|$ represents the maximum and minimum of absolute difference of comparison sequence as respectively. $|x_0(j) - x_i(j)|$ presents the absolute difference of comparison sequence. ρ is Resolution Coefficient and ρ takes 0.5 normally.
Step 3. Determine criteria weight using entropy method

(1) Assuming that P_{ij} is the contribution value of the jth criteria under the ith supplier among the criteria of each supplier composing the matrix D.

$$P_{ij} = \frac{a_{ij}}{\sum\limits_{i=1}^{m} a_{ij}} (i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n). \tag{2}$$

(2) E_j represents the total value of all suppliers contribution to the jth criteria.

$$E_j = -\frac{1}{\ln m} \Big/ \sum_{j=1}^{m} P_{ij} \ln P_{ij} \quad (j = 1, 2, \ldots, m). \tag{3}$$

(3) Define the difference coefficient of criteria $g_j = 1 - E_j, (j = 1, 2, \ldots, m)$, $(0 < g_j < 1)$, is a positive criteria. The bigger g_j is, the more information that criteria j provides to the suppliers comprehensive evaluation, and then the bigger weight of criteria j is.
(4) Normalize the difference coefficient of criteria g_j, then, calculate using the following formula to get the weight of the criteria.

$$w_j = g_j \Big/ \sum_{j=1}^{n} g_j. \tag{4}$$

Step 4. Calculate the comprehensive values
Calculate the comprehensive values using the following formula.

$$D_i = \sum_{j=1}^{n} w_j \delta_i(j) \ \ (i = 1, 2, \ldots, m, i = 1, 2, \ldots, n). \tag{5}$$

The positive value of D_i shows the proximity between ith supplier and the best supplier. Therefore, the suppliers are ranked by the value of D_i to choose the best supplier.

4 Application Analysis

The case is based on seven material suppliers of a manufacturing enterprise. In order to keep a longtime relationship, these suppliers will be evaluated and sorted by using the method of this paper. The criteria data of each supplier is shown in Table 1.

(1) Normalize the criteria and the result is shown in Table 2.
(2) Calculate the gray correlation coefficient of the criteria,

$$\min_i \min_j |x_0(j) - x_i(j)| = 0, \min_i \max_j |x_0(j) - x_i(j)| = 1.$$

The results are shown in Table 3.
(3) Determine the weight using entropy method W_j = (0.0284, 0.0632, 0.0683, 0.0916, 0.0280, 0.0199, 0.0133, 0.0818, 0.0599, 0.0891, 0.0112, 0.0420, 0.0211, 0.1228, 0.0667, 0.1927).
(4) Calculate the comprehensive evaluation value D_i = (0.4943, 0.4161, 0.5333, 0.3671, 0.4630, 0.4683, 0.3656).

The order of supplier quality can be get according to the results of the comprehensive evaluation value and the result is $M3 > M1 > M6 > M5 > M2 > M4 > M7$. In the result, we can see that supplier 3 is the best supplier with the highest scoring; Although supplier 7 get the worst ranking, it does best in efficiency of order

Table 1 The criteria data of a manufacturing supplier

Criteria	M1	M2	M3	M4	M5	M6	M7
Product cost	81	85	76	83	84	79	86
Transportation cost	40	48	45	42	46	43	47
Inventory cost	32	30	34	33	31	29	35
Capability of transportation and distribution	90	84	96	78	87	77	88
Accuracy of delivery	90	87	94	84	92	95	89
Efficiency of order processing	89	94	87	90	90	91	97
Qualified rate of delivery	90	85	87	91	89	92	86
Production flexibility	89	84	78	82	96	94	88
Scale of production	82	85	74	72	75	73	78
Capability of R&D	76	72	83	68	84	80	74
Cooperative relationship	80	78	76	77	81	79	82
Credibility	93	87	90	80	82	84	88
Management level	92	96	94	86	90	88	91
Utilization of renewable energy	56	48	62	52	53	50	49
Capability of waste disposal	78	80	72	83	71	79	70
Fit of green concept	69	73	60	82	61	66	63

Note: the unit of cost criteria is million, the unit of others is percentage

Table 2 The result of the criteria normalized

Criteria	M1	M2	M3	M4	M5	M6	M7
Product cost	0.5	0.1	1	0.3	0.2	0.7	0
Transport cost	1	0	0.375	0.75	0.25	0.625	0.125
Inventory cost	0.5	0.833	0.167	0.333	0.667	1	0
Capability of transportation and distribution	0.684	0.368	1	0.053	0.526	0	0.579
Accuracy of delivery	0.545	0.273	0.909	0	0.727	1	0.455
Efficiency of order processing	0.2	0.7	0	0.3	0.3	0.4	1
Qualified rate of delivery	0.714	0	0.286	0.857	0.571	1	0.143
Production flexibility	0.611	0.333	0	0.222	1	0.889	0.556
Scale of production	0.769	1	0.154	0	0.231	0.077	0.462
Capability of R&D	0.5	0.25	0.938	0	1	0.75	0.375
Cooperative relationship	0.667	0.333	0	0.167	0.833	0.5	1
Credibility	1	0.538	0.769	0	0.154	0.308	0.615
Management level	0.6	1	0.8	0	0.4	0.2	0.5
Utilization of renewable energy	0.571	0	1	0.286	0.357	0.143	0.071
Capability of waste disposal	0.615	0.769	0.154	1	0.077	0.692	0
Fit of green concept	0.409	0.591	0	1	0.045	0.273	0.136

Table 3 The gray correlation coefficient of criteria

Criteria	M1	M2	M3	M4	M5	M6	M7
Product cost	0.5	0.357	1	0.417	0.385	0.625	0.333
Transport cost	1	0.333	0.444	0.667	0.4	0.571	0.364
Inventory cost	0.5	0.75	0.375	0.429	0.6	1	0.333
Capability of transportation and distribution	0.613	0.442	1	0.345	0.514	0.333	0.543
Accuracy of delivery	0.524	0.407	0.846	0.333	0.647	1	0.478
Efficiency of order processing	0.385	0.625	0.333	0.417	0.417	0.455	1
Qualified rate of delivery	0.636	0.333	0.412	0.778	0.538	1	0.368
Production flexibility	0.563	0.429	0.333	0.391	1	0.818	0.529
Scale of production	0.684	1	0.371	0.333	0.394	0.351	0.481
Capability of R&D	0.5	0.4	0.889	0.333	1	0.667	0.444
Cooperative relationship	0.6	0.429	0.333	0.375	0.75	0.5	1
Credibility	1	0.52	0.684	0.333	0.371	0.419	0.565
Management level	0.556	1	0.714	0.333	0.455	0.385	0.5
Utilization of renewable energy	0.538	0.333	1	0.412	0.438	0.368	0.35
Capability of waste disposal	0.565	0.684	0.371	1	0.351	0.619	0.333
Fit of green concept	0.458	0.55	0.333	1	0.344	0.407	0.367

processing and cooperation relations; supplier 4 has an advantage in Fit of Green Concept which is the best weight among the seven suppliers. When the companies make the final decisions, they can refer to the comprehensive evaluation results of sequencing, and combined with their own actual situation to choose suitable suppliers.

5 Conclusion

This paper mainly concerns on the combination of lean logistics and closed-loop supply chain to put forward the thoughts of lean closed-loop supply chain. Then, this article discusses the question of evaluation and selection of manufacturing enterprise supplier in lean closed-loop supply chain. Based on the literature review, this paper makes a deep analysis of the characteristics of lean logistics and closed-loop supply chain to construct a supplier evaluation criteria system. As to overall evaluating method, the paper constructs the selection and evaluation model of manufacturing enterprise supplier with the combination of gray relational analysis method and entropy weight method. As the model uses entropy method to determine the weights according to the number of the information contained in the original data, it is relatively objective and effectively avoids the influence of subjective factors when scoring. So it provides a simple and effective method for the manufacturing enterprise on the question of evaluating and selecting. Finally, the example analyses illustrate the model being with the maneuverability and applicability.

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A Study on Running Mechanism of Regional Innovation System Based on Knowledge Flow

Yijun Ye, Xin Gu, Hui Li and Yijun Chen

Abstract Regional innovation system (hereinafter referred to as the "RIS") is a system of regional organizations that are geographic division and associated with each other. It supports and accelerates collaborative innovation activities between the subjective elements (innovative institutes and organizations), and promotes distribution, transfer and recombination of non-subjective elements (innovative material conditions required) between the various subjects, up to the efficient allocation and recombination of resources, and to enhance creativities and vitalities throughout the region. In the course of collaborative innovation, resources allocation and recombination, the knowledge continues to achieve "knowledge spiral". The essence of RIS is displayed—process of knowledge flow and conversion. Three of the most dynamic innovative activities can reflect the running mechanism of RIS. These are collaborative innovation of Industry-University-Research institute, organization with supply chain relationships, and organization with industrial clusters or spatial agglomeration. This paper respectively establishes a structured process model of knowledge flow based on three innovative activities to analyze the process and the features of knowledge flow, which are the path, the scale and frequency, the depth and breadth, to reveal the running mechanism of regional innovation system.

Keywords RIS · Knowledge flow · Collaborative innovation · Running mechanism of RIS

Y. Ye (✉) · X. Gu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: yeyi93@sina.com

Y. Ye · Y. Chen
School of Economy & Management, Sichuan University of Science & Engineering, Zigong 643000, Sichuan, People's Republic of China

H. Li
School of Computer Science, Sichuan University of Science & Engineering, Zigong 643000, Sichuan, People's Republic of China

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1 Introduction

Geographical diversification and rapid technological progress are creating new challenges for innovation capacities of a region that seeks for international competitive advantages. To meet these challenges, the region is required to expand its knowledge resources, to improve knowledge flow and share between innovative subjects. However, cross-border collaborative innovation between the subjects is risky and difficult, and less than half of such alliances achieve their goals [3]. Thus, it has become a key issue that how to promote, maintain and enhance regional innovation abilities.

In this paper, we want to advance our understanding of the processes in which knowledge flow is more likely to take place in the collaborative innovation actions, and their impact on the performance of the collaborative innovation subjects. More specifically, we focus on the impact of heterogeneous knowledge as a critical antecedent of knowledge flows and a removal object of their performance implications.

Our study makes two key contributions to the literature on regional innovation system (hereinafter referred to as the "RIS"). First, from the perspective of knowledge flows, we study that the internalization and externalization of knowledge flows drive the recombination and distribution of innovative elements between innovative subjects, and the improvement of collaborative innovation abilities. Second, we study the process of the knowledge flow of the subjects with different relationships. Specifically, we respectively develop a structured process model of knowledge flow based on three innovative activities to analyze the process and the features of knowledge flow, which are the path, the scale and frequency, the depth and breadth.

In sum, our study explores heterogeneous knowledge as an important collaborative antecedent for understanding when and why knowledge is more likely to be transferred between the innovative subjects, and their relative effects on the recombination and distribution for innovative elements. These ideas about the different role and relevance of knowledge flows are likely to be of interest not only for researchers in regional economy, but also for governments and managers in collaborative innovation.

Our paper is structured as follows. In the next section, we present a brief literature review of research on RIS. Later, from three stages (knowledge share, creation, and advantage), we elaborate the process of knowledge flow between Industry-University-Research institute. In the following two sections, we describe the knowledge flow of supply chain organization with different dominant relationships, and of industrial cluster or spatial agglomeration.

2 Review of Theoretical Studies on RIS

From the national level to talk about innovation system, the researches of RIS are known as the national innovation system, first proposed by Trevor [16] in1988 and first introduced to China by Chen [4] in 1994. The researches on the national innovation system naturally have extended to internal administrative regions in a State. In 1992, Professor Cooke [5] first proposed the "cross-borders" concept of RIS, which also made cross-border RIS another hot spot.

Nelson [10] argued that RIS, in order to lead to innovation, is a system consists of the regional regulations, rules and practice. The geographic boundaries of the system are not necessarily limited within a country, may also be formed by the transnational regions of geographical proximity. In this system, there is an organization system made up of organizations of the geographical division and the culture associated with each other, which supports and promotes innovation. The system covers subjective elements (creative agencies and organizations) and non-subjective elements (material conditions needed for innovation). Specifically, the so-called subjective elements is as following: enterprises, intermediary agencies and the governments and "knowledge organizations" [7], such as universities and research institutes. According to views of Autio [2], the subjective elements consist of two subsystems. Those are "knowledge application and development subsystem" and "knowledge production and diffusion subsystem". The center of the former are enterprises, around are customers, suppliers, collaborators and competitors. The enterprises, the customers and the suppliers constitute a longitudinal network. The enterprise, the collaborators and the competitors constitute a horizontal network. The latter consists of institutes of public research and education, and intermediary institutes of technology or labor or others. Both of them exists flow and interaction of knowledge, resources and human capital. Non-subjective elements contain four systems of the regional politics, regional education and research, industry, and regional innovation environments (including regional institutional environment, regional infrastructure and demand). The interrelation and interaction of the four parts [9] promote upgrading of the industrial structure and gaining the regional competitive advantages.

Gu [8] thought three aspects could describe the running process of RIS. These are knowledge flow, industrial cluster and spatial agglomeration. The combination of learning each other, knowledge production, spatial proximity, and social embeddedness [6] is along with technology transfer and acquisition in the region [13]. Regardless of market or non-market deals, its essence is a process of knowledge flow or knowledge diffusion or knowledge spillover. Based on the case studies of three regions of Norway, Asheim and Isaksen [1] thought knowledge flow and interactive learning have a major role to enhance innovative abilities of enterprises [14]. Peng [12] argued that internal knowledge transfer in RIS would have an important impact on the quality and efficiency of the system.

Nearly 30 years, many scholars have had in-depth studies on RIS from different perspectives. The studies of RIS in China have tended to add "Cross-administration" and stressed the leading position of governments at all levels, especially in the construction of RIS [19]. In the research literatures, there are two aspects. One is mechanism researches on RIS, which are the definition, structure of constitute, running laws and mechanism. Another is empirical researches of it. These are the capacities and effects, policies and environment, and how to build RIS. Either the direction or angle, the scholars are trying to figure out the contents and meanings of the "architecture" and "elements" in the RIS, as well as their relationships with creativity and innovation.

A growing number of scholars agree that effective operation of RIS is based on knowledge flowing [15, 17, 18], the process of which is the "knowledge spiral" of the SECI model [11]. Knowledge flow is carried by the mobility, the distribution, and the combination of regional innovation elements. At the same time, the knowledge flow conversely promotes the mobility, the distribution, and the combinations of them in the region to achieve innovative collaboration between regional innovation subjects.

The running of RIS embodies in the most dynamic innovation activities. These are collaborative innovation of Industry-University-Research institute, organization with supply chain relationships, and with industrial cluster or spatial agglomeration [20]. Different relationships between innovative subjects display different knowledge flow. And the different knowledge flow (knowledge flow of scale and frequency, depth and breadth) not only reflects a close degree, also reveals forms of flow and combination each other, and shows different running features of the RIS.

3 Knowledge Flow Between Industry, University, and Research Institute

The knowledge flow of Industry-University-Research institute is evidenced by cooperation between enterprises, universities and research institutes. Each of them shares and absorbs existing knowledge through learning each other. One hand, innovative subjects can create more knowledge. On the other hand, the knowledge internalizes and externalizes into sharing knowledge stock to gain a knowledge advantage (see Fig. 1).

(1) Knowledge Share Stage

At the beginning of collaborative innovation of Industry-University-Research institute, the knowledge exchange, resource sharing and matching between the innovative subjects have its obstacles. And then knowledge flow contributes to diffusing and combining heterogeneous knowledge of subjects effectively. Universities or research institutes transfer professional and technical knowledge to enterprises. At the same time, market and technology knowledge are transferred to the Universities or research institutes by the enterprises. Continuous knowledge transferring and collaborative learning between the subjects help to adjust the distribution of resources, to remove the obstacle factors of knowledge flow. So that, knowledge flows from disorder to order, explicit and tacit knowledge are shared to the fullest extent.

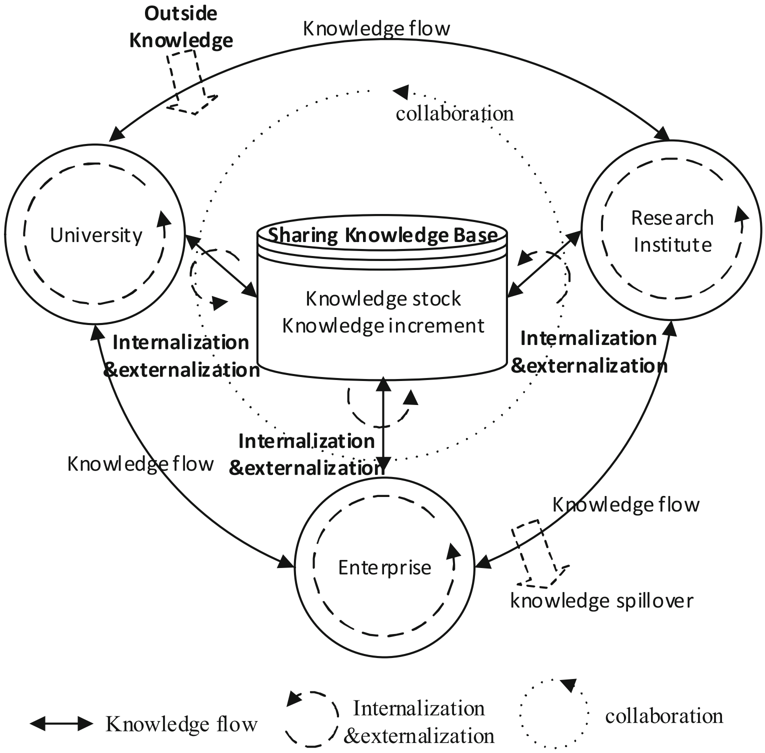

Fig. 1 Process of knowledge flow between the institutes of Industry-University-Research

With the increase of knowledge sharing, knowledge flow and stock continue to expand. And the repetitive knowledge or outdated knowledge also accumulate, which, to some extent, restrict the efficiency of knowledge flow. The subjects integrate various knowledge flow and stock to a sharing knowledge base that remove invalid and redundancy of knowledge, to facilitate the flowing and sharing of knowledge on a computer platform or other. External organizations share the part of the knowledge by transfer or spillover.

(2) Knowledge Creation Stage

Internalization and externalization of knowledge is the core of knowledge creation. Driven by innovative values, firstly, the subjects internalize and externalize the new explicit and tacit knowledge shared, to achieve internal “knowledge spiral” and form a new incremental knowledge. Secondly, when heterogeneous knowledge frequently transfer between the subjects in the process of cross-organizational collaboration innovation, a cross-organizational “knowledge spiral” also is achieved.

(3) Knowledge Advantage Stage

The knowledge advantage is also shaped by the process of knowledge creation. In the knowledge creation stage, heterogeneous knowledge constantly promotes the creation of new knowledge through knowledge aggregation, recombination and activation. The new knowledge undoubtedly increases the stock of knowledge, and optimizes the structure of existing knowledge, and forms knowledge advantage through knowledge spillover and spread.

4 Knowledge Flow Between Supply-Chain Organizations

The knowledge flow between supply-chain organizations refers to knowledge diffusion and transfer in the process of innovative activities between supply-chain enterprises. Different properties lead to different innovative relationships, and form the different patterns of knowledge flow.

4.1 Knowledge Flow of the Mode of Supplier-Manufacturer-Distributor

The model of supplier-manufacturer-distributor is the most basic form of supply-chain relationships. According to the supply-chain thought, the supplier, the manufacturer, the distributor is an integral part of the whole industrial chain to meet consumer demand by collaborative innovation. Knowledge flow displays a chain mode: customer-distributor-manufacturer-supplier. In this chain structure, different subjects have different knowledge properties. Customer has itself of potential or dominant demand, also grasps many of product cost, and technological performance, quality and brand knowledge. Through customer of inquiry or purchased, or survey questionnaire, distributor masters many of market demands and product competition information. Manufacturer possesses production technology and capacity, process technology, cost and quality, and production operation management and so on. Supplier holds raw materials of cost, quality, production technology, and process technology and so on. From a marketing point of view, firstly, knowledge flow of supplier-manufacturer-distributor mode transfers between customer and seller. Secondly, distributor and manufacturer, manufacturer and supplier are followed. See Fig. 2. In the three transfer process, the subjects internalize and externalize the information or knowledge gained by exchange, transfer them to the next link of the chain. And then, the innovative resources of the whole chain have been reallocated and adjusted to meet consumer demands.

With the different role of heterogeneous knowledge in collaborative innovation, the innovative subject with most scarce knowledge dominates knowledge flowing, and determines the type, size, frequency of knowledge flow across the whole supply chain. Either of them would seek to acquire stock knowledge of other innovators, to stimulate stock knowledge transfer and creation, and to strengthen the relationships

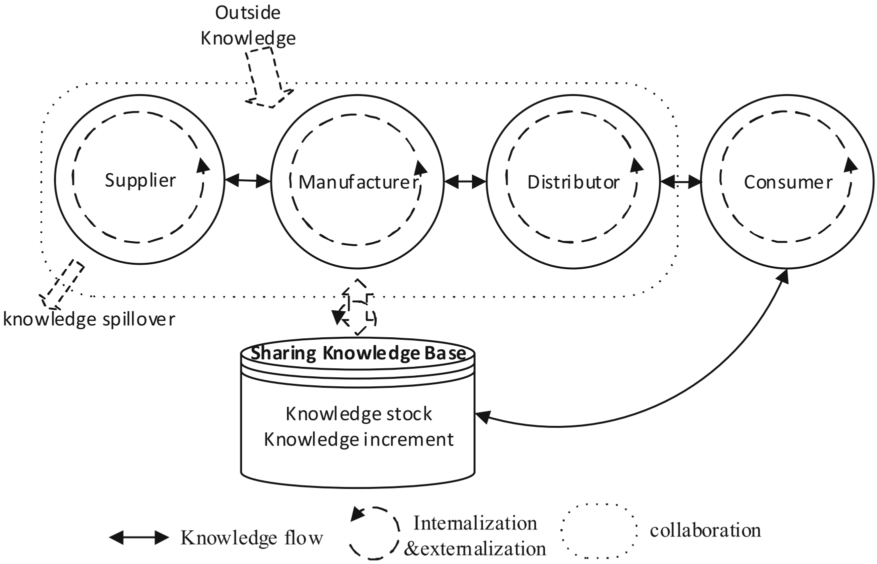

Fig. 2 The process of knowledge flow of Supplier-Manufacture-Distributor model

between collaborative innovations. It also builds a sharing knowledge base to promote knowledge sharing and creating again.

4.2 Knowledge Flow Under the Guidance of Designer and Marketing Enterprises

The supply-chain relationship under the guidance of designer and marketing enterprises is currently a common form in consumer market. See Fig. 3. Designer and marketing enterprise can accurately analyze customer demands, has a strong design team and brand, and can effectively affect market demands as well as the entire production and supply system. The enterprise can rapidly turn customer demands into a product entity, involving the cost of materials, techniques, processes and so on. It transfers them to manufacturers and suppliers to improve the skills and abilities of production, and to complete manufacturing process. It also can lead and control the distributor by virtue of his advantages. In this model, knowledge flow of the traditional supplier-manufacturer-distributor chain is relatively small between the subjects; heterogeneous knowledge is more apparent, and more complementary. Stock and increase of the knowledge come largely from directional flow of the designer and marketing enterprise, little from reverse flow. That leads to a strong attachment. In order to improve the efficiency of the directional flow of knowledge,

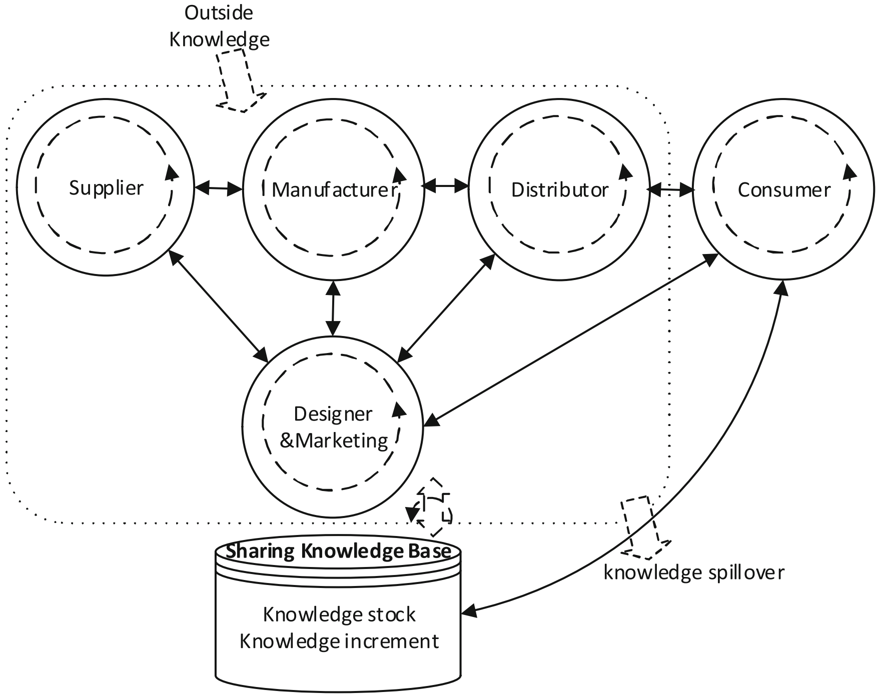

Fig. 3 Process of knowledge flow under the guidance of designer and marketing enterprise

it builds a comprehensive knowledge-sharing platform to consolidate its knowledge advantage.

5 Knowledge Flow of Industrial Cluster or Spatial Agglomeration

Industrial cluster are collection of a type of companies and institutes interconnected, geographically concentrated in a specific area. The formation of industry cluster begins with innovative centers, polarization and diffusion of which improve innovative activities in lower area.

Innovation centers tend to be the organizations with collaborative innovation abilities or intent. These are supply-chain organization, or Industry-University-Research institute. See Fig. 4. Due to polarization and diffusion effect, some potential innovative centers attract more subjects to participate in collaborative innovation, such as governments, universities, research institutes, intermediaries and so on. That leads to the more resources (technologies, capitals, and labors and so on) gathering. Extension of the core center helps to greater levels of aggregation.

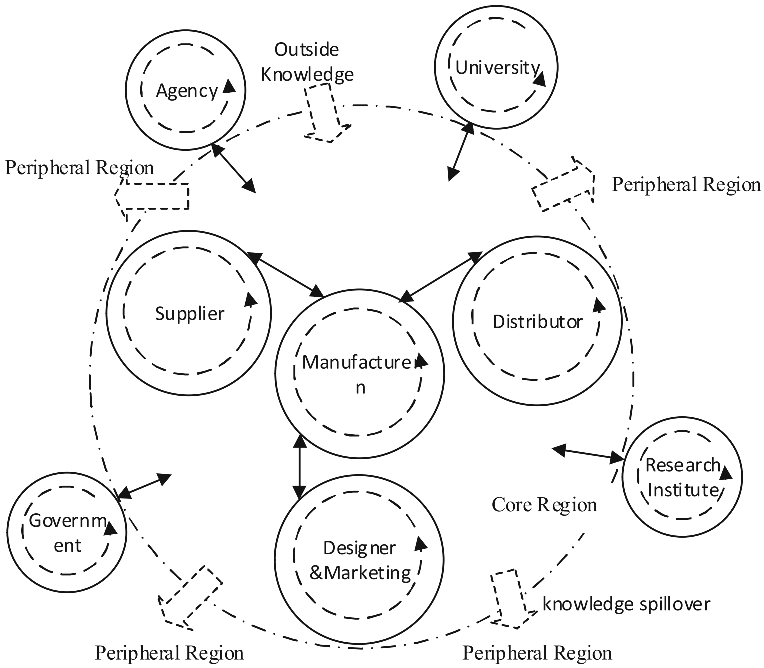

Fig. 4 Process of knowledge flow of industrial clusters or spatial agglomeration

6 Conclusion

RIS promotes regional synergy and innovative abilities. Regional collaborative innovation stems from the existence of complementary heterogeneous knowledge, which results in the supply and the demand of knowledge and improves the flow of knowledge between the subjects. This paper analyzes the knowledge evolution rules between Industry-University-Research institutes, supply-chain organizations of two modes, industrial cluster or spatial agglomeration, and explains the mechanism of the innovative elements agglomeration, combination, and assignment in the process of knowledge flow. So, we think that knowledge flow not only promotes to restructure the innovative elements and to allocate them efficiently within an organization, but also helps to accumulate and distribute the innovative elements, greatly improve the collaborative innovation abilities between organizations, and perfect the entire organizational structure.

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Regional Economic Difference Analysis and Path Selection from the Perspective of Spatial Structure

Qian Fang and Yi Sheng

Abstract By using of variation coefficient, Theil coefficient and clustering analysis method, this paper makes deep analysis on the regional economic differences in Sichuan from the perspective of spatial structure. The results show that: the 21 cities and districts show obvious difference in the aspects of economic aggregate, industrial structure, technology and employment, etc.; the regional economic differences are mainly caused by the differences between the five economic zones. The 21 cities and districts are divided into 8 classes of areas, distributed on the "two axes" and "two circles". The main axis includes the 1–5 classes of areas, which is the significant support of Sichuan's economy with big economic volume. The 6th class of areas includes 5 cities and districts, distributed on the subordinate axis which crosses over the main axis in X-shape. Many new growth poles are distributed in this class of areas. The 7th and 8th Classes of areas are distributed in two circles. Based on the above analysis and learning experiences from developed countries like the United States, France, Japan and Germany on the spatial strategy to narrow the regional difference, this paper puts forward path selection for implementation of multipoint and multipolar strategies.

Keywords Perspective of spatial structure · Multipoint and multipolar support · Selection

1 Introduction

Regional economic difference is a common problem existing in regional development [3], and also is the inner motive power of development. It reflects the change of economic interests distribution pattern among various regions and the requirement for competition and balance of economic interests [3]. Cultivation of new growth

Q. Fang (✉) · Y. Sheng
Institute of Economics, Sichuan Academy of Social Sciences, Chengdu 610072, People's Republic of China
e-mail: lily_lily009@163.com

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poles centered on narrowing the regional economy difference is an important means to promote the spatial economy move towards equilibrium, and further to enhance the overall regional strength. In 2013, in the face of weakening of global economy, downturn of domestic economic and the increasing pressure of industrial structure adjustment, Sichuan's development strategy of multipoint and multipolar support was aimed to realize optimization of regional spatial structure and form a new pattern of vigorous development of the whole province, through "improving the primate city, focusing on breakthrough of secondary cities, and consolidating the base economy".

2 Quantitative Analysis of the Regional Economic Difference in Sichuan

The following analysis of Sichuan's region economic difference is carried out from three aspects-discrete degree, difference decomposition and territorial classification, providing theoretical support for the selection of the province's growth poles and support points.

1. Degree of Regional Economy Difference

Considering the base differences on various indicators, in order to eliminate the base interference, this paper uses coefficient of variation to measure the difference degree of the key economic indicators of the 21 cities (21 cities including Chengdu, Mianyang, Neijiang, in Nanchong city, Leshan, Zigong and Luzhou, Deyang, Guangyuan, Suining, Meishan, Guang An Men Wai, Florida, Ya'an, China, Ziyang, Panzhihua, Liangshan Prefecture, Ganzi, ABA). The bigger the coefficient of variation is, the greater the regional difference is. The smaller the coefficient of variation is, the less the regional difference is. The calculation formula of variation coefficient is as follows:

$$C_v = \frac{\sigma}{\overline{X}} = \sqrt{\sum_{i=1}^{n}(x_i - \overline{x})/n} \Bigg/ \left(\sum_{i=1}^{n} x_i/n\right).$$

Therein, C_v represents the coefficient of variation; σ represents the sample standard deviation; x_i represents the ith sample; $\overline{X}$ represents the sample average.

The variation coefficients of key economic indicators in 21 cities of Sichuan are shown in Table 1. In the 12 key indicators, the top three variation coefficient include R&D personnel convert into full-time personnel (2.11), the third industry (2.03) and regional GDP (1.34). Scientific research ability, the third industry and economic scale are the main performance of regional differences. The variation coefficient of "regional GDP" and "per capita GDP" is respectively 1.34 and 0.42. The discrete degree of economic aggregate indicator is three times that of per capita indicator, so it is visible that regional differences are more embodied on the economic scale. From the angle of the three industries, the variation coefficients of the added value of the first, second and third industries in the 21 cities and districts are respectively

Table 1 Variation coefficients of key indicators in Sichuan

Indicators	Regional GDP	Per capita GDP	Winter resident population	Population density	Urbanization rate	The first industry
Variation coefficient	1.34	0.42	0.7	0.72	0.24	0.53
Indicators	The second industry	The third industry	Per capita income of rural residents	Per capita disposable income of urban residents	Number of employed person	R&D personnel convert into full-time personnel
Variation coefficient	1.15	2.03	0.19	0.11	1.23	2.11

Note Calculated according to the 2012 statistical data of Sichuan

0.53, 1.15 and 2.03. In Sichuan which is at the mid-term stage of industrialization, the agriculture is no longer the leading role of economic growth. On the contrary, the second and the third industries have become the important source of regional differences. In addition, the variation coefficients of “the number of employed person”, “R&D personnel convert into full-time personnel” indicators are relatively larger, which means the human resources and scientific and technological innovation are the important variables for regional differences.

2. Regional Economic Difference Decomposition

In order to grasp the regional economic difference of Sichuan, Theil Index Decomposition method is also used in this paper, decomposing the economic difference between the five zones into economic zone intra-difference (intra-group difference) and economic zone inter-difference (inter-group difference).

Theil Index Decomposition formula is as follows:

$$G = G_w + G_b,$$
$$G_0 = (1/N_g) \times \sum \ln(\overline{y}/y_i),$$
$$G = \sum_g u_g G_{0g} + \sum_g M_g \ln(u_g/Y_g).$$

Therein, G, G_w, G_b represent overall regional difference, intra-group difference and inter-group difference respectively. The total sample is divided into G group(s) ($g = 1, 2, \cdots, 5$); N_g represents the sample number of the g group; u_g represents the proportion of the population of the g group to the total population; y_i represents the per capita income of the i sample; M_g represents the proportion of the income of the g group to the total revenue; Y_g represents the proportion of the income of the g group to the total revenue. $\overline{y}$ is the mean value of y_i. Through calculation, the G_{0g} of the five economic zones is 0.046, 0.006, 0.089, 0.021, 0.016 respectively, and further get the intra-group difference and the inter-group difference:

Intra-group difference: $G_w = \sum u_g G_{0g} = 0.0329$,
Inter-group difference: $G_b = \sum M_g \ln(u_g/Y_g) = -0.0542$,
Theil index: $G = |G_w + G_b| = |-0.0542 + 0.0329| = 0.0213$.

The inter-group contribution to regional economic difference of Sichuan is $-5.42\,\%$, and the intra-group contribution is $3.29\,\%$, the inter-group contribution portion is more than the intra-group contribution. This shows that the regional economic difference is mainly caused by the differences between the five economic zones. By comparing the Theil index of 2012 and 2003 [5], the Theil index of 2012 is smaller than that of 2003 (0.09); the intra-group and inter-group coefficient of 2012 are also smaller than that of 2003 [5]. This shows that Sichuan's regional economy difference is narrowed in the recent decade, and the main root for the narrowed difference is the narrowing of inter-group difference.

3. Cities and Districts Difference of Economic Development

Cluster analysis is also used in this paper for classifying the 21 cities and districts. Set 9 classification variables, namely, the regional GDP, winter resident population, urbanization rate, the added value of the first industry, the added value of the second industry, the added value of the third industry, industrial added value, population density and "R&D personnel convert into full-time personnel". The distance between the samples is calculated using Euclidean Distance. Calculation formula is as follows:

$$\mathrm{SEUCLID} = \sum_{i=1}^{k} (x_i - y_i)^2.$$

Therein, $k = 1, 2, 3, \cdots, 9$, representing nine variables for every sample; x_i represents the value of sample x at the variable i. y_i represents the value of sample y at the variable i. Cluster analysis is made for the 21 cities and districts by using of SPSS.17, as shown in the tree diagram in Fig. 1.

Fig. 1 Tree diagram of cluster analysis of 21 cities and districts

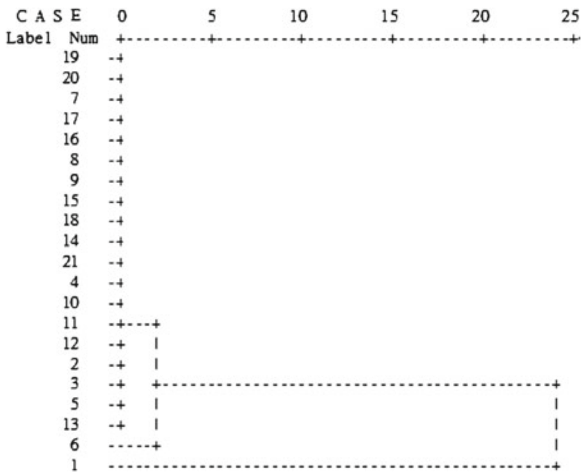

Table 2 Variation coefficients of key indicators in Sichuan

Spatial location	Classification and area	Characteristics
Main axis	Class 1 (Chengdu)	Big economic size; Large population (14 million), high population density (1181); high urbanization rate (68 %);The third industry development is better than that of the second industry
	Class 2 (Panzhihua)	General economic size; small population (1.2 million), low population density (176); high urbanization rate (63 %); The added value of the second industry accounts for 76 %, and the third industry accounts for 21 %. Industries account for 95 % of the second industry, a typical industrial city
	Class 3 (Mianyang)	Relatively big economic size; relatively large population (4.64 million), low population density (232); general urbanization rate (43 %); The added value of the first industry accounts for 16 %, the second industry accounts for 52 %, and the third industry accounts for 31 %
	Class 4 (Deyang)	Relatively big economic size; relatively large population (3.5 million), relatively high population density (589); general urbanization rate (45 %); The added value of the first industry accounts for 15 %, the second industry accounts for 60 %, and the third industry accounts for 25 %. Industries account for 93 % of the second industry, a typical industrial city
	Class 5 (Yibin)	Relatively big economic size; relatively large population (4.4 million), general population density (343); medium urbanization rate (41 %); The added value of the first industry accounts for 15 %, the second industry accounts for 62 %, and the third industry accounts for 23 %
Subordinate axis	Class 6 (Neijiang, Guangan, Dazhou, Ziyang, Liangshan)	General economic size; relatively large population (4 million), relatively high population density (430); low urbanization rate (35 %); The added value of the first industry accounts for about 20 %, the second industry accounts for more than 55 %, and the third industry accounts for about 25 %
Small circle	Class 7 (Zigong, Luzhou, Leshan, Nanchong, Meishan)	General economic size; relatively large population (3.9 million), relatively high population density (446); general urbanization rate (41 %); The added value of the first industry accounts for about 15 %, the second industry accounts for about 60 %, and the third industry accounts for about 25 %

(continued)

Table 2 (continued)

Spatial location	Classification and area	Characteristics
Large circle	Class 8 (Guangyuan, Suining, Yaan, Bazhong, Aba, Ganzi)	Small economic size; small population (2 million), low population density (210); low urbanization rate (35 %); The added value of the first industry accounts for about 20 %, the second industry accounts for below 50 %, and the third industry accounts for about 30 %

21 cities and districts are divided into 8 classes, and their characteristics are shown in Table 2.

Spatial distribution of different classes of regions is as shown in Fig. 2. The 1–5 classes of areas are on the line of main axis, which is the important economic corridor of Sichuan. Except from Panzhihua, the other four cities' economic size all rank the top four in Sichuan. The five cities and districts on the axis all have their own characteristics. Chengdu is the provincial capital, the primate city, and the core growth pole. Deyang is China's major equipment manufacturing base, and an important industrial city of Sichuan. Yibin is developed in wine industry and comprehensive energy industry; Mianyang has strong strength in electronic information, new materials,

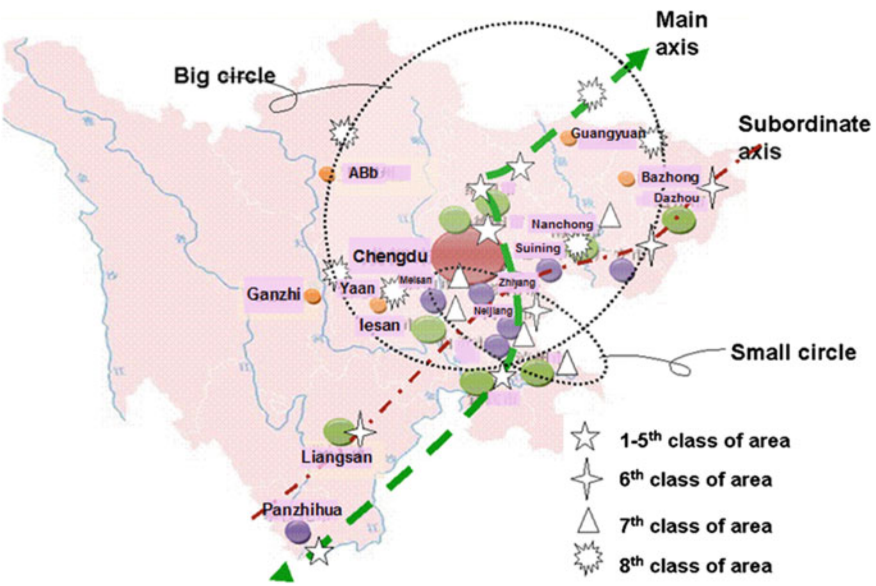

Fig. 2 Spatial distribution of different classes of areas in Sichuan

metallurgical machinery and food processing industry; Panzhihua mainly focuses on development of steel, vanadium and titanium, energy and chemical industry.

Five cities and districts of the 6th class are located on the subordinate axis, crossing with the main axis in X-type. Except Liangshan District, the other four cities all have high population density. Guang'an, Luzhou and Liangshan are the key new growth poles of Sichuan.

Obviously, the two axes are the major strategic areas of the central government and the provincial government. For example in 2013, the National Development and Reform Commission approved to set up "Panxi strategic resources innovation development experimental zone"; Sichuan government introduced "the policy measures for supporting the construction of Mianyang Science and Technology City", "implementation opinions on supporting the construction of the Sichuan and Chongqing cooperation demonstration zone (Guang'an area)", "opinions on promoting Luzhou's sustainable development of resource-dependent city", etc. Many cities on the two axes are becoming new economic growth poles and support points.

The 7th Class of areas is mainly distributed in south of Sichuan (Nanchong is in the northeast), as shown in Fig. 2 in the small dotted circle area. This region's agricultural economy still occupies a certain proportion, and there is good foundation for development of the third industry.

The 8th class of areas is mainly scattered in the northeast and northwest of Sichuan, as shown in Fig. 2 in the big dotted circle area. This region has small population, small density, and low urbanization rate. The industrial development focuses on ecological agriculture, energy and chemical industry, etc.

3 Space Strategies for Narrowing the Regional Difference in Developed Countries

To narrow the regional difference, developed countries including the United States, France, Germany and Japan all have made a lot of work on the space structure, aiming to promote space equilibrium, expand regional cooperation, strengthen the spatial linkage, and narrow the difference of regional economy by reducing the transaction cost and migration cost.

1. Cultivate Growth Poles and Points to Promote Spatial Equilibrium

From the progression pattern of urbanization of the developed countries, we can learn their thought in narrowing the difference of regional development. Britain's urbanization takes light industry as the forerunner, takes the transportation as the ligament, spontaneously forms and goes on under the driving of industrialization. In France, the central cities drive the development of small and medium-sized cities. In Germany, the whole country develops in balance, sets the principle of urban and rural equivalence [11].

The first key point for developed countries to foster growth poles lies in "multi" strategy, so as to fight against all sorts of problems brought by "single" strategy. At the regional level, "multi" strategy is to avoid problems such as unbalanced regional development, serious polarization in the core area, and insufficient diffusion ability. At the city level, "multi" strategy is a good way to alleviate the urban diseases. Most of the developed countries narrowed the difference of regional development through "multipolar" strategy, realizing balanced development and common development. American metropolitan statistical area, French balanced metropolis, German multi-center urban structure, as well as the "circle in New York metropolitan circle", and the "pole in pole of German metropolitan circle", are all perfect example of this.

2. Support Pole and Point Development of Space Planning

Seen from Europe and the United States and Asian developed countries, most of these countries have carried out space planning and multipole cultivation, such as Japan's "national comprehensive development planning", Germany's "space order development planning", France's "territorial control planning", Britain's "national planning policies", Netherlands' "spatial development planning", and so on. These spatial regulation and control functions are manifested on space constraints and space stress. Through "space encourage", "space admission", "spatial limitation" and some other measures, coordinate the relationships between central and local, inter-regional, urban and rural, resource development and environmental protection [4]. In addition, in the formulation of planning, the developed countries all stressed the relationship between human and environment, emphasized on the fairness and the intergenerational relations. As prescribed in article 106 of the German Federal Constitution, Germany should pursue regional balanced development and common prosperity. On regional planning policy, there are two things needing to adhere: one is "to form equal living environment across the country and reduce the regional differences"; the other is "to pursue sustainable development and leave opportunity for the offspring survival and development" [7].

3. Implement Larger Scope of Regional Cooperation

Wide-area cooperation not only conforms to the trend of regional economic integration, but also accords with the large zone development view. It is an important path to narrow the difference of regional development. In order to solve a series of problems due to population growth, the American Regional Planning Association launched "America 2050" project, specifying the major 10 metropolitan circle clusters of the USA. The project's long-term goal is to narrow the population and wealth gap between the rapid developed coastal regions and the inland rural areas and industrial declined cities, inspire the potential to make every member have the ability to realize the American dream. In general, to 2050, American regional balanced development will be carried out in metropolitan clusters and form new development poles with high competitiveness, which will participate in the global competition as new geographic units.

4. Build Multi-Level Urban System

In order to narrow the difference of regional development and promote regional balanced development, the United States adopted a balanced development mode for building multi-level urban system, namely, taking the "metropolitan circle" and "urban belt" as the core, the medium and small towns as the pivot. On the one hand, build international metropolis which have high concentration degree and core competitiveness relying on the metropolitan circle, urban belt and big cities; attract the world attention with the of the, with the "huge pole" and "super pole", laying the foundation of regional core competitiveness. On the other hand, pay attention to development of small and medium-sized towns, diverte the population of big cities. In 1960s, the United States implemented test plan of "demonstration city", carrying out redevelopment for the central area of big cities. This plan diverted population of big cities and promoted small towns development. According to the data of United States Census Bureau, "in the United States, there are 131 cities with a population of 100000 to 200000, 878 cities with a population of 30000 to 100000, and more than 34000 small cities (towns) with a population of few thousands to 30000. Small cities (towns) of less than 100000 people accounts for about 99 % of the total number of cities in the United States" [6].

As an imitator of the United States, Japan also established multi-level urban system, namely the metropolitan circle system. The urban system is divided into the capital circle (i.e., Tokyo circle) and local circle. And the local circle is divided into four classes: the first class includes Osaka and Nagoya circle; the second class includes Fukuoka, Hiroshima, Sendai, Sapporo and some other wide-area center cities; the third class includes all medium-sized cities, including local industrial cities and cities with population of about 100000 people; the fourth class includes all small cities, including the local cities with population of below 100000 people [8].

5. Form Intensive Rail Transit System

Traffic system is the foundation for strengthening the regional connection, promoting factor flow, and expanding the opening degree to the outside world. In all previous national comprehensive plans, Japan has formulated corresponding regional transportation planning, emphasizing on public transport priority and focusing on rail transit construction. At present, the Tokyo metropolitan circle has formed a regional rail transit network constituted of Shinkansen, light rails and subways. Among the people of Tokyo metropolitan circle who go to work or school every day, 86 % of them choose rail transit, and the proportion is as high as 91 % at peak time, ranking the first in the world. At the same time, perfect rail transportation has very important effect to optimize the spatial structure. The light rail along the Tokyo center linked the city heart and 7 subordinate hearts, and radiated to the suburbs and adjacent small and medium-sized cities with these subordinate hearts as starting points. For example, the Shinkansen line extends from Tokyo station to other cities of the metropolitan circle and even larger area, effectively relieving the dense population pressure in Tokyo and improving the urban construction, speeding up the high-end resources of Tokyo spread to surrounding areas, and promoting the optimization of spatial structure of Tokyo metropolitan circle [2].

4 Path Selection for Implementation of Multipoint and Multipolar Strategy in Sichuan

In order to optimize the spatial structure and promote the development of Sichuan's economy to a higher level, in terms of cultivating new growth poles and support points, we can consider from the following aspects:

1. Build Multi-Level and Multi-Function Urban System

Within the economic zone, we should take the central city as the core, form a well-proportioned and well-spaced urban system where the large, medium and small cities (towns) are in harmonious development, especially take the lead in promoting economic development of the axis cities that have close economic relation, so as to promote the formation of urban clusters. In terms of promoting the development of regional central cities, we should pay attention to both the existing advantages of the five cities on the main axis, and the cultivation of new growth points on the subordinate axis (see Fig. 2), so as to form urban clusters with complementary functions. For areas with less population and small density, we may refer to the principle of "small is beautiful" as followed by Germany [10], guide the industry incline to small and medium-sized cities and small towns, so as to promote construction of infrastructure facilities and perfect the functions. Of course, in addition to promoting the regional balanced development from the aspect of industrial angle, we also need to make efforts from the perspectives of employment and science and technology, so as to reduce the regional differences.

2. Promote Wide-Area Cooperation with Space Development Planning

Wide-area cooperation is a development trend, also is an important path for forming growth pole in the new geographical space. From the point of space structure, areas which are closely linked to the development of Sichuan include: Chengdu-chongqing Economic Zone, Tianfu New District, Silk Economic Belt and the Yangtze River Economic Belt and so on. These areas are important opportunities for Sichuan's economic development. Wide-area cooperation needs to cooperate with top design, needs assurance of long-term plan. Sichuan has to timely formulate a space development plan which is harmonious with development of these areas and conforms to the territory plan, economic plan, and industrial park planning. This space development plan should follow three principles: first is to promote space equilibrium from industry, city and regional perspectives; second is to improve people's life quality and promote the improvement of the public service and ecological environment; third is to improve the utilization of urban land and open space. At the same time, strengthening the spatial development planning is also an important method to avoid risks of "excessive suburbanization" and "excessive urbanization". In the process of space development in developed countries, the relevant laws and regulations have played important role in guiding the standard space development, such as London's Act on Green Belt Development Limitation. Therefore, we should introduce relevant policies cooperating with the "spatial development planning", so as to strengthen the executive power with system construction, and enhance the cohesion between regions.

3. Explore Cross-Regional Cooperation Mechanism

For encouraging cross-regional cooperation, we need to establish an effective organization to secure the feasibility and fairness of the cooperation. As a model of cross-regional cooperation of local government, the only official interstate regional planning cooperation organization in Germany, "Berlin-Brandenburg United regional Planning Department" is such a precious case. Berlin-Brandenburg United regional Planning Department is composed by "Berlin urban development department" and "Brandenburg infrastructure and regional planning department". The "state planning meeting" attended by the state (city) governors of both parties is the supreme council of the organization, which decides the basic frame and principle of united regional planning. In order to fully guarantee the impartiality of the planning and decision-making, the "partners principle" stipulates that, the head of each office and other staff need to come from different states [1]. Sichuan should encourage those cities and districts which have formed cooperation relationship to establish effective organization. Such organization is not used for merging on administrative system, but it can promote the regional integration process through formulation and implementation of mutual benefiting regional development strategy and space planning framework. We can learn the "partners principle" of Berlin-Brandenburg United regional Planning Department, letting the different regions express their demands and seek interests sharing under the win-win cooperation mechanism.

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Multi-agent Based Intelligent Supply Chain Management

Ye Wang and Denial Wang

Abstract For supply chain management, the information will help to quantify the value of the implementation of strategic coordination and information sharing between supply chain members. For this reason, we discussed the use of modeling through Agents, the Agent structure, Agent interaction, and decision-making and operational process between Agent-based supply chain system, etc. Based on all above research, we simulate and analyze the intelligent coordination algorithm processes and its influence to the whole supply chain values.

Keywords Multi-agent · Supply chain management

1 Introduction

There are increasing research interests in using data mining techniques in intelligent supply chain management. In recent years, agent technology has become a hot topic of computer simulation of logistics system. Distributed smart structures research in logistics simulation through using Agent has the ability to reason, to achieve the purpose of selected behavior and interactions with other Agent. Every customer's problems can be decomposed into large-scale multi-agent Modeling, calculation task control, information sharing between the customer, and problem solving steps. Using Agent technology, exploring a transparent, scalable, distributed architecture of supply chain simulation to the user, using MAS technology in various supply chain structures, which has proved its influence and importance in the future research of intelligent supply chain management.

Y. Wang (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 550593760@qq.com

D. Wang
Canada Bombardier Limited, 800 René-Lévesque Blvd, West Montreal,
QC, Canada

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Virtual market is another type of typical supplier and seller based business relation operating model, which is an advanced form of e-commerce development, is currently the most successful global commerce application model, which also represents a significant development direction for the future of e-commerce. The virtual market can be achieved virtually through using computer simulation and virtual reality technology on functions group co-operation, marketing research, marketing opportunity analysis, marketing segmentation, target marketing selection and positioning, and the nature of the process carried out in all levels of management and business processes of enterprises, in order to enhance decision-making and control of enterprises at all levels.

In this paper, we designed a new virtual architecture through using MAS and data mining technology with the purpose of improving enterprise production efficiency and services level. We applied detailed supply chain analysis intelligently based on agent technology, which wins the support of many companies; discovers new patterns through data mining techniques, and explores new methods of analysis, association rules, classification and clustering rules, provides a new perspective for the human analysis of intelligent supply chain management. Research on the relations between intelligent agents and data mining technologies, and this association research led agent job doing faster and better.

2 Background

1. Data Mining

Data mining is the process of generating various data models as per basic business processes, analyzing and discovering data rules based on various algorithms. The overall process of finding and interpreting patterns and models from data involving repeated steps of data collection, cleaning, transformation, rules mining, data prediction, prediction evaluation, knowledge discovery [1].

2. Agent Concept

Agent is a computer program that exists in some environment and is capable of performing an autonomous activity in order to gain its desired objectives; Intelligent agent is an agent capable of learning, capable of mining and storing knowledge about the environment it is situated in; Multi-agent system contains agents and intelligent agents capable of interaction through an information exchange [2].

3. Data Mining Agent

Every task will have at least one agent; and the data mining goal is to find the path analysis, association rules, sequential patterns, and clustering and classification rules, re-interpret the data, communication between data mining agents and other agents, providing high-quality data, etc. Typical data mining agent needs process large amounts of information, and which must be able to provide useful knowledge for another agent [3, 4].

4. Data Mining Algorithm

Typically, data mining algorithm uses one or more objective functions, using several search methods (e.g. heuristic algorithm, a gradient descent method, maximum and minimum method, network deduction method, etc.), to find out the data inherent relations inside the data body. Data mining algorithms can be divided according to the way instructive mining type and non-instructive type, also known as supervised learning and unsupervised learning. In supervised learning, instructors give a signal first, providing category labeling and classification costs for every input sample of the training set, and looking into the direction of reducing overall cost. In unsupervised learning algorithm, which does not have explicit instructors, the system will automatically form clusters on the input samples [5].

Although data mining does not need real-time processing for most of the time, which can use static off-line data, but it does require real-time or fast data mining algorithms, which will use dynamic online data. Agent-based modeling of data mining is automated (e.g. relying on machine learning), or semi-automated (for example, using data mining algorithms repeatedly), to explore the objective laws of the transaction. There are quite some typical data mining algorithms as shown at below figure, combination of which specific data mining algorithms can be applied on the specific circumstances and applications [6] (Fig. 1).

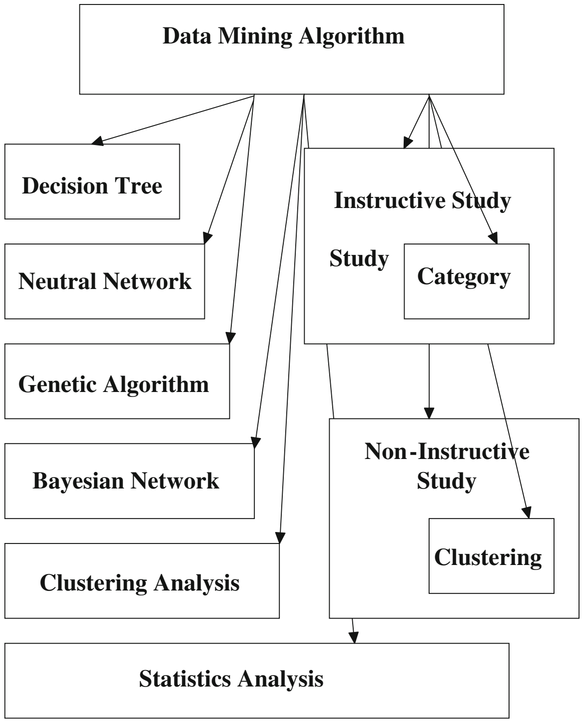

Fig. 1 Architecture of data mining algorithms

5. Agent Oriented Programming and Multi-agent System

There are features of hierarchical, dynamic, autonomous, local interaction and global emergence for multi-agent system with complex open environment normally, whose development can be simplified through different views of analyzing the scale and complexity of systems based on the software engineering principles of decomposition, modularity and separation of concerns. Agent oriented programming needs four layers of programmability, i.e. individual agent layer, interactive agent layer, environment layer, and multi-agent organization layer, so as to provide programming support to achieve the MAS autonomy, social agents interaction, environment residence and global MAS organization. (1) Individual agent layer runs as the basic unit of the target software system, whose autonomy is unique from other programming design patterns. How to describe and implement agent autonomy is the main contents of individual agent layer; (2) Interactive agent layer, each agent inside MAS is not isolated and closed, each of them has limited resources, information, knowledge and capabilities, which needs interaction to achieve global design targets of MAS; (3) environment layer, agent either individual or MAS, which resides in a particular environment and needs bi-directional interaction with the environment; (4) Multi-agent organization layer, agent inside MAS has behavior autonomy, which needs MAS to run in a coordinated and consistent way and balance the local autonomy and global constraints of software agent behavior [7, 8]. There are quite some open source MAS platform, e.g. JADE. JADE is a Java based agent development environment, which can achieve multi-agent system through middleware and comply with the specification of FIPA (Foundation of Intelligent Physical Agents); JADE is a cross-platform tool and provide debugging GUI tools, etc. [9].

3 MAS Based Supply Chain Management

3.1 Data Collection and Pre-processing

The Data Management Agent is an agent that handles several data management tasks, including raw data backup, data cleaning, normalization, and generating datasets as per pre-defined logic, which may be updated automatically based on periodic or final testing results. User interface agent is used for querying concerned configuration information from environment, and which provide an interactive GUI interface for sending and receiving concerned information with end users. Data pre-processing agent is used for querying production or testing data from production environment, data cleaning and transformation as per business analysis training purposes (Fig. 2).

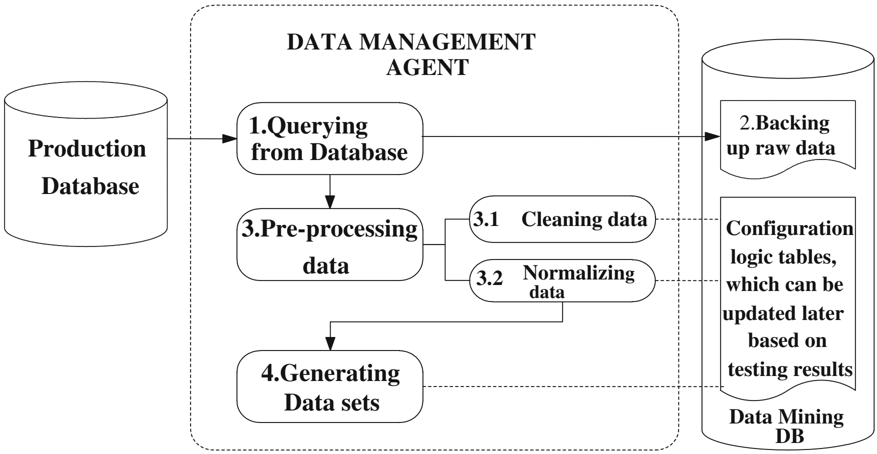

Fig. 2 Architecture of data management agent

3.2 Data Mining and Rules Generating

Normally there are two main methods for data mining and rules generating of supply chain management, i.e. one for theory analysis, e.g. expert system, which can judge based on experts' experiences, etc. the second one is the real data based analysis, which includes math statistics, logic analysis, intelligent algorithms, etc. Detailed mining procedure includes two models, frequent item sets mining and association rules mining.

Basic steps include: (1) Objectives and Tasks analysis and prediction; (2) Business data preparation and pre-processing; (3) Business data mining; (4) results analysis and rules generating; (5) Application of testing results. Key factors analysis include: (1) finance (costing, etc.) analysis; (2) transportation (route, costing, performance, efficiency, etc.) analysis; (3) sales (association, products, etc.) analysis; (4) inventory (costing, missing parts, etc.) analysis; (5) supply (delivery, prices, performance, etc.) analysis.

For this research, we use typical association rules mining, clustering analysis, Apriori algorithm, genetic algorithm, neural algorithm, rough sets analysis, etc. for extracting the associations among major supply chain elements (Figs. 3, 4 and 5).

3.3 Data Predicting and Evaluating

This section mainly covers (1) Integration agent, which collects and optimizes source or intermediate prediction data through integration of concerned expert system, history data, etc.; (2) Management agent, which stores the detailed information of all

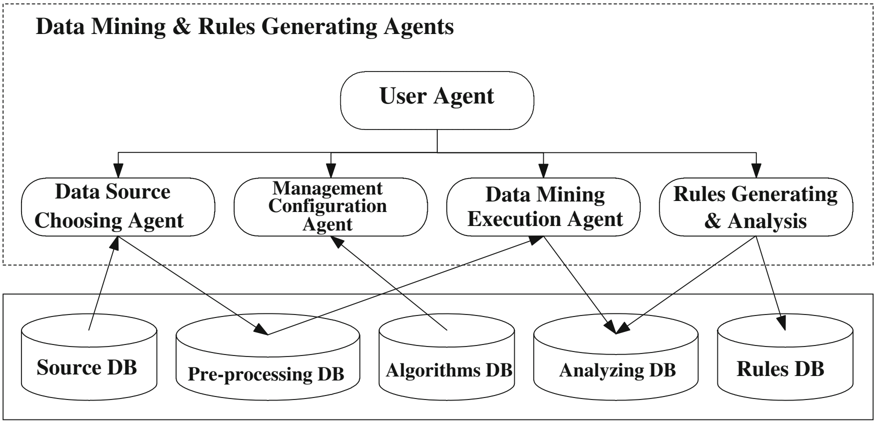

Fig. 3 MAS architecture for data mining and rules generating

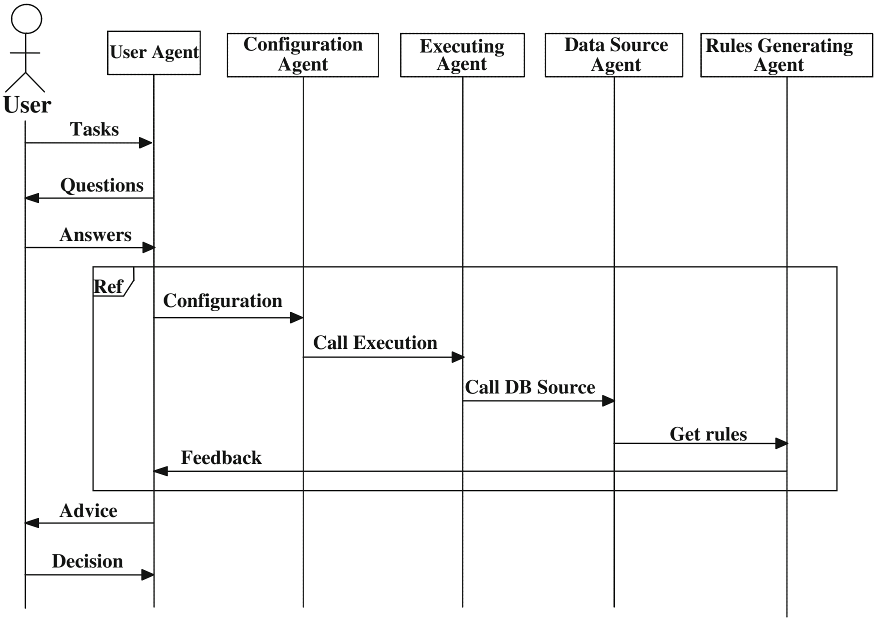

Fig. 4 MAS Sequence diagram for data mining and rules generating

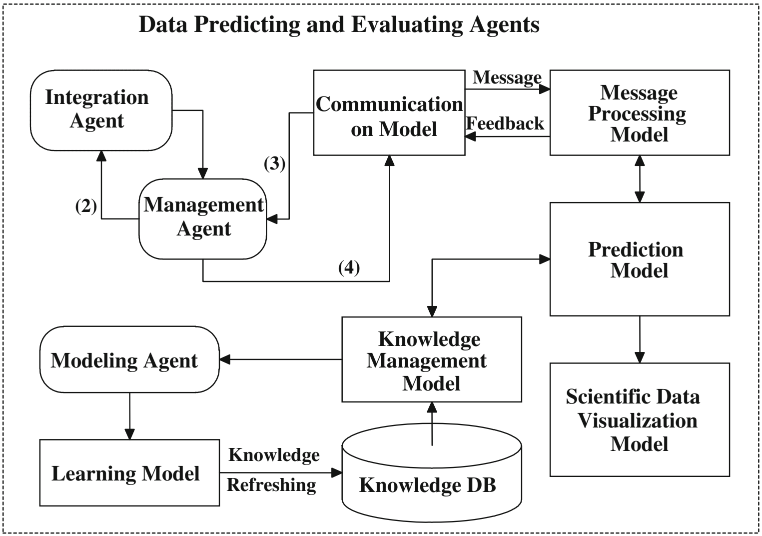

Fig. 5 MAS architecture for data predicting and evaluating

agents, e.g. their name, address, type, functions, etc.; (3) communication model, which covers a group of communication agents and responsible for various communication tasks; (4) Message processing model, which is responsible for receiving and distributing messages/feedbacks; (5) Prediction model, which adopts the combination of data mining algorithms as per pre-defined knowledge or rules inside the system, generate concerned predication rules first, give prediction based on above rules generated, measure and analyze the prediction, feedback and refresh the system knowledge database, etc.

4 Achievements and Conclusions

MAS based negotiation model in this paper, use the concept of "negotiation—negotiation process—negotiation thread" to describe multi-agent multi-issue negotiation, which supports various negotiations based on a flexible negotiation protocol support. The model supports study inside the agent negotiation process. We applied and tested this negotiation model in the intelligent supply chains, simulate the buying/selling behaviors of the simulation agents. During the test process, agent can play a proposer role to start the negotiation, or play a participator to join a negotiation started by other agents. Negotiation between any agents can construct a negotiation thread; any agent started negotiation can make a process, and which can covers multiple threads; the entire system is the set of all negotiation issues in the negotiation process within te he system. Agent learning tasks in the negotiation process includes guessing costs of opponent agents based on its initial input, mining the relations between the initial inputs of opponents and the estimated costs through using the incentive mechanism of machine learning; Agent will refresh its estimated costs every time which receives the new input from opponent agent based on above knowledge. The test indicates that the model can achieve the key role of negotiation issue inside the intelligent supply chain; the agent negotiation performance and efficiency can be improved through the combination of intelligent data mining algorithms. In the future, we will continue to study the impact of key study mechanisms on the efficiency of MAS based intelligent supply chain.

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Prognostics for State of Health Estimation of Battery System Under Uncertainty Based on Adaptive Learning Technique

Fan Li, Yusheng Wang and Duzhi Wu

Abstract This paper addresses the State of health (SOH) estimation for system in the prognostics and health management (PHM) of the electronics systems. Due to complicated operation conditions, it is necessary to derive and implement the prognostics with uncertain situations. In this paper, a Bayesian filtering approach based on the adaptive learning for the Gaussian process regression (GPR) model is presented for the SOH estimation of system under uncertain conditions. Instead of assuming the certain state space model for the degradation trend directly, the distribution of the degradation process is investigated to learn from the inputs based on available measurements. In order to capture the time-varying degradation behavior, the proposed method represents the statistical property of the degradation process through distribution learning with the GPR model. By exploiting the distribution information of degradation process, the particle filter can be implemented to predict the SOH of system. Experiments and comparison analysis are provided to demonstrate the efficiency of the proposed approach.

Keywords Prognostics · State of health · State estimation · Adaptive learning · Uncertainty

1 Introduction

With the development of the manufacturing assemblies and new materials, the batteries driven system has been widely used in military electronics, aerospace avionics, portable devices and other automotive vehicles [1]. However, battery deteriorates and failures during usage have common occurred in practice, which can lead directly to

F. Li (✉) · Y. Wang
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: lifanscu@sina.com

D. Wu
Department of Fundamental Studies, Logistical Engineering University, Chongqing 400016, People's Republic of China

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systems performance reduce and many costs for catastrophic failure [2]. For this challenge, the prognostics and health management for electronics devices has received great attentions, which determine the advent of systems failure and mitigate system risk through evaluating the system reliability in terms of its current life-cycle conditions [3]. The estimation of system future health state and the remaining useful life (RUL) prediction are core components for the PHM of electronics devices, which mainly focus on predicting the health state and estimating its RUL, then maintenance decisions can be made based on the actual conditions of system and the risk factors can be mitigated in time. With the increasing demand for reducing the life-cycle cost of battery driven equipments and in order to provide the useful prognostic information in reliability monitoring for battery systems health management, the SOH estimation can be exploited to predict the health situations in terms of available measurements with the degradation cycles [4–6].

Due to complicated uncertainties for system operations, the parameters for describing degradation model may have difference between various conditions, but modeling effectively for degradation process under uncertainty has gained less attention. Recently, with the modeling flexibility and the ability to provide uncertainty representation, the Gaussian process regression (GPR) has been investigated for lithium-ion batteries prognostics [7], where the degradation trend are learned from training data set with combination Gaussian process functions. As an alternative to learn the degradation trend directly, learning for representing the parameters distribution of degradation process has not been studied yet.

In this paper, consider the uncertainties in batteries prognostics, the novelty approach for SOH estimation of the batteries is presented through integrating the adaptive learning for GPR into the particle filtering. The proposed method consists of two phases, in the first phase, the GPR can be used for learning to construct the probability density function (pdf) of degradation model parameter process with the training data sets from uncertain batteries conditions. Secondly, based on the distribution information of the parameters for the degradation process, the particle filtering can be utilized to obtain the SOH estimation of the battery. In order to avoid full data storage and excessive computational complexity, the adaptive and recursively learning algorithms are investigated. Finally, the experiments are provided based on the NASA batteries data sets to demonstrate the performance of the new prognostic method.

The rest of this paper is organized as follows. In Sect. 2, the motivation of this study is described. In Sect. 3, an overview of Bayesian estimation and GPR are provided firstly, and then the adaptive learning and SOH prognostics method are developed. Then, the experiments and analysis are given in Sect. 4 to show the performance of proposed prognostic algorithm. Finally, conclusions are drawn in Sect. 5.

2 Motivation

Due to the complicated factors such as operation environment of batteries, assemblies technology and material properties, initial conditions and so on, the actual capacity degradation process are different between batteries in each operations [8]. Thus, the prognostics for batteries is necessarily affected by large uncertainties. Most popular methods used to deal with battery system prognostics under uncertainties are based on the data-driven methods and model-based methods [9, 10]. The data-driven methods attempt to learn the trend of batteries degradation from the obtained measurement data directly. But the monitoring data from batteries in complex conditions are hard to be fully exploited and some regressors may easily been affected by extreme data which usually appear near the cycles which the self-recharge happen during the batteries capacity fading. Meanwhile, with some offline learning which need to use the full data from historical monitor, the prognostic algorithm always need to load heavily computational burden [11].

On the other hand, by assumption the certain degradation parameters model, the classical filter methods can be exploited to predict the SOH of batteries, but it can show good performance if the used degradation model can represent the actual system's behavior accurately. However, a host of practical settings in batteries usage involve the uncertainties. Hence, it's hard to obtain the accuracy state process model or parameter description in practice. In addition, since the uncertain environment and measurement noises, the degradation model parameters which characterize the batteries conditions will be random and usually with non-linear transition, so the dynamical degradation process is difficult to model by some certain space state model, even there is no universally accepted best model for the degradation parameters [12]. Hence, to make the effective representation for the degradation process is the key for batteries prognostics. Although some hybrid approaches which incorporate the pattern or model identify into the stochastic filter can make some improvement, but the complicated and non-linear transition of the degradation parameter process under uncertainties which are very common in practice are lack of consideration.

3 Methods

3.1 Bayesian Filtering Framework

There are many valuable prognostics method existed for SOH estimation and RUL prediction of electronics products such as fuzzy logic, neural networks and some artificial intelligent methods. Besides, the stochastic filtering approaches such as Kalman filtering [13], extended Kalman filtering [14], Unscented filtering and Bayesian filtering [15] are another classical method which is booming used for the SOH estimation of electronics products in literatures. In these methods, the problem of SOH prognostics is converted to the state estimation with the following state space model:

$$x_k = f_{k-1}(x_{k-1}, w_{k-1}), \tag{1}$$

$$z_k = h_k(x_k, v_k), \tag{2}$$

where the vector x_k is the unobservable state, $f(\cdot)$ is the state transition function, z_k is the measurement with the measurement function $h(\cdot)$, w_k and v_k are the process and measurement noises respectively. The functions $f(\cdot)$ and $h(\cdot)$ are possibly time-varying and nonlinear. The goal is to estimate the unobservable state x_k or approximate its posterior pdf condition on the sequence of noisy measurements $[z_1, z_2, \ldots, z_k]$ denoted as Z_k.

Suppose that the density $p(x_{k-1}|Z_{k-1})$ is available at previous time, then in the light of the states follow the first order Markov process, the prediction of the conditional pdf $p(x_k|Z_{k-1})$ which means the pdf of x_k given all measurements up to time $k-1$ can be given by:

$$p(x_k|Z_{k-1}) = \int p(x_k|x_{k-1})p(x_{k-1}|Z_{k-1})dx_{k-1}. \tag{3}$$

When the new measurement becomes available, from the Bayes theorem, the updating of the posteriori pdf of x_k can be obtained as:

$$p(x_k|Z_k) = \frac{p(z_k|x_k)p(x_k|Z_{k-1})}{p(z_k|Z_{k-1})}, \tag{4}$$

where the pdf $p(z_k|Z_{k-1})$ can be determined by:

$$p(z_k|Z_{k-1}) = \int p(z_k|x_k)p(x_k|Z_{k-1})dx_k. \tag{5}$$

If $f(\cdot)$ and $h(\cdot)$ are linear, and w_k and v_k are additive, independent, and Gaussian, then the solution of Bayesian filter is the Kalman filter. But in practice, the dynamical system is usually nonlinear. Thus, by using the sequential Monte Carlo method, the particle filter was invented to recursively implement the Bayesian estimator through representing the required posterior density function by a set of random samples with associated weights and to compute the estimates based on these samples and weights. Actually, the true posterior can be approximated by exploiting the discrete weighted samples, i.e.,

$$p(x_k|Z_k) \approx \sum_{i=1}^{N} \omega_k^i \delta(x_k - x_k^i), \tag{6}$$

where $x_k^i, i = 1, \ldots, N$ be the samples that are generated from the posterior density $p(x_k^i|Z_k)$, and ω_k^i is the associated weight of the ith particle.

However, since the true posterior is usually unknown in practice, as the alternative, a so-called importance density $q(x_k^i|Z_k)$ which is easily obtained can be used to draw the samples. By assuming that the current state independent of the measurement at previous time and the state process follow the first order Markov process, then the weights associated with particle x_k^i can update recursively as

$$\omega_k^i \propto \omega_{k-1}^i \frac{p(z_k|x_k^i)p(x_k^i|x_{k-1}^i)}{q(x_k^i|x_{k-1}^i,\ z_k)}. \tag{7}$$

It can be shown that as $N \to \infty$, the approximation of Eq. (6) approaches the true posterior density $p(x_k|Z_k)$. A common chosen of the importance density is taking $q(x_k^i|x_{k-1}^i,\ z_k) = p(x_k^i|x_{k-1}^i)$, since the bootstrap probability density can be obtained easily. Then, the weight updating becomes: $\omega_k^i = \omega_{k-1}^i p(z_k|x_k^i)$, and the normalized weight are given by:

$$\hat{\omega}_k^i = \omega_k^i / \sum_{i=1}^{N} \omega_k^i. \tag{8}$$

To avoid the degeneracy of the particles, the re-sampling need to conducted.

However, it can be seen that a limitation associated with these classical Bayesian filter is the dynamical system model or parametric descriptions for state and observation need to be exploited for the sampling and weights calculation. Usually, in the prognostics for electronics system, it may be difficulty to describe state transition of the degradation process accurately during the degradation period, therefore, the importance sampling are hard to be implement, especially in complicated situation with uncertainty. Nevertheless, this limitation associated with the traditional Bayesian filter-based prognostics can be properly alleviated through the learning technique by fully using the data available.

3.2 Gaussian Process Regression

In fact, many parameter vectors which capture the time-varying situations in degradation cycles of the electronics devices need to be treated as a dynamical process. In order to represent the system degradation behavior, The Gaussian process is considered. A stochastic process $\{g(x) : x \in \mathscr{X}\}$, indexed by elements from some set $\mathscr{X}$, is a Gaussian process with mean function $m(x)$ and covariance function $k(x, x')$, if for any finite set of elements $x_1, \ldots, x_m \in \mathscr{X}$, the associated finite set of random variables $g(x_1), \ldots, g(x_m)$ have a multivariate Gaussian distribution.

It can be denote by $g(x) \sim GP(m(x), k(x, x'))$. Actually, the mean function and covariance function are defined as:

$$m(x) = E[g(x)],\ k(x, x') = E[(g(x) - m(x))(g(x') - m(x'))],$$

for any $x, x' \in \mathscr{X}$.

Gaussian process represents distributions over functions. It provides a method for modeling probability distribution under multiple corruptions in complicated or uncertainty situations. When the accurately describe for the dynamical parameter process is hard to be obtained in advance, the Gaussian process regression (GPR) can be exploited to supply the approximation distribution of the parameter process through learning from the training data available [16].

Consider a set of training data $S = \{x_i, y_i\}_{i=1}^N$, the relationship between input x_i and output y_i can be modeled by $y_i = g(x_i) + \epsilon_i$, where ϵ_i is zero mean, Gaussian white noise with variance σ_n^2. From the GPR, if the prior distribution over $g(x_i)$ be assumed as Gaussian process, the posterior distribution over outputs conditioned on sample set S and the test input x_* is also a Gaussian process, and the mean and variance can be given by:

$$\bar{g_*} = E[g_*|x_*, S] = k_*^T K^{-1} y, \tag{9}$$

$$cov(g_*) = k(x_*, x_*) - k_*^T K^{-1} k_*, \tag{10}$$

where K is the covariance matrix whose entries is determined by the kernel function i.e., $K_{ij} = k(x_i, x_j)$. In order to capture the uncertainty of state process and the influence of noise, the kernel function can be expressed as $k(x_i, x_j) = k_g(x_i, x_j) + k_n(x_i, x_j)$, and the squared exponential kernel and constant kernel function are chosen as the covariance function of Gaussian process:

$$k_g(x_i, x_j) = \sigma_g^2 \exp\left[-\frac{(x_i - x_j)^2}{2l^2}\right], \tag{11}$$

$$k_n(x_i, x_j) = \sigma_n^2 \delta_{ij}. \tag{12}$$

The parameters $\Theta = [\sigma_h, \sigma_n, l]$ are so-called hyper-parameters of the Gaussian process, which are actually the parameters of the covariance function. The hyper-parameters can be determined by using the optimization strategy which is to maximize the log-likelihood function given by:

$$\log p(y|X, \Theta) = -\frac{1}{2} y^T (K + \sigma_n^2 I)^{-1} y - \frac{1}{2}\log(|K + \sigma_n^2 I|) - \frac{n}{2}\log(2\pi).$$

Therefore, the learning process with GPR need to select the mean function and covariance firstly, then the hyper-parameters can be determined with the training data. After that, the prediction of the distribution parameter can be yielded with the new inputs.

3.3 Adaptive Learning-Based Prognostics

When the new inputs become, from the Eqs. (9)–(10), it can be seen that the mean and variance function of Gaussian process need to learn from the whole training set, which make each update in the training phase requires to compute the inverse of the $N \times N$ covariance matrix. In order to reduce the computation and memory demand, instead of using the off-line learning directly, the adaptive technique can be exploited to make the learning procedure recursively implement. To do this, denote the inverse of the covariance matrix of the Gaussian process as Q_N, i.e.,

$$Q_N^{-1} = \begin{bmatrix} \mathrm{K}_{N-1} & \mathrm{k}_N \\ \mathrm{k}_N^T & k_N \end{bmatrix},$$

where, the vector k_N has the elements $\mathrm{k}_N(i) = k(x_i, x_N), i = 1, \ldots, N-1$, and the scalar $k_N = k(x_N, x_N)$. It can be seen that the updating of the inverse of the growing matrix can be expressed as:

$$Q_N = \mathrm{b}_N^{-1} \begin{bmatrix} \mathrm{Q}_{N-1}\mathrm{b}_N + \mathrm{r}_N\mathrm{r}_N^T & -\mathrm{r}_N \\ -\mathrm{r}_N^T & 1 \end{bmatrix},$$

where, $\mathrm{r}_N = \mathrm{Q}_{N-1}\mathrm{k}_N$, and $\mathrm{b}_N = k_N - \mathrm{r}_N^T\mathrm{k}_N$.

Denote $\mathrm{d}_N = \mathrm{Q}_N\mathrm{y}_N$, where $\mathrm{y}_N = [y_1, \ldots, y_N]^T$ is the all output of the training data up to current time, we have:

$$\mathrm{d}_N = \begin{bmatrix} \mathrm{d}_{N-1} - \mathrm{b}_N^{-1}\mathrm{r}_N e_N \\ \mathrm{b}_N^{-1} e_N \end{bmatrix},$$

where $e_N = y_N - \mathrm{k}_N^T\mathrm{d}_{N-1}$, and this term can be viewed as the bias of the prediction since the $\mathrm{k}_N^T\mathrm{d}_{N-1}$ is the prediction when the input at time N arrives.

Then, the mean and the covariance in the next time can be updated by:

$$\bar{g}_{N+1} = \mathrm{k}_{N+1}^T\mathrm{d}_N, cov(g_{N+1}) = k(x_{N+1}, x_{N+1}) - \mathrm{k}_{N+1}^T Q_N \mathrm{k}_{N+1},$$

where k_{N+1} is the N dimension vector with the element $\mathrm{k}_{N+1}(i) = k(x_{N+1}, x_i)$, $i = 1, \ldots, N$. The whole procedure can be described as follows.
(1) Initialization

$$Q_1 = (k(x_1, x_1))^{-1}, \quad d_1 = Q_1 y_1. \tag{13}$$

(2) Iterate FOR $i = 1, \ldots, N$

$$\mathrm{k}_i = [k(x_i, x_1), \ldots, k(x_i, x_{i-1})]^T, \tag{14}$$

$$\mathrm{r}_i = \mathrm{Q}_{i-1}\mathrm{k}_i, \tag{15}$$

$$
\begin{aligned}
\mathrm{b}_i &= k(x_i, x_i) - \mathrm{r}_i^T \mathrm{k}_i, && (16)\\
Q_i &= \mathrm{b}_i^{-1} \begin{bmatrix} \mathrm{Q}_{i-1}\mathrm{b}_i + \mathrm{r}_i\mathrm{r}_i^T & -\mathrm{r}_i \\ -\mathrm{r}_i^T & 1 \end{bmatrix}, && (17)\\
e_N &= y_i - \mathrm{k}_i^T \mathrm{d}_{i-1}, && (18)\\
\mathrm{d}_i &= \begin{bmatrix} \mathrm{d}_{i-1} - \mathrm{b}_i^{-1} e_i \mathrm{r}_i \\ \mathrm{b}_i^{-1} e_i \end{bmatrix}. && (19)
\end{aligned}
$$

END FOR

(3) Calculate the mean and covariance with sample in next time:

$$
\begin{aligned}
\mathrm{k}_{N+1} &= [k(x_{N+1}, x_1), \ldots, k(x_{N+1}, x_N)]^T, && (20)\\
\bar{g}_{N+1} &= \mathrm{k}_{N+1}^T \mathrm{d}_N, && (21)\\
cov(g_{N+1}) &= k(x_{N+1}, x_{N+1}) - \mathrm{k}_{N+1}^T Q_N \mathrm{k}_{N+1}. && (22)
\end{aligned}
$$

When the degradation model or parameters description are unknown under uncertain environment, the GPR model can be utilized for learning the distribution information, then the particle filter can be exploited for the SOH prediction. Therefore, the proposed method comprises two phases. In the training phase, the adaptive learning process based on GPR models is conducted for learning the appropriate distribution to represent the transition of state process from the training data, in which the nonlinear and time-varying state process can be treat as the Gaussian process with associated mean and covariance. In the prediction phase, with the statistical properties of the degradation process, the state samples and associated important weights can be yielded based on the importance sampling. The steps of our proposed method are summarized as follows.

Step 1. Initialization: Given the trained data set $S_L = \{(x_i, z_i)\}_{i=1}^L$ and $D_L = \{(x_i, y_i)\}_{i=1}^L$, where the $y_i = \Delta x_i = x_{i+1} - x_i$. Then, determine the hyper-parameters and set the initial values.

Step 2. Using Eqs. (13)–(22), the updating of distribution parameters can be computed through the adaptive learning for GPR.

Step 3. Denote $GP_\mu(\Delta x_{l-1}^{[i]}; D_L)$ as the mean of Gaussian process and $N(z_l; GP_\mu(x_l^{[i]}, S_L), GP_\Sigma(x_l^{[i]}, S_L))$ represents the Gaussian pdf with the mean $GP_\mu(x_l^{[i]}, S_L)$ and the Covariance $GP_\Sigma(x_l^{[i]}, S_L)$, then the importance sampling can be implemented:

(a) FOR $i = 1, \ldots, N$

$$
\begin{aligned}
&\text{sample } x_l^{[i]} \sim x_{l-1}^{[i]} + GP_\mu(\Delta x_{l-1}^{[i]}; D_L),\\
&\omega_l^{[i]} \propto \omega_{l-1}^{[i]} \mathcal{N}(z_l; GP_\mu(x_l^{[i]}, S_L), GP_\Sigma(x_l^{[i]}, S_L)),
\end{aligned}
$$

END FOR

(b) Calculate the normalization weights $\hat{\omega}_l^{[i]}$ and effective sample size N_{eff}
(c) IF $N_{eff} < N_{th}$

$$[\{\tilde{x}_l^{[i]}, \tilde{\omega}_l^{[i]}\}_{i=1}^{N}] = \text{re-sampling}[\{x_l^{[i]}, \hat{\omega}_l^{[i]}\}_{i=1}^{N}].$$

(d) IF $l < L$, let $l = l + 1$, turn to a);
Step 4. The state and its covariance can be calculated by:

$$\hat{x}_k = \sum_{i=1}^{N} \tilde{\omega}_k^{[i]} \tilde{x}_k^{[i]}, \quad P_k = \sum_{i=1}^{N} \tilde{\omega}_l^{[i]} [\hat{x}_k - \tilde{x}_k^{[i]}][\hat{x}_k - \tilde{x}_k^{[i]}]^T.$$

4 Experiments

4.1 Data from Lithium-Ion Battery

In this study, the SOH estimation was conducted with the lithium-ion batteries data obtained from the data repository of the NASA Ames' Prognostics Center of Excellence (PCoE) [17]. In the SOH prognostics of batteries, the main measurements which can be used for representing SOH of batteries are the battery capacity. In this experiment, these capacity data sets had been measured from a battery prognostics test bed when the lithium-ion batteries were run through different operation profiles include charge, discharge and impedance at room temperature. With the accelerated aging of the batteries for the repeated charge and discharge cycles, the end-of-life criterion of the batteries is a 30 % fade in rated capacity, then the tests were stopped. The battery capacity at cycles which percentage to the initial capacity was adopted to measure the SOH.

For tracking the batteries capacity fading, the exponential model (21) is commonly used to represent the capacity degradation trends in many cases.

$$Q = a \times \exp(b \times l) + c \times \exp(d \times l), \tag{23}$$

where Q is the capacity of the battery and l is the cycle number. The degradation model parameters are a, b, c and d, where a and c capture the internal impedance, b and d are related to the aging rate. Unfortunately, the capacity degradation model is just a empirical approximation of the actual dynamical degradation in which the parameters process is hard to be modeled in advance and the modeling error always exists. Hence, to make the effective representation for the degradation process needs to make full use of the data available under the uncertainty. In this study, the data from battery No. 7 was used to validate the proposed method, where the discharge was carried out with 2 A constant current level until the battery voltage fell to 2.2 V.

4.2 SOH Prediction

From the proposed approach, the training phase contained two aspects. Firstly, in the GPR learning, the GPR models could be chosen with the linear mean function $m(x) = ax + b$ and the kernel function expressed by Eqs. (11)–(12), thus the hyper-parameters $\Theta = [a, b, \sigma_n, \sigma_g, l]$ were optimized with the maximization of the log-likelihood function. Then, using adaptive learning with the training sets, the mean and covariance functions of Gaussian process were estimated. After that, the obtained distribution from data were treated as the importance density to produce the particles and associated weights, the resampling procedure is implemented as the standard particle filter algorithm. In this case, the parameters of the degradation process were viewed as the state vectors. Similar to the particle filtering updating, when the weighted samples $\tilde{x}_l^{[i]} = (a_l^{[i]}, b_l^{[i]}, c_l^{[i]}, d_l^{[i]})$ were obtained, the battery capacity prediction $Q_{l+p}^{[i]}$ at p step after current cycle l can be computed by exploiting the degradation parameter samples $\tilde{x}_l^{[i]}$ for the ith trajectory. Finally, the p-step prediction at cycle l can be estimated.

Consider that the prediction began at cycle 100 for the current battery No. 7, and then the prediction results are shown in Fig. 1.

From the Fig. 1, it can be seen that the prediction results can capture the SOH of the degradation process at most cycles especially the cycles near the beginning cycle of prediction. Therefore, from these results, the proposed method shows the effective prediction under the uncertain description of degradation model.

Moreover, in order to further evaluate the proposed prognostic method, compare our method which is based on the adaptive learning for GPR and particle filtering (GPR-PF) with the method presented in [7], which the GPR model was used directly for prediction. The prediction was set at cycle100 in both two methods, and then the prediction results are shown in Fig. 2.

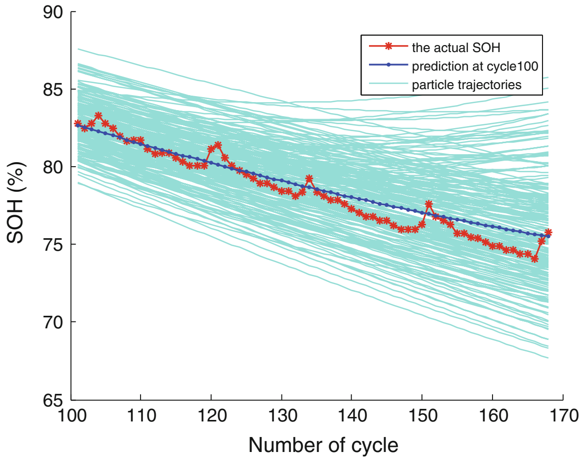

Fig. 1 The SOH prediction for battery No. 7 at cycle 100

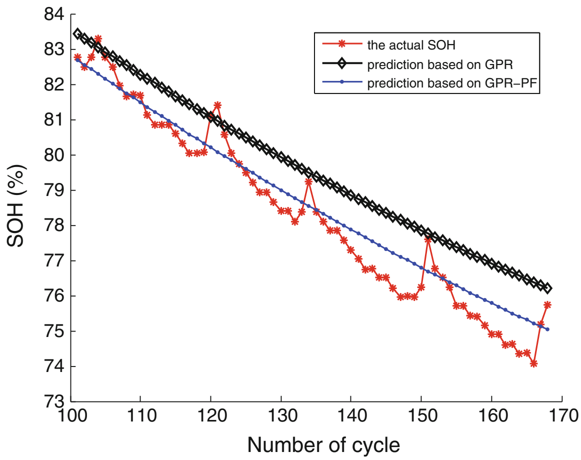

Fig. 2 Prediction results based on two methods for battery No. 7

From the Fig. 2, it can be seen that for the battery No. 7, the prognostics based on adaptive learning and particle filtering match the SOH of battery degradation batter than the method only take the GPR model into account. The reasons may lie in that the learning phase in the later depend too much on the assumption about the initial distribution parameters such as the mean functions and so on, and the new measurements may not be fully used for each updating.

5 Conclusions

The degradation for systems under complicated conditions or working environment is more and more common in practice, and different conditions may have difference. Thus, the prognostics for SOH estimation under uncertain conditions meet many challenges such as the accurate dynamical process model for the degradation behavior can not be obtained in advance. Therefore, make the representation of the degradation process effectively from the available measurements is the key for the SOH prediction. In this paper, we presented a health state estimation approach based on adaptive learning for GPR and the particle filtering algorithm. In order to represent the density of the degradation model parameters under uncertain condition, the adaptive learning for GPR is used to learn the distribution parameters from the obtained measurements. Based on the distribution information of the degradation process, the importance sampling for particle filtering can be implemented.

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Benefit Distribution of the Agricultural Products Green Supply Chain Based on Modified Shapley Value

Yanling Xu, Chen Peng, Caoyu Wang, Jin Xie and Zhi Li

Abstract In this paper, on the basis of the Shapley value benefit distribution strategy, taking into account comprehensively the factors influencing the stability of the agricultural products green supply chain systems, we modify the Shapley value by using analytic hierarchy process (AHP) method and build the modified benefit distribution model of the agricultural products green supply chain systems. At the end, the feasibility of the strategy is illustrated by a set of experiments.

Keywords Green supply chain · Shapley value · Contribution rate · AHP

1 Introduction

Green supply chain of agricultural products, which integrates the supplier of agricultural production, agricultural producers, processors, retailers and logistics service providers as one, provides customer-oriented agricultural products. It helps to achieve the goal of saving transaction costs, to improve the efficiency of resource utilization, and to maximize the value of entire supply chain. Thus the overall competitive advantages of supply chain will be improved [1]. For a long time, the regional nature of agricultural production and the universal consumption of agricultural products, the

Y. Xu · Z. Li (✉)
Department of Mathematics and Statistics, College of Science,
Huazhong Agricultural University, Wuhan 430070, People's Republic of China
e-mail: hzau_lizhi@mail.hzau.edu.cn

P. Chen
College of Economics & Management, Huazhong Agricultural University,
Wuhan 430070, People's Republic of China

C. Wang
College of Resources & Environment, Huazhong Agricultural University,
Wuhan 430070, People's Republic of China

J. Xie
College of Public Administration, Huazhong Agricultural University,
Wuhan 430070, People's Republic of China

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limitations of agricultural production and the global consumption of agricultural products, and the dispersion of agricultural production along with the diversity of agricultural products demand, all cause the temporal and spatial conflicts between agricultural production and consumption of agricultural products. However, the key to solve this problem is to establish a green supply chain of agricultural products to ensure effective flow of logistics, information flow and capital flow [2]. In agricultural green supply chain, each link point contributes to their core competence in such aspects of production, acquisition, distribution, and links up with each other to achieve product circulation and the distribution of benefits. Once the product is consumed, owing to the independence of each link point, agricultural supply chains can be disintegrated, and then all link points will combine into a new supply chain according to the market situation and new factors. However, any of the link point to participate in the supply chain, whose fundamental purpose is to maximize the economic benefits, and whether the income distribution is reasonable or not will directly affect the efficiency and stability of the supply chain. Therefore, to establish the reasonable mechanism of income distribution is one of the key issues that must be discussed in supply chain collaboration.

W. Sterm points out that agricultural supply chain is a super organization, a non-linear system through “farm to table” process and with obvious characteristics of “dual drive mode of producer and consumer”. Stability of supply chain partnership is a dynamic equilibrium relationship, that is to say in the supply chain with multiple members participating in, each member would choose a mutual cooperation behavior which is the best to the entire supply chain development and establish a dynamic balance with friendly and cooperative relations [3]. There are many factors that affect the stability of the supply chain, in which how to measure each point’s contribution rate to stability from multiple dimensions is the key to the overall stability of structure in supply chain. For instance, at the beginning of 2015 Xinjiang Guannong Fruit & Antler Group Co. Ltd and S.F. Express jointly build characteristics of agricultural supply chain by the O2O mode [4]. However how to stabilize this product supply chain and achieve a reasonable distribution of benefits is an urgent problem.

This paper analyzed the Shapley value model of partner benefit distribution proposed by Shapley [5], and applied this model to solve problems about the distribution of benefits in the agricultural green supply chain. However, Shapley value does not consider the overall stability of the supply chain. Therefore, in this paper we considered the various factors affecting stability and determined the contribution factor of each link point by analytic hierarchy process (AHP), then adjusted the weights on the benefit distribution. And finally, a modified benefit distribution model of the agricultural products green supply chain systems is built.

2 Methodology and Model

2.1 The Model of Shapley Value

Shapley value is a mathematical method given by Shapley. Using an axioma-tic approach, Shapley constructed a solution remarkable not only for its charismatic and insightful definition, but also for its unique characterization by a set of reasonable axioms. In the Shapley value, the profit for each player is the sum of the products of their marginal contributions in a given coalition and the probability of that coalition occurring over all permutations [6]. When there are n players engaging in an economic activity, each form of cooperation combined by a number of players will get certain benefits. And when the interest's activities between players are nonconfrontational, the increasing of player in cooperation does not cause reduction in benefits which will bring about the greatest benefits. Shapley value is a kind of scheme to assign the maximum benefit.

Shapley model considered cooperative games in characteristic function form (now sometimes also called "coalitional form") defined by a finite set $I = \{1, 2, \ldots, n\}$ of players, and a real-valued "characteristic function", defined on all subsets of I.

$$v(\Phi) = 0, \tag{1}$$

$$v(s_1 \cup x_2) \geq v(s_1) + v(s_2), s_1 \cap s_2 = \Phi. \tag{2}$$

The interpretation of v is that for any subset s of I the number $v(s)$ is the worth of the coalition. If s_1 and s_2 are two disjoint subsets of I , then the worth of the coalition $s_1 \cup x_2$ in Eq. (2) is equal to at least the worth of its parts acting separately.

We assume x_i represents the sharing which the player i in I got from the maximum benefit function $v(I)$. On the basis of cooperation, the sharing of cooperative games is denoted by $x = (x_1, x_2, \ldots, x_n)$. Clearly, a successful cooperation must satisfy the following conditions:

$$\sum_{i=1}^{n} x_i = v(I), i = 1, 2, \ldots, n, \tag{3}$$

$$x_i \geq v(i), i = 1, 2, \ldots, n. \tag{4}$$

$\phi_i(v)$ denotes the sharing of player i under the cooperation I. The Shapley value of every player in cooperation is:

$$\Phi(v) = (\phi_1(v), \phi_2(v), \ldots, \phi_n(v)),$$

$$\phi_i(v) = \sum_{s \subset S_i} (|s|)\,[v(s) - v(s \backslash i)], \quad i = 1, 2, \ldots, n, \tag{5}$$

$$w(|s|) = \frac{(n - |s|)!(|s| - 1)!}{n!}, \tag{6}$$

where s_i represents all subsets containing the member i in set I, $|s|$ denotes the number of elements in the subset s, $w(|s|)$ denotes a weighting factor, $v(s)$ represents benefit of the subset s, and $v(s\backslash i)$ denotes the benefit gaining by the subset s in removal of the player i. Based on the model above, it is easily to obtain answers of the benefit distribution.

2.2 The Modified Shapley Value in Agricultural Products Green Supply Chain

In the above benefit distribution of the agricultural products supply chain, it only considers the common benefit contribution rate of manufacturers, suppliers, distributors and does not take the stability into consideration. Shapley value assumes that the members of the supply chain have a equal contribution rate for the overall stability in the model. That is, for members' set $I = \{1, 2, \ldots, n\}$ of the agricultural products' supply chain, the contribution rate of each member for stabilizing the supply chain are: $\bar{R} = \frac{1}{n}$. Obviously, this is an ideal situation. Benefit distributed in this way, members in supply chain will only consider their own benefit in cooperation.

However, there are also improvement of the interest allocation with the Shapley value. For example, Shapley value does not consider the stable problem of the entire agricultural supply chain. Cooperative coordination among members in the supply chain, market competition, co-intimacy and other factors will have impacts on the healthy and stable development of the supply chain. Therefore, it is necessary to study the stability of the supply chain of agricultural products.

In this paper we mainly studied the benefit distribution of green supply chain. The green supply chain is a stable and sustainable supply chain in which the impact of each member on the stability of the entire supply chain is different. So, we need to make certain correction of Shapley value in line with the requirements of green supply chain.

In order to ensure the sustainable development of the agricultural products supply chain, we introduce the contribution rate of stability to correct benefit distribution of partners. The contribution rate of stability is a concept which was introduced into the supply chain to represent everyone's contribution rate for the stability in n-person games. Considering the contribution rate while allocating the benefit of each member which will promote members' effort to maintain the stability of the supply chain.

2.3 AHP

It can be found easily that there are many factors which can affect the stability of cooperation from different angel. Each factor has different influence degree. Those factors can be roughly divided into several dimensions, and each dimension can be evaluated by several elements. We calculated the members' contribution rate of stability by simple and effective Analytic Hierarchy Process (AHP). AHP provides a methodology to calibrate the numeric scale for the measurement of quantitative as well as qualitative performances [7]. Based on the results of the contribution rate, we can adjust the benefit distribution weights got by the Shapley value.

Basic steps involved in this AHP are as follows:

Step 1. Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

Step 2. Compare each element in the corresponding level, then determine the matrix of pairwise comparisons. $u_i, u_j (i, j = 1, 2, 3, \ldots, m)$ represent the m factors, denotes the relative importance of u_i on u_j. The matrix of pairwise comparisons P (judgement matrix) is determined by u_{ij}:

$$P = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1m} \\ u_{21} & u_{22} & \cdots & u_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ u_{m1} & u_{m2} & \cdots & u_{mm} \end{bmatrix}.$$

Step 3. Perform calculations to find the maximum eigen value $\lambda_{\max}$ of the judgement matrix, and then calculate the eigenvector w corresponding to eigen value $\lambda_{\max}$.

Step 4. Measure the consistency of the judgments and normalize values for each criteria/alternative. Whether the distribution of weight is reasonable still should be measured by $CR = {}^{CI}\!/_{RI}$. Where CR denotes the consistency ratio of the judgement matrix, RI represents the random consistency index of the judgement matrix, CI denotes the consistency index of the judgement matrix, and $CI = \frac{\lambda_{\max} - m}{m-1}$.

When the CR is less than 0.1, we can think that P owns the consistency with satisfaction.

Step 5. If the maximum Eigen value, CI, and CR are satisfactory then decision is taken based on the normalized values; else the procedure is repeated till these values lie in a desired range.

After getting the normalized values, the weight of all factors on the contribution to stability is obtained. Let k_j be the weight of the jth factor to the stability and x_{ij} be the score of the ith member on jth factor, the contribution rate of stability of player i names w_i. In that way, the contribution rate of stability is:

$$w_i = \sum_{j=1}^{m} k_j x_{ij} (i = 1, 2, \ldots, n \quad j = 1, 2, \ldots, m).$$

3 Application

3.1 An Example of Shapley Value in Agricultural Supply Chain

In the agricultural supply chain, in order to maximize economic benefits, independent manufacturers, suppliers and distributors integrate their core competence. Therefore, the agricultural supply chain can be regarded as the benefit distribution problem of multi-person cooperative, which can be solved by Shapley value.

According to the news reported by Tianshan net, Xinjiang Guannong Fruit & Antler Group Co. Ltd and S.F. Express jointly build special agricultural supply chain by the O2O mode. We assume the farmers as manufacturers, Guannong Fruit & Antler Group Co. Ltd as suppliers, and distributors is S.F. Express. It makes a green supply chain of characteristic agricultural products, and constitutes a "three points on one line" supply pattern. Suppose manufacturers, suppliers, distributors as three members A, B, C, if they worked on one's alone, each member can get a profit of 100,000 yuan. If A, B combined, they can get 700,000 yuan. If A, C jointed, a profit of 50 million can be got. If B, C cooperated, then 400,000 yuan can be created. If A, B, C jointed, they can gain one million yuan.

If divided equally, each member shares 333,000 yuan, this sharing scheme can not promote the circulation of agricultural supply chain. Because A, B considered the total benefit 666,000 yuan was less than the benefit of A, B combined, and then they less inclined to join the supply chain. So, how to allocate the one million yuan reasonable? Consider the Shapley value to solve this problem.

We denote the cooperation of three members A, B, C as I = 1, 2, 3, the individual benefit is 100,000 yuan, find all forms of cooperation that A participating in: $S_1 = \{1, 1\cup 2, 1\cup 3, 1\cup 2\cup 3\}$. According to the above conditions, $\Phi(v)$ can be evaluated in the light of Shapley value. The benefit distribution $\Phi_1(v)$ of member A in agricultural supply chain is shown in Table 1.

From the last line of Table 1, $\Phi_1(v) = 400{,}000$ yuan. Similarly, $\Phi_2(v) = 350{,}000$ yuan, and $\Phi_3(v) = 250{,}000$ yuan. It is easy to verify that $\Phi_1(v) + \Phi_2(v) + \Phi_3(v) =$

Table 1 The benefit distribution $\Phi_1(v)$ of member A in agricultural supply-chain

S_1	1	$1 \cup 2$	$1 \cup 3$	$1 \cup 2 \cup 3$
v_s	100,000	700,000	500,000	100,000
$v_(s/1)$	0	100,000	100,000	400,000
v_s-$v_(s/1)$	100,000	600,000	400,000	600,000
$\|s\|$	1	2	2	3
$w(\|s\|)$	1/3	1/6	1/6	1/3
$w(\|s\|)[v(s) - v(s/1)]$	100,000/3	100,000	200,000/3	200,000

1,000,000 yuan, and $\Phi_1(v), \Phi_2(v), \Phi_3(v) > 100{,}000$ yuan, $\Phi_1(v)+\Phi_2(v) > 700{,}000$ yuan, $\Phi_1(v)+\Phi_3(v) > 500{,}000$ yuan and $\Phi_2(v)+\Phi_3(v) > 400{,}000$ yuan. Therefore, while the three members cooperate with each other to construct the agricultural supply chain, the profits they got are greater than the separate manufacture produced, and are also greater than the pairwise cooperation benefits.

3.2 Result Analysis

It can be seen from the above example, B combining with C get 400,000 yuan profit, B and A get profit of 700,000 yuan, from which we can learn A is stronger than C in bring benefit to B. Clearly, the income distribution of A should be larger than others from the one million yuan profit cooperation, which matches the result of Shapley value that 400,000 yuan is for A, then B, C corresponding to 350000, 250000 yuan. It reflected the importance of A for obtaining benefit in agricultural supply chain.

As can be seen, the benefit distribution of agricultural supply chain with Shapley value avoids unfair distribution model. Besides, it can improve the utilization of resources and achieve to maximize the entire value of agricultural supply chain.

3.3 Application of the Modified Shapley Value Based on the Contribution Rate

Assume the influence on the stability in the supply chain of agricultural products are mainly quantified from three dimensions with 9 different factors. The scheme for the correction process of Shapley value was given out in Fig. 1

These factors are denoted by $x_1, x_2, \ldots, x_9$ and the judgment matrix of related 9 factors is:

$$P = \begin{bmatrix} 1 & 2 & 2 & 3 & 4 & 5 & 5 & 1/3 & 6 \\ 1/2 & 1 & 2 & 2 & 3 & 3 & 4 & 1/3 & 4 \\ 1/2 & 1/2 & 1 & 1 & 2 & 2 & 4 & 1/4 & 4 \\ 1/3 & 1/2 & 1 & 1 & 3 & 2 & 2 & 1/4 & 3 \\ 1/4 & 1/3 & 1/2 & 1/3 & 1 & 2 & 3 & 1/5 & 3 \\ 1/5 & 1/3 & 1/2 & 1/2 & 1/2 & 1 & 3 & 1/5 & 3 \\ 1/5 & 1/4 & 1/4 & 1/2 & 1/3 & 1/3 & 1 & 1/6 & 2 \\ 2 & 3 & 4 & 4 & 5 & 5 & 6 & 1 & 5 \\ 1/6 & 1/4 & 1/4 & 1/4 & 1/3 & 1/3 & 1/2 & 1/5 & 1 \end{bmatrix}.$$

Applying the hierarchy analysis, we got the weights of nine factors. The results are shown in Table 2.

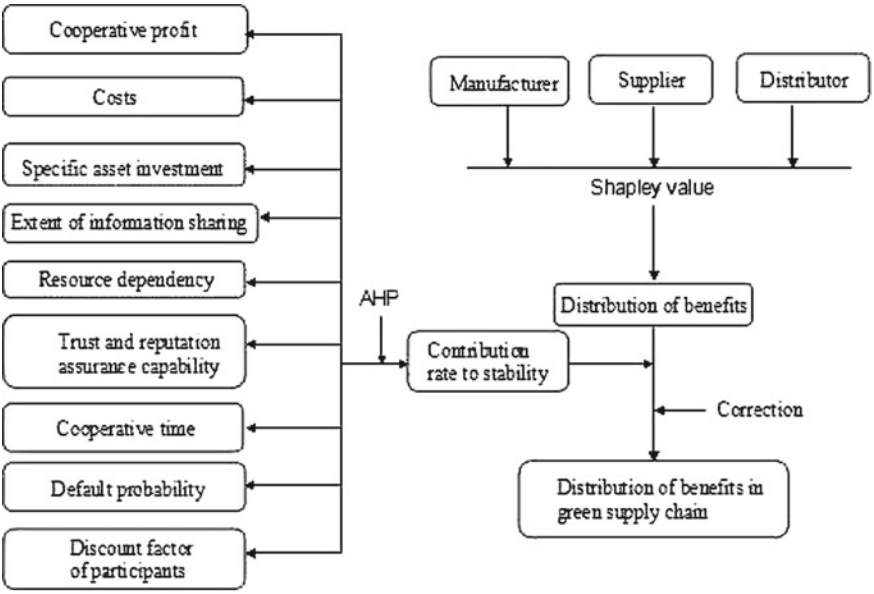

Fig. 1 The correction process of Shapley value

Table 2 Three dimensions, nine factors and their weights

Dimension	Factor	Weight
Competitiveness	Cooperative profit	365/1777
	Costs	579/4198
	Specific asset investment	121/1259
Coordination	Extent of information sharing	402/4517
	Resource dependency	597/9596
	Trust and reputation assurance capability	218/4059
Intimacy	Cooperative time	202/5953
	Default probability	665/2258
	Discount factor of participants	53/1948

Through expert evaluating method we determined three members' scores in nine factors in the supply chain. The scores are shown in Table 3.

Finally, We use the above results to calculate the contribution rate of stability w_i. After calculating the weight sum, we obtain the following results:

$$w_A = \sum_{j=1}^{9} k_j x_{Aj} = \frac{124}{401}, \quad w_B = \sum_{j=1}^{9} k_j x_{Bj} = \frac{133}{428}, \quad w_C = \sum_{j=1}^{9} k_j x_{Cj} = \frac{293}{771}.$$

Table 3 The scores of A, B, C

Factors	A	B	C
Cooperative profit	0.3641	0.3307	0.3052
Costs	0.3198	0.2185	0.4617
Specific asset investment	0.2186	0.571	0.2104
Extent of information sharing	0.519	0.2353	0.2457
Resource dependency	0.283	0.106	0.611
Trust and reputation assurance capability	0.3113	0.223	0.4657
Cooperative time	0.2262	0.454	0.3198
Default probability	0.2526	0.324	0.4234
Discount factor of participants	0.2477	0.2745	0.4778

According to the analysis above, the overall benefit of cooperation is $v(I)$. $v(i)$ denotes the benefit of the ith member, the difference between W_i and the average contribution rate is $\Delta w_i = w_i - \frac{1}{n}$. Thus, the modified benefit value by Δw_i is $\Delta v_i = v(I) \times \Delta w_i$.

Finally, the actual distribution value of benefit is $v(i)' = v(i) + \Delta v(i)$.

The specific correction process is as follows:

When $\Delta w_i \geq 0$, it indicates the member owns a higher contribution rate than the average value for the overall stability of the supply chain. So, more benefit should be given to the member so as to encourage members to continue maintaining the whole supply chain's stability. At this time, the added benefit value is $\Delta v_i = v(I) \times \Delta w_i$ and the actual value of the benefit sharing is $v(i)' = v(i) + \Delta v(i)$.

When $\Delta w_i \leq 0$, it indicates that the contribution rate of the member done for the supply chain's stability is less than the average. This means that the members have not done enough contribution to the cooperation's green development. In this situation, penalty should be given when benefit was allocated. The reduced interest is $\Delta v(i) = v(I) \times |\Delta w_i|$. And the actual value of the benefits sharing is $v(i)' = v(i) + \Delta v(i)$.

Obviously, there has:

$$\sum_{i=1}^{n} v(i)' = \sum_{i=1}^{n} [v(i) + v(I) \times \Delta w_i] = \sum_{i=1}^{n} \left[v(i) + v(I) \times \sum_{i=1}^{n} \Delta w_i \right]$$
$$= \sum_{i=1}^{n} v(i) = v(I).$$

Table 4 The final and initial distribution of benefit

	Manufacturer A	Supplier B	Distributor C
The initial distribution of benefit	40	35	25
The final distribution of benefit	4345/112	3929/116	7107/260

In the example above, when the data is taken into the process of amendment, the final distribution of benefits can be obtained (with the initial distribution of benefits) in Table 4.

By this modification method, profit allocation of supply chain members will be closely related to their contribution to the stability of the supply chain. In this way, we can encourage members of the agricultural products supply chain to maintain the stability and sustainable development by active and effective cooperation. Also it can make Chinese agricultural products supply chain toward the direction of the green supply chain, and ensure stable and rich living of Chinese residents.

4 Conclusions

Benefits distribution of agricultural supply-chain is a complex issue, this paper has a research on benefits distribution of the supply chain based on the existing data. In other words, we have already known the profit among members of various combinations, by these specific data to learn the status of each member in the supply chain, accordingly determined the distribution weights of benefits. In the improved model, if there are some difficulties in getting data in real life, it can consider to compare various factor indicators influencing the members' status by the method of fuzzy mathematics, neural networks and AHP, and then get the required data of Shapley value for the benefits distribution. After obtaining the results of benefits distribution, each member's contribution rate for stability can be analyzed by the AHP method. Next, the benefits distribution can be modified based on the contribution rate, and eventually a more stable and effective agricultural products green supply chain are constructed.

Agricultural products green supply chain is the key to solve space-time contradiction between agricultural production and agricultural products consumption. In order to achieve stable cooperation of supply chain members and efficient allocation of interest, it is necessary to have a research on the stability of agricultural supply chain. In modern society, this benefit distribution modification method based on the stability of supply chain is not only suitable for the circulation of agricultural products, and effective circulation in the logistics, information flow, many supply chain flow of funds should have the stability guarantee.

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Multi-Mode Discrete Time-Cost-Environment Trade-Off Problem of Construction Systems for Large-Scale Hydroelectric Projects

Huan Zheng

Abstract This paper presents a multi-mode discrete time-cost-environment trade-off problem of construction systems for large scale hydroelectric projects. The objective functions are to minimize the total project cost, project duration, crashing cost, and environmental impact. Furthermore, an adaptive-hybrid genetic algorithm is developed for finding feasible solutions. The one-point crossover and repairing strategy for mutation are designed to avoid infeasible solutions. Finally, the Jinping-II Hydroelectric Project is used as a practical example to demonstrate the practicality and efficiency of the model. Results and sensitivity analysis are presented to highlight the performances of the optimization method, which is very effective and efficient as compared to other algorithms.

Keywords Time-cost-environment · Trade-off · Construction project · Genetic algorithm

1 Introduction

This paper focuses on the multi-mode discrete time-cost-environment trade-off problem (M-DTCETP) in Jinping-II Hydroelectric Project for minimizing the total project cost, project duration, crashing cost, and environmental impact. The discrete time-cost trade-off problem (DTCTP), which was introduced by Harvey and Patterson [1] and Hindelang and Muth [2], is an important subject in the project scheduling theory and applications. Every activity can be executed in the crashing way in which the project direct costs are used to shorten the activity duration. The crashing duration of activities was introduced to DTCTP [3], where the duration/cost of an activity is determined by the mode selection and the duration reduction (crashing) applied within the selected mode. This leads to a multi-mode DTCTP. Recently, construction has been

H. Zheng (✉)
School of Administration, Chongqing Technique and Business University, Chongqing 400067, People's Republic of China
e-mail: huanhuanzheng@163.com

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accused of causing environmental problems ranging from excessive consumption of global resources both in terms of construction and operation to the pollution of the surrounding environment [4]. In particular, hydroelectric project is regarded as one of the most critical factors contributing to changes of river environment [5], in which eco-environmental impact may arise during all project phases [6]. In this paper, it is suggested that the environment of a construction project may be affected by mode selection. As such, in expedition of a hydroelectric project, its environmental impact should be taken into consideration along with the time and cost trade-offs.

Therefore, this paper considers that construction managers need to develop a project management decision for directing and controlling the total project duration, project costs, and environmental impact in a construction projects in order to achieve management objectives. This leads to a multi-mode discrete time-cost-environment trade-off problem (M-DTCETP), which is an extension of DTCTP. In this paper, the four objectives of the M-DTCETP are considered: (1) minimization of the total project cost; (2) minimization of the total project duration; (3) minimization of the total crashing cost; (4) minimization of the environmental impact.

This paper will effectively solve the M-DTCETP. The remainder of this paper is organized as follows: In Sect. 2, a multi-objective M-DTCETP is described, and assumptions and notation are also presented for this problem. A multi-objective optimization model is then proposed for the M-DTCETP. In Sect. 3, we propose an a-hGA for solving the problem in construction projects. Sect. 4 involves a case study regarding the works of construction systems for large-scale hydroelectric projects. Finally, concluding remarks and future research are outlined.

2 Problem Description and Mathematical Formulation Model

2.1 Problem Description

This paper considers the problem in large construction projects, especially for large scale hydroelectric projects. Assume that the interrelated activities must be executed in a certain order before the entire task can be completed. This study focuses on developing an a-hGA technique to optimize the starting time and crashing time of each activity in the project with fixed costs, variable costs and the constraints of total budget. The multi-objective optimization model designed in this study aims to simultaneously minimize total project costs, project duration, crashing costs, and environmental impact.

2.2 Assumptions

To model the time-cost-environment trade-off of construction systems for large-scale hydroelectric projects in this paper, assumptions are as follows:

(1) A single project consists of a number of activities, and the minimum crashed duration is known [7, 8].
(2) The fixed cost, unit variable cost, and the unit crashing cost of each activity are known.
(3) Capital used by all activities does not exceed limited quantities in any time period, and the total project budget is within deterministic limit.
(4) The starting time of each activity is dependent upon the completion of its predecessor.
(5) Alterable costs increase linearly with the duration of each activity which is reduced from its normal duration to its crashed duration.
(6) The total project cost can be divided into fixed cost and variable cost and crashing cost. The unit variable cost keeps the same value during the whole activity duration.
(7) When an activity is beginning, it cannot be interrupted.
(8) Managerial objectives are to minimize the total project cost, project duration, crashing cost, and environmental impact.
(9) The decision maker takes a compromise attitude to risk.

Based upon the assumptions above, we propose a model of multiple objective M-DTCETP for construction systems.

2.3 Model Formulation

The problem is represented on an activity-on-node (AON) network with a single starting and a single ending node both corresponding to dummy activities. The following notation is used.
Index:

i: index of activity in a project, where $i = 1, 2, \ldots, I$,
j: index of mode for crashing time, where $j = 1, 2, \ldots, m_i$,
p: index of Score for environmental impact of each activity,
t: index of time period in a project, where $t = 1, 2, \ldots, ceil(T_I)$.

Certain Parameters:

B: available total budget,
C_{a_i}: unit variable cost of Activity i,
$ceil(\cdot)$: take $\cdot$ up to the nearest the integer,
C_{f_i}: fixed cost of Activity i,

$d_i^{\min}$: minimum crashed duration of Activity i,
k_i : incremental crashing cost of Activity i,
l: maximum capital used by all activities in any time period,

m_i: number of possible modes of Activity i,
$Pre(i)$: set of the immediate predecessors of Activity i,
$Q_{i,p}^{j}$: score p of environmental impact in Activity i using the jth crashing mode,
w_i: weight of Activity i compared to other activities in the project,
$w_{i,p}^{j}$: weight of Score p of environmental impact in Activity i using the jth crashing mode,
D_i: normal duration of Activity i,
d_i: crashed duration of Activity i,
T_i: earliest starting time of Activity i,
T_1 : project starting time,
T_{I+1}: project completion time,
$T_{(I+1)c}$: project completion time under normal conditions,
T: specified project completion time.

Decision variables:

Y_i : crashing time of Activity i.

$$x_{ijt} = \begin{cases} 1, \text{ if Activity } i \text{ in mode } j \text{ scheduled in time } t \\ 0, \text{ otherwise.} \end{cases}$$

The decision variable Y_i is to confirm the finishing time of the current activity with the certain crashing time. The decision variable x_{ijt} decides whether current activity scheduled in this certain time or not.

Functions:

z_1: total project cost,
z_2: total project duration,
z_3: total crashing cost,
z_4: total environmental impact.

2.4 Multi-Objective Model

Based on the requirement of the manager's objectives for the project, an optimization model is proposed to solve it. The following subsections in this paper explain the multi-objective model in details with objectives and constraints separately in order to illustrate the model more clearly.

(1) Objective Functions

The presented optimization model is formulated in order to provide the capability of minimizing project time and cost, while minimizing its environmental impact. To this end, the model incorporates four major objective functions as shown in the following four equations to enable the evaluation of the performance in project time, cost, and environment, respectively.

Usually total project cost changes along with many factors, such as fixed cost, duration, and crashing time decision of each activity. Therefore, the decision makers aim at achieving the best option of executing the process for which the total project cost is minimal. The total project cost is calculated by the sum of fixed cost, variable cost, and crashing cost of each activity. It is denoted that the total of fixed cost of Activity i + unit variable cost of Activity i × duration of Activity i in a certain executed crashing mode as shown in the Eq. (1). The first objective is to minimize the expected total project cost, which is the minimization the sum of the completion cost for all activities.

$$\min z_1 = \sum_i C_{f_i} + d_i C_{a_i} + \sum_i k_i Y_i. \tag{1}$$

The second objective seeks to minimize the total project duration, which is the makespan between the project starting time and project completion time. It is also the minimization the sum of the duration for all activities.

$$\min z_2 = T_{I+1} - T_1. \tag{2}$$

The third objective is to minimize total crashing cost as follows. It indicates that we should minimize the crashing cost for each activity as much as possible. As is generally known, decision makers confirm an expected duration of each activity beforehand to coordinate many factors. In practical implementation, if the activity finishes too short, it would cause additional costs, unexpected change to environment or leading to punish cost. Thus, crashing cost should be minimize individual although the existence of the first objective [5].

$$\min z_3 = \sum_i k_i Y_i. \tag{3}$$

The fourth objective minimize environmental impact that is measured and quantified. It enables the aggregation of the estimated environmental impact for all the considered activities to provide an overall environmental impact at the project level using a simple weighted approach.

$$\min z_4 = \sum_i w_i \sum_p w_{i,p}^j \times Q_{i,p}^j. \tag{4}$$

(2) Constraints

Precedence constraint: In project, precedence is an important basic term ensuring the rationality of the arrangement. Under this term, successive activities must be and can only be started with a certain crashing time option when all the predecessors have already been completed. Therefore, it is used for Activity i considering its immediate Predecessor e, one by one, here, the index $e \in Pre(i)$, where $Pre(i)$ is the set of the immediate predecessors of Activity i. And the relationship among the starting time and duration of Predecessor e and the starting time of Activity i should be the starting time of Predecessor $e+$ the duration of Predecessor $e-$ the starting time of Activity $i \leq 0$.

All of the predecessors of Activity i in the precedence constraint should be ensured that none of the precedence constraints are violated as shown in Eq. (5).

$$T_e + d_e - T_i \leq 0, \ \forall e \in Pre(i), \tag{5}$$

where $i = 1, 2, \ldots, I$.

Crashing time constraint: The crashed duration is equal to the normal duration of Activity i minus its crashing time. That is shown in Eq. (6).

$$d_i = D_i - Y_i. \tag{6}$$

On the other hand, it is that the crashing time cannot exceed the difference between normal duration and minimum crashed duration of Activity i.

$$Y_i \leq D_i - d_i^{\min}. \tag{7}$$

Total budget constraint: It is also basic and important for project to limit the total capital within deterministic limit (i.e., B) used by the project. The range of total project cost is between its normal cost and its crashed total cost during the project execution. The following equations can be used to describe the sum of the capital of the project which are in certain crashing time options in Eq. (8).

$$z_1 \leq B. \tag{8}$$

Logical constraints: In order to describe some non-negative variables and 0–1 variables in the model for practical situation, the constraints in Eqs. (9) and (10) are presented.

$$D_i, d_i, Y_i, T_i, T \geq 0, \tag{9}$$

$$x_{ijt} = 0 \text{ or } 1, \tag{10}$$

where $i = 1, 2, \ldots, I$, $j = 1, 2, \ldots, m_i$, $t = 1, 2, \ldots, ceil(T_I)$.

Cash flow constraint: The sum of total fixed cost, variable cost, and crashing cost of the activities that are scheduled in time period t cannot exceed the capital limit per time period. The sum of the capital of the activities which are scheduled in a certain time period during the whole project duration, as well as in a certain crashing time option is shown in Eq. (11).

$$\sum_i \frac{(C_{f_i} + d_i C_{a_i} + k_i Y_i)}{d_i} x_{ijt} < l, \ t = 1, 2 \ldots, ceil(T_I), \ j = 1, 2, \ldots, m_i. \tag{11}$$

Duration constraint: As is generally known, the decision makers should confirm the project duration beforehand to coordinate the parallel projects or other resources. Certainly, the duration are determined by the decision makers based on their accumulated work experience regarding to the appropriate finishing time of activities. So it can not exceed the project completion time which is shown in Eq. (12).

$$T_{I+1} \leq T. \tag{12}$$

Based on the above discussion, by integrating Eqs. (1)–(12), the mathematical model of M-DTCETP of construction systems for large-scale hydroelectric projects could be stated as follows:

$$\begin{cases} \min z_1 = \sum_i (C_{f_i} + d_i C_{a_i}) + \sum_i k_i Y_i \\ \min z_2 = T_{I+1} - T_1 \\ \min z_3 = \sum_i k_i Y_i \\ \min z_4 = \sum_i w_i \sum_p w_{i,p}^j \times Q_{i,p}^j \\ s.t. \begin{cases} T_e + d_e - T_i \leq 0, \forall i \\ d_i = D_i - Y_i, \forall i \\ Y_i \leq D_i - d_i^{\min}, \forall i \\ z_1 \leq B, \forall i \\ D_i, d_i, Y_i, T_i, T \geq 0, \forall i \\ x_{ijt} = 0 \text{ or } 1,\ i = 1, 2, \ldots, I,\ j = 1, 2, \ldots, m_i,\ t = 1, 2, \ldots, ceil(T_I) \\ T_{I+1} \leq T \\ \sum_i \frac{(C_{f_i} + d_i C_{a_i} + k_i Y_i)}{d_i} x_{ijt} < l,\ t = 1, 2 \ldots, T_I. \end{cases} \end{cases} \tag{13}$$

3 Multi-Mode Discrete Time-Cost-Environment Trade-Off Problem Via Adaptive Hybrid Genetic Algorithm

For the multi-objective model we formulated above, it is possible to find several Pareto optimal solutions for the problem. However, in construction project practice, only exact one optimized solution could conduct the decision-making in pressing situation. Thus, the weighting method is applied to transform the multi-objective model into a single-objective one.

The proposed method in this paper is an originality being from the combination of those methods referred above.

In the method of this paper, firstly, the weight-sum procedure is used to concentrate multiple objectives in management practice so as to reflect the importance of each objective in the construction manager's mind. Secondly, priority-based encoding is introduced for activity priority, and multistage-based encoding for activity crashed time for GA encoding, with corresponding GA decoding and GA evaluation proposed by Gen. Aiming at the above GA, the one-point crossover operator for activity and a repairing strategy for mutation operator for activity crashed time is adopted. Finally the iterative hill climbing routine and adaptive regulation mechanism are introduced to carry out searches around a convergence solution in the GA loop and to get the faster algorithm convergence. In this study, the objectives of this approach is to minimize the makespan and cost and minimize the environmental impact while the precedence constrained are satisfied.

4 Case Study: The Time-Cost-Environment Trade-Off for Jinping-II Hydroelectric Project

This section is the practical application to a working procedure at a large-scale hydroelectric construction project. The procedure contains eleven activities and two dummy activities (start and end activity). Each activity has certain maximal crashing time limit.

(1) Presentation of the Case Problem
We introduced the above data obtained from Jinping-II hydroelectric project of Ertan hydropower development company into the proposed model, and got the project scheduling model for this project. Project scheduling is one of the basic tasks in managing most of their construction projects. For important strategy meaning of a large-scale hydroelectric construction project, more effective and viable methods of project management are required. It is current and the information can also be used widely in similar projects (Fig. 1).

To optimize all aspects of the project, we want to pursue management objectives through a better arrangement of activity sequences and crashing time. The proposed model and method is used to help the project manager optimally schedule the construction. The project has 10 activities from preliminary work to clearing up and finishing work. Each of these has certain predecessors, successors, and normal finishing

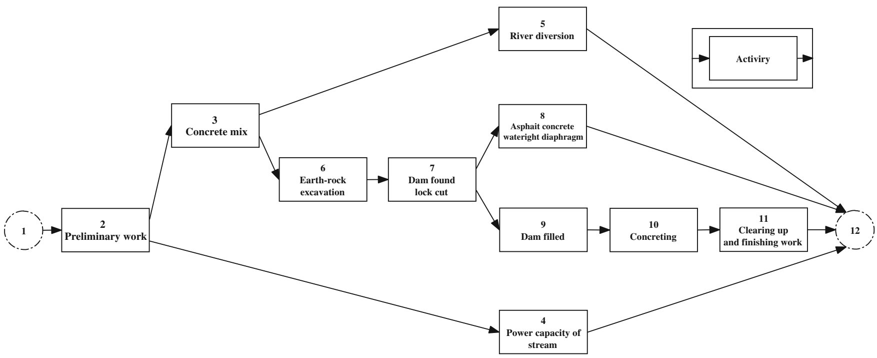

Fig. 1 Configuration of the construction project

time according to the construction managers. Here, the company traditionally uses the month as a time unit (i.e. 1 month per unit). Two dummy activities were set up to help for the convenience of the model.

Based on the representation of the case problem, the proposed methods can be used to model it in Eq. (13) and obtain the project scheduling model for our project.

Other relevant data are as follows: total budget is 534, maximum amount of capital is 25 unite for each period, project completion duration under normal condition 87 months and decision maker expected project completion duration below 92 months. The duration of each activity is as follows: $D_1 = 0$, $D_2 = 13$, $D_3 = 6$, $D_4 = 9$, $D_5 = 18$, $D_6 = 13$, $D_7 = 10$, $D_8 = 8$, $D_9 = 7$, $D_{10} = 6$, $D_{11} = 8$, $D_{12} = 0$.

(2) Result of the Case Problem

The parameters of the computation for the problem was set as follows:

Based on the above model, we uses the proposed (f)a-hGA using Visual C++ language and run on Pentium 4, 2.40 GHz clock pulse with 1024 MB memory, and tested the performance of this method with the actual data obtained from the above project.

The evolutionary parameters for the problem was set as follows: *pop*_size was 20, the rate of crossover and mutation is 0.6 and 0.1 respectively, max _generation was 200, the optimistic-pessimistic parameter is $\lambda = 0.5$, and the expected value of specified project completion time is 40.

The results are shown in Table 1, which are obtained based on the following parameter values, i.e., $\eta_1 = 0.2$, $\eta_2 = 0.4$, $\eta_3 = 0.1$, $\eta_4 = 0.3$. It should be noted that the results are obtained based on the following optimistic-pessimistic index, i.e., $\lambda = 0.5$. Using the chromosome illustrated above, we obtain Table 2.

The detailed results are shown in Table 1, with the dummy activities not included. When the weight-sum procedures are used to deal with multiple objectives, equivalent treatment is proposed to obtain the fitness of each chromosome.

The above strategy is offered for the project, that is: arrange the activities in the order proposed in Table 2, and choose the corresponding crashing time in accordance with the required certain processing time and given budget which results in the decision-maker satisfied.

Table 1 Optimal solution for $\lambda = 0.5$, $\eta_1 = 0.2$, $\eta_2 = 0.4$, $\eta_3 = 0.1$, $\eta_4 = 0.3$

$z_1 = 525$	$Y_2 = 5, Y_3 = 0, Y_4 = 0, Y_5 = 0, Y_6 = 2$
$z_2 = 76$	$Y_7 = 0, Y_8 = 0, Y_9 = 0, Y_{10} = 0, Y_{11} = 0$
$z_3 = 9.2$	$t_2 = 18, t_3 = 4, t_4 = 7, t_5 = 17, t_6 = 24$
$z_4 = 190$	$t_7 = 10, t_8 = 8, t_9 = 6, t_{10} = 6, t_{11} = 7$

Table 2 Schedule for the M-DTCETP in Jinping-II Hydroelectric Project

$a_1(0) : 0–0$	$a_2(8) : 0–17$	$a_3(0) : 17–23$	$a_4(0) : 17–26$	$a_6(2) : 22–47$	$a_5(0) : 26–44$
$a_7(0) : 46–57$	$a_9(0) : 5–62$	$a_{10}(0) : 62–68$	$a_8(0) : 62–71$	$a_{11}(0) : 68–76$	$a_{12}(0) : 76–76$

Considering a given budget, with regard to the number of activities and the corresponding crashing time within a certain process time and the project duration, total crashing cost and environmental impact are often conflicting. The best way to handle multi-objective optimization is to keep dependent on the decision-maker's objective. Generally, the solution to this problem is a balance of multiple objectives.

5 Conclusion

In this paper, the proposed time-cost-environment trade-off model attempts to minimize total project costs, total completion time, total crashing costs and the environmental impact with reference to fix costs, variable costs, crashing costs, duration of activities, the constraint of capital limit per unit time and total budget. The main advantage of the proposed method is that it provides a systematic workable method for the problem that facilitates the decision-making process. We have applied the model to construction systems for large-scale hydroelectric projects (Jinping-II) in the southwest region of China.

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Airline Planning Modelling-Based Carbon Taxes Setting Problem Under Changing Transportation Environment

Rui Qiu, Xiaoling Song and Lin Zhong

Abstract This paper discusses a carbon tax setting problem from an airline's perspective under a fuzzy environment, which is a multi-objective optimization process. Uncertain parameters are depicted as fuzzy variables and fuzzy expected value notions are introduced to cope with the uncertainty. A fuzzy logic controlled genetic algorithm with entropy-Bolitzmann selection is designed as a combined solution method to solve the above problem. Finally, the results of a illustrative example for the carbon tax setting problem are proposed to show the practicality and efficiency of the optimization method.

Keywords Carbon tax · Multi-objective optimization · FLC-GA with EBS · Fuzzy environment

1 Introduction

Aviation alters the combinations of the atmosphere worldwidely and then makes climate change and ozone depletion. The Intergovernmental Panel on Climate Change (IPCC) made the last major international assessment of these influences in 1999. Lee et al. [1] provided a comprehensive updated assessment of aviation. Since the 1999 assessment, scientific advances have sharpened the quantitative evaluation, reducing key uncertainties, yet the basic conclusions maintain the same. Sufficient attentions are given to remain both in the field of the science and policy (mainly because of the historically staggering aviation growth rate and the truth that the Kyoto Protocol did not include the international aviation) over the potential importance of future aviation carbon emissions and their contribution to climate variation. Therefore, a further state-of-the-art assessment updating that was considered essential since many important literatures have been published.

R. Qiu (✉) · X. Song · L. Zhong
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: qiurui2015@163.com

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The European Commission suggested airline companies in emissions trading scheme as a measure to fight global warming by reducing CO_2 emissions in a 2006 proposal [2]. In addition, Alonso et al. [3] indicated that world aviation activities held approximately 3.5 % of anthropogenic global warming. Starting off with intra-European flights in 2011, airline companies are requested to maintain allowances for their CO_2 emissions. Non-European airline companies will be involved with their flights that run within and outside the European Union. In the proposal, the amount of allowances for the aviation industry is designed to stabilize emissions at 2005 levels. Airlines will get an initial quantity of allowances free of charge. However, they have to acquire extra allowances (most likely from other industries), in case they need more allowances. Simulations state that aircraft emissions in lack of any constraint will become one of the main CO_2 emissions wrapped by the European Union Emissions Trading Scheme [4].

This paper is structured as follows. Following the introduction, in Sect. 2, the key problem for the airline is described and the uncertain environment is defined. A multi-objective programming model for the carbon tax setting problem with uncertainty and the formulation of its equivalent crisp model for solving the problem is the scope of Sect. 3. In Sect. 4, we design a fuzzy logic controlled genetic algorithm with entropy-Bolitzmann selection is to solve the equivalent crisp model. The results and comparisons analysis of a numerical example are presented to demonstrate the practicality and efficiency of the optimization method in Sect. 5. In the final section, the conclusions and directions for future research are presented.

2 Key Problem Statement

The growth of global demand for aviation potentially conflicts with national and international emissions goals, unless cutbacks in aviation carbon emissions per passenger kilometer could be achieved [5, 6]. In the low-carbon air transportation system, the international organization makes the price of carbon tax for the airline firstly, and after knowing the price, the airline makes air fare and air route selecting decision under the low-carbon environment. The carbon tax price which international organization sets effects the decision of the airline. In the meantime, the total actual carbon emission of all flights must reach the carbon intensity target. Therefore, this is a process of interaction and can be summarized as a bi-level programming problem where the upper level being the international organization, and the lower level being the airline.

The need to address uncertainty in carbon tax setting problem is widely awaked, as uncertainties exist in all kinds of system components. For example, the passenger number of every flight is not fixed because of the influences of many uncertain elements. In the global aviation industry, where accurate statistical data are often effected by weather, temperature and location, it is proper for using fuzzy variables to model the statistical data and pilots' experience. In this study, because it is very

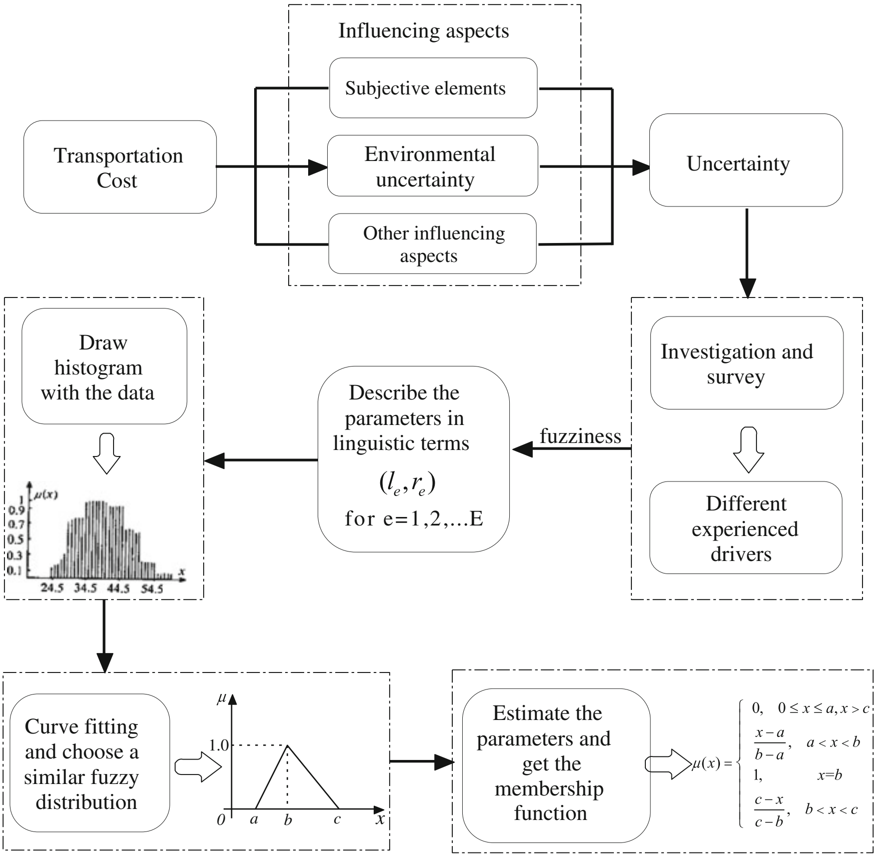

Fig. 1 Flow chart of uncertain approach to transportation cost

difficult to estimate the precise value of passenger number of every flight, with pilots giving a range, i.e., viz (a, b), as shown in Fig. 1.

3 Modelling

First, the assumptions are given, and then the relationship composed of the international organization and airline objectives and limits are formulated.
1. Problem Assumptions
The mathematical model represented has the following assumptions:

(1) The total flow of aviation aircrafts on each route cannot exceed its maximal passing capacity. All air routes are certain in the network.
(2) Neglecting congestion and assuming that demand is fixed, passengers are allotted to shortest paths from their departure to arrival nodes.

(3) The international organization which is mainly discussed sets the carbon tax, and others don't set it.
(4) Considering the transportation cost and carbon emissions of each flight as fuzzy variables, with attributes decided using statistical data and pilots' experience.

2. Notation

Index

i: index of node, where $i \in \Gamma = \{1, 2, \ldots, I\}$;
k: index of flight, where $k \in \Theta = \{1, 2, \ldots, K\}$;
a: index of arcs, $\mathscr{A}_1$ is set of carbon tax arcs, $\mathscr{A}_2$ is set of no carbon tax arcs; $a \in \mathscr{A} = \mathscr{A}_1 \cup \mathscr{A}_2 = \{1, 2, \ldots, m_1\} \cup \{m_1+1, m_1+2, \ldots, m_1+m_2\} = \{1, 2, \ldots, m\}$,
i^-: $\{(j, i) \in \mathscr{A} : j \in I\}$;
i^+: $\{(i, j) \in \mathscr{A} : j \in I\}$;

Parameters

I: number of nodes;
K: number of flights;
m: number of total arcs;
m_1: number of carbon tax arcs;
m_2: number of no carbon tax arcs;
h_a: regular tariff per unit of $a \in \mathscr{A}_1$;
f_a: regular tariff per unit of $a \in \mathscr{A}_2$;
c: carbon tax of per unit length;
x_a: maximal flow on arc $a \in \mathscr{A}_1$;
y_a: maximal flow on arc $a \in \mathscr{A}_2$;
l_a: length of arc $a \in \mathscr{A}$;
$N^k_{\min}$: basic passenger number of flight k;
$N^k_{\max}$: maximal passenger capacity of flight k;
n^k: passenger number of flight k
$\tilde{g}^k_a$: cost per unit of $a \in \mathscr{A}_1$ for flight k;
$\tilde{d}^k_a$: cost per unit of $a \in \mathscr{A}_2$ for flight k;
$\tilde{q}^k$: carbon emission of per unit length of flight k;

Decision Variables

x^k_a: binary variables used to determine whether select arc $a \in \mathscr{A}_1$ for flight k;
y^k_a: binary variables used to determine whether select arc $a \in \mathscr{A}_2$ for flight k;
p^k: average price of flight k;

3. ARS Model

The low-carbon air transportation planning problem in the world aviation industry is on account of air route selection by the airline. The emphasis is focused on by the airline manager is how to assign air routes and set airfares. The airline considers maximizing the total aviation benefit. To measure airline economic performance, the total aviation benefit function is employed. The total aviation benefit is composed of two sectors: income sector and cost sector. Based on the analysis above, the following global model for the multi-objective optimization model with fuzzy variables can be formulated as:

$$\begin{cases} \min\limits_{x,y} A_{\text{Impact}} = \sum\limits_{k\in\Theta} \tilde{q}^k \left(\sum\limits_{a\in\mathscr{A}_1} l_a x_a^k + \dfrac{\sum\limits_{a\in\mathscr{A}_2} l_a y_a^k}{2} \right) \\ \max\limits_{p,x,y} W_{\text{Benefit}} = \sum\limits_{k\in\Theta} p^k n^k - \sum\limits_{k\in\Theta} \sum\limits_{a\in\mathscr{A}} ((h_a + \tilde{g}_a^k + c)x_a^k + (\tilde{d}_a^k + f_a)y_a^k) l_a \\ s.t. \begin{cases} n^k = [N_{\max}^k - \sigma \sum\limits_{a\in\mathscr{A}} l_a(x_a^k + y_a^k) - \kappa p^k], k \in \Theta \\ N_{\min}^k \le n^k \le N_{max}^k, k \in \Theta \\ \sum\limits_{k\in\Theta} x_a^k \le x_a, a \in \mathscr{A} \\ \sum\limits_{k\in\Theta} y_a^k \le y_a, a \in \mathscr{A} \\ x_a^k = 0 \text{ or } 1, a \in \mathscr{A}, k \in \Theta \\ y_a^k = 0 \text{ or } 1, a \in \mathscr{A}, k \in \Theta. \end{cases} \end{cases}$$

4. Techniques for Handling Fuzzy Objectives

As discussed above, a multi-objective model with fuzzy objectives is constructed. Since uncertain quantities cannot be minimized or maximized, the fuzzy objective is also unable to be maximized or minimized. Therefore, certain techniques need to be employed. In this paper, the expected value is employed to deal with the objective functions.

The expected value is widely adopted in many areas to measure the mean. In the fuzzy programming, it can also be used. Here, the expected value is employed to deal with the objective function. There are many relevant definitions about the expected value in fuzzy theory, such as Pos, Nec and Cr. The measure Pos means an absolutely optimistic attitude while Nec means an absolutely pessimistic attitude. The measure Cr means a composite attitude which as a combination of half optimistic and half pessimistic. In a realistic decision problem, the attitudes of the different decision makers are different. Thus, the expected value based on Me is adopted. Then the multi-objective model is transformed as:

$$
\begin{cases}
\min\limits_{x,y} A_{\text{Impact}} = \sum\limits_{k\in\Theta} \frac{(1-\lambda)q^{k1}+q^{k2}+\lambda q^{k3}}{2} \left(\sum\limits_{a\in\mathscr{A}_1} l_a x_a^k + \frac{\sum\limits_{a\in\mathscr{A}_2} l_a y_a^k}{2} \right) \\
\max\limits_{p,x,y} W_{\text{Benefit}} = \sum\limits_{k\in\Theta} p^k n^k - \sum\limits_{k\in\Theta} \sum\limits_{a\in\mathscr{A}} \left(\left(h_a + \frac{(1-\lambda)g_a^{k1}+g_a^{k2}+\lambda g_a^{k3}}{2} + c \right) x_a^k \right. \\
\qquad \left. + \left(\frac{(1-\lambda)d_a^{k1}+d_a^{k2}+\lambda d_a^{k3}}{2} + f_a \right) y_a^k \right) l_a \\
s.t. \begin{cases}
n^k = [N_{\max}^k - \sigma \sum\limits_{a\in\mathscr{A}} l_a (x_a^k + y_a^k) - \kappa p^k], k \in \Theta \\
N_{\min}^k \le n^k \le N_{\max}^k, k \in \Theta \\
\sum\limits_{k\in\Theta} x_a^k \le x_a, a \in \mathscr{A} \\
\sum\limits_{k\in\Theta} y_a^k \le y_a, a \in \mathscr{A} \\
x_a^k = 0 \text{ or } 1, a \in \mathscr{A}, k \in \Theta \\
y_a^k = 0 \text{ or } 1, a \in \mathscr{A}, k \in \Theta.
\end{cases}
\end{cases}
$$

4 Procedure Based on FLC-GA with EBS

The proposed model offers the low-carbon aircraft industry with an effective tool to treat with the air route selection optimization. However, the inherently complex environment, with a changing climate, and fluctuant aviation transportation demand, usually needs the proposed model to dynamically satisfy various scenarios. Therefore, a procedure for international organization-airline formulation based on FLC-GA with EBS is planned to simulate the first-rank strategies for the air route selection optimization and further accelerates the airline to evolve effective strategies.

In the method of this paper, firstly, a weighted-sum procedure is employed to cope with the multiple objectives in the international organization decisions [7]. Secondly, entropy-Bolitzmann selection method and fuzzy logic controllers are introduced to escape from the local optimum and adaptively adjust the rates of crossover and mutation operators [8]. In this study, the objectives of this approach is to maximize the aviation benefit and minimize the environmental impact while the precedence constrained are satisfied.

5 Practical Application

In this section, an airline is used as a practical application case to demonstrate the practicality of proposed optimization method. Through the numerical example on the data set is employed from a case study, the proposed method is recognized. Data about transportation cost and tariff, flight type, air route network, and other respects involved in the numerical example are based on the statistical data from international aviation industry. This numerical example is introduced to show the potential realistic applications of the proposed method. Hence, due to the macro scale, aviation transportation is a hard problem for the airline. Moreover, the realistic conditions of the air route network in the global aviation industry also awkward increase the transportation management difficulty.

All data are from the historical data of an airline in 2013. Two types of flights in the air transportation system are considered, which pilots work along different paths linking the departure nodes and arrival nodes, with the arrival nodes having the realistic demand of timeliness. The necessary information for every kind of carriers and the particulars of arcs in the whole air route network are shown in Table 1. The air route network in the project is composed of 6 nodes and 7 arcs, the first three arcs are carbon tax arcs while the others are no carbon tax arcs. An abstracted air route network is illustrated in Fig. 2. We let the parameters of passenger number function are $\sigma = 0.001$, $\kappa = 0.002$. For each arc in the air route network, there is a fuzzy transportation cost. For the flights, the maximal passenger capacity, the basic passenger number and per unit length carbon emission are considered, and the last one parameter is a fuzzy parameter. The corresponding data of which are stated in Tables 2, 3 and 4. It should be noticed that the fuzzy parameters in Tables 2, 3 and 4 are got by the following steps: (1) investigations and surveys. For each type of flights, 10 pilots are requested to conduct the investigation for many periods. Each pilot provides

Table 1 Data information of regular tariff per unit, maximal flow and length of $a \in \mathscr{A}$

Variable	Arc index						
	$a = 1$	$a = 2$	$a = 3$	$a = 4$	$a = 5$	$a = 6$	$a = 7$
h_a (RMB/km)	12	11	16	0	0	0	0
f_a (RMB/km)	0	0	0	12	15	14	15
x_a	3	7	6	0	0	0	0
y_a	0	0	0	8	9	5	5
l_a (km)	13	14	13	14	13	12	11

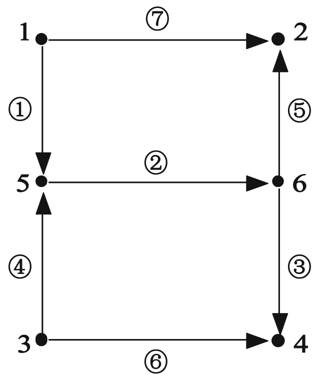

Fig. 2 The transportation route in the data simulation

Table 2 Data information of cost per unit of arc $a \in \mathscr{A}_1$

Variable	Flight index	Arc index		
		$a = 1$	$a = 2$	$a = 3$
$\tilde{g}_a^k$ (RMB/km)	$k = 1$	(4.3, 4.5, 4.8)	(4.3, 4.5, 4.8)	(4.3, 4.7, 4.9)
	$k = 2$	(4.3, 4.5, 4.8)	(4.3, 4.5, 4.8)	(4.3, 4.7, 4.9)

Table 3 Data information of cost per unit of arc $a \in \mathscr{A}_2$

Variable	Flight index	Arc index			
		$a = 4$	$a = 5$	$a = 6$	$a = 7$
$\tilde{d}_a^k$ (RMB/km)	$k = 1$	(4.7, 5.0, 5.2)	(4.5, 4.8, 5.1)	(4.3, 4.5, 4.8)	(4.5, 4.8, 5.1)
	$k = 2$	(4.7, 5.0, 5.2)	(4.5, 4.8, 5.1)	(4.3, 4.5, 4.8)	(4.5, 4.8, 5.1)

Table 4 Data information of basic passenger number, maximal passenger capacity and carbon emission of per unit length of different flights

Variable	Flight index	
	$k = 1$	$k = 2$
N_{min}^k	80	97
N_{max}^k	220	233
$\tilde{q}^k$	(4.3, 4.5, 4.8)	(4.3, 4.5, 4.8)

us with the ranges of the transportation cost relying on their experiences; (2) making the minimum and maximum value of all groups as the lower and upper bound of the fuzzy number; (3) supposing that the most possible value to approximately follow normal distributions for every period, and using the maximum likelihood estimation method to estimate the two parameters (i.e., expected value and variance) for the normal distributions; (4) using goodness-of-fit testing to justify the appropriateness of the normal distribution in modeling the observed data; and (5) finally, the fuzzy number is obtained. The optimistic-pessimistic parameter is given by the decision maker is $\lambda = 0.5$.

In order to demonstrate the practicality and efficiency of the proposed method for the carbon tax setting problem which is presented in this paper, the fuzzy logic controlled genetic algorithm with entropy-Bolitzmann selection was developed and ran on MATLAB (the population size $N_{\text{pop-size}} = 60$, the probability of crossover $p_c(0) = 0.4$, the probability of mutation $p_m(0) = 0.4$, and the parameters of entropy-Bolitzmann selection $N = 100$, $\beta = 0.15$, $\varepsilon = 0.002$). And we let $c = 56$, after running 500 generations, the final solution is $(x_1^1, x_2^1, x_3^1, y_4^1, y_5^1, y_6^1, y_7^1, x_1^2, x_2^2, x_3^2, y_4^2, y_5^2, y_6^2, y_7^2, p^1, p^2) = (1, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0, 1, 1, 2300.2, 3265.7)$. In addition, the objective function values are $(A_{\text{Impact}}, W_{\text{Benefit}}) = (127.3, 82627.2)$.

6 Conclusions and Future Research

This paper studied a carbon tax setting problem from an airline's perspective. For the airline, there are two objectives, so this model is also a multi-objective model. Since the environment of the carbon tax setting problem is fuzzy, the relevant objectives of the model are considered with fuzzy numbers. Then an ARS model with fuzzy numbers is proposed. To cope with fuzzy numbers, the expected value based on the fuzzy measure Me is adopted, which allows the pessimistic-optimistic parameters to be adjusted by the decision maker and thus is more appropriate for use in the real world situations. From this method, a crisp model for the ARS model is built. To solve the crisp model, a FLC-GA with EBS is designed with an interactive evolutionary mechanism. Finally, we give a numerical example to show the feasibility of the proposed method.

In the future, our research plans to focus on different uncertain environment (e.g. rough), carbon tax setting problem and air route selection problem in multiple stages.

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An Integrated Inventory Control and Transportation Model Under Carbon Emission Trade

Zhimiao Tao and Ziyan Tang

Abstract As one cost-effective instrument to reduce carbon emissions, carbon emission trade is implemented more and more widely. In this paper, we develop a deterministic inventory model under carbon emission trade. This inventory model is assumed that backorder is allowed and the lead time is not zero. We also discuss derive the impacts of the carbon emission trade on optimal inventory policy and actual carbon emission. The numerical examples and analytic results provide interesting managerial insights.

Keywords Integrated inventory model · Carbon mission trade · Economic order quantity (EOQ)

1 Introduction

The fifth assessment report of International Panel on Climate Change (IPCC) says that human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems [5]. Carbon dioxide (CO_2) is a kind of main greenhouse gases. The carbon emissions are the results of human's activities such as fossil fuel consumption, deforestation. The growing concern for global warming caused by the increased atmospheric concentration of CO_2 has a significant effect on environmental and energy policies and economic activities [4, 12]. Many countries and organization use legislations or design mechanism to reduce the total amount of carbon emission. Among them, carbon emission trading is generally regarded as one of the most cost-effective market-based mechanisms. Many emission trading schemes have been developed, including the European Union Emissions Trading System (EU ETS), the Regional Greenhouse Gas Initiative (RGGI), New

Z. Tao (✉) · Z. Tang
Business School, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: taozhimiao@scu.edu.cn

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Zealand Emissions Trading Scheme, Tokyo metropolitan trading scheme and the New South Wales Greenhouse Gas Abatement Scheme. The global carbon market is expected to reach US $2 trillion by 2025 [7].

Under the strict regulations on carbon emissions, firms have to reduce emission during operations. Some of them focus on physical processes, e.g., replacing energy inefficient equipment and facilities, redesigning products and packaging, deployment and use of less polluting sources of energy [3]. Meanwhile, they can also optimize their operations decisions in production, transportation, and inventory to reduce carbon emissions. This approach may reduce more carbon emissions with less or no cost than adopting low-energy-consumption technologies [2].

Inventory control, an important part of supply chain management, consumes significant amounts of energy in the process processes of delivering and storing products, resulting in the creation of large amounts of carbon emissions from the transportation and warehouse operations [9, 11]. So considering carbon emission actives in the inventory strategies is meaningful under the mechanism of emission trade. The studies on operations decisions under carbon emission regulations are not rich enough. Hua et al. [7] review less than 10 papers on this topic, such as [6, 10]. Apart from these, Chen et al. [3] provide a condition under which it is possible to reduce emissions by modifying order quantities by using economic order quantity (EOQ) model. Arıkan and Jammernegg [1] consider the single period inventory model with product carbon footprint constraint. Konur [8] analyzes an integrated inventory control and transportation problem with environmental considerations.

This paper focuses on a inventory model with nonzero lead time and finite reconsignment rate under the carbon emission trading. The emissions are caused by the transportation and holding activities and measured in tonnes (or kg) of CO_2 equivalent. The mechanism adopted here is the so-called cap-and-trade (also called as cap-and-price), i.e., penalizing emissions that exceed the specified cap and encouraging emissions that are lower than the cap by rewarding firms that emit less than their cap. We develop the mathematical model for the integrated inventory control and transportation problem and derive the optimal order policy and analyze the the impacts of emission cap and carbon price on the optimal order quantities, total cost and total emission.

Section 2 develops the mathematical model for the integrated inventory control and transportation problem and derive the optimal order policy. Section 3 analyzes the the impacts of emission cap and carbon price on the optimal order quantities, total cost and total emission. In Sect. 4, we present several numerical examples to illustrate practical insights from the analytical results. Concluding remarks and suggest topics for feature research are outlined in Sect. 5.

2 Mathematical Model

There are existing several emission regulation mechanisms in practice. Carbon tax is the mechanism to impose a financial penalty, a tax, per unit of carbon emitted. Cap-and-offset is to tax only emissions that exceed a certain threshold. For cap-and-trade mechanism, a firm is allocated a limit or cap on carbon emissions. If its amount of carbon emissions exceeds the carbon cap, it can buy the right to emit extra carbon from the carbon trading market. Otherwise, it can sell its surplus carbon credit [7]. Obviously, the cap-and-trade mechanism is the most general one among the existing mechanisms. In other words, carbon tax and cap-and-off set can be regarded as specific versions of cap-and-trade. In fact, if the cap is zero, then cap-and-trade degenerates into carbon tax. If the purchase price is sale price is zero if the firm has surplus carbon credit, then cap-and-trade degenerates into cap-and-offset. The cap-and-trade makes a tradeoff by using market.

2.1 Assumptions

To formulate the mathematical model for the inventory model under cap-and-trade mechanism, following assumption are considered:

(1) Backorder is allowed and there exists shortage cost.
(2) The leadtime is not zero.
(3) Demand is continuous and uniform.
(4) The ordering cost or set up cost, holding cost per unit per unit time are fixed.
(5) The stages of transportation and inventory generates carbon emissions.
(6) The carbon emissions from logistics per order is linear in the order quantity and the carbon emissions from warehouse is linear in the inventory.
(7) The carbon unit selling and purchasing prices are constants, only affected by the carbon cap of regulatory authorities.

2.2 Notations

We introduce the notations used in the paper as follows:
Parameters:

D: demand rate,
P: Production and replenishment rate,
A: ordering or setup cost once,
H: holding cost per unit per time,
B: shortage cost per unit per unit time,
C: carbon price per unit (ton),
α: carbon emission quotas per unit time,
e: carbon emissions associated per order initiated,
g: carbon emissions associated per unit held in inventory per unit time,
TC: total cost.

Decision variable:

Q: optimal ordering size,
X: trading quantities of carbon emission.

Remark 1 If the firm sells its emission quota, then X is negative. Otherwise, it is nonnegative.

2.3 Modeling

Without considering the emission condition, the the process of the problem is shown in Fig. 1, where T-axis and S-axis represents time and inventory level, respectively.

Figure 1 indicates a circle of the inventory problem. The length of circle is t unit time; $t - t_3$ is time of shortage; $t_1 + t_2$ is the time of replenishment. It follows the assumptions that:

$$\begin{cases} Q = Dt \\ Pt_1 = Dt_3 \\ D(t - t_3) = Pt_2, \end{cases} \tag{1}$$

The optimal ordering size and corresponding total cost are:

$$\min TC(Q) = \sqrt{2HAD}\sqrt{\frac{B}{B+H}}\sqrt{\frac{P-D}{P}}, \tag{2}$$

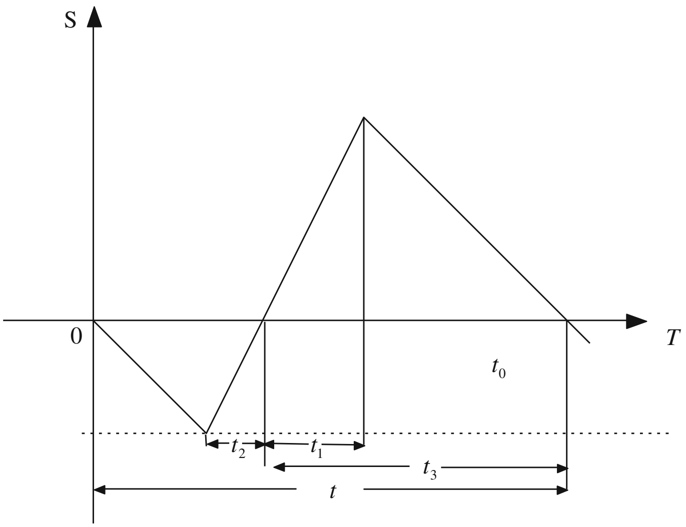

Fig. 1 Inventory process

and

$$Q^0 = \sqrt{\frac{2AD}{H}}\sqrt{\frac{B}{B+H}}\sqrt{\frac{P}{P-D}}, \tag{3}$$

respectively. As the cap-and-trade is involved, the total cost is:

$$\widetilde{TC} = \frac{1}{2Pt}HD(P-D)t_3^2 + \frac{1}{2Pt}BD(P-D)(t-t_3)^2 + \frac{A}{t} - CX. \tag{4}$$

Meanwhile, the carbon emission constraint is formulated as:

$$CE + X = \alpha, \tag{5}$$

where CE denotes the total emission in the processes of logistics and inventory, that is:

$$CE = \frac{e}{t} + \frac{1}{2Pt}gD(P-D)t_3^2. \tag{6}$$

When $t_3 = 0$ and $t \to +\infty$ i.e. $Q \to +\infty$, $CE = 0$. This case indicates the decision maker can make use of the shortage to avoid the carbon emission because there is no emission in the shortage stage. In fact, the extreme case is unlikely to happen in real-world. However, it implies that the total emission decreases as the ordering size increases and the time of shortage increases.

Substituting (5) and (6) into (4), we get

$$\widetilde{TC} = \frac{(P-D)D}{2Pt}[(H+Cg)t_3^2 + B(t-t_3)^2] + \frac{A+Ce}{t} - C\alpha. \tag{7}$$

Let the both of the partial derivatives of $\widetilde{TC}$ on t and t_3 are zeros, i.e.,

$$\begin{aligned}\frac{\partial\widetilde{TC}}{\partial t} = &-\frac{(P-D)D}{2Pt^2}[(H+Cg)t_3^2 + B(t-t_3)^2] + \frac{(P-D)D}{Pt}B(t-t_3)\\ &-\frac{A+Ce}{t^2} = 0,\end{aligned} \tag{8}$$

and

$$\frac{\partial\widetilde{TC}}{\partial t_3} = \frac{(P-D)D}{Pt}[(H+Cg)t_3 - B(t-t_3)] = 0, \tag{9}$$

It follows from (9) that

$$t_3 = \frac{Bt}{H+Cg+B}. \tag{10}$$

Substituting (10) into (8), we have

$$t^* = \sqrt{\frac{2(A+Ce)}{(H+Cg)D}}\sqrt{\frac{H+Cg+B}{B}}\sqrt{\frac{P}{P-D}}. \tag{11}$$

Then

$$Q^* = Dt^* = \sqrt{\frac{2(A+Ce)D}{H+Cg}}\sqrt{\frac{H+Cg+B}{B}}\sqrt{\frac{P}{P-D}}, \tag{12}$$

and

$$\widetilde{TC}^* = \sqrt{2(H+Cg)(A+Ce)D}\sqrt{\frac{B}{H+Cg+B}}\sqrt{\frac{P-D}{P}} - C\alpha. \tag{13}$$

From (12), if $C = 0$, then

$$Q^* = \sqrt{\frac{2AD}{H}}\sqrt{\frac{H+B}{B}}\sqrt{\frac{P}{P-D}},$$

and

$$\widetilde{TC}^* = \sqrt{2AHD}\sqrt{\frac{B}{H+B}}\sqrt{\frac{P-D}{P}},$$

which implies that the decision maker does not care about carbon emissions and will adopt the optimal order policy for the classical EOQ model when the carbon credit is free. When $C \to \infty$, then $Q^* \to \infty$ and $\widetilde{TC}^* = 0$ which indicates that when carbon credit is very expensive, there decision maker should minimize carbon emissions.

3 Sensitivity Analysis

In what follows, ,we will study the impacts of carbon price,and carbon cap on order decisions, carbon emissions, and total cost. The following theorem states the impact of carbon trade on the order quantity.

Theorem 1 *If* $\frac{e}{g} \geq \frac{A}{H}$, $Q^* > Q^0$.

Proof By comparing Q^0 and Q^*, the conclusion is trivial.

Remark 2 If $\frac{e}{g} < \frac{A}{H}$, the relationship between of Q^0 and Q^* is not deterministic. For example, let $P = 1000$, $D = 200$, $A = 100$, $H = 10$, $e = 5$, $g = 1$, $B = 20$, then $\frac{e}{g} = 5 < 10 = \frac{A}{H}$. From (3), $Q^0 = 40\sqrt{15}$. If $C = 10$, $q^* = 40\sqrt{2} = Q^0$; If $C = 20$, $Q^* = \frac{200\sqrt{6}}{3} > Q^0$; If $C = 5, ^* = \frac{100\sqrt{21}}{3} < Q^0$.

In [7], if $\frac{e}{g} < \frac{A}{H}$, then $Q^* < Q^0$. However, this conclusion doesn't hold any more as the shortage is allowed. The relationship is affected not only by the order of $\frac{e}{g}$ and $\frac{A}{H}$, but also the value of shortage cost B and carbon emission price C.

Theorem 2 *Compared with the EOQ model, if the following condition is satisfied:*

$$\frac{H}{A} \leq \frac{e}{g} \leq \frac{A}{H+B}, \tag{14}$$

the cap-and-trade mechanism induces there tailer to reduce carbon emissions.

Proof For the EOQ model, the emission, denoted by CE^0 is

$$CE^0 = \sqrt{\frac{HD}{2A}}\sqrt{\frac{B}{H+B}}\sqrt{\frac{P-D}{D}}\left(e + g\frac{AB}{H+B}\right), \tag{15}$$

The emission under cap-and-trade mechanism, denoted by CE^*,

$$CE^0 = \sqrt{\frac{HD}{2A}}\sqrt{\frac{B}{H+B}}\sqrt{\frac{P-D}{D}}\left(e + g\frac{AB}{H+B}\right), \tag{16}$$

To compare CE^* and CE^0, the quotient of CE^* divided by CE^0 is

$$\frac{CE^*}{CE^0} = \sqrt{\frac{(H+Cg)A}{H(A+Ce)}}\sqrt{\frac{H+B}{H+Cg+B}}\frac{e + g\frac{(A+Ce)B}{H+Cg+B}}{e + g\frac{AB}{H+B}},$$

Since $\frac{H}{A} \leq \frac{e}{g}$, then

$$\sqrt{\frac{(H+Cg)A}{H(A+Ce)}} \geq 1,$$

It follows from $\frac{e}{g} \leq \frac{A}{H+B}$ that

$$\frac{e + g\frac{(A+Ce)B}{H+Cg+B}}{e + g\frac{AB}{H+B}} \geq 1,$$

And the factor $\sqrt{\frac{H+B}{H+Cg+B}}$ must less than 1 strictly if g and C are not zeros. Therefore,

$$\frac{CE^*}{CE^0} = \sqrt{\frac{(H+Cg)A}{H(A+Ce)}}\sqrt{\frac{H+B}{H+Cg+B}}\frac{e + g\frac{(A+Ce)B}{H+Cg+B}}{e + g\frac{AB}{H+B}} < 1,$$

i.e., $CE^* < CE^0$.

Remark 3 If shortage is not allowed and replenishment time is zero, cap-and-trade mechanism must induce reduction of carbon emissions. However, in the case considered in this paper, reduction of carbon emissions occurs only if condition (14) holds.

Theorem 3 *For fixed A, H, D, P, g, e, changes of total costs under cap-trade-trade mechanism depend on the relationship of the carbon C and cap α, as follows:*

$$TC^* > (=, <)TC^0 \Leftrightarrow \alpha < (=, >)\frac{\sqrt{2BD(P-D)}}{\sqrt{CP}}\frac{\sqrt{He(H+Cg+B)+Bg(A+Be)}}{\sqrt{(H+Cg+B)(H+B)}}, \tag{17}$$

Proof The difference between of TC^* and TC^0

$$\begin{aligned}
\Delta TC &= TC^* - TC^0 \\
&= \sqrt{2(H+Cg)(A+Ce)D}\sqrt{\frac{B}{H+Cg+B}}\sqrt{\frac{P-D}{P}} - C\alpha \\
&\quad - \sqrt{2AHD}\sqrt{\frac{B}{H+B}}\sqrt{\frac{P-D}{P}} \\
&= \sqrt{\frac{2DB(P-D)}{P}}\left[\sqrt{\frac{(H+Cg)(A+Ce)}{H+Cg+B}} - \sqrt{\frac{AH}{H+B}}\right] - C\alpha \\
&= \sqrt{\frac{2DB(P-D)}{P}}\sqrt{\frac{C(H^2e+HCge+BHe+BAg+B^2ge)}{(H+Cg+B)(H+B)}} - C\alpha > (=, <)0 \\
&\Rightarrow \alpha < (=, >)\frac{\sqrt{2BD(P-D)}}{\sqrt{CP}}\frac{\sqrt{He(H+Cg+B)+Bg(A+Be)}}{\sqrt{(H+Cg+B)(H+B)}},
\end{aligned}$$

Form Theorems 1 and 2, when conditions (14) and (17) are satisfied that the retailer can reduce carbon footprint and total cost simultaneously.

Corollary 1 *There exists a threshold α_0:*

(1) If $\alpha < \alpha_0$, then the retailer should buy $\alpha_0 - \alpha$ units of carbon credit.
(2) If $\alpha > \alpha_0$, then the retailer should sell $\alpha - \alpha_0$ units of carbon credit.
(3) If $\alpha = \alpha_0$, then the retailer should neither sell nor buy carbon credit.

Here,

$$\alpha_0 = \frac{\sqrt{2BD(P-D)}}{\sqrt{CP}}\frac{\sqrt{He(H+Cg+B)+Bg(A+Be)}}{\sqrt{(H+Cg+B)(H+B)}}.$$

Proof we can derive the above results easily from Theorem 3.

Corollary 1 shows that whether the retailer should sell or buy carbon credit depends on the carbon cap. When the cap is lower than a threshold, he should sell carbon credit; when the cap is higher than the threshold, he should buy carbon credit; and the

Table 1 Parameters and results

A	H	A	e	g	Q^0	Q^*	α_0	X	TC	ΔCE	ΔTC
150	0.5	0.6	500	1	8243	8243	8243	−412	2356	0	95
200	0.6	0.7	400	1	7223	7223	7223	212	3215	0	−34
250	0.4	0.5	600	1.5	12223	9222	10237	−2789	5215	192	613

transfer quantity is the difference between the cap and the threshold. Otherwise,he should neither sell nor buy carbon credit. It is noted that the first term of the threshold is the amount of carbon emissions from logistics while the second term is that from warehouse.

4 Numerical Examples

In this section we present a series of numerical examples to illustrate the above analytical results and provide some interesting observations. Let $D = 60{,}000$, $C = 0.2$, $\alpha = 8000$, and the rest of the parameters and the results are summarized in Table 1.

Table 1 also indicates that whether the retailer should buy carbon credit depends on the carbon cap as follows: if it is less than a threshold, he should buy carbon credit. The last but one column in Table 1 shows that the cap-and-trade mechanism induces the retailer to reduce carbon emissions; otherwise, it cannot induce the retailer to reduce carbon emissions. It is noted from the last column of Table 1 that the retailer's cost may decrease, i.e., the cap-and-trade mechanism does not necessarily result in a higher cost for the retailer.

5 Conclusion

By involving the factor of carbon emissions, we studied the a inventory problem under cap-and-trade. In the inventory problem, shortage is allowed and the replenishment time is not zero. By comparing the results of the proposed model and the classical EOQ model, we found the relationships of optimal policy and parameters are more complex. The result "the cap induces emission reduction" holds only if there are some special condition. The optimal order size, total emission and total cost are not only effected by the cap and carbon price but also other parameters.

Several extensions of the proposed approach are worthwhile further investigating. Future research may consider the stochastic demand inventory, multi-item inventory problem. Also, the different transportation modes may result in interesting conclusions.

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The Supply Chain Network Equilibrium Model with Fuzzy Demand Price

Zezhong Wu

Abstract A single-commodity equilibrium model of a competitive supply chain network in the case of fuzzy demands associated with the demand markets is developed. The network structure of the supply chain is identified and equilibrium conditions are derived. A finite-dimensional variational inequality formulation is established. Two numerical examples is given.

Keywords Equilibrium model · Variational inequalities · Fuzzy demand price

1 Introduction

The topic of supply chain analysis is interdisciplinary by nature since it involves manufacturing, transportation and logistics, as well as retailing/marketing. It has been the subject of a growing body of literature [23] with the associated research being both conceptual in nature [20, 21], due to the complexity of the problem and the numerous agents such as manufacturers, retailers, and consumers involved in the transactions, as well as analytical [5, 6, 8, 22].

Lee and Billington [10] expressed the need for decentralized models that allow for a generalized network structure and simplicity in the study of supply chains. Anupindi and Bassok [1], in turn, addressed the challenges of formulating systems consisting of decentralized retailers with information sharing. Lederer and Li [9], on the other hand, studied competition among firms that produce goods or services for customers who are sensitive to delay time. Corbett and Karmarkar [3] were concerned with the equilibrium number of firms in oligopolistic competition in a supply chain. In order to allow for the closed form determination of the equilibrium number of firms they assumed that the firms in the same tier were characterized by identical linear

Z. Wu (✉)
School of Applied Mathematics, Chengdu University of Information Technology, Chengdu 610225, People's Republic of China
e-mail: 450856710@qq.com

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production cost functions. Equilibrium models have a long tradition in transportation modeling as well as in economics [2, 11].

Many researchers [12–17], in addition to, practitioners, have described the various networks that underlie supply chain analysis and management. The equilibrium model is drawn from economics and, in particular, from network economics [11]. Manufacturers are assumed to be involved in the production of a homogeneous product which is then shipped to the retailers. Manufacturers obtain a price for the product (which is endogenous) and seek to determine their optimal production and shipment quantities, given the production costs as well as the transaction costs associated with conducting business with the different retailers. Retailers, in turn, must agree with the manufacturers as to the volume of shipments since they are faced with the handling cost associated with having the product in their retail outlet. In addition, they seek to maximize their profits with the price that the consumers are willing to pay for the product being endogenous. Consumers determine their optimal consumption levels from the various retailers subject both to the prices charged for the product as well as the cost of conducting the transaction (which, of course, may include the cost of transportation associated with obtaining the product from the retailer). In this paper, we mainly consider a single-commodity equilibrium model of a competitive supply chain network with fuzzy demand prices associated with the demand markets. The network structure of the supply chain is identified and equilibrium conditions are derived by means of variational inequality. We solve the equilibrium model by a revised Quasi-Newton Method, and give two numerical examples.

The paper is organized as follows. In Sect. 3, we present the competitive supply chain network model with fuzzy demand price, derive optimality conditions for its decision-makers, and then present the governing equilibrium conditions. We also derive the finite-dimensional variational inequality formulation of the problem. In Sect. 4, we give the transformation form of equilibrium model in order to solve model. In Sect. 5, we give two numerical examples to determine the equilibrium product flows and prices and also provide a discussion of the model and results. We conclude the paper with Sect. 6.

2 Preliminaries

A fuzzy set of R^n is a mapping $\mu : R^n \to [0, 1]$. For each such fuzzy set μ, we denote by $[\mu]^\alpha = \{x \in R^n : \mu(x) \geq \alpha\}$ for any $\alpha \in (0, 1]$, its $\alpha-$cut set. By *supp* μ we denote the support of μ, i.e., $\{x \in R^n \,|\mu(x) > 0\}$. By $[\mu]^0$ we define the closure of *supp* μ.

Definition 1 [24] A fuzzy number μ is a fuzzy set with the following properties:

1. μ is normal, i.e., there exists an $x_0 \in R^n$ such that $\mu(x_0) = 1$;
2. μ is convex fuzzy set, i.e., $\mu(\lambda x+(1-\lambda)y) \geq \min(\mu(x), \mu(y))$, $x, y \in R^n$, $\lambda \in [0, 1]$;
3. $[\mu]^0$ is compact.

Let E denote the family of fuzzy numbers. Obviously, $[\mu]^\alpha$ is a nonempty compact convex subset of R (denoted $[\mu_*(\alpha), \mu^*(\alpha)]$) for any $\mu \in E$ and $\alpha \in [0, 1]$. A fuzzy number is a generalized interval.

A precise number a is a special case of fuzzy number encoded as

$$\tilde{a}(t) = \begin{cases} 1, & \text{if } t = a \\ 0, & \text{if } t \neq a. \end{cases}$$

However, a precise number will be denoted as usual, in particular number 0.

For fuzzy numbers $\mu, \nu \in E$ represented by $(\mu_*(\alpha), \mu^*(\alpha))$ and $(\nu_*(\alpha), \nu^*(\alpha))$ respectively and for each number λ, we define the addition $\mu \tilde{+} \nu$ and scalar multiplication $\lambda\mu$ as follows:

$$(\mu \tilde{+} \nu)(x) = \sup_{y+z=x} \min[\mu(y), \nu(z)],$$

$$(\lambda\mu)(x) = \begin{cases} \mu(\lambda^{-1}x), & \text{if } \lambda \neq 0 \\ 0, & \text{if } \lambda = 0 \end{cases} \text{ for } \mu, \nu \in E,\ \lambda \in R.$$

It is well known that for any $\mu, \nu \in E$ and $\lambda\mu \in E$ and $[\mu \tilde{+} \nu]^\alpha = [\mu]^\alpha \tilde{+} [\nu]^\alpha$, and $[\lambda\mu]^\alpha = \lambda[\mu]^\alpha$, i.e.,

$$(\mu \tilde{+} \nu)_*(\alpha) = \mu_*(\alpha) + \nu_*(\alpha),\ (\mu \tilde{+} \nu)^*(\alpha) = \mu^*(\alpha) + \nu^*(\alpha),$$

$$(\lambda\mu)_*(\alpha) = \begin{cases} \lambda\mu_*(\alpha), & \text{if } \lambda \geq 0 \\ \lambda\mu^*(\alpha), & \text{if } \lambda < 0 \end{cases} \text{ and}$$

$$(\lambda\mu)^*(\alpha) = \begin{cases} \lambda\mu^*(\alpha), & \text{if } \lambda \geq 0 \\ \lambda\mu_*(\alpha), & \text{if } \lambda < 0 \end{cases} \text{ for every } \alpha \in [0, 1].$$

Remark 1 It is obvious from above that for each fuzzy number μ parameterized by $[\mu_*(\alpha), \mu^*(\alpha)]$, for $\alpha \in [0, 1]$ and each real number r, $[\mu \tilde{+} r]^\alpha = [\mu_*(\alpha) + r, \mu^*(\alpha) + r]$.

For $x = (x_1, x_2, \ldots, x_n), y = (y_1, y_2, \ldots, y_n) \in R^n$, we define $x \leq y$ iff $x_i \leq y_i (i = 1, 2, \ldots, n)$, and $x < y$ iff $x \leq y$ and $x \neq y$.

Definition 2 A triangular fuzzy number $\tilde{A}$ can be defined by a triplet (a_1, a_2, a_3). Its conceptual schema and mathematical form are shown as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x \leq a_1 \\ \frac{x-a_1}{a_2-a_1}, & a_1 < x \leq a_2 \\ \frac{a_3-x}{a_3-a_2}, & a_2 < x \leq a_3 \\ 0, & x > a_3. \end{cases}$$

A triangular fuzzy number has been shown in Fig. 1.

Its interval formulation is: $[a_1 + (a_2 - a_1)\alpha, a_3 - (a_3 - a_2)\alpha], \forall\alpha \in [0, 1]$.

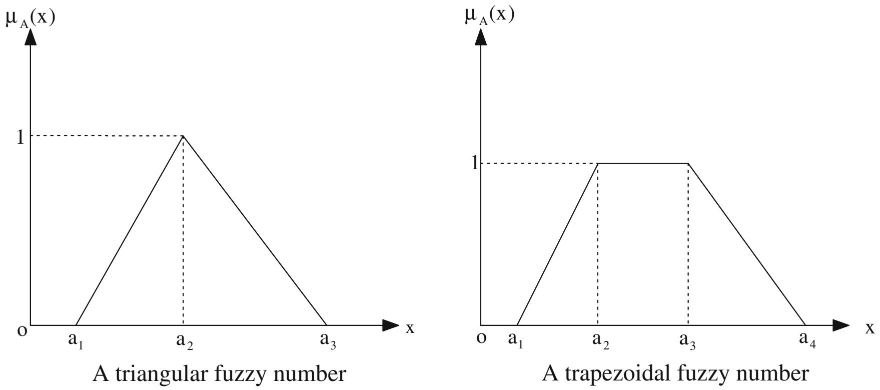

Fig. 1 A triangular fuzzy number

Definition 3 A trapezoidal fuzzy number $\tilde{A}$ can be defined by a quadruplet (a_1, a_2, a_3, a_4). Its conceptual schema and mathematical form are shown as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x \le a_1 \\ \frac{x-a_1}{a_2-a_1}, & a_1 < x \le a_2 \\ 1, & a_2 < x \le a_3 \\ \frac{a_4-x}{a_4-a_3}, & a_3 < x \le a_4 \\ 0, & x > a_4. \end{cases}$$

A trapezoidal fuzzy number has been shown in Fig. 1.

Its interval formulation is: $[a_1 + (a_2 - a_1)\alpha, a_4 - (a_4 - a_3)\alpha], \forall\alpha \in [0, 1]$.

3 The Supply Chain Network Equilibrium Model

In this section, we develop the supply chain network model with manufacturers, retailers, consumers. The supply chain network structure with direct marketing at equilibrium, which we establish in this section is as depicted in Fig. 2a.

Specifically, we consider m manufacturers who are involved in the production of a product, which can be purchased by n retailers, also can be purchased by consumers of o demand markets. They make the product available to consumers located at o demand markets by k. We denote a typical manufacturer by i, a typical retailer by j, a typical demand market by k.

We first focus on the manufacturers. We then turn to the retailers and, subsequently, to the consumers. The complete equilibrium model is then constructed along with the variational inequality formulation of the governing equilibrium conditions.

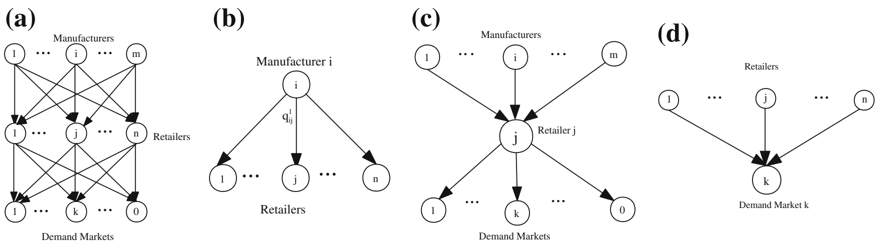

Fig. 2 The network structure of the supply chain at equilibrium

3.1 The Behavior of the Manufacturers and Their Optimality Conditions

Let q_{ij} denotes that the manufacturer i ships the product to the retailer j. We group all q_{ij} into the column vector $Q^{11} = (q_{11}, q_{12}, \ldots, q_{1n}, \ldots, q_{m1}, \ldots, q_{mn})^T \in R_+^{mn}$.

We assume that each manufacturer i is faced with a production cost function f_i, in general, on the entire vector of production outputs, that is, $f_i = f_i(Q^{11}),\ i = 1, 2, \ldots, m$.

We associate with each manufacturer and retailer pair (i, j) a transaction cost of the product denoted by c_{ij}. We consider the situation in which the transaction cost of the product between a manufacturer and retailer pair is given by $c_{ij} = c_{ij}(q_{ij}),\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n$.

To help fix ideas (cf. Fig. 2b), and in order to facilitate the ultimate construction of the supply chain networks in equilibrium, we depict the manufacturer and retailers as nodes and the transactions between a manufacturer i and the retailers $j,\ j = 1, 2, \ldots, n$, as links. We also depict the manufacturer and demand markets as nodes and the transactions between a manufacturer i and the demand markets $k,\ k = 1, 2, \ldots, o$, as links.

The total costs incurred by a manufacturer i for the product, thus, are equal to the sum of his production cost for the product plus the total transaction costs. His revenue, in turn, is equal to the price that the manufacturer charges for the product (and the retailers are willing to pay) times the total quantity obtained/purchased of the product from the manufacturer by all the retail outlets and all the demand markets. If we let ρ_{1ij} denote the price charged for the product by manufacturer i to retailer j (i.e., the supply price), and ρ_{1ik} denote the direct marketing price charged for the product by manufacturer i to demand market k, we have:

$$\begin{cases} \max \ \sum\limits_{j=1}^{n} \rho_{1ij} q_{ij} - f_i(Q^{11}) - \sum\limits_{j=1}^{n} c_{ij}(q_{ij}) \\ \text{s.t. } q_{ij} \geq 0,\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n. \end{cases} \tag{1}$$

Assuming that the production cost functions and the transaction cost functions for each manufacturer are continuous differentiable and convex. The optimal conditions of Eq. (1) are equivalent to the form of the variational inequality as follows,

$$\sum_{j=1}^{n}\left(\frac{\partial f_i(Q^{11*})}{\partial q_{ij}}+\frac{\partial c_{ij}^{*}}{\partial q_{ij}}-\rho_{1ij}^{*}\right)\times(q_{ij}-q_{ij}^{*})\geq 0,\ \forall Q^{11}\in R_{+}^{mn}. \tag{2}$$

The optimality conditions are expressed by Eq. (2) have a nice economic interpretation. Equation (2) represents that a manufacturer will ship a positive amount of the product to a retailer (and the flow on the corresponding link will be positive) if the price that the retailer is willing to pay for the product is equal to the manufacturer's sum of marginal production and transaction costs; if sum exceed what the retailer is willing to pay for the product, then the flow on the link will be zero.

We assume that the manufacturers compete in noncooperative fashion. Given that the governing optimization/equilibrium concept underlying noncooperative behavior is that of [4, 18, 19], which states that each manufacturer will determine his optimal production quantity and shipments, given the optimal ones of the competitors, the optimality conditions for all manufacturers simultaneously can be expressed as the following variational inequality: Determine $Q^{11}\in R_{+}^{mn}$ satisfying:

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\left[\frac{\partial f_i(Q^{11*})}{\partial q_{ij}}+\frac{\partial c_{ij}^{*}}{\partial q_{ij}}-\rho_{1ij}^{*}\right]\times(q_{ij}^{l}-q_{ij}^{l*})\geq 0. \tag{3}$$

3.2 The Behavior of the Retailers and Their Optimality Conditions

The retailers, in turn, are involved in transactions both manufacturers since they wish to obtain the product for their retail outlets, as well as with the consumers, who are the ultimate purchasers of the product. Hence, the network structure of retailer $j's$ transactions is as depicted in Fig. 2c. Thus, a retailer conducts transactions both with the manufacturers as well as with the consumers at the demand markets. Note the Fig. 2c as did Fig. 2b, only depicts the network structure of the transactions involved. Later, we will also associate flows with the links as well as prices with the nodes.

A retailer j is faced with what we term a fuzzy handling cost, which may include, for example, the display and storage cost with the product. We denote this cost for the product by c_j and, in the simplest case, we would have that c_j is a function of $\sum_i^m q_{ij}$, that is, the handing cost of a retailer is a function of how much of the product he has obtained from the various manufacturers. However, for the sale of generality, and to enhance the modeling of competition, we allow the function to, in general, depend also on the amounts of the product hold by other retailers and, therefor, we may write $\tilde{c}_j=\tilde{c}_j(Q^{11}),\ \forall j$.

The retailers associate a price with the product at their retail outlet, which is denoted by ρ_{jk}, for retailer j. This price, as we will show, will also be endogenously determined in the model. Assuming, as mentioned in Sect. 1, that the retailers are also profit-maximizers, the optimization problem of a retailer j is given by:

$$\max \sum_{k=1}^{o} \rho_{jk} q_{jk} - c_j(Q^{11}) - \sum_{i=1}^{m}\sum_{k=1}^{s} \rho_{1ij} q_{ij} \tag{4}$$

$$\text{s.t.} \begin{cases} \sum_{k=1}^{o} q_{jk} \le \sum_{i=1}^{m} q_{ij} \\ q_{ij} \ge 0, \ q_{jk} \ge 0, \ \forall i, j. \end{cases} \tag{5}$$

Objective function (4) expresses that the difference between the revenues minus the handling cost and the pay out to the manufacturers should be maximized. Constraint condition (5) simply expresses that consumers cannot purchase more from a retailer than is held in stock.

We denote the Lagrangian multiplier as: γ_j, $(j = 1, 2, \ldots, m)$, then the Lagrangian function is:

$$L_j(\gamma_j) = \sum_{k=1}^{o} \rho_{jk} q_{jk} - c_j(Q^{11}) - \sum_{i=1}^{m} \rho_{1ij}(q_{ij}) + \gamma_j \left(\sum_{i=1}^{m} q_{ij} - \sum_{k=1}^{o} q_{jk} \right). \tag{6}$$

Assuming that the handling cost for each retailer is continuous differentiable and convex. Then the optimal conditions of (6) are equivalent to the form of the variational inequality as follows,

$$\begin{cases} \left(\frac{\partial c_j(Q^{11*})}{\partial q_{ij}} + \rho_{1ij}^* - \gamma_j^* \right) \times (q_{ij} - q_{ij}^*) \ge 0 \\ (\gamma_j^* - \rho_{jk}^*) \times (q_{jk} - q_{jk}^*) \ge 0 \\ \left(\sum_{i=1}^{m} q_{ij}^* - \sum_{k=1}^{s} q_{jk}^* \right) \times (\gamma_j - \gamma_j^*) \ge 0. \end{cases}$$

The optimality conditions for all the retailers coincide with the solution of the variational inequality: Determine $(Q^{11*}, Q^{2*}, \gamma^*) \in R_+^{mn+no+n}$ satisfying:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} \left[\frac{\partial c_j(Q^{11*})}{\partial q_{ij}} + \rho_{1ij}^* - \gamma_j^* \right] \times [q_{ij} - q_{ij}^*] + \sum_{j=1}^{n}\sum_{k=1}^{o} [-\rho_{jk}^* + \gamma_j^*]$$
$$\times [q_{jk} - q_{jk}^*] + \sum_{j=1}^{n} \left[\sum_{i=1}^{m} q_{ij}^* - \sum_{k=1}^{o} q_{jk}^* \right] \times [\gamma_j - \gamma_j^*] \ge 0. \tag{7}$$

We now highlight the economic interpretation of the retailers' optimality conditions. From the second term in inequality (7), we have that, if consumers at demand market k purchase the product from a particular retailer j, that is, if the q_{jk}^* is positive, then the price charged by retailer j, ρ_{jk}^*, is equal to γ_j^*, which, from the third term in the inequality, serves as the price to clear the market from retailer j. Also, note that, from the second term, we see that if no product is sold by a particular retailer, then the price associated with holding the product can the price charged to the consumers. Furthermore, from the first term in inequality (7), we can infer that, if a manufacturer transacts with a retailer resulting in a positive flow of the product between the two, then the price γ_j^* is equal to the retailer $j's$ payment to the manufacturer, ρ_{1ij}^*, plus its marginal cost of handling the product from the retailer.

3.3 The Equilibrium Conditions of Demand Markets

In this section, we discuss the fuzzy equilibrium conditions for demand markets, and then discuss the defuzzification equilibrium conditions.

1. The Fuzzy Equilibrium Conditions of Demand Markets

We now describe the consumers located at the demand markets. The consumers take into account in making their consumption decisions not only the price charged for the product by the retailers but also the transaction cost to obtain the product. We let $\tilde{c}_{jk}$ denote the fuzzy transaction cost associated with obtaining the product by consumers at demand market k from retailer j and recall that $\bar{q}_{jk}$ denotes the amount of the product purchased (or flowing) between retailer j and consumers at demand market k. We assume that the fuzzy transaction cost is continuous, positive, and of the general form $\tilde{c}_{jk} = \tilde{c}_{jk}(Q^2),\ \forall j, k$, where recall that Q^2 is the $no-$dimensional column vector of product flows between the retailers and the demand markets.

In Fig. 2d, the network of transactions between the retailers and the consumers at demand market k is depicted. Each demand market is represented by a node and the transactions, as previously, by links.

Let $\tilde{\rho}_{3k}$ denote the fuzzy price of the product at demand market k. Further, denote the demand for the product at demand market k by d_k and assume, as given, the continuous demand functions: $\tilde{\rho}_{3k} = \tilde{\rho}_{3k}(D),\ \forall k$, where $D = (d_1, d_2, \ldots, d_o)^T$ is the $o-$dimensional column vector of demand. Hence, the fuzzy price for consumers for the product at a demand market depends, in general, not only on the demand for consumers for the product at a demand market but also on the demands of the product at the other demand markets. Thus, consumers at a demand market, in a sense, also compete with consumers at other demand markets.

The consumers take the fuzzy price charged by the retailers for the product, whose, recall was denoted by $\tilde{\rho}_{2j}$ for retailer j, plus the transaction cost associated with obtaining the product, in making their consumption decisions.

The fuzzy equilibrium conditions for consumers at demand market k, hence, take the form: for all retailers $j,\ j = 1, 2, \ldots, n$,

$$\tilde{\rho}_{2j} + \tilde{c}_{jk}(Q^2) \begin{cases} = \tilde{\rho}_{3k}, & \text{if } \bar{q}_{jk} > 0 \\ \succeq \tilde{\rho}_{3k}, & \text{if } \bar{q}_{jk} = 0, \end{cases} \tag{8}$$

and for all consumers $k,\ k = 1, 2, \ldots, o$,

$$\tilde{\rho}_{3k}(D) \begin{cases} \succeq 0, & d_k = \sum_{j=1}^{n} \bar{q}_{jk} \\ = 0, & d_k \leq \sum_{j=1}^{n} \bar{q}_{jk}. \end{cases} \tag{9}$$

We set $v = \sum_{j=1}^{n} \bar{q}_{jk} - d_k$, then (8) can be written as:

$$\tilde{\rho}_{3k}(D) \begin{cases} \succeq 0, & v = 0 \\ = 0, & v \geq 0. \end{cases} \tag{10}$$

Conditions (8) state that, in equilibrium, if the consumers at demand marker k purchase the product from retailer j, then the fuzzy price charged by the retailer for the product plus the fuzzy transaction cost does not exceed the fuzzy price that consumers are willing to pay for the product. Conditions (10) state, in turn, that if the quantities purchased of the product from the retailers will be equal to the demand for the product at the demand market, then the fuzzy equilibrium price the consumers are willing to pay for the product at the demand market is positive. For conditions (8) and (10), we have the following property.

Property 1 *In equilibrium, conditions (8) and (10) will have to hold for all demand markets k, and can also be expressed as a fuzzy variational inequality problem, and given by: Determine* $(Q^2, D) \in R_+^{no+o}$ *such that:*

$$\sum_{j=1}^{n}\sum_{k=1}^{o}[\rho_{jk} + \tilde{c}_{jk}(Q^2)] \times [\bar{q}_{jk} - \bar{q}_{jk}^*] - \sum_{k=1}^{o} \tilde{\rho}_{3k}^*(D) \times [d_k - d_k^*] \succeq 0, \forall (Q^2, D) \in R_+^{no+o}. \tag{11}$$

2. The Defuzzification Equilibrium Conditions

In order to transform uncertainty (11) for the deterministic problem, we have to defuzzify the fuzzy function and need to consider some distance measures as in [25]. The signed distance between the real numbers a and 0, denoted by $d_0(a, 0)$ is given by $d_0(a, 0) = a$. Hence the signed distance of $A_L(\alpha)$ and $A_R(\alpha)$ measured from 0 are $d_0(A_L(\alpha), 0) = A_L(\alpha)$ and $d_0(A_R(\alpha), 0) = A_R(\alpha)$ respectively.

The signed distance of the interval $[A_L(\alpha), A_R(\alpha)]$ measured from the origin 0 by $d_0([A_L(\alpha), A_R(\alpha)], 0) = \frac{1}{2}[d_0(A_L(\alpha), 0) + d_0(A_R(\alpha), 0)] = \frac{1}{2}(A_L(\alpha) + A_R(\alpha)])$, where $A_L(\alpha), A_R(\alpha)$ exist and are integrable for $\alpha \in [0, 1]$.

For each $\alpha \in [0, 1]$, the crisp interval $[A_L(\alpha), A_R(\alpha)]$ and the level α fuzzy interval $[[A_L(\alpha), A_R(\alpha)]; \alpha]$ are in one to one correspondence. The signed distance from $[[A_L(\alpha), A_R(\alpha)]; \alpha]$ to $\tilde{0}$ (where $\tilde{0}$ is the 1 level fuzzy point which maps to the origin) is $d_0([[A_L(\alpha), A_R(\alpha)]; \alpha], \tilde{0}) = d_0([A_L(\alpha), A_R(\alpha)], 0) = \frac{1}{2}(A_L(\alpha) + A_R(\alpha)])$.

The signed distance of fuzzy number $\tilde{A}$ measured from $\tilde{0}$ defined as $d(\tilde{A}, \tilde{0}) = \frac{1}{2}\int_0^1 (A_L(\alpha) + A_R(\alpha))d\alpha$. We mainly discuss the signed distance of the triangular fuzzy number and the trapezoidal fuzzy number.

For the triangular fuzzy number, we have:

$$d(\tilde{A}, \tilde{0}) = \frac{1}{2}\int_0^1 [a_1 + (a_2 - a_1)\alpha + a_3 - (a_3 - a_2)\alpha]d\alpha = \frac{a_1 + 2a_2 + a_3}{4}.$$

Similarly, for the trapezoidal fuzzy number, we have:

$$d(\tilde{A}, \tilde{0}) = \frac{1}{2}\int_0^1 [a_1 + (a_2 - a_1)\alpha + a_4 - (a_4 - a_3)\alpha]d\alpha = \frac{a_1 + a_2 + a_3 + a_4}{4}.$$

Therefore, by the signed distance method, we can transform the fuzzy equilibrium conditions (11) into the equilibrium conditions.

(1) If $\tilde{c}_{jk}(Q^2), \tilde{\rho}_{3k}(D)$ is a triangular fuzzy number, let $\tilde{c}_{jk}(Q^2) = (c_{jk1}, c_{jk2}, c_{jk3})$, $\tilde{\rho}_{3k}(D) = (\rho_{3k1}, \rho_{3k2}, \rho_{3k3})$ then Eq. (11) can be transform into the form as follows,

$$\sum_{j=1}^{n}\sum_{k=1}^{o}\left[\rho_{jk} + \frac{c_{jk1} + 2c_{jk2} + c_{jk3}}{4}\right] \times [q_{jk} - q_{jk}^*] - \sum_{k=1}^{o}\frac{\rho_{3k1} + 2\rho_{3k2} + \rho_{3k3}}{4} \times [d_k - d_k^*] \succeq 0, \forall (Q^2, D) \in R_+^{no+o}. \tag{12}$$

(2) If $\tilde{c}_{jk}(Q^2), \tilde{\rho}_{3k}(D)$ is a trapezoidal fuzzy number, let $\tilde{c}_{jk}(Q^2) = (c_{jk1}, c_{jk2}, c_{jk3}, c_{jk4})$, $\tilde{\rho}_{3k}(D) = (\rho_{3k1}, \rho_{3k2}, \rho_{3k3}, \rho_{3k4})$ then Eq. (11) can be transform into the form as follows, $\forall (Q^2, D) \in R_+^{no+o}$

$$\sum_{j=1}^{n}\sum_{k=1}^{o}\left[\rho_{jk} + \frac{c_{jk1} + 2c_{jk2} + c_{jk3} + c_{jk4}}{4}\right] \times [q_{jk} - q_{jk}^*] - \sum_{k=1}^{o}\frac{\rho_{3k1} + \rho_{3k2} + \rho_{3k3} + \rho_{3k4}}{4} \times [d_k - d_k^*] \succeq 0. \tag{13}$$

3.4 The Equilibrium Conditions of the Whole Supply Chain

In equilibrium, we must have that the sum of the optimality conditions for all manufacturers, as expressed by inequality (3), the optimality conditions for all retailers, as expressed by inequality (7) and the optimality conditions for all demand markets, as expressed by inequality (12) (or (13)) must be satisfied. We state this explicitly in the following definition:

Definition 4 (*The supply chain network equilibrium*). The equilibrium state of the supply chain with fuzzy demand price is one where the product flows between the distinct tiers of the decision-makers coincide and the product flows and prices satisfy the sum of the variational inequalities (3), (7) and (12).

We now establish the equivalent form of supply chain network equilibrium as follows.

Theorem 1 (The variational inequality formulation) *The equilibrium conditions governing the supply chain model with competition are equivalent to the solution of the variational inequality problem given by: Determine* $(Q^{11*}, Q^{2*}, \tilde{\rho}^*) \in \Re$ *satisfying*

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\left[\frac{\partial f_i(Q^{11*})}{\partial q_{ij}}+\frac{\partial c_{ij}^*}{\partial q_{ij}}+\frac{\partial c_j(Q^{11*})}{\partial q_{ij}}\right]\times[q_{ij}-q_{ij}^*]+\sum_{j=1}^{n}\sum_{k=1}^{o}\left[\frac{\partial \frac{c_{jk1}+2c_{jk2}+c_{jk3}}{4}(Q^{2*})}{\partial q_{jk}}\right]$$
$$\times [q_{jk}-q_{jk}^*]-\sum_{k=1}^{o}\frac{\rho_{3k1}+2\rho_{3k2}+\rho_{3k3}}{4}\times[d_k-d_k^*]\geq 0, \tag{14}$$

where $\Re \equiv \{(Q^{11*}, Q^{2*}, \tilde{\rho}^*) \in R_+^{no+mn+o}\}$. *Similarly, we can get*

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\left[\frac{\partial f_i(Q^{11*})}{\partial q_{ij}}+\frac{\partial c_{ij}^*}{\partial q_{ij}}+\frac{\partial c_j(Q^{11*})}{\partial q_{ij}}\right]\times[q_{ij}-q_{ij}^*]+\sum_{j=1}^{n}\sum_{k=1}^{o}\left[\frac{\partial \frac{c_{jk1}+c_{jk2}+c_{jk3}+c_{jk4}}{4}}{\partial q_{jk}}\right]$$
$$\times [q_{jk}-q_{jk}^*]-\sum_{k=1}^{o}\frac{\rho_{3k1}+\rho_{3k2}+\rho_{3k3}+\rho_{3k4}}{4}\times[d_k-d_k^*]\geq 0. \tag{15}$$

4 Model Transformation

In order to solve the variational inequality (14) (or 15), we have to simplify model.

Let
$X=(Q^{11}, Q^2, \gamma, \tilde{\rho})^T,\ F(X)=(F^1(X), F^2(X), F^3(X), F^4(X))^T$,
$F^1(X)=(\ldots, F^1_{ij}(X), \ldots)^T$,
$F^2(X)=(\ldots, F^2_{jk}(X), \ldots)^T$,
$F^3(X)=(\ldots, F^3_{j}(X), \ldots)^T,\ F^4(X)=(\ldots, F^4_{k}(X), \ldots)^T$.
The four vector functions can be defined as follows,

$$F^1_{ij}(X)=\frac{\partial f_i(Q^{11*}, Q^{12*})}{\partial q_{ij}}+\frac{\partial c_{ij}^*}{\partial q_{ij}}+\frac{\partial c_j(Q^{11*})}{\partial q_{ij}}-\gamma_j^*,$$
$$F^2_{jk}(X)=\gamma_j^*+\frac{\partial \frac{c_{jk1}+c_{jk2}+c_{jk3}+c_{jk4}}{4}(Q^{2*})}{\partial q_{jk}}-\frac{\rho_{3k1}+2\rho_{3k2}+\rho_{3k3}}{4},$$

$$F_j^3(X) = \sum_{i=1}^{m} q_{ij}^* - \sum_{k=1}^{o} q_{jk}^*,$$
$$F_k^4(X) = \frac{\rho_{3k1} + 2\rho_{3k2} + \rho_{3k3}}{4}.$$

Thus, the variational inequality (14) can be written as:

$$F(X^*)^T(X - X^*) \geq 0, \forall X \in \Re_+. \tag{16}$$

The nonlinear complementary problem (NCP) of (16) is: find $X^* \in R_+$, such that:

$$F(X^*)^T X^* = 0, \quad F(X^*) \succeq 0. \tag{17}$$

By means of a merit function invented by [7], $\phi(a, b) = [\sqrt{a^2 + b^2} - (a + b)^2] : R^2 \to R_+$, the relevant NCP formulation (16) can be equivalently transformed into an unconstrained continuously differentiable minimization formulation:

$$\min_{\bar{X} \in \Re^{mn+no+n+o}} \Phi(\bar{X}), \tag{18}$$

where $\Phi(\bar{X}) = \sum_{i=1}^{m}\sum_{j=1}^{n} \Phi(q_{ij}, \bar{F}_{ij}^1(\bar{X})) + \sum_{i=1}^{m}\sum_{k=1}^{o} \Phi(q_{ik}, \bar{F}_{jk}^2(\bar{X})) + \sum_{j=1}^{n} \Phi(\gamma_j, \bar{F}_j^3(\bar{X})) + \sum_{k=1}^{o} \Phi(\rho_{3k}, \bar{F}_k^4(\bar{X}))$.

5 Numerical Examples

In this section, we apply the modified quasi-Newton method to a numerical example.

Example 1 The numerical example 1, depicted in Fig. 3a, consisted of two manufacturers, three retailers, two demand markets.

The production cost functions for the manufacturers for the product were given by $f_1(q) = 2.5(q_1)^2 + q_1q_2 + 2q_1$, $f_2(q) = 2.5(q_2)^2 + q_1q_2 + 12q_2$, where, $q_1 = q_{11} + q_{12} + q_{13} + \hat{q}_{11} + \hat{q}_{12}$, $q_2 = q_{21} + q_{22} + q_{23} + \hat{q}_{21} + \hat{q}_{22}$.

The transaction cost functions faced by the manufacturers and associated with transacting with the retailers for the product were given by:

$$c_{11}(q_{11}) = q_{11}^2 + 3.5q_{11},\ c_{12}(q_{12}) = q_{12}^2 + 3.5q_{12},$$
$$c_{13}(q_{13}) = 0.5(q_{13})^2 + 5q_{13},\ c_{21}(q_{21}) = 0.5(q_{21})^2 + 3.5q_{21},$$
$$c_{22}(q_{22}) = 0.5(q_{22})^2 + 3.5q_{22},\ c_{23}(q_{23}) = 0.5(q_{23})^2 + 5q_{23}.$$

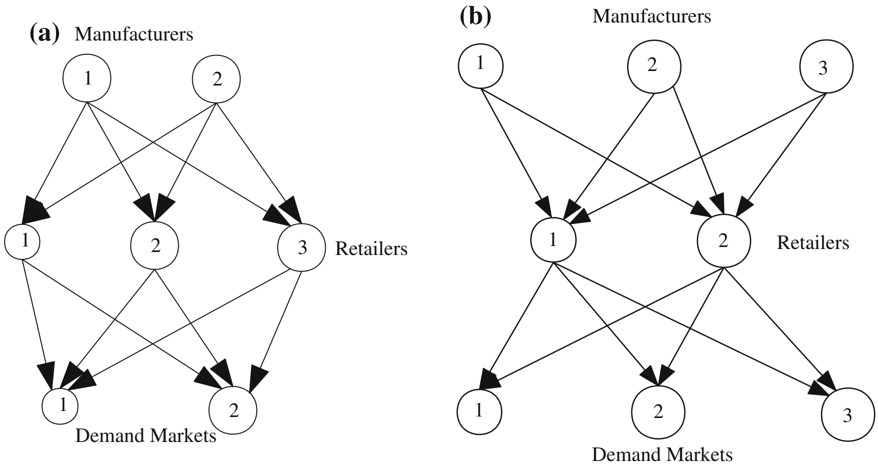

Fig. 3 Two examples

The handling costs of the retailers for the product, in turn, were given by: $c_1(Q^{11}) = 0.5(q_{11}+q_{21})^2$, $c_2(Q^{11}) = 0.5(q_{12}+q_{22})^2$, $c_3(Q^{11}) = 0.5(q_{13}+q_{23})^2$.

The fuzzy transaction costs between the retailers and the consumers for the product at the demand markets were given by:

$$\tilde{c}_{11}(Q_2) = (0.5, 1, 1.5)\bar{q}_{11} + (4, 5, 6),\ \tilde{c}_{12}(Q_2) = (0.5, 1, 1.5)\bar{q}_{12} + (4, 5, 6),$$
$$\tilde{c}_{21}(Q_2) = (0.5, 1, 1.5)\bar{q}_{21} + (4, 5, 6),\ \tilde{c}_{22}(Q_2) = (0.5, 1, 1.5)\bar{q}_{22} + (4, 5, 6),$$
$$\tilde{c}_{31}(Q_2) = (0.5, 1, 1.5)\bar{q}_{31} + (4, 5, 6),\ \tilde{c}_{32}(Q_2) = (0.5, 1, 1.5)\bar{q}_{32} + (4, 5, 6).$$

The fuzzy price function of demand markets:

$$p_1(D) = \left(\frac{5}{7}, \frac{6}{7}, 1\right)d_2 - \left(1, \frac{8}{7}, \frac{9}{7}\right)d_1 + \left(\frac{1500}{7}, \frac{2000}{7}, \frac{2500}{7}\right),$$
$$p_2(D) = \left(\frac{5}{7}, \frac{6}{7}, 1\right)d_1 - \left(1, \frac{8}{7}, \frac{9}{7}\right)d_2 + \left(\frac{1500}{7}, \frac{2000}{7}, \frac{2500}{7}\right).$$

We set the initial point $x^0 = (x_1^0, \ldots, x_j^0, \ldots, x_{17}^0)^T, x_j^0 = 10,\ j = 1, 2, \cdots, 17$. The calculation was implemented in MATLAB 7.1. The accuracy is taken as 10^{-8}. We can obtain the following results as Table 1, 2 and 3. The fuzzy price of the consumer market:

$$\tilde{\rho}_1 = (204.2947, 275.7232, 347.1518), \tilde{\rho}_2 = (204.2947, 275.7232, 347.1518).$$

Table 1 Manufacturer's production

Production	q_i
Manufacturer 1	35.364661
Manufacturer 2	34.573210

Table 2 The production flow from manufacturer to the retailer

q_{ij}	Retailer 1	Retailer 2	Manufacturer 3
Manufacturer 1	9.859068	9.859068	15.645985
Manufacturer 2	12.881787	12.881786	8.809636

Table 3 The output flow from retailer to the demand market

$\bar{q}_{ij}$	Demand marker 1	Demand market 2
Retailer 1	11.370427	11.370427
Retailer 2	11.370427	11.370427
Retailer 3	12.227811	12.227811
Demand	34.968665	34.968665

Example 2 The numerical example 2, depicted in Fig. 3b, consisted of three manufacturers, two retailers, three demand markets. Manufacturer's production cost function is:

$$f_1(q) = 2.5q_1^2 + q_1q_2 + 2q_1, \ f_2(q) = 2.5q_2^2 + q_1q_2 + 2q_2,$$
$$f_3(q) = 0.5q_3^2 + 0.5q_1q_3 + 2q_3.$$

The transaction costs function of manufacturers and related Retailers:

$$c_{11}(q_{11}) = q_{11}^2 + 3.5q_{11}, \ c_{12}(q_{12}) = q_{12}^2 + 3.5q_{12},$$
$$c_{21}(q_{21}) = 0.5q_{21}^2 + 3.5q_{21}, \ c_{22}(q_{22}) = 0.5q_{22}^2 + 3.5q_{22},$$
$$c_{31}(q_{13}) = 0.5q_{31}^2 + 5q_{31}, \ c_{32}(q_{23}) = 0.5q_{32}^2 + 5q_{32}.$$

Accordingly, the management costs of retailers: $c_1(Q^1) = 0.5(q_{11}+q_{21}+q_{31})^2$, $c_2(Q^1) = 0.5(q_{12} + q_{22} + q_{32})^2$.

The fuzzy price function of demand markets:

$$p_1(D) = \left(\frac{5}{7}, \frac{6}{7}, \frac{6}{7}, 1\right)d_2 - \left(1, \frac{8}{7}, \frac{8}{7}, \frac{9}{7}\right)d_1 + \left(\frac{1500}{7}, \frac{2000}{7}, \frac{2000}{7}, \frac{2500}{7}\right),$$
$$p_2(D) = \left(\frac{5}{7}, \frac{6}{7}, \frac{6}{7}, 1\right)d_1 - \left(1, \frac{8}{7}, \frac{8}{7}, \frac{9}{7}\right)d_2 + \left(\frac{1500}{7}, \frac{2000}{7}, \frac{2000}{7}, \frac{2500}{7}\right),$$

Table 4 Manufacturer's production

Production	q_i
Manufacturer 1	22.724080
Manufacturer 2	25.248978
Manufacturer 3	101.154278

$$p_3(D) = \left(\frac{5}{7}, \frac{6}{7}, \frac{6}{7}, 1\right)d_1 - \left(\frac{6}{14}, \frac{9}{14}, \frac{9}{14}, \frac{12}{14}\right)d_2 - \left(\frac{5}{14}, \frac{7}{14}, \frac{9}{14}\right)d_3 + \left(\frac{1500}{7}, \frac{2000}{7}, \frac{2000}{7}, \frac{2500}{7}\right).$$

Retailers and consumers in the demand market for transaction costs:

$$\tilde{c}_{11}(Q_2) = (0.5, 1, 1, 1.5)\bar{q}_{11} + (4, 5, 5, 6),\ \tilde{c}_{12}(Q_2) = (0.5, 1, 1, 1.5)\bar{q}_{12} + (4, 5, 5, 6),$$
$$\tilde{c}_{13}(Q_2) = (0.5, 1, 1, 1.5)\bar{q}_{13} + (4, 5, 5, 6),\ \tilde{c}_{21}(Q_2) = (0.5, 1, 1, 1.5)\bar{q}_{21} + (4, 5, 5, 6),$$
$$\tilde{c}_{22}(Q_2) = (0.5, 1, 1, 1.5)\bar{q}_{22} + (4, 5, 5, 6), \tilde{c}_{23}(Q_2) = (0.5, 1, 1, 1.5)\bar{q}_{23} + (4, 5, 5, 6).$$

Take the initial point: $X^0 = (x_1^0 \ \dots \ x_j^0 \ x_{17}^0)^T, x_j^0 = 10, j = 1, 2, \dots, 17$. With the revised quasi-Newton method for solving nonlinear complementarity problem, We can obtain the following results as Table 4, 5 and 6. By the signed distance method, the fuzzy demand price can be by means of defuzzification: $\bar{\rho}_1 = 271.5117$, $\bar{\rho}_2 = 271.5117$, $\bar{\rho}_3 = 271.5117$.

Table 5 The production flow from manufacturer to the retailer

q_{ij}	Retailer 1	Retailer 2
Manufacturer 1	11.362040	11.362040
Manufacturer 2	12.624489	12.624489
Manufacturer 3	50.577139	50.577139

Table 6 The output flow from retailer to the demand market

$\bar{q}_{ij}$	Demand market 1	Demand market 2	Demand market 3
Retailer 1	24.854556	24.854556	24.854556
Retailer 2	24.854556	24.854556	24.854556
Demand	49.709112	49.709112	49.709112

6 Conclusion

In this paper, we have proposed a theoretically rigorous framework for the modeling and computation of solutions to supply chain network problems within an equilibrium context in the case of fuzzy demand prices associated with the demand markets. The equilibrium conditions were established, the modified Quasi-Newton Method was proposed for the computation of the equilibrium prices and product shipments. Two illustrative supply chain network examples were considered in the computations.

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Dynamic Optimal Allocation of Irrigation Water Resources for Multi-crop in Multiple Agricultural Subareas with Fuzzy Random Seasonal Inflow and Rainfall

Xinxin Xu, Ziqiang Zeng and Edward Minchin

Abstract This paper studies the dynamic optimal allocation of irrigation water resources for multi-crop in multiple agricultural subareas. A multistage irrigation scheduling decision making model is developed which takes into account the decision variable, state variable, state transition equation, initial and terminal conditions, constraints, crop-water production function, and evaporated and leached water. In order to deal with the uncertainty of seasonal inflow and rainfall, the fuzzy random simulation is employed. Results analysis for a case problem is presented to demonstrate the performance of the optimization method, which is proved to be very effective and efficient compared to the actual irrigation scheduling situation.

Keywords Agriculture · Irrigation · Water resources · Fuzzy · Dynamic systems

1 Introduction

Agriculture is a main user of the world's water resources [1]. The irrigation water allocation is a key problem in agricultural water management. An important issue in sustainable agriculture is to optimize productivity with respect to resource inputs such as water [2]. Traditionally, agricultural research is focused primarily on maximizing the yield per unit area by allocating water to different crops according to their water requirements [3–8]. In the recent years, focus is also shifting to increase productivity within the constraints of available limited water resources. Vedula et al. [9] proposed a linear programming model for optimal use of ground and surface water to maximize the annual relative yields of the crops. Gorantiwar and Smout [4] developed

X. Xu · Z. Zeng (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: zengziqiang@scu.edu.cn

E. Minchin
Rinker School of Construction Management, University of Florida, Gainesville, FL 32611, USA

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a resource allocation, area and water allocation model with limited water supply through a variable depth irrigation approach. These studies have made significant improvements in the area of agricultural water management.

The literature review indicated that most of the optimization models used an economic criterion to find out the optimal cropping pattern or irrigation schedule to maximize the benefits for the optimal allocation of land and water resources. In fact, the irrigation scheduling is a multistage decision making process [10] which is influenced by uncertain factors including seasonal inflow and rainfall. The irrigation water management are mostly not dynamic in the above mentioned optimization models. Therefore these optimization models may optimize for a relative optimized level and may not give an overall optimal solution under a dynamic decision making viewpoint.

The present study aims to develop a dynamic optimization model for irrigation water resources allocation for multi-crop in multiple agricultural subareas. The uncertain events in this environment including seasonal inflow and rainfall are characterized by both fuzzy uncertainty and randomness, the so-called twofold uncertainty. In this case, fuzzy random variables, introduced by Kwakernaak [11, 12] and Kruse and Meyer [13] in modeling and analyzing "imprecise values" associated with the sample space of a random experiment through the use of fuzzy-set functions can be employed. The mathematical optimization technology proposed in this paper is actually a soft water path [14] which seeks to improve the overall productivity of water use and deliver water services matched to the needs of end users.

2 Key Problem Statement

Agricultural irrigation systems are often composed of various interconnected components that exhibit more complexities than its individual parts, yielding much complicated information that can hardly be neglected [15]. Taking Dujiangyan Irrigation District in China as an example, the main source of water comes from the seasonal inflow of Min River and the rainfall in this area which may change during different periods in a year. Most of the water will be stored in the reservoir in this area except the evaporated water into air and the leached water into ground. The water stored in the reservoir will be dynamically allocated for agricultural water use and non-agricultural water use, such as industrial water use, municipal water use, and environmental water use. The water allocated for agricultural water use will be distributed in multiple periods for irrigating multiple crops in different subareas (see Fig. 1). The goal of the water manager is to maximize the net benefit to the local agricultural economy. However, if the anticipated water is not delivered, the user will have to either curtail their irrigation plans or obtain water from more expensive ways such as withdrawing groundwater.

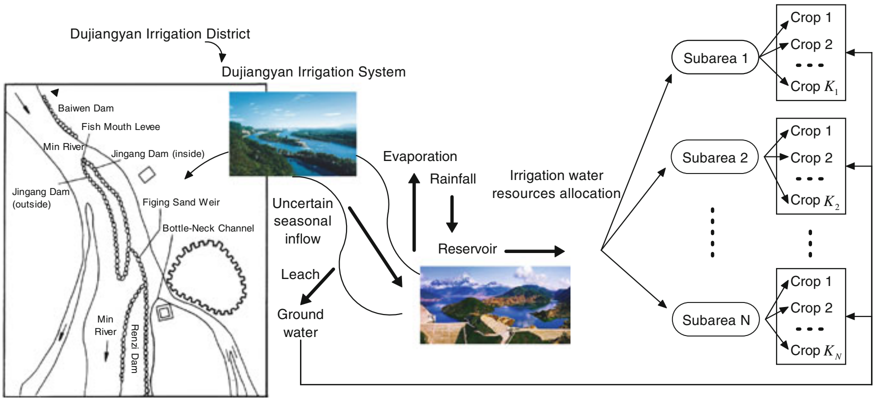

Fig. 1 Irrigation water resources allocation problem in Dujiangyan Irrigation District

3 Dynamic Modelling Approach

The optimization of irrigation water resources allocation for multi-crops in multiple agricultural subareas with fuzzy random seasonal inflow and rainfall is done based on the benefit function. The decision variable, state variable, state transition equation, and constraints of the model are also defined as below.

1. Benefit Function

The benefit function is regarded as the objective function of the model. It indicates the annual net irrigation benefit of the local agricultural economy for all subareas, which is expressed as below,

$$B = \max\{G - C\}, \tag{1}$$

where B (10^3 RMB) is the maximized total net benefit of local agricultural economy from irrigation scheduling for all subareas during a year; G (10^3 RMB) and C (10^3 RMB) are the annual gross income and total cost from irrigation scheduling for all subareas, respectively. Here it is assumed that all the crops in each subarea are bringing in one harvest a year. The expressions of G and C are listed as follows.

Gross Income:

$$G = \sum_{i=1}^{N} \sum_{k=1}^{K_i} p_i^k U_i^k A_i^k, \tag{2}$$

where i is the index of subarea ($i = 1, 2, \ldots, N$); k is the type of crop ($k = 1, 2, \ldots, K_i$); p_i^k (RMB/kg) is the unit price of crop k in subarea i; U_i^k (kg/ha) is the yield per unit area of crop k in subarea i; A_i^k (ha) is the cultivated area of crop k in subarea i.

Total Cost:

$$C = \sum_{i=1}^{N}\sum_{k=1}^{K_i}(B_i^k + Y_i^k U_i^k + W_i^k Q_i^k)A_i^k, \tag{3}$$

where B_i^k (RMB/ha) is the basic cost (fixed cost which is independent of the yield) per unit area of crop k in subarea i; Y_i^k (RMB/kg) is the variable cost per unit yield of crop k in subarea i; W_i^k (RMB/m^3) is the irrigation price of crop k in subarea i; Q_i^k (m^3/ha) is the irrigation water amount per unit area.

2. Decision and State Variables for Dynamic Irrigation Scheduling
The decision variables of this model are defined as A_i^k (ha), i.e., the cultivated area of crop k in subarea i, and x_i^k (m^3), i.e., the allocated irrigation water for crop k in subarea i in period t. It is not hard to know that,

$$Q_i^k A_i^k = \sum_{t=1}^{T} x_i^k(t), \quad \forall i, \forall k, \tag{4}$$

where t is the planning period associated with crop growth stage ($t = 1, 2, \ldots, T$). The state variable of this model is defined as $S(t)$, i.e., the total available water stored in the reservoir at the end of period t.

3. State Transition Equation for Irrigation Water Resources Allocation
As described in the key problem statement, the irrigation water resources allocation problem discussed here is actually a multistage decision making process, and follows a state transition equation as shown below,

$$S(t) = S(t-1) + \tilde{\tilde{f}}(t) + \tilde{\tilde{r}}(t) - e(t) - g(t) - n(t) - \sum_{i=1}^{N}\sum_{k=1}^{K_i} x_i^k(t), \tag{5}$$

where $\tilde{\tilde{f}}(t)$ (m^3) is the seasonal inflow in period t; $\tilde{\tilde{r}}(t)$ (m^3) is the rainfall in period t; $e(t)$ (m^3) is the evaporated water in period t; $g(t)$ (m^3) is the leached water into ground in period t; $n(t)$ (m^3) is the non-agricultural water use in period t; x_i^k (m^3) is the irrigation water allocated to crop k in subarea i in period t. The dynamic relationships between these variables are shown in Fig. 2, in which the available water stored in reservoir in each period will be lost through evaporation and leaching into ground, and replenished through seasonal inflow and rainfall. It will be used for non-agricultural water use and agricultural water use for irrigating crops in multiple subareas.

4. Initial and Terminal Conditions
The state variable $S(t)$ should follows the following initial and terminal conditions, $S(0) = S_0, \quad S(T) \geq S_T$, where S_0 (m^3) is the initial stored water in the reservoir at the beginning of the first period, and S_T (m^3) is the minimal stored water level limit at the end of the final period.

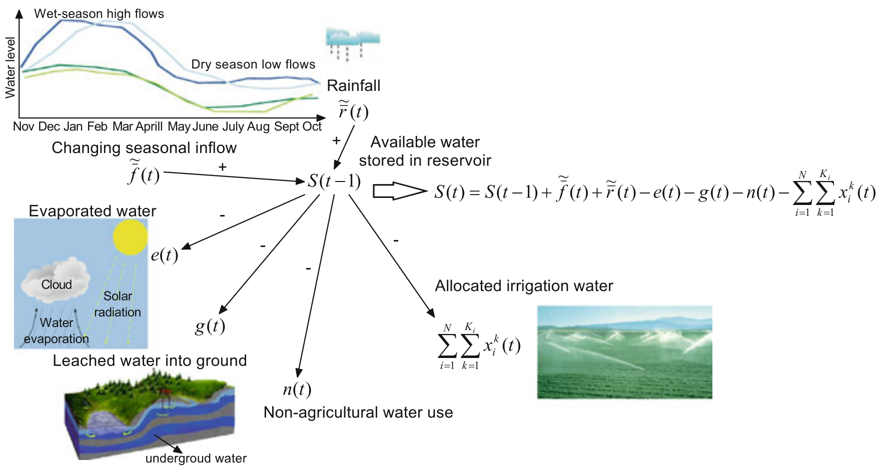

Fig. 2 Dynamic relationships between decision and state variables and relevant parameters

5. Constraints

The decision variables are constrained by three kinds of restrictions, i.e., non-negative constraints, total cultivated area limitation, and agricultural policy restraint, which are described in details as follows.

Non-negative constraints:

$$x_i^k(t) \geq 0, \quad A_i^k \geq 0, \quad \forall i, \forall k. \tag{6}$$

Total cultivated area limitation:

$$\sum_{i=1}^{N}\sum_{k=1}^{K_i} A_i^k \leq A_0, \tag{7}$$

where A_0 (ha) is the total available cultivated area.

Agricultural policy restraint:

The local government requests that the cultivated area of food crop must come to a certain ratio (F %) for achieving food self-supporting ability. The constraint is expressed as below,

$$\sum_{i=1}^{N}\sum_{k=1}^{K_i} AF_i^k \Big/ \sum_{i=1}^{N}\sum_{k=1}^{K_i} A_i^k \geq F\,\%, \tag{8}$$

where AF_i^k (ha) is the cultivated area of food crop k in subarea i; F % is the lowest rate limitation that the cultivated area of food should achieve.

6. Crop-Water Production Function
The crop-water production function expresses the relationship between Q_i^k (m^3/ha) and U_i^k (kg/ha). In this paper, the quadratic relationship is considered,

$$U_i^k = a_i^k + b_i^k Q_i^k + c_i^k (Q_i^k)^2 \tag{9}$$

where a_i^k, b_i^k, and c_i^k are empirical coefficients.

7. Evaporated and Leached Water
The evaporated and leached water in each period are considered to be linearly related to the total available water stored in the reservoir at the end of the last period, i.e.,

$$e(t) = \theta(t)S(t-1), \text{ and } g(t) = \phi(t)S(t-1), \tag{10}$$

where $\theta(T)$ and $\phi(T)$ are the evaporation and leaching coefficients of the stored water in each period.

8. Global Model
By integrating the benefit function, state transition equation, initial and terminal conditions, constraints, and crop-water production function, a multistage irrigation scheduling decision making model for multi-crop in multiple agricultural subareas is built as shown below,

$$\begin{cases} \max\{\sum_{i=1}^{N}\sum_{k=1}^{K_i} p_i^k U_i^k A_i^k - \sum_{i=1}^{N}\sum_{k=1}^{K_i}(B_i^k + Y_i^k U_i^k + W_i^k Q_i^k)A_i^k\} \\ s.t. \begin{cases} S(t)=S(t-1)+\tilde{\bar{f}}(t)+\tilde{\bar{r}}(t)-e(t)-g(t)-n(t)-\sum_{i=1}^{N}\sum_{k=1}^{K_i} x_i^k(t), \ \forall t \\ S(0)=S_0, \quad S(T)\ge S_T \\ x_i^k(t)\ge 0, \quad A_i^k \ge 0, \quad \forall i, \forall k \\ Q_i^k A_i^k = \sum_{t=1}^{T} x_i^k(t), \quad \forall i, \forall k \\ \sum_{i=1}^{N}\sum_{k=1}^{K_i} A_i^k \le A_0 \\ \sum_{i=1}^{N}\sum_{k=1}^{K_i} AF_i^k / \sum_{i=1}^{N}\sum_{k=1}^{K_i} A_i^k \ge F\,\% \\ U_i^k = a_i^k + b_i^k Q_i^k + c_i^k (Q_i^k)^2, \quad \forall i, \forall k \\ e(t)=\theta(t)S(t-1), \quad \forall t \\ g(t)=\phi(t)S(t-1), \quad \forall t. \end{cases} \end{cases} \tag{11}$$

4 Fuzzy Random Simulation of Seasonal Inflow and Rainfall

In order to deal with the uncertainty of the seasonal inflow and rainfall, the fuzzy random simulation is employed here. The historical data of local seasonal inflow and rainfall show that they are seasonal changed under different probabilities within different value ranges. The value ranges of seasonal inflow and rainfall in each period could be divided into different interval numbers, such as low, medium, and high. The probability of occurrence of the seasonal inflow and rainfall in each period

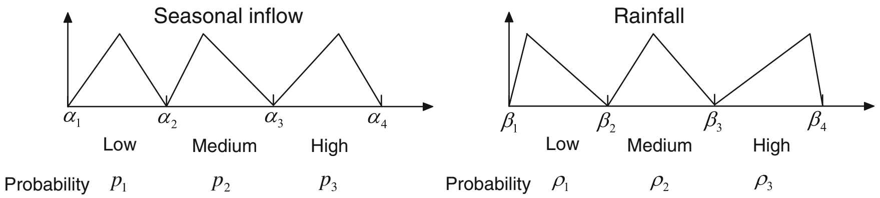

Fig. 3 Fuzzy random numbers for seasonal inflow and rainfall

falls into an interval could be estimated based on historical data. Figure 3 shows an example of fuzzy random numbers for seasonal inflow and rainfall.

The simulation steps for generating the values of seasonal inflow and rainfall for each period are listed as follows.

Step 1. Define the membership functions of seasonal inflow and rainfall as below,

Seasonal inflow:

$$\tilde{\bar{f}}(t)(\omega) = \begin{cases} (\alpha_1, \alpha_l, \alpha_2),\ p = p_1, \omega = low \\ (\alpha_2, \alpha_m, \alpha_3),\ p = p_2, \omega = medium \\ (\alpha_3, \alpha_h, \alpha_4),\ p = p_3, \omega = high. \end{cases}$$

Rainfall:

$$\tilde{\bar{r}}(t)(\omega) = \begin{cases} (\beta_1, \beta_l, \beta_2),\ p = \rho_1, \omega = low \\ (\beta_2, \beta_m, \beta_3),\ p = \rho_2, \omega = medium \\ (\beta_3, \beta_h, \beta_4),\ p = \rho_3, \omega = high. \end{cases}$$

Step 2. Generating random numbers x that follow uniform distribution within the range [0, 1].

Step 3. If $x \in [0, p_1]$, select seasonal inflow fuzzy membership function $(\alpha_1, \alpha_2, \alpha_3)$ (i.e., $\omega = low$), and generate the seasonal inflow value according to the membership of the triangular fuzzy number $(\alpha_1, \alpha_2, \alpha_3)$; if $x \in [p_1, p_1 + p_2]$, select seasonal inflow fuzzy membership function $(\alpha_2, \alpha_m, \alpha_3)$ (i.e., $\omega = medium$), and generate the seasonal inflow value according to the membership of the triangular fuzzy number $(\alpha_2, \alpha_m, \alpha_3)$; otherwise, if $x \in [p_1 + p_2, 1]$, select seasonal inflow fuzzy membership function $(\alpha_3, \alpha_h, \alpha_4)$ (i.e., $\omega = high$), and generate the seasonal inflow value according to the membership of the triangular fuzzy number $(\alpha_3, \alpha_h, \alpha_4)$.

Step 4. If $y \in [0, \rho_1]$, select rainfall fuzzy membership function $(\beta_1, \beta_2, \beta_3)$ (i.e., $\omega = low$), and generate the seasonal inflow value according to the membership of the triangular fuzzy number $(\beta_1, \beta_2, \beta_3)$; if $y \in [\rho_1, \rho_1 + \rho_2]$, select rainfall fuzzy membership function $(\beta_2, \beta_m, \beta_3)$ (i.e., $\omega = medium$), and generate the rainfall value according to the membership of the triangular fuzzy number $(\beta_2, \beta_m, \beta_3)$; otherwise, if $y \in [\rho_1 + \rho_2, 1]$, select rainfall fuzzy membership function $(\beta_3, \beta_h, \beta_4)$ (i.e., $\omega = high$), and generate the rainfall value according to the membership of the triangular fuzzy number $(\beta_3, \beta_h, \beta_4)$.

5 Application Example

In order to demonstrate the effectiveness of the proposed model, an application example is employed here. The case description, solution method, and results analysis are presented as below.

1. Case Description
The irrigation district considered in this paper has three subareas, i.e., Dongjiageng County ($i = 1$), Xinmin County ($i = 2$), and Sancha County ($i = 3$). Each subarea can plant three kinds of crops, i.e., rice ($k = 1$), oilseed rape ($k = 2$), and cotton ($k = 3$). The total available cultivated area $A_0 = 945$ ha; the initial stored water in the reservoir at the beginning of the first period $S_0 = 1.25 \times 10^7$ m^3; the minimal stored water level limit at the end of the final period $S_T = 1.0 \times 10^7$ m^3; the empirical coefficients of crop-water production function, the unit price of crop k in subarea i, the basic cost (fixed cost which is independent of the yield) per unit area of crop k in subarea i, the variable cost per unit yield of crop k in subarea i, the irrigation price of crop k in subarea i, are estimated as shown in Table 1. The seasonal inflow in period t, the rainfall in period t, the evaporation and leaching coefficients are shown in Table 2. The total planning periods associated with crop growth stage T is 4. The ratio for achieving food self-supporting ability is $F\,\% = 40\,\%$.

2. Results Analysis
To show the practicality and efficiency of the optimization method for the above problem, the fuzzy random simulation-based particle swarm optimization is implemented to solve model (11), and the results are compared with actual allocation plan as listed in Table 3. As shown, the solution of the case problem is expressed by A_i^k and $x_i^k(t)$. By comparing the annual net irrigation benefit of the case problem with the actual situation in Table 3, the findings indicate that there exist differences between solutions generated by the optimization method and the actual annual net irrigation benefit. The net increase of the annual net irrigation benefit is 2,800,000 RMB, and the rate of increase is 17.9 %. This improvement can bring considerable economic benefit. This means the current irrigation plan is not optimal in terms of theory. In fact, in current practice, the decision makers usually make their decisions depending only on experience. Therefore, the optimization results can be used to provide decision makers with a theoretical optimal dynamic allocation of irrigation water for guiding current practice.

Table 1 Data information of case problem-I

Parameters	Index of subarea	Type of crop		
		Rice ($k = 1$)	Oilseed rape ($k = 2$)	Cotton ($k = 3$)
p_i^k (RMB/kg)	Dongjiageng County ($i = 1$)	1.5	15.5	11.5
	Xinmin County ($i = 2$)	1.6	14.5	12.0
	Sancha County ($i = 3$)	1.5	15.0	12.5
B_i^k (RMB/ha)	Dongjiageng County ($i = 1$)	3120	4720	4120
	Xinmin County ($i = 2$)	3230	4680	4210
	Sancha County ($i = 3$)	3180	4750	4160
Y_i^k (RMB/kg)	Dongjiageng County ($i = 1$)	0.80	6.50	4.50
	Xinmin County ($i = 2$)	0.85	6.00	4.00
	Sancha County ($i = 3$)	0.80	7.00	4.50
W_i^k (RMB/m^3)	Dongjiageng County ($i = 1$)	0.23	0.25	0.30
	Xinmin County ($i = 2$)	0.22	0.27	0.31
	Sancha County ($i = 3$)	0.25	0.28	0.34
a_i^k	Dongjiageng County ($i = 1$)	3305	1400	1020
	Xinmin County ($i = 2$)	3280	1460	1100
	Sancha County ($i = 3$)	3340	1420	1080
b_i^k	Dongjiageng County ($i = 1$)	3.1	1.4	2.8
	Xinmin County ($i = 2$)	3.3	1.3	2.7
	Sancha County ($i = 3$)	3.2	1.2	2.9
c_i^k	Dongjiageng County ($i = 1$)	5.82×10^{-4}	5.98×10^{-4}	8.12×10^{-4}
	Xinmin County ($i = 2$)	6.13×10^{-4}	6.38×10^{-4}	7.96×10^{-4}
	Sancha County ($i = 3$)	5.95×10^{-4}	5.76×10^{-4}	8.24×10^{-4}

Table 2 Data information of case problem-II

Parameters	Index of stage			
	$t = 1$	$t = 2$	$t = 3$	$t = 4$
$\tilde{\bar{f}}(t)$ (10^6 m^3)	(1.73, 1.86, 1.93)	(7.24, 8.43, 9.56)	(12.45, 14.32, 15.89)	(5.48, 6.32, 7.12)
$\tilde{\bar{r}}(t)$ (10^6 m^3)	(0.65, 0.79, 0.87)	(0.91, 1.12, 1.28)	(0.74, 0.83, 0.94)	(0.42, 0.56, 0.68)
$n(t)$ (10^3 m^3)	3368.4	3898.1	3567.4	3735.5
$\theta(t)$	5.6 %	12.9 %	7.5 %	2.6 %
$\phi(t)$	3.8 %	4.6 %	3.7 %	4.1 %

Table 3 Results of case problem

Parameters	Index of subarea	Type of crop		
		Rice ($k = 1$)	oilseed rape ($k = 2$)	cotton ($k = 3$)
A_i^k (ha)	Dongjiageng County ($i = 1$)	123	101	82
	Xinmin County ($i = 2$)	134	96	75
	Sancha County ($i = 3$)	141	105	88
$x_i^k(1)$ (10^4 m^3)	Dongjiageng County ($i = 1$)	6.85	2.46	2.35
	Xinmin County ($i = 2$)	7.33	2.61	2.25
	Sancha County ($i = 3$)	7.82	2.72	2.94
$x_i^k(2)$ (10^4 m^3)	Dongjiageng County ($i = 1$)	6.12	2.81	2.43
	Xinmin County ($i = 2$)	7.37	2.32	2.31
	Sancha County ($i = 3$)	7.55	2.13	2.37
$x_i^k(3)$ (10^4 m^3)	Dongjiageng County ($i = 1$)	5.61	2.98	2.49
	Xinmin County ($i = 2$)	6.95	2.51	2.45
	Sancha County ($i = 3$)	7.57	2.61	2.12
$x_i^k(4)$ (10^4 m^3)	Dongjiageng County ($i = 1$)	6.12	2.91	2.27
	Xinmin County ($i = 2$)	6.45	2.13	2.17
	Sancha County ($i = 3$)	7.28	2.75	2.36
Annual net irrigation benefit	Optimized (10^7 RMB)	Actual (10^7 RMB)	Net increase (10^7 RMB)	Rate of increase (%)
B	1.84	1.56	0.28	17.9

6 Conclusion

In this article, the dynamic optimal allocation of irrigation water resources for multi-crop in multiple agricultural subareas with fuzzy random seasonal inflow and rainfall is studied. A multistage irrigation scheduling decision making model is established which takes into account the decision variable, state variable, state transition equation, initial and terminal conditions, constraints, crop-water production function, and evaporated and leached water. The fuzzy random simulation is employed to deal with the uncertainty of seasonal inflow and rainfall. A case problem is presented which is solved by implementing the fuzzy random simulation-based particle swarm optimization. The performance of the optimization method proposed in this paper is demonstrated to be very effective and efficient compared to the actual irrigation scheduling based on the results analysis.

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Part III
Information Technology

Optimal Choice of Parameters for Unknown Function in Big Data Analysis Problems

Asaf Hajiyev and Abdullayeva Narmina

Abstract New form of regression models with increasing number of unknown parameters and unknown and different values of errors variance are considered. It is supposed that a number of unknown parameters can increase when number of observations becomes large. At the each point there is only one observation, which does not allow to estimate variances. The new method for estimating of unknown parameters, choice of an optimal number of unknown parameters and construction a confident band for unknown function in these models is suggested. Numerical examples, demonstrating these results are given.

Keywords Regression models · Increasing number of parameters · Least square estimators · Confidence band · Eigen-value

1 Introduction

Each process is described by behaviour of some function, which theoretically depends on various parameters, but in fact on empirical observations. Such function can be called regression or relationship. There are a lot of books and papers with regression models [2, 5, 6] but in spite of this investigation of regression models with increasing number of unknown parameters still remains as an important for applications and there are a lot of scholars who active works in this field.

One of the important problems in statistical data analysis is deriving of such relationship, which based on empirical observations. Although some relationship is postulated on theoretical grounds, sometimes the theories were originally obtained from empirical observations. Moreover, sometimes relationship needs to be empirically

A. Hajiyev (✉)
Institute of Systems Control, Azerbaijan National Academy of Sciences, Baku, Azerbaijan
e-mail: asaf.hajiyev@gmail.com

A. Narmina
Azerbaijan Turizm University, Baku, Azerbaijan

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tested. In statistical data analysis an increasing of number of observations (Big data) allows to derive more exact relationship. Other side, statistical analysis of big data leads to complicated technical and as well mathematical problems and needs to develop the new methods and approaches from various branches of mathematics.

Some relationship can be discovered or verify easy, if we can neglect a random part (error of observations) of observations. But if a random part of observations plays essential role then it leads to complicated situation and needs a creation of theory of big data analysis, where specific role plays the conditions for errors of observations.

In the problems of big data analysis when we do not have enough information about process, for finding relationship (estimating of unknown function) sometimes it is necessary to introduce new parameters, whose number can growing up, if number of observations becomes large (big data). Some models with increasing number of unknown parameters were investigated in [3, 4].

Significant problem here is an optimal choice of unknown parameters, which leads to other problems such as, construction and convergence of parameter estimators, their properties, unbiased, consistent and others. For construction of some estimators we need information about errors of observations. The typical problem for applications is a situation, when errors of observations are different and unknown. In the literature there are not so many papers, linked with such models. Some models with unknown and different errors variance have been considered in [1, 7].

In this paper we consider the models, where one or more parameters (we call them independent parameters) affect other variables (called dependent variables or response variables, also can be called observations). Such models are called regression models and we concentrate our attention on such models. Although there are a lot papers published in the field of regression models, but models with increasing numbers of unknown parameters investigated not deep. In this paper we investigate regression models with increasing number of unknown parameters.

2 Construction of the Models

Let us assume that as a matter of experience it is observed (response) variable y_i, $i = 1, 2, \ldots, N$, where

$$y_i = f(x_i) + \varepsilon_i, \quad i = 1, 2, \ldots, N. \tag{1}$$

The variables y_i, $i = 1, 2, \ldots, N$ depend on many (dependent) parameters $\theta = (\theta_1, \theta_2, \ldots, \theta_m, \ldots)^T$, whose number $m(N)$ depend on N and $m(N)$ moreover can increase, when $N \to \infty$.

Consider the regression model:

$$y_i = f(x_i, \theta) + \varepsilon_i, \quad i = 1, 2, \ldots, N, \tag{2}$$

where x_i is the point of observation, y_i an observable value, ε_i a random error at the point x_i and $\theta = (\theta_1, \theta_2, \dots, \theta_m, \dots)^T$ is the vector of unknown parameters. Let's suppose that the number of unknown parameters $m(N)$ depends on the number of observations N and $m(N)$ may increase, when N becomes larger. Such regressions are typical for application, because big number of parameters allows better to approximate relationship and called, regression models with increasing number of unknown parameters.

The variances of observation error $\varepsilon_i, i = 1, 2, \dots, N$ are unknown and may be different. We also assume that at each point x_i there is only one observable value y_i that does not allow estimation of the variance. Such models are typical for applications because at the practice we do not have information about variances and more over they are different at each point of observation. Some approaches for investigation of such models have been proposed in [1, 7]. Regression models with an increasing number of unknown parameters and with unknown and different variances of observation error are of interest in important applications. The reason for this is that, with an increased number of unknown parameters, the unknown function can be approximated more accurately in experiments.

Moreover, in some applications, repeated tests at a single point are costly (financially and technically), which hampers the estimation of the unknown error variance, which is different at different observation points. Regression models have been widely addressed in numerous publications [2, 5, 6], but models with an increasing number of unknown parameters have received little attention, which motivates our interest in this subject. The main aim of our investigations is:

(1) Estimating of unknown parameters in regression (linear and nonlinear) models;
(2) Direct estimating (without estimating of a variance) the elements of the covariance matrix of the vector, where is the least square estimator (l.s.e.);
(3) Construction of a confidence band for the unknown function.

3 Linear Regression Models

$f(x, \theta) = \theta_1\phi_1(x) + \theta_2\phi_2(x) + \dots + \theta_{m(N)}\phi_{m(N)}(x)$, where $\phi_1(x), \phi_2(x), \dots, \phi_{m(N)}(x)$ is a system of linearly independent and bounded functions. Equation (1) can be rewritten in a vector form as $Y = X\theta + \varepsilon$, where Y is the vector of observable values, X is the design matrix, defined as $X = \parallel xij \parallel, x_{ij} = \phi_i(x_j), i = 1, 2, \dots, m; j = 1, 2, \dots, n$; with $\theta = (\theta_1, \theta_2, \dots, \theta_{m(N)})$ being the vector of unknown parameters and $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots, \varepsilon_N)$ denoting the error-vector. The number of unknown parameters $m(N)$ depends on the number of observations N and moreover $m(N)/N \to \infty$, as $N \to \infty$.

The sequence $\varepsilon_1, \varepsilon_2, \dots, \varepsilon_N$ is assumed to have uniformly bounded and independent random variables with: $E\varepsilon_i = 0$, $E\varepsilon_i{}^2 = \sigma_i{}^2$, being unknown, different and $0 < (\sigma_*)^2 \leq \sigma_i{}^2 \leq \sigma^{*2} < \infty$.

Let $\theta^* = (X^T - X)^{-1}X^TY^Y$ be the l.s.e and $trA = \sum_{i=1}^{n} a_{ii}$ be the trace of the matrix A with elements a_{ij}.

Definition 1 The vector $\theta = (\theta_1, \theta_2, \ldots, \theta_{m(N)})^T$ with random elements and increasing dimension converges to zero in probability

$$\theta \xrightarrow{P} 0, \text{ if } \sum_{i=1}^{m(N)} \theta_i{}^2 \xrightarrow{P} 0 \text{ as } N \to \infty,$$

where $\xrightarrow{P} 0$ means convergence in probability.

Denote $0 < \lambda_1(N) \leq \lambda_2(N) \leq \cdots \lambda_m(N)$ eigen-values of the matrix $(X^T X)/N$.

Let us take any $\delta > 0$ and consider:

$$P\big\{/\theta^* - \theta/ \geq \delta\big\} \leq P\big\{/(X^T X)^{-1} X^T (X\theta + \varepsilon) - \theta/ \geq \delta\big\}$$
$$= P\big\{/(X^T X)^{-1} X^T \varepsilon/ \geq \delta\big\}.$$

Using Chebyshev inequality we have

$$P\big\{/\theta^* - \theta/ \geq \delta\big\} \leq E\big\{(X^T X)^{-1} X^T \varepsilon\varepsilon^T X (X^T X)^{-1}\big\} = (1/N)tr(X^T X)^{-1}.$$

As $tr(X^T X/N)^{-1} = \sum_{i=1}^{m} \lambda_i$, where λ_i is an eigen-value of the matrix $(X^T X/N)^{-1}$, then we are getting $(X^T X/N)^{-1}$, then we are getting

$$P\{/\theta^* - \theta/ \geq \delta\} \leq E(1/N)tr(X^T X)^{-1} \leq m\lambda_1/N,$$

thus if $m\lambda_1/N \to 0$ as $N \to \infty$ then we have $P\{/\theta * -\theta/ \geq \delta\} \to 0$ i.e.

$$/\theta^* - \theta/ \xrightarrow{P} 0, \quad \text{i.e. } \theta^* \text{ is a consistent estimator of } \theta. \tag{3}$$

Remark 1 Condition $m\lambda_1/N \to 0$ as $N \to 0$ is not only sufficient but also necessary condition for consistency of estimator θ^*.

Definition 2 The vector $\theta^P = (\theta_1^P, \theta_2^P, \ldots, \theta_{m(N)}^P, 0, \ldots, 0)^T$ is called m-finite and p-consistent estimator of the vector $\theta^P = (\theta_1, \theta_2, \ldots, \theta_{m(N)}, \theta_{m(N)+1}, \ldots)^T$, if $\forall\delta > 0 \quad P\{\sum_{i=1}^{m(N)} (\theta_i^P - \theta_i) \leq \delta\} \geq p$ holds true, as $N \to \infty$.

4 Estimating of the Elements of Covariance Matrix

Consider the covariance matrix:

$$C_N = E(\theta^* - \theta)(\theta^* - \theta)^T = (1/N)(X^T X/N)^{-1}[X^T(E\varepsilon\varepsilon^T)x/N](X^T X/N)^{-1},$$

where the matrix $[X^T(E\varepsilon\varepsilon^T)x/N]$ is unknown.

As the random variables $\varepsilon_1, \varepsilon_1, \ldots, \varepsilon_N$ are independent with $E\varepsilon_i = 0,\ E\varepsilon_{i^2} = \sigma_i^2$ then $X^T(E\varepsilon\varepsilon^T)x/N = X^T I(\sigma^2)X$, where $I(\sigma^2) = \| a_{ij} \|, i, j = 1, 2, \ldots m;\ a_{ij} = \sigma_i \sigma_j \delta_{ij},\ \delta ij(i, j = 1, 2, \ldots, N)$ is Kronecker symbol.

Denote

$$
\begin{aligned}
D_N &= X^T I(\sigma^2)X/N, \quad D_N = \| d_{kl} \|, k, l = 1, 2, \ldots, m;\\
y^* &= X\theta^*, \quad I_{kl}(x) = \| a_{ij}^{kl} \|, i, j = 1, 2, \ldots, m;\\
\| a_{ij}^{kl} \| &= \phi_k(x_j)\phi_l(x_j)\delta_{ij}, \quad d_{kl}^* = (1/N)(y^* - y)^T I_{kl}(x)(y^* - y),\\
D_N^* &= \| d_{kl}^* \|, k/l = 1, 2, \ldots, m;
\end{aligned}
$$

where $I(\sigma^2) = \| z_{ij} \|$ is unknown matrix, $\| z_{ij} \| = \sigma_i \sigma_j \delta_{ij}$. The following theorem is true.

Theorem 1 *Let $E\varepsilon_i{}^4 < \infty$ and $(m\sqrt{m})/(N\lambda_1(N)) \to 0$, as $N \to \infty$, then $(d_{ij}^* - d_{ij}) \xrightarrow{P} 0,\ E(d_{ij}^* - d_{ij}) \to 0$ as $N \to \infty$.*

Remark 2 In Theorem 1 we do not need the existence of the limit $d_{kl}{}^*$ and d_{kl}. Matter is that the difference between them converges to zero, in probability.

Theorem 2 has the same proof line as Theorem 2 in [6].

Theorem 2 *If $(m\sqrt{m})/(N\lambda_1(N))$ will be bounded, then $\sqrt{N}(\theta^* - \theta) \Rightarrow N(0, C_N)$ as $N \to \infty$, where $\Rightarrow N(0, C_N)$ means a convergence in probability to the normal distribution with the covariance matrix C_N.*

Proof For proving of Theorem 2 it is necessary to show that under the conditions of the Theorem 2 the vector $(\theta^* - \theta)^T$ has asymptotically normal distribution and further use criterion on normality [3].

Remark 3 According to the Theorem 1 the elements of the matrix D_N^* is a consistent and asymptotically unbiased estimator of the elements of the matrix D_N, then for applications instead of the matrix we can use the matrix $C_N^* = (1/N)(X^T X/N)^{-1} D^* (X^T X/N)^{-1}$. Different approaches for estimating the elements of covariance matrix C_N were suggested in [1, 4, 7].

5 Nonlinear Regression Models

Let's assume that $f(x, \theta)$ in Eq. (2) is a nonlinear function and $f(x, \theta), \partial f(x, \theta)/\partial\theta$, $\partial^2 f(x, \theta)/\partial\theta_i \partial\theta_j$, $(i, j = 1, 2, \ldots, m)$ are bounded and continuous functions of $(x, \theta), \theta \in \Theta$ is a compact set. Denote $fij = \partial f(x_j, \theta)/\partial\theta_i$, $F_N(\theta)$-the matrix with elements $f_{ij}\theta$, $0 < \mu_1^N(\theta) \leq \cdots \leq \mu_m^N(\theta)$-eigen-values of the matrix $[F_N^T(\theta)F_N(\theta)/N]$ and $B(r)$ be the sphere of the radius $r > 0$ centred at the point

θ^*. Least squares estimator of θ is constructed by the iterative process:

$$\theta_N(s+1) = \theta_N(s) + [F_N^T(\theta_N(s))F_N(\theta_N(s))]^{-1}F_N^T(\theta_N(s))(y - f(x, \theta_N(s))). \tag{4}$$

The question arises as to whether iterative process Eq. (4) converges or not. Relation (4) can be represented as: $\theta_N(s+1) = u(\theta_N(s)) = \theta_N(s) + A_N(\theta_N(s))\delta_N(\theta_N(s))$, where

$$A_N(\theta_N(s) = [F_N^T(\theta_N(s))F_N(\theta_N(s))/N]^{-1}F_N^T(\theta_N(s)),$$
$$\delta_N(\theta_N(s)) = y - f(x, \theta_N(s)),$$
$$\delta_N^*(\theta_N(s)) = y - f(x, \theta^*).$$

Define

$$\zeta_{N,r}^p(\theta) = m(\partial A_N(\theta)/\partial\theta_p)\varepsilon,\ p = 1, 2, \ldots, m;\ \theta \in B(r),$$
$$L_p = \partial u_N(\theta)/\partial\theta_p,$$
$$\tau_N(r) = \max_{p=1,2,\ldots,m}\ \sup_{\theta\in\Theta} \parallel L_p \parallel.$$

Below, by convergence of random variables is understood as convergence in probability.

Theorem 3 *If there exists such N, that $m(N)^5/[N(\lambda_1^N(\theta))^4] \to 0, r \to 0$, then $m(N)\tau_N(r) \to 0$ and for any p, $\zeta_{N,r}^p(\theta) \to 0, r \to 0$.*

Introduce $\rho_N(\theta) = u_N(\theta) - \theta$, $\rho^* = \rho(\theta^*)$.

Theorem 4 *Let $\theta(0) \in B(r)$ and $\tau_N(r) + (\parallel \rho^* \parallel)/r < 1$. Then under the conditions of Theorem 3, there exists a random variable such that $\sqrt{N}(\theta_N - \theta^*) \Rightarrow N[0, \sum(\theta^*)$ as $N \to \infty$, where*

$$\sum(\theta^*) = [F_N^T(\theta^*)F_N(\theta^*)/N]^{-1}[F_N^T(\theta^*)I(\sigma^2)F_N(\theta^*)/N][F_N^T(\theta^*)F_N(\theta^*)/N]^{-1},$$

i.e. θ_N is a $\sqrt{N}$ consistent estimator and θ_N can be used as l.s.e. on N observations. Using the approach suggested in [7], (similarly as for linear models) the elements of a covariance matrix can be estimated.

Remark 4 Theorems 3 and 4 show that convergence of the iterative process (4) depends on zero step ($\theta(0)$) of iteration. If for iterative process (4) we can get zero iteration near of the true value of θ (i.e. in the sphere $B(r)$, $\theta(0) \in B(r)$) then iterative process will be converged.

6 Construction of the Asymptotic Confident Bands

Consider the quadratic form:

$$(\theta^* - \theta)^T (D_N)^{-1} (\theta^* - \theta) \le \chi^2_\gamma(m)/N. \tag{5}$$

According to Theorem 4 the left side of Eq. (5) has asymptotically chi-square distribution random with degrees of freedom m. In Eq. (5) instead of $D_N{}^{-1}$ (according to the Theorem 2) can be used estimates [7] the matrix $D_N{}^{-1}$ elements. For the constructing of a confidence band for $f(x, \theta)$ it is necessary to find $inf\ f(x, \theta)$ and $sup\ f(x, \theta),\ \theta \in \varepsilon_r(\theta)$, which are lower and upper boundaries of a confidence band and $\varepsilon_\gamma(\theta) = [\theta : (\theta^* - \theta)^T (D_N^{-1})(\theta^* - \theta) \le \chi^2_\gamma(m)/N]$ is the confidence ellipsoid, $\chi^2_r(m)$ is the $r > 0$ level quantile of the chi-square distribution with m degrees of freedom.

7 Optimal Choice of a Number of Unknown Parameters. Linear Model

Consider

$$f(x, \theta) = \sum_{i=1}^{m(N)} \theta_i \phi_i < \infty, /\phi_i(x)/ \le 1, \sum_{i=1}^{m(N)} \theta_i^2 < \infty.$$

The problem is $\forall \delta > 0$ and given $0 < p < 1$, $N > 0$ to find such $m(p, N, \delta)$, for which

$$P\left\{\sum_{i=1}^{m(N)} (\theta_i{}^* - \theta i)^2 < \delta\right\} \ge p$$

holds true, where $\theta_i *$ is the l.s.e. on N observations. For simplicity we assume $E\varepsilon_i = 0$, $E\varepsilon_i^2 \le 1$.

Consider $y_i = \sum_{i=1}^{m(N)} \theta_i \phi_i(x) + \delta_i$, whereas $N \to \infty$. Assuming that for large values of

$$N P\left\{\sum_{i=1}^{\infty} (\theta_i^* - \theta_i)^2 < \delta\right\} \approx P\left\{\sum_{i=1}^{m(N)} (\theta_i^* - \theta_i)^2 < \delta\right\}.$$

If the conditions of the Theorem 1 hold true, then we get $P\{\sum_{i=1}^{m(N)} (\theta_i^* - \theta_i)^2 < \delta\} \ge 1 - (m + 1)/(N\lambda_1(N)\delta)$ from Chebyshev inequality.

Taking $p = 1 - (m + 1)/(N\lambda_1(N)\delta)$ we get $m = (1 - p)(N\lambda_1(N)\delta) - 1$. Now in the capacity of a consistent estimator of the vector $\theta = (\theta_1, \theta_2, \ldots, \theta_N)^T$ we can take the vector $\theta^P = (\theta_1^P, \theta_2^P, \ldots, \theta_{m(N)}^P, 0, \ldots, 0)^T$, where m was found, above. According to the Theorem 1 the vector θ^* is a consistent estimator of θ.

Example 1 Let us assume that for approximation of the function $f(x)$ we will use Chebyshev polynomials of the first order $p_1(x), p_2(x), \ldots, p_n(x)$ with weight function $h(x)$. The question is: how many parameters we have to take for unbiased and consistent estimating of unknown parameters and the elements of covariance matrix as well.

Chebyshev polynomials of the first order has the following form

$$p_{n+1}(x) = 2xp_n(x) - p_{n-1}(x),\ p_0(x) = 1,\ p_1(x) = x,\ x \in [-1, 1],$$

with the weight function, $h(x) = 1/(\sqrt{1-x^2} \quad x \in (-1, 1)$.

Simple calculations yield that for elements of the matrix $(X^T X/N)$ we have

$$x_{ij} = (1/N)\sum_{i=1}^{N} p_i(x_k)p_j(x_k)h(x_k).$$

Let us take observations at the points $x_i = -1 + 2(i-1)/N,\ i = 2, 3, \ldots, N$. Then for $N \to \infty$ we have

$$x_{ij} \to \int_{-1}^{1} p_i(x)p_j(x)h(x)dx = \begin{cases} 0, & \text{if } i \neq j \\ \pi/2, & \text{if } i = j > 0 \\ \pi, & \text{if } i = j = 0. \end{cases}$$

Thus, for $N \to \infty$ limit matrix $(X^T X/N)$ has the following form

$$\begin{matrix} 0 & \pi/2 & 0 & \cdots\cdots & & 0 \\ 0 & 0 & \pi/2 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & \pi/2 & 0 \\ 0 & 0 & 0 & \cdots & 0 & \pi/2 \end{matrix}$$

The eigen-values of this matrix are defined as $\lambda_1 = \pi/2, \lambda_2 = \pi/2, \ldots, \lambda_{m-1} = \pi/2, \lambda_m = \pi$. Let us consider 1.000 observations (i.e. $N = 1000$). If we take 10 parameters (i.e. $m = 10$), then we have $m = N^{1/3}$, $m\lambda_1/N \to 0$ and $m\lambda_1\sqrt{m}/N \to 0$, hence above received results can be applied and we are coming to the following conclusion.

It means that if we have 1000 observations, then it is enough to take number of unknown parameters $m = 10$ and we can construct consistent estimator

$\theta^* = (\theta_1^*, \theta_2^*, \ldots, \theta_{10}^*, 0, \ldots, 0)^T$, which converges to the unknown parameter

$$\theta = (\theta_1, \theta_2, \ldots, \theta_{10}, \theta_{11}, \ldots)^T,$$

with rate of convergence less than $m\lambda_1/N = N^{1/3}\pi/2/N = \pi/200 \approx 0,15$ and with the rate of convergence for the elements of covariance matrix less than

$$m\lambda_1\sqrt{m}/N = N^{1/3}(\pi/2)N^{1/6}/N \approx 0,27.$$

8 Application

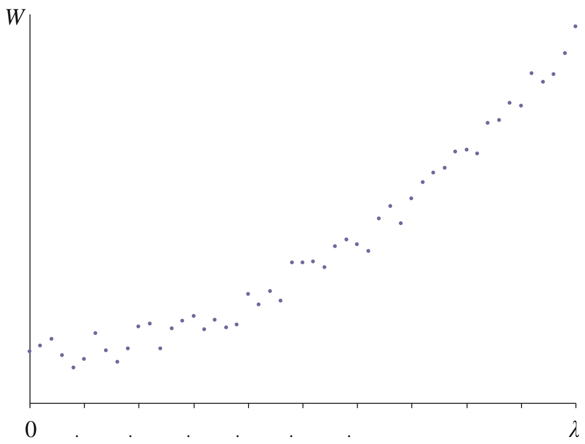
Consider two elevators, which serve customer at the building with 15 floors. We are interested in behaviour of a customer average waiting time before serve; denote w (see Fig. 1).

We approximate behaviour of this characteristic by Chebyshev polynomials of the first type, i.e.

$$w(t) = f(t) + \varepsilon_t, \;\; t = t_1, t_2, \ldots, t_N, \ldots,$$

where $f(t)$ is Chebyshev polynomial. We do not have information about variances of errors (ε_t). First approach is to supposed that they are the same at the each point, try to estimate them and afterward construct a confident band for unknown function using standard approach (lower and upper borders of a confident band have red colour, Fig. 2). Second approach to use above mentioned results (blue colour, Fig. 2). This approach for some case can give narrow confident band. Below there is giving process

Fig. 1 Figure for application result



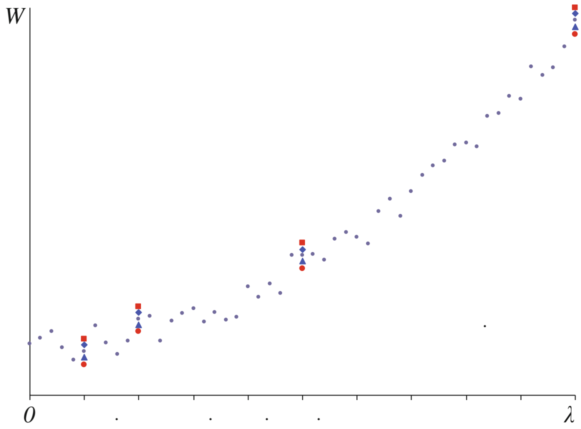


Fig. 2 Figure for application result

of constructing a confident band by standard approach and by method suggested in the paper. We use the result of modelling some queues.

9 Conclusion

The results of this paper allow to analyse big data, where number of unknown parameters can increase, variance of the errors are unknown and moreover at the each point there is only one observation. Such problems are typical for applications because sometimes an experiment takes a lot of efforts (financial and other expenses) and to repeat or get additional observations not possible. From other hand there are not possibility to measure or estimate variance and use standard approach. In this situation our approach effectively can be used.

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The Stroke Manager App—Individual and Mobile Support for Stroke Patients and Their Caregivers

Roland A. Görlitz

Abstract Today, there is a smartphone app for almost everything. Even though "apps" for mobile health (mHealth) seem to be a promising approach to address individual needs of patients and caregivers that are affected by a chronic medical condition, they are still scarce and their benefits have not been studied. Since stroke is the archetype of a chronic disease, this paper proposes an mHealth concept for stroke patients and their caregivers that combines individual information with mobile IT and serious games to support the rehabilitation, therapy adherence, and secondary stroke prevention. Based on literature and initial expert interviews, current shortcomings of German outpatient settings have been identified. They are addressed through the mHealth-based Stroke Manager App (SMA). Its concept has been evaluated by an online survey and the prototype will be evaluated in a field study. In this paper the SMA, survey results and the field study's evaluation framework is presented.

Keywords mHealth · Healthcare · Stroke · Mobile IT · Patient-centered

1 Introduction

With the advent of smartphones, mHealth has changed tremendously. Instead of supplying dedicated, additional devices to the users, it is now feasible to support patients with applications on their smartphones that they can inte-grate easily into their everyday-lives. Generally, smartphones are always turned on, constantly online, and close to their user allowing easy integration of regular but individual services. Furthermore, smartphones possess several built-in sensors and can easily integrate external devices, e.g. for measuring blood pressure, blood glucose level etc. These characteristics are very useful for supporting patients with chronic medical conditions [2, 5, 24].

R.A. Görlitz (✉)
Karlsruhe Institute of Technology, Kaiserstraβe 12, Karlsruhe, Germany
e-mail: goerlitz@kit.edu

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Stroke is an archetype of a chronic disease that leaves the major burden on outpatient treatment and the leading cause of adult disability that results in long-term, post-acute therapy and rehabilitation [19]. In Germany, for example, the annual costs related to stroke incidents in 2008 were 8.1 Billion Euros and the prospected costs until 2025 are expected to accumulate to 108 Billion Euros [15]. The patients' therapy adherence has a significant impact on the healthcare costs [1, 10]. Unfortunately, stroke is a very striking incident and patients indicate in surveys that they do not have enough information and support to effectively cope with their individual situation and home reha-bilitation, respectively [27]. Nevertheless, an effective secondary stroke prevention and improved stroke rehabilitation would decrease stroke reoccurrences and societal healthcare costs induced by stroke incidents [23].

Since stroke patients and their caregivers are frequently overexerted by the sudden complexity of their everyday lives, they need individual and constant support along the complete care pathway, which cannot be fully provided by professional healthcare service provider (e.g. physicians, therapists, home-care nurses etc.). Therefore, mobile smartphone apps have the potential to support them individually in their post-clinical phase. In this paper, an mHealth concept and its prototypical implementation as Stroke Manager App (SMA) is presented. The concept and its underlying assumptions were evaluated by an online survey. The prototype was evaluated in a workshop and a field study.

2 Methodology

First, the problems and needs of stroke patients and their relatives have been analyzed in a thorough literature analysis and expert interviews with members of a stroke support group. Furthermore, current mHealth literature regarding concepts and ideas to address the stroke patient's major problems were examined. The mHealth concept was developed based on the findings. The concept's main assumptions and functions have been evaluated by an online survey that was conducted with German stroke patients and caregivers June through July 2012. The participants were recruited in German online stroke communities and motivated by announcing a lottery of Amazon coupons. As depicted in Fig. 1, the survey included five parts to confirm the main assumptions of the SMA concept (e.g. stroke patients have one major caregiver, they

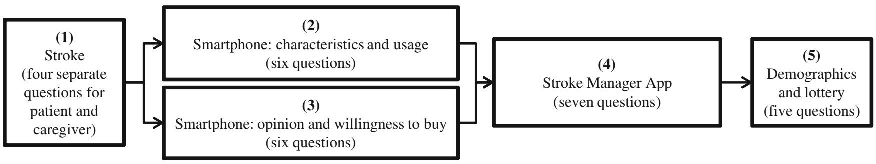

Fig. 1 Online survey structure

use smartphones mostly running Android, currently there is no useful stroke app, and the proposed functions are useful):

Part (1) consisted of general questions concerning the stroke incident to identify patients, caregivers, and their relationship;

In part (2) the respondents that have a smartphone, were asked questions about their smartphone's characteristics (operating system etc.) and usage (overall and explicitly for post-clinical stroke management);

In part (3) the respondent that did not use a smartphone, were asked questions about their willingness to buy a smartphone soon;

Part (4) included questions for each participant to rate smartphone app functions addressing stroke patients' major problems (information deficit, rehabilitation support, adherence support) on a 5-item Likert scale. Each of the function was described and screenshots of the prototype were shown;

Part (5) consisted of demographic questions and questions related to the lottery.

The SMA prototype was created using an evolutionary prototyping approach [29] including constant tests and refinements. Initial expert interviews and the online survey results mainly contributed to the development. Additionally, a final workshop and a field study were prepared. In the workshop, the usability and suitability of the SMA prototype were evaluated by stroke patients and their caregivers in an artificial environment. In the field study, stroke patients used the SMA prototype for several weeks in their everyday environment. The study was designed to evaluate the SMA's impact on information provision, home-based rehabilitation and therapy adherence even though a baseline of stroke patients without using the SMA cannot be recorded.

3 Related Work

There is an ever-growing variety of mHealth apps, but there are few evaluated apps for supporting stroke patients individually. Smartphone apps that support physicians are being increasingly used and evaluated, for example apps for an improved sharing of patient related information between physicians [28], for visualizing 2D and 3D diagnosis results [22], for remote diagnosis [6, 13, 25] or for supporting the stroke diagnosis [8].

Unfortunately, to the knowledge of the author there is no peer-reviewed literature about stroke-specific and patient-centered smartphone apps that support stroke patients or caregivers individually in their everyday lives. Albeit their missing peer-reviewed evaluation, there are patient-centered apps aiming at supporting stroke patients that are available in the app markets. Apps like FAST Test or StopMyStroke provide assistance in diagnosing an acute stroke, but their impact is unclear because a stroke usually appears without forewarning and it is unlikely that people download the app before they even know that they are dealing with a very time critical stroke. Nevertheless, a very important feature of those apps is informing about risk factors of stroke. My Heart & Stroke Health provides the user with functions to calculate their individual stroke risk, creation of a blood pressure action plan and recipes for a healthier diet.

Stroke patients looking for apps supporting their post-clinical care are likely to be more successful to find appropriate apps if they know exactly what the app should do. There are apps supporting patients suffering aphasia like SprechBegleiter (engl: speech advisor), Wort Domino (engl: word domino), EasySpell or mobile112. There is a wide range of apps that help monitoring blood pressure or blood glucose, provide exercises for patients, use serious games to improve concentration and attention of patients, and aim at improving medication adherence.

However, there is neither an app available that specifically supports the post-clinical, everyday stroke manage-ment nor an app that involves the caregiver or relatives of the stroke patient. Furthermore, patients need to perform a cumbersome search to find the appropriate apps, which is particularly difficult for non-English stroke patients because most apps only support the English language. Furthermore the provided information about post-clinical stroke management might be country specific and lead to wrong decisions if applied to the wrong country. This might be an issue for adherence and rehabilitation assistance as well.

On the one hand, a comprehensive approach is promising to provide the most important functions for patients and their caregivers from a single source that is easy to find. On the other hand, apps that support the post-clinical management of stroke patients and their caregivers have not been evaluated in terms of feasibility, usability, and improved patient outcome. For other chronic diseases there are similar apps that have been evaluated. For example, apps to support patients in pulmonary rehabilitation [20], high risk cardiac [16] or diabetes mellitus [12]. For example, Marshal et al. [20] have evaluated a smartphone app that provides exercises with real time feedback, records heart rates and blood oxygen level, and transfers the measured data to a local laptop or network PC. Another example is an app that uses smartphones to provide telemonitoring of patients in their home environment [17]. Thus, state-of-the-art literature proves that mHealth concepts using smartphone apps can effectively support patients with chronic medical conditions in the post-clinical phase, but no comprehensive concept has been provided for the case of stroke.

4 The mHealth Concept and Stroke Manager App (SMA)

The mHealth SMA concept should provide individual and patient-centered support of stroke patients in inpatient and outpatient settings. Using information technology rather "young" stroke patients (<65 years old) are supported along the complete care pathway (see Fig. 2) while focusing on the post-clinical phase in which many health-care service provider (physicians, therapists etc.) are involved partly. Thus, mainly aiming at supporting the individual issues of the post-clinical stroke management: information provision, home-based rehabilitation support, and therapy adherence [3, 14, 26, 30].

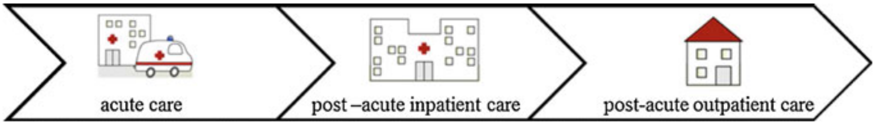

Fig. 2 Illustration of stroke patients' general care pathway

An mHealth approach using a smartphone app is promising because stroke patients do not need any additional devices if they already use a smartphone. This greatly facilitates the distribution and acceptance of the mHealth tool because patients can simply download the app from an app market and it is easily integrated into the everyday usage of the smartphone.

As depicted in Fig. 3, the concept addresses the three domains stroke information, rehabilitation support and ad-herence support. The SMA provides information for stroke patients and their caregivers. There is a set of general information about the stroke itself, the different treatment phases, effective secondary prevention, and tips on how to cope with the repercussions of the stroke. Up-to-date information might be access from health websites. Further-more, the app could be used as a gateway to online support groups or domain experts providing individual feedback. Easy access to an online community might foster social support that helps patients with chronic medical conditions to deal with their situation [18]. An online community also establishes the opportunity for patient and caregiver to interact with other people in a similar situation. The stroke information functions of the SMA can be used by patient as well as caregiver if both possess a smartphone.

The other two functions, rehabilitation and adherence support, are only designed for the stroke patients them-selves. For the mobile rehabilitation support at home, a serious games approach is used allowing stroke patients to exercise their possibly impaired cognitive and motor skills. As in most chronic diseases, adherence is also

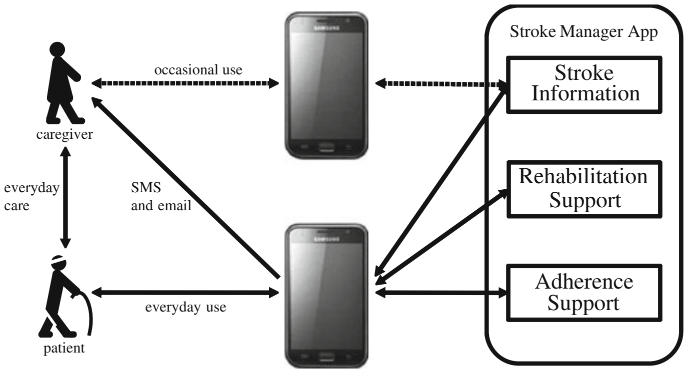

Fig. 3 Illustration of the mHealth SMA concept supporting stroke patients and their caregivers individually

a major problem in stroke after-care [9]. Since it decreases over time, it is important to keep stroke patients adherent on a long-term basis. Therefore, a calendar with a history and reporting function is part of the SMA. It allows patients to track and evaluate their appointments, therapy sessions, medication, and home exercises while being reminded. Tracking the history allows the integration of feedback mechanisms to motivate the stroke patients for a better adherence. Recording the adherence also creates data about therapy adherence that is currently not available when evaluating effects of post-clinical therapies. Additionally, a report function is integrated that optionally sends an email or SMS to the caregiver.

The mHealth prototype SMA was implemented as an Android native app because Android phones currently have the highest market share in Germany, which is also supposed to increase in the near future. Furthermore, Android based phones are among the cheapest phones available and use the open source operation system Android, which makes it more reasonable to buy for patients that are already financially stressed due to their chronic medical condition and allows easy integration of additional devices, respectively. Android also provides several amenities for developers because there is a free IDE, Java is supported, databases functions are already included in native Android (SQLite), there are open source graphic packages as well as games, and there are small restrictions for the market [7].

Stroke Information. Since stroke patients generally have high information deficits concerning their stroke-related situation [27], the information provision is very important. Therefore, general stroke-specific information were included in the SMA prototype. The included information categories encompass topics ranging from information about stroke in general and the care pathway of patients to information about how to participate again in everyday life activities. Furthermore it provides patients and caregivers with explanations on typical technical terms and help-ful contacts. Figure 4 shows screenshots of single information articles. The content has been compiled and evaluated as described by Cavel et al. [4] in several expert workshops with physicians, therapists, stroke patients and caregiving relatives. In the SMA prototype the information is organized in single HTML-articles which are easy to update. The layout is defined by a CSS file and the hierarchy of the articles is saved in a separate XML file.

A connection to an online stroke community as proposed by the SMA concept is not realized in the SMA prototype because there are several German online stroke communities which are all infrequently used. If in the future one community or website emerges as the leading stroke-related health portal, it can easily be integrated.

Rehabilitation Support. The main idea of home-based rehabilitation support is to use serious games and to use the smartphone itself as a rehabilitation supporting device. The goal for the SMA prototype is to create a functional area where patients can choose between different exercises that support their cognitive and motor rehabilitation on an individual level. The prototype demonstrates how such a support can be achieved. Two games were integrated in order to show how a smartphone can be used to support stroke rehabilitation. The games have different levels to allow patients to raise the difficulty according to their ability. Additionally, their achievements are

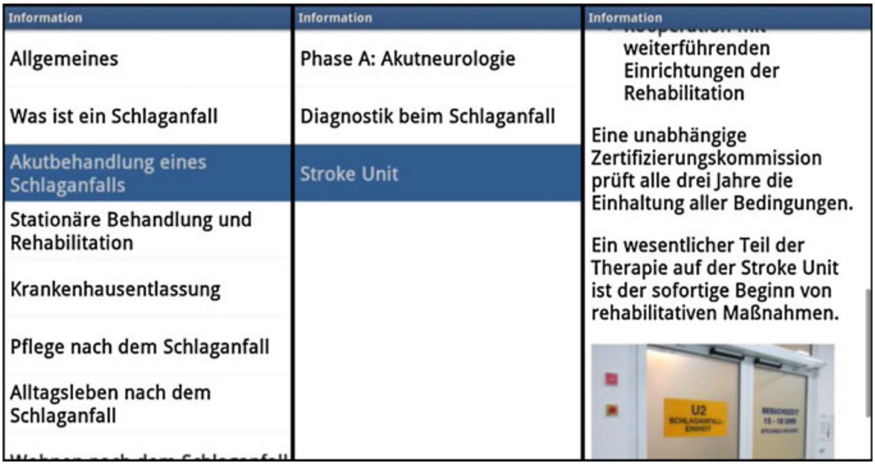

Fig. 4 Screenshots of the SMA prototype's provided information (*left* overview of the information categories, *middle* overview of the available information in one category, *right* example information page)

tracked and pre-sented to them in form of a high score table to include motivational aspects.

The first exemplary cognitive-skill exercise is a simple memory game which is open source (see left screenshot in Fig. 5). It aims at providing a cognitive exercise to the patients because they have to recognize certain objects and remember their position to solve the game. From that database a high score table is generated that

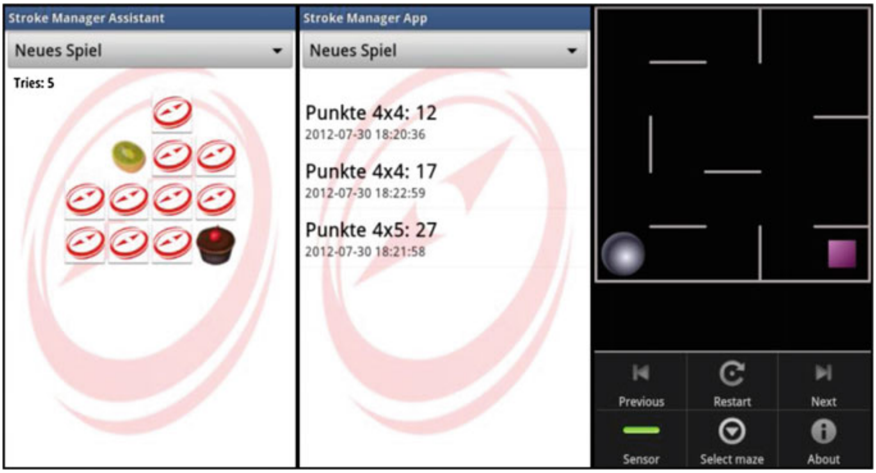

Fig. 5 Screenshots of the SMA prototype's functions supporting rehabilitation (*left* memory game, *middle* high score table of memory game, *right* TiltMazes game)

enables the pa-tients to see their achieved points over time and to compare them against each other (see middle screenshot in Fig. 5).

The motor-skill exercise is realized as a simple maze game TiltMazes which is also open source (see right screenshot in Fig. 5). It combines a cognitive task (get the ball to the square) with a motor activity (move the ball by tilting the smartphone) using the motion sensors of the smartphone. The game provides several difficulty levels and tracks the steps a player needs to complete a level. For physically impaired patients it is possible to deactivate the sensor-driven control and to move the ball by touch via screen. Two games have been integrated into the SMA prototype and adapted to meet the requirements in terms of layout, handling and achievement tracking.

Adherence Support. The SMA prototype aims at supporting the patient in achieving a high level of therapy adherence. The basic principle to realize that goal is to provide a calendar and reminders for the patients. While doing so the SMA collects information to measure therapy adherence and based on that it provides analysis to the patient and involves the caregiver with a report on a daily basis.

All appointments are stored in an SQLite database on the Smartphone and are represented to the patient as a calendar (see left screenshot in Fig. 6). To remind patients of their appointments a notification is used that also causes the Smartphone to vibrate (see middle screenshot in Fig. 6). For motivational reasons for every upcoming appointment the current adherence is shown and apart from the general appointment information, the patient should mark an appointment as attended or not. If the patient is reminded to use one of the games, an option is provided to switch to the game immediately. In case the patient choses to skip the appointment, the patient should also chose the reason for doing so.

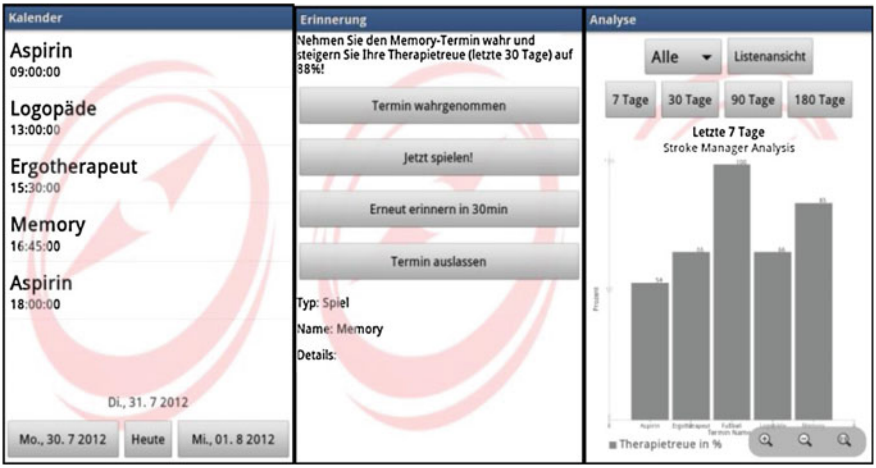

Fig. 6 Screenshots of the SMA prototype's functions supporting adherence (*left* calendar showing daily appointments, *middle* appointment notification, *right* adherence analysis)

Based on all the appointments' status, an adherence analysis is created for the patient (see right screenshot in Fig. 6). The SMA prototype provides the function to calculate the rate of appointments attended relative to the number of all appointments for a certain period of time. The open source library Achartengine was used to represent the adherence as bar charts. Because the display of a smartphone provides a limited area to draw bar charts, a scrollable list is also provided.

At a predefined time of the day a report is generated from the database data. The report consists of all appointments of the recent day with their current status. The patient can choose for every appointment if being included into the daily report. The report is then delivered by email or SMS to a caregiver. Currently, the report is only send via email because when using SMS costs are incurred to patient or caregiver. While email allows the report to include graphics and long text, SMS is restricted to text and costs depending on the text length. The caregiver receiving the report gets the opportunity to have a daily overview about the appointments of the patient and, in case of arising problems, the caregiver can double check with the patient.

5 Evaluation

The evaluation was performed two-staged. First, the mHealth concept was evaluated using an online survey. Then, the SMA prototype was evaluated in a final workshop and a subsequent field study. In the following sections, the results are presented.

Evaluation of the mHealth concept was achieved through a survey that was conducted from June through July 2012 and posted online in German stroke communities. Overall, 85 complete surveys were available, but four of them were neither stroke patients nor caregiver, thus there were a total of $n = 81$ (41 patients and 40 caregivers) responses that have been used to evaluate the mHealth concept. The average age of the participants was $45 + / - 11$ (patients $47 + / - 10$ and caregivers $44 + / - 11$). Thus, the participants' age average is more than 25 years below the average age of a stroke patient [11]. But since the SMA concept targets rather young and technophile stroke patients, it is a deliberate bias rooted in the average age of online community members. The gender distribution is nearly equal, which matches findings of Heuschmann et al. [11] about general characteristics of stroke patients in Europe. The caregivers were almost all female (90 %), whereas usually 65 % of them are female [21].

In the first parts of the survey, the general assumptions for the SMA concept were confirmed. 74.07 % of the respondents stated that there is one major caregiver and all of the participating caregivers have at least a mobile phone. Therefore, the mHealth concept engaging one caregiver through reports sent by email or SMS makes sense. Furthermore, a smartphone app can be used by the majority of the respondents because 58.01 % (60.98 % only patients) possess a smartphone and another 20.59 % (18.75 % only patients) plan to buy one in the next 12 months. Additionally, 59.26 % of the respondents that neither possess a smartphone nor plan on buying one, state the high costs as leading cause preventing them from buying one. This will change in the future because the price of technically sufficient smartphones will continue to decrease. However, even though most of the responding stroke patients have smartphones, they do not use apps to support their post-clinical stroke management or therapy. Only two participants stated using information and calendar functions, even though 70.37 % would expect a stroke-related app to be useful. In contrast to the current statistics, the used operating systems Android and iOS are almost equally represented with 38.64 and 36.36 %, respectively. Unfortunately, a quarter of the participants stating that they have a smartphone did not know their operating system.

As depicted in Table 1 and 2, the survey's fourth part showed that a majority of the participants rates the functions conceived in the SMA concept as useful. As expected, the highest general consent was on the information functionality (75.31 %). Thus, this part of the concept should be fully implemented. Curiously, calendar functions like appointments and reminders are also rated as very useful, although almost none of the respondents use existing apps for their stroke management. Contrary to the posed hypothesis, the stroke patients and their caregivers are divided about the usefulness of games as rehabilitation support. Most of the patients do not think they are useful whereas most of the caregivers stated the opposite. On the other hand, reports to the caregiver are perceived as useful from patients and caregivers alike. Overall, the adherence analysis' usefulness has the least approval, but this is probably due to a missing motivational character or overall understanding of this concept because one third rates it as neither important nor unimportant.

Table 1 Survey results of part 4 for patients ($n = 41$) in percent: rating of specific SMA functions

Question	1	2	3	4	5
Information	39.02	34.15	9.76	7.32	9.76
Reminder	31.71	34.15	14.63	7.32	12.2
Calendar	26.83	43.9	9.76	9.76	9.76
Games	17.07	24.39	21.95	24.39	12.2
Report	17.07	31.71	24.39	14.63	12.2
Analysis	9.76	31.71	36.59	4.88	17.07

(1: important, 2 slightly important, 3 neither, 4 slightly unimportant, 5 unimportant)

Table 2 Survey results of part 4 for caregivers ($n = 40$) in percent: rating of specific SMA functions

Question	1	2	3	4	5
Information	47.5	30	12.5	10	0
Reminder	32.5	32.5	22.5	7.5	5
Calendar	2	45	20	10	5
Games	25	35	30	5	5
Report	12.5	37.5	30	15	5
Analysis	17.5	22.5	40	10	10

(1: important, 2 slightly important, 3 neither, 4 slightly unimportant, 5 unimportant)

SMA-prototype

Since the SMA prototype is developed in an agile and evolutionary approach (see Tate [29]), patients and their caregivers from a local stroke support group were constantly involved in developing the three main functionalities of the SMA concept (stroke information, rehabilitation support, and adherence support). Thus, the user interface and the implemented functions have been constantly evaluated and refined. However, according to Zelkovitz et al. [31] a software prototype should be evaluated according to its applicability to solve a problem. Therefore, the SMA prototype will be tested in a field study and its influence on the post-clinical stroke management regarding information provision, home-based rehabilitation, and therapy adherence is recorded.

Before the beginning of the field study, a workshop will be organized to evaluate the SMA's usability and suitability in an artificial environment. Several stroke patients that are currently in postclinical phase will participate. They will be confronted with special tasks about the three functional areas of the SMA. The patients will be observed while completing the tasks and asked questions afterwards.

The goal of the field study is to support stroke patients and their caregivers in the post-clinical stroke management. Therefore, the addressed issues, i.e. information, rehabilitation, and adherence, have to be operationalized through other than the common clinical measures. The information provision can be measured through questionnaires about the patients' knowledge of stroke, secondary prevention and local support opportunities. The answers are then compared to a reference group that did not use the SMA [14, 23, 26, 27]. However, the impact of the rehabilitation and the adherence support is difficult to measure because a comparison to a reference group and acquiring a base line of the patients' general adherence and rehabilitation is not possible. Therefore, the data from the patients using the SMA in the field study will be compared to generally available data [3, 14, 26] to evaluate the effect of the SMA.

6 Conclusions

In this paper an mHealth concept and its prototypical implementation for patients and caregivers afflicted by the chronic medical condition stroke were introduced. Literature and initial expert interviews with stroke patients con-firmed that they are in a unique situation in which they need individual support in their everyday lives that cannot be fully provided by professionals (physicians, therapists, home care nurses etc.) that act on singular points. A more holistic and patient-centered view along the complete care pathway view is needed. Information technologies, especially smartphone apps have the potential to address the individual situation because patients use them regularly, they are mobile and they provide the functionality to support the everyday life of a chronic patient. However, currently there is no application that comprehensively addresses stroke-specific needs.

The SMA fills this gap by providing an individual app that addresses the stroke patients' information deficits and supports adherence as well as home-based rehabilitation. To evaluate the SMA concept's assumptions, we used an online survey. The results confirmed that stroke patients have one specific caregiver and both want more information and would appreciate support in their appointment management. Surprisingly, stroke patients did not favor the idea of individual and mobile rehabilitation support through serious games whereas most of the caregivers did. Furthermore, the survey results might also be useful for other researchers because they showed that more than 50 % of technophile stroke patients use smartphones and another 19 % want to buy one soon. The major operating systems are Android and iOS. The SMA prototype has been developed as an Android app according to the functions of the SMA concept. In contrast to other apps that are generally evaluated isolated, this paper describes the evaluation of the SMA prototype in a field study.

The SMA prototype can then serve as a base technology for further research in the field of patient-centered, long-term IT support for patients with chronic medical conditions. On the one hand, the mHealth concept, prototype and its evaluation framework can be adapted to create a more holistic approach to supporting patients along the complete care pathway suffering from other chronic diseases (e.g. COPD, CHF etc.). On the other hand, it fosters further IS research because the SMA can easily integrate different telemedicine devices to support home-based measurements vital parameters or can serve as a gateway for the online community access.

The online survey showed that there is still a lot of potential for improving the appointment analysis and the serious games. In corporation with therapists and physicians, stroke-specific games can be integrated into the SMA to connect individual patient support with professional healthcare services.

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A Class of Chance Constrained Linear Bi-Level Programming with Random Fuzzy Coefficients

Xiaoyang Zhou, Yan Tu, Ruijia Hu and Benjamin Lev

Abstract In this paper, we consider a class of linear bi-level programming with random fuzzy coefficients, which has no mathematical meaning because of the uncertain factors. So in order to make it solvable, we introduced the linear chance constrained bi-level model. And some theorems are proposed to obtain the equivalent model. Then we employ the interactive programming technique to deal with the bi-level equivalent model. At last an illustrative example is present to show the efficiency.

Keywords Linear bi-level programming · Random fuzzy variable · Chance constraints · Interactive programming technique

1 Introduction

Motivated by the game theory of Stackelberg [1], several authors studied bi-level programming intensively and contributed to its proliferation. The original formulation for bi-level programming appeared in 1973 by Bracken and McGil [2]. In 1977, Candler and Norton [3] proposed the bi-level and multilevel programming. Bi-level programming problem is a hierarchical programming problem with two levels.

X. Zhou
International Business School, Shaanxi Normal University, Xi'an 710062, People's Republic of China

Y. Tu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: tuyan_belle@163.com

R. Hu
School of Economy & Trade, Hunan University, Changsha 410079, People's Republic of China

B. Lev
Decision Sciences Department, LeBow College of Business, Drexel University, Philadelphia 19104, USA

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The hierarchical optimization structure appears naturally in many applications when lower level actions depend on and also influence upper level decisions.

In realistic world, in order to handle the uncertainty in bi-level decision making problems, some scholars established optimization models with uncertain variables, such as, Sakawa and Matsui [4, 5], Xu et al. [6, 7]. As we know, bi-level decision making models with uncertain variables could not be solved directly, we have to use some philosophy deal with the uncertainty decision making.

In [8], Charnes and Cooper proposed the stochastic chance constrained programming. In [9], Liu presented chance constrained programming with fuzzy coefficients. In [10], Terol designed flexible decision making models in the distance metric optimization framework for problems including parameters which are represented by fuzzy numbers. In [11], Slowinski applied the method of rough sets to solve the uncertain problem in the medical domain. However, in a decision-making process, we may face a hybrid uncertain environment. In such situations, the use of fuzzy set theory to represent unknown parameters provides an interesting help. Thus, these coefficients may be dealt with a random variable whose parameters are assumed to be fuzzy numbers due to the decision maker's subjectivity. In other words, we may employ random fuzzy theory to deal with this combined uncertainty of randomness and fuzziness.

With respect to these mathematical programming problems including randomness and fuzziness, since they are not well-defined problems due to randomness and fuzziness, it is necessary that we consider a certain optimization criterion so as to transform these problems into well-defined problems. However,since they are usually transformed into nonlinear programming problems, it is difficult to find a global optimal solution directly. Therefore, in this paper, we construct an efficient solution method to find a global optimal solution of deterministic equivalent problem including more complicated constraints. This stimulates the author to employ the latest development of mathematics on uncertainty theory to study the bi-level programming problem in random fuzzy environment.

2 Random Fuzzy Linear Chance Constrained Bi-Level Programming

We propose the bi-level programming with chance constrained objectives and chance constraints based on the philosophy: selecting the decision by optimizing the optimistic objective value with a given confidence level subject to some chance constraints.

So we can propose the random fuzzy chance constrained bi-level programming as follows:

$$
\begin{aligned}
&\max_{x} \ F' \\
&\text{s.t.} \begin{cases}
Ch\{\bar{\tilde{a}}_1^T x + \bar{\tilde{b}}_1^T y \geq F'\}(\zeta_1) \geq \eta_1 \\
Ch\{\bar{\tilde{c}}_{1r_1}^T x + \bar{\tilde{d}}_{1r_1}^T y \leq \bar{\tilde{e}}_{1r_1}\}(\delta_{1r_1}) \geq \gamma_{1r_1}, \ r_1 = 1, 2, \ldots, p_1 \\
\text{where } y \text{ solves:} \\
\max_{y} \ f' \\
\text{s.t.} \begin{cases}
Ch\{\bar{\tilde{a}}_2^T x + \bar{\tilde{b}}_2^T y \geq f'\}(\zeta_2) \geq \eta_2 \\
Ch\{\bar{\tilde{c}}_{2r_2}^T x + \bar{\tilde{d}}_{2r_2}^T y \leq \bar{\tilde{e}}_{2r_2}\}(\delta_{2r_2}) \geq \gamma_{2r_2}, \ r_2 = 1, 2, \ldots, p_2 \\
x, y \geq 0,
\end{cases}
\end{cases}
\end{aligned}
\tag{1}
$$

where $Ch\{\cdot\}$ are the chance measure of the random fuzzy event θ_1, ζ_1, θ_2, ζ_2, δ_{1r_1}, γ_{1r_1}, δ_{2r_2}, γ_{2r_2} are predetermined confidence levels.

In order to understand the Ch measure, we first introduce the basic definitions and properties as follows:

Definition 1 [12] Let $\xi = (\xi_1, \xi_2, \ldots, \xi_n)$ be a random fuzzy vector on the possibility space $(\Theta, \mathscr{P}(\Theta), Pos)$, and $f : \mathbf{R}^n \to \mathbf{R}$ be continuous functions. Then the primitive chance of random fuzzy event characterized by $f(x, \xi) \leq 0$ is a function from [0,1] to [0,1], defined as

$$
Ch\{f(x,\xi) \leq 0\}(\alpha) = \sup\{\beta \,|Pos\,\{\theta \in \Theta \,|Pr\,\{f(x,\xi(\theta)) \leq 0\} \geq \beta\} \geq \alpha\}.
$$

By Definition 1, Model (1) can be also written as follows:

$$
\begin{aligned}
&\max_{x} \ F' \\
&\text{s.t.} \begin{cases}
Pos\left\{\theta | Pr\{\bar{\tilde{a}}_1(\theta)^T x + \bar{\tilde{b}}_1(\theta)^T y \geq F'\} \geq \eta_1\right\} \geq \zeta_1 \\
Pos\left\{\theta | Pr\{\bar{\tilde{c}}_{1r_1}(\theta)^T x + \bar{\tilde{d}}_{1r_1}(\theta)^T y \leq \bar{\tilde{e}}_{1r_1}(\theta)\} \geq \gamma_{1r_1}\right\} \geq \delta_{1r_1} \\
\quad r_1 = 1, 2, \ldots, p_1 \\
\text{where } y \text{ solves:} \\
\max_{y} \ f' \\
\text{s.t.} \begin{cases}
Pos\left\{\theta | Pr\{\bar{\tilde{a}}_2(\theta)^T x + \bar{\tilde{b}}_2(\theta)^T y \geq f'\} \geq \eta_2\right\} \geq \zeta_2 \\
Pos\left\{\theta | Pr\{\bar{\tilde{c}}_{2r_2}(\theta)^T x + \bar{\tilde{d}}_{2r_2}(\theta)^T y \leq \bar{\tilde{e}}_{2r_2}(\theta)\} \geq \gamma_{2r_2}\right\} \geq \delta_{2r_2} \\
\quad r_2 = 1, 2, \ldots, p_2 \\
x, y \geq 0,
\end{cases}
\end{cases}
\end{aligned}
\tag{2}
$$

where $Pos\{\cdot\}$ is the possibility of the fuzzy event and $Pr\{\cdot\}$ are the probability of the random event.

In the following, we focus on the special random fuzzy variables with normal distributions whose mean values are LR fuzzy random variables, and introduce the equivalent formulas as follows.

Lemma 1 *Let* $\xi_1 = (\mu_1, \alpha_1, \beta_1)_{LR}$ *and* $\xi_2 = (\mu_2, \alpha_2, \beta_2)_{LR}$ *be LR fuzzy numbers, then we have* $\xi_1 + \xi_2 = (\mu_1 + \mu_2, \alpha_1 + \alpha_2, \beta_1 + \beta_2)_{LR}$ *and* $\xi_1 - \xi_2 = (\mu_1 - \mu_2, \alpha_1 + \beta_2, \beta_1 + \alpha_2)_{LR}$.

Theorem 1 *Suppose that* $\bar{\tilde{a}}_1 = (\bar{\tilde{a}}_{11}, \bar{\tilde{a}}_{12}, \ldots, \bar{\tilde{a}}_{1n_1})^T$, $\bar{\tilde{b}}_1 = (\bar{\tilde{b}}_{11}, \bar{\tilde{b}}_{12}, \ldots, \bar{\tilde{b}}_{1n_2})^T$ *are normally distributed random fuzzy vectors, that is,* $\bar{\tilde{a}}_1 \sim \mathcal{N}(\tilde{u}_1^a(\theta), V_1^a)$ *and* $\bar{\tilde{b}}_1 \sim \mathcal{N}(\tilde{u}_1^b(\theta), V_1^b)$*; where* $\tilde{u}_1^a(\theta) = (\tilde{u}_{11}^a(\theta), \tilde{u}_{12}^a(\theta), \ldots, \tilde{u}_{1n_1}^a(\theta))^T$, $\tilde{u}_1^b(\theta) = (\tilde{u}_{11}^b(\theta), \tilde{u}_{12}^b(\theta), \ldots, \tilde{u}_{1n_2}^b(\theta))^T$*, and* $\tilde{u}_{1j}^a(\theta)$, $\tilde{u}_{1k}^b(\theta)$ *are LR fuzzy variables characterized by the following membership functions, respectively,*

$$\mu_{\tilde{u}_{1j}^a(\theta)}(t) = \begin{cases} L\left(\frac{u_{1j}^c - t}{\alpha_{1j}^c}\right), \ t \le u_{1j}^c \\ R\left(\frac{t - u_{1j}^c}{\beta_{1j}^c}\right), \ t \ge u_{1j}^c \end{cases} \qquad \theta \in \Theta \tag{3}$$

and

$$\mu_{\tilde{u}_{1k}^b(\theta)}(t) = \begin{cases} L\left(\frac{u_{1k}^b - t}{\alpha_{1k}^b}\right), \ t \le u_{1k}^b \\ R\left(\frac{t - u_{1k}^d}{\beta_{1k}^b}\right), \ t \ge u_{1k}^b \end{cases} \qquad \theta \in \Theta, \tag{4}$$

where α_{1j}^c, β_{1j}^c *are left and right spreads of* $\tilde{u}_{1j}^a(\theta)$*; and* α_{1k}^b, β_{1k}^b *are left and right spreads of* $\tilde{u}_{1k}^b(\theta)$, $j = 1, 2, \ldots, n_1, k = 1, 2, \ldots, n_2$ *and reference functions* $L, R : [0, 1] \to [0, 1]$ *with* $L(1) = R(1) = 0$ *and* $L(0) = R(0) = 1$ *are non-increasing, continuous functions.*

Assume that for any $\theta \in \Theta$, $\tilde{u}_{1j}^a(\theta)$ *and* $\tilde{u}_{1k}^b(\theta)$ *are independent random variables. Then, we have*

$$Pos\left\{\theta | Pr\{\bar{\tilde{a}}_1(\theta)^T x + \bar{\tilde{b}}_1(\theta)^T y \ge F'\} \ge \eta_1\right\} \ge \zeta_1,$$

if and only if

$$F' \le (u_1^{aT} x + u_1^{bT} y) + \Phi^{-1}(1 - \eta_1)\sqrt{x^T V_1^a x + y^T V_1^b y} + R^{-1}(\zeta_1)(\beta_1^{aT} x + \beta_1^{bT} y),$$

where Φ *is the standard normally distributed function,* $\eta_1, \zeta_1 \in (0, 1)$ *are predetermined confidence levels.*

Remark 1 Especially, when the reference function $L(x) = R(x) = 1 - x, x \in [0, 1]$, the LR fuzzy variables are specified to triangular LR fuzzy variables, then we have:

$$Pos\left\{\theta | Pr\{\bar{\tilde{a}}_1(\theta)^T x + \bar{\tilde{b}}_1(\theta)^T y \ge F'\} \ge \eta_1\right\} \ge \zeta_1$$

is equivalent to:

$$F' \leq (u_1^{aT}x + u_1^{bT}y) + \Phi^{-1}(1-\eta_1)\sqrt{x^T V_1^a x + y^T V_1^b y} + (1-\zeta_1)(\beta_1^{aT}x + \beta_1^{bT}y).$$

Remark 2 Also we can transform the constraints of the lower level chance constraint into it's crisp equivalence according to Theorem 1. So we have

$$\begin{aligned} &Pos\left\{\theta | Pr\{\bar{\tilde{a}}_2(\theta)^T x + \bar{\tilde{b}}_2(\theta)^T y \geq F'\} \geq \eta_2\right\} \geq \zeta_2 \\ &\Leftrightarrow F' \leq (u_2^{aT}x + u_2^{bT}y) + \Phi^{-1}(1-\eta_2)\sqrt{x^T V_2^a x + y^T V_2^b y} \\ &\quad + R^{-1}(\zeta_2)(\beta_2^{aT}x + \beta_2^{bT}y). \end{aligned} \tag{5}$$

Theorem 2 *Suppose that* $\bar{\tilde{c}}_{1r_1} = (\bar{\tilde{c}}_{1r_11}, \bar{\tilde{c}}_{1r_12}, \ldots, \bar{\tilde{c}}_{1r_1n_1})^T$, $\bar{\tilde{d}}_{1r_1} = (\bar{\tilde{d}}_{1r_11}, \bar{\tilde{d}}_{1r_12}, \ldots, \bar{\tilde{d}}_{1r_1n_2})^T$ *are normally distributed random fuzzy vectors with the fuzzy mean vectors* $\tilde{u}^c_{1r_1}(\theta) = (\tilde{u}^c_{1r_11}(\theta), \tilde{u}^c_{1r_12}(\theta), \ldots, \tilde{u}^c_{1r_1n_1}(\theta))^T$, $\tilde{u}^d_{1r_1}(\theta) = (\tilde{u}^d_{1r_11}(\theta), \tilde{u}^c_{1r_12}(\theta), \ldots, \tilde{u}^d_{1r_1n_2}(\theta))^T$, *and covariance matrixes* $V^c_{1r_1}$, $V^d_{1r_1}$, *written as* $\bar{\tilde{c}}_{1r_1} \sim \mathcal{N}(\tilde{u}^c_{1r_1}(\theta), V^c_{1r_1})$ *and* $\bar{\tilde{d}}_{1r_1} \sim \mathcal{N}(\tilde{u}^d_{1r_1}(\theta), V^d_{1r_1})$; $\bar{\tilde{e}}_{1r_1}$ *is a random fuzzy variable with the fuzzy mean variable* $\tilde{u}^e_{1r_1}(\theta)$ *and the variance* $(\sigma^e_{1r_1})^2$, *written as* $\bar{\tilde{e}}_{1r_1} \sim \mathcal{N}(\tilde{u}^e_{1r_1}(\theta), (\sigma^e_{1r_1})^2)$, *where* $\tilde{u}^c_{1r_1j}(\theta)$, $\tilde{u}^d_{1r_1k}(\theta)$ *and* $\tilde{u}^e_{1r_1}(\theta)$ *are fuzzy variables characterized by the following membership functions, respectively,*

$$\mu_{\tilde{u}^{c/d/e}_{1r_1j}(\theta)}(t) = \begin{cases} L\left(\frac{u^{c/d/e}_{1r_1j} - t}{\alpha^{c/d/e}_{1r_1j}}\right), \ t \leq u^{c/d/e}_{1r_1j} \\ R\left(\frac{t - u^{c/d/e}_{1r_1j}}{\beta^{c/d/e}_{1r_1j}}\right), \ t \geq u^{c/d/e}_{1r_1j} \end{cases} \quad \theta \in \Theta, \tag{6}$$

where $\alpha^c_{1r_1j}$, $\beta^c_{1r_1j}$ *are left and right spreads of* $\tilde{u}^c_{1r_1j}(\theta)$; $\alpha^d_{1r_1k}$, $\beta^d_{1r_1k}$ *are left and right spreads of* $\tilde{u}^d_{1r_1k}(\theta)$; $\alpha^e_{1r_1}$, $\beta^e_{1r_1}$ *are left and right spreads of* $\tilde{u}^e_{1r_1}(\theta)$, $r_1 = 1, 2, \ldots, p_1$, $j = 1, 2, \ldots, n_1$, $k = 1, 2, \ldots, n_2$ *and reference functions* $L, R : [0, 1] \to [0, 1]$ *with* $L(1) = R(1) = 0$ *and* $L(0) = R(0) = 1$ *are non-increasing, continuous functions.*

Assume that for any $\theta \in \Theta$, $\bar{\tilde{c}}_{1r_1j}(\theta)$, $\bar{\tilde{d}}_{1r_1k}(\theta)$, $\bar{\tilde{e}}_{1r_1}(\theta)$ *are independent random variables. Then, we have*

$$Pos\left\{\theta | Pr\{\bar{\tilde{c}}_{1r_1}(\theta)^T x + \bar{\tilde{d}}_{1r_1}(\theta)^T y \leq \bar{\tilde{e}}_{1r_1}(\theta)\} \geq \gamma_{1r_1}\right\} \geq \delta_{1r_1}, \ r_1 = 1, 2, \ldots, p_1,$$

if and only if

$$\begin{aligned} &(u^{cT}_{1r_1}x + u^{dT}_{1r_1}y - u^e_{1r_1}) + \Phi^{-1}(\gamma_{1r_1})\sqrt{x^T V^c_{1r_1} x + y^T V^d_{1r_1} y + (\sigma^e_{1r_1})^2} \\ &\quad - R^{-1}(\delta_{1r_1})(\beta^e_{1r_1} + \alpha^{cT}_{1r_1}x + \alpha^{dT}_{1r_1}y) \leq 0. \end{aligned}$$

Remark 3 Especially, when the reference function $L(x) = R(x) = 1-x, x \in [0, 1]$, the LR fuzzy variables are specified to triangular LR fuzzy variables, then we have

$$Pos\{\theta | Pr\{\bar{\tilde{c}}_{1r_1}(\theta)^T x + \bar{\tilde{d}}_{1r_1}(\theta)^T y \leq \bar{\tilde{e}}_{1r_1}(\theta)\} \geq \gamma_{1r_1}\} \geq \delta_{1r_1},\ r_1 = 1, 2, \ldots, p_1$$

is equivalent to

$$\begin{aligned}&(u_{1r_1}^{cT} x + u_{1r_1}^{dT} y - u_{1r_1}^{e}) + \Phi^{-1}(\gamma_{1r_1})\sqrt{x^T V_{1r_1}^c x + y^T V_{1r_1}^d y + (\sigma_{1r_1}^e)^2}\\ &\quad -(1-\delta_{1r_1})(\beta_{1r_1}^e + \alpha_{1r_1}^{cT} x + \alpha_{1r_1}^{dT} y) \leq 0.\end{aligned}$$

Remark 4 Also we can transform the constraints of the lower level chance constraint into it's crisp equivalence according to Theorem 2. So we have

$$\begin{aligned}&Pos\{\theta | Pr\{\bar{\tilde{c}}_{2r_2}(\theta)^T x + \bar{\tilde{d}}_{2r_2}(\theta)^T y \leq \bar{\tilde{e}}_{2r_2}(\theta)\} \geq \gamma_{2r_2}\} \geq \delta_{2r_2}\\ &\Leftrightarrow (u_{2r_2}^{cT} x + u_{2r_2}^{dT} y - u_{2r_2}^{e}) + \Phi^{-1}(\gamma_{2r_2})\sqrt{x^T V_{2r_2}^c x + y^T V_{2r_2}^d y + (\sigma_{2r_2}^e)^2}\\ &\quad -R^{-1}(\delta_{2r_2})(\beta_{2r_2}^e + \alpha_{2r_2}^{cT} x + \alpha_{2r_2}^{dT} y) \leq 0.\end{aligned} \tag{7}$$

In this paper, let us put our focus on the normally distributed random fuzzy variable with triangular LR fuzzy mean value, so based on the above Theorems 1 and 2, Remarks 1–4, we can get the equivalent crisp model for Model (2) as follows:

$$\begin{aligned}&\max_x\ F'\\ &\text{s.t.}\begin{cases} F' \leq (u_1^{aT} x + u_1^{bT} y) + \Phi^{-1}(1-\eta_1)\sqrt{x^T V_1^a x + y^T V_1^b y}\\ \quad + (1-\zeta_1)(\beta_1^{aT} x + \beta_1^{bT} y)\\ (u_{1r_1}^{c} x + u_{1r_1}^{d} y - u_{1r_1}^{e}) + \Phi^{-1}(\gamma_{1r_1})\sqrt{x^T V_{1r_1}^{cT} x + y^T V_{1r_1}^{dT} y + (\sigma_{1r_1}^e)^2}\\ \quad - (1-\delta_{1r_1})(\beta_{1r_1}^e + \alpha_{1r_1}^{cT} x + \alpha_{1r_1}^{dT} y) \leq 0,\ r_1 = 1, 2, \ldots, p_1\\ \text{where } y \text{ solves:}\\ \max_y\ f'\\ \text{s.t.}\begin{cases} F' \leq (u_2^{aT} x + u_2^{bT} y) + \Phi^{-1}(1-\eta_2)\sqrt{x^T V_2^a x + y^T V_2^b y}\\ \quad + (1-\zeta_2)(\beta_2^{aT} x + \beta_2^{bT} y)\\ (u_{2r_2}^{c} x + u_{2r_2}^{d} y - u_{2r_2}^{e}) + \Phi^{-1}(\gamma_{2r_2})\sqrt{x^T V_{2r_2}^{cT} x + y^T V_{2r_2}^{dT} y + (\sigma_{2r_2}^e)^2}\\ \quad - (1-\delta_{2r_2})(\beta_{2r_2}^e + \alpha_{2r_2}^{cT} x + \alpha_{2r_2}^{dT} y) \leq 0,\ \ r_2 = 1, 2, \ldots, p_2\\ x, y \geq 0. \end{cases} \end{cases}\end{aligned} \tag{8}$$

Also, Model (8) can be written as

$$
\begin{aligned}
&\max_{x}\ (u_1^{aT}x + u_1^{bT}y) + \Phi^{-1}(1-\eta_1)\sqrt{x^T V_1^a x + y^T V_1^b y} + (1-\zeta_1)(\beta_1^{aT}x + \beta_1^{bT}y)\\
&\text{s.t.}\begin{cases}
(u_{1r_1}^c x + u_{1r_1}^d y - u_{1r_1}^e) + \Phi^{-1}(\gamma_{1r_1})\sqrt{x^T V_{1r_1}^{cT}x + y^T V_{1r_1}^{dT}y + (\sigma_{1r_1}^e)^2}\\
\quad -(1-\delta_{1r_1})(\beta_{1r_1}^e + \alpha_{1r_1}^{cT}x + \alpha_{1r_1}^{dT}y) \le 0,\ r_1 = 1, 2, \ldots, p_1\\
\text{where } y \text{ solves:}\\
\max_{y}\ (u_2^{aT}x + u_2^{bT}y) + \Phi^{-1}(1-\eta_2)\sqrt{x^T V_2^a x + y^T V_2^b y} + (1-\zeta_2)(\beta_2^{aT}x + \beta_2^{bT}y)\\
\text{s.t.}\begin{cases}
(u_{2r_2}^c x + u_{2r_2}^d y - u_{2r_2}^e) + \Phi^{-1}(\gamma_{2r_2})\sqrt{x^T V_{2r_2}^{cT}x + y^T V_{2r_2}^{dT}y + (\sigma_{2r_2}^e)^2}\\
\quad -(1-\delta_{2r_2})(\beta_{2r_2}^e + \alpha_{2r_2}^{cT}x + \alpha_{2r_2}^{dT}y) \le 0,\ \ r_2 = 1, 2, \ldots, p_2\\
x, y \ge 0.
\end{cases}
\end{cases}
\end{aligned}
\tag{9}
$$

3 Illustrative Example

The following illustrative example is given to show the application of the proposed models and algorithms.

$$
\begin{aligned}
&\max\ F(x,y) = \bar{\tilde{a}}_{11}x_1 + \bar{\tilde{a}}_{12}x_2 + \bar{\tilde{a}}_{13}x_3 + \bar{\tilde{b}}_{11}y_1 + \bar{\tilde{b}}_{12}y_2\\
&\text{s.t.}\begin{cases}
\bar{\tilde{c}}_{11}x_1 + \bar{\tilde{c}}_{12}x_2 + \bar{\tilde{c}}_{13}x_3 \le y_1\\
\bar{\tilde{c}}_{21}x_1 + \bar{\tilde{c}}_{22}x_2 + \bar{\tilde{c}}_{23}x_3 \le y_2\\
x_1, x_2, x_3 \ge 0\\
\text{where } y \text{ solves:}\\
\max\ f(x,y) = \bar{\tilde{a}}_{21}x_1 + \bar{\tilde{a}}_{22}x_2 + \bar{\tilde{a}}_{23}x_3 + \bar{\tilde{b}}_{21}y_1 + \bar{\tilde{b}}_{22}y_2\\
\text{s.t.}\begin{cases}
\bar{\tilde{d}}_{11}x_1 + \bar{\tilde{d}}_{12}x_2 + \bar{\tilde{d}}_{13}x_3 + \bar{\tilde{d}}_{14}y_1 + \bar{\tilde{d}}_{15}y_2 \le \bar{\tilde{e}}_1\\
\bar{\tilde{d}}_{21}x_1 + \bar{\tilde{d}}_{22}x_2 + \bar{\tilde{d}}_{23}x_3 + \bar{\tilde{d}}_{24}y_1 + \bar{\tilde{d}}_{25}y_2 \le \bar{\tilde{e}}_2\\
y_1, y_2 \ge 0,
\end{cases}
\end{cases}
\end{aligned}
\tag{10}
$$

where

$$
\begin{aligned}
&\bar{\tilde{a}}_{11} \sim N(\tilde{a}_{11}, 1) \text{ with } \tilde{a}_{11} = (9, 11, 12), && \bar{\tilde{a}}_{21} \sim N(\tilde{a}_{21}, 1) \text{ with } \tilde{a}_{21} = (2, 4, 5),\\
&\bar{\tilde{a}}_{12} \sim N(\tilde{a}_{12}, 4) \text{ with } \tilde{a}_{12} = (5, 6, 8), && \bar{\tilde{a}}_{22} \sim N(\tilde{a}_{22}, 1) \text{ with } \tilde{a}_{22} = (1, 1, 3),\\
&\bar{\tilde{a}}_{13} \sim N(\tilde{a}_{13}, 2) \text{ with } \tilde{a}_{13} = (6, 7, 8), && \bar{\tilde{a}}_{23} \sim N(\tilde{a}_{23}, 1) \text{ with } \tilde{a}_{23} = (3, 6, 9),\\
&\bar{\tilde{b}}_{11} \sim N(\tilde{b}_{11}, 1) \text{ with } \tilde{b}_{11} = (0, 2, 3), && \bar{\tilde{b}}_{21} \sim N(\tilde{b}_{21}, 4) \text{ with } \tilde{b}_{21} = (1, 3, 4),\\
&\bar{\tilde{b}}_{12} \sim N(\tilde{b}_{12}, 1) \text{ with } \tilde{b}_{12} = (0, 1, 2), && \bar{\tilde{b}}_{22} \sim N(\tilde{b}_{22}, 1) \text{ with } \tilde{b}_{22} = (1, 2, 3),\\
&\bar{\tilde{c}}_{11} \sim N(\tilde{c}_{11}, 3) \text{ with } \tilde{c}_{11} = (1, 2, 3), && \bar{\tilde{c}}_{21} \sim N(\tilde{c}_{21}, 1) \text{ with } \tilde{c}_{21} = (3, 5, 7),\\
&\bar{\tilde{c}}_{12} \sim N(\tilde{c}_{12}, 1) \text{ with } \tilde{c}_{12} = (1, 2, 3), && \bar{\tilde{c}}_{22} \sim N(\tilde{c}_{22}, 3) \text{ with } \tilde{c}_{22} = (1, 3, 5),
\end{aligned}
$$

$$
\begin{array}{ll}
\bar{\tilde{c}}_{13} \sim N(\tilde{c}_{13}, 1) \text{ with } \tilde{c}_{13} = (3, 4, 5), & \bar{\tilde{c}}_{23} \sim N(\tilde{c}_{23}, 1) \text{ with } \tilde{c}_{23} = (3, 4, 5), \\
\bar{\tilde{d}}_{11} \sim N(\tilde{d}_{11}, 1) \text{ with } \tilde{d}_{11} = (1, 2, 3), & \bar{\tilde{d}}_{21} \sim N(\tilde{d}_{21}, 1) \text{ with } \tilde{d}_{21} = (1, 3, 5), \\
\bar{\tilde{d}}_{12} \sim N(\tilde{d}_{12}, 1) \text{ with } \tilde{d}_{12} = (1.5, 2, 2.5), & \bar{\tilde{d}}_{22} \sim N(\tilde{d}_{22}, 1) \text{ with } \tilde{d}_{22} = (1, 2, 3), \\
\bar{\tilde{d}}_{13} \sim N(\tilde{d}_{13}, 1) \text{ with } \tilde{d}_{13} = (1, 2, 3), & \bar{\tilde{d}}_{23} \sim N(\tilde{d}_{23}, 1) \text{ with } \tilde{d}_{23} = (0, 1, 2), \\
\bar{\tilde{d}}_{14} \sim N(\tilde{d}_{14}, 1) \text{ with } \tilde{d}_{14} = (1, 2, 3), & \bar{\tilde{d}}_{24} \sim N(\tilde{d}_{24}, 1) \text{ with } \tilde{d}_{24}=(0.5, 1, 1.5), \\
\bar{\tilde{d}}_{15} \sim N(\tilde{d}_{15}, 1) \text{ with } \tilde{d}_{15} = (0, 1, 2), & \bar{\tilde{d}}_{25} \sim N(\tilde{d}_{25}, 1) \text{ with } \tilde{d}_{25} = (1, 2, 3), \\
\bar{\tilde{e}}_{1} \sim N(\tilde{e}_{1}, 9) \text{ with } \tilde{e}_{1} = (450, 500, 550), & \bar{\tilde{e}}_{2} \sim N(\tilde{e}_{2}, 9) \text{ with } \tilde{e}_{2}=(700, 800, 900)
\end{array}
$$

are independent random fuzzy coefficients.

According to Model (1), we can obtain the following model, in which we use the expected operator to handle the objective functions and employ the chance constrained operator to deal with the constraints.

$$
\begin{array}{l}
\max \ F' \\
\text{s.t.} \left\{
\begin{array}{l}
Pos\{Pr\{\bar{\tilde{a}}_{11}x_1 + \bar{\tilde{a}}_{12}x_2 + \bar{\tilde{a}}_{13}x_3 + \bar{\tilde{b}}_{11}y_1 + \bar{\tilde{b}}_{12}y_2 \geq F'\} \geq \eta_1\} \geq \zeta_1 \\
Pos\{Pr\{\bar{\tilde{c}}_{11}x_1 + \bar{\tilde{c}}_{12}x_2 + \bar{\tilde{c}}_{13}x_3 \leq y_1\} \geq \gamma_{11}\} \geq \delta_{11} \\
Pos\{Pr\{\bar{\tilde{c}}_{21}x_1 + \bar{\tilde{c}}_{22}x_2 + \bar{\tilde{c}}_{23}x_3 \leq y_2\} \geq \gamma_{12}\} \geq \delta_{12} \\
x_1, x_2, x_3 \geq 0 \\
\text{where } y \text{ solves:} \\
\max \ f' \\
\text{s.t.} \left\{
\begin{array}{l}
Pos\{Pr\{\bar{\tilde{a}}_{21}x_1 + \bar{\tilde{a}}_{22}x_2 + \bar{\tilde{a}}_{23}x_3 + \bar{\tilde{b}}_{21}y_1 + \bar{\tilde{b}}_{22}y_2 \geq f'\} \geq \eta_2\} \geq \zeta_2 \\
Pos\{Pr\{\bar{\tilde{d}}_{11}x_1 + \bar{\tilde{d}}_{12}x_2 + \bar{\tilde{d}}_{13}x_3 + \bar{\tilde{d}}_{14}y_1 + \bar{\tilde{d}}_{15}y_2 \leq \bar{\tilde{e}}_1\} \geq \gamma_{21}\} \geq \delta_{21} \\
Pos\{Pr\{\bar{\tilde{d}}_{21}x_1 + \bar{\tilde{d}}_{22}x_2 + \bar{\tilde{d}}_{23}x_3 + \bar{\tilde{d}}_{24}y_1 + \bar{\tilde{d}}_{25}y_2\} \leq \bar{\tilde{e}}_2\} \geq \gamma_{22}\} \geq \delta_{22} \\
y_1, y_2 \geq 0.
\end{array}
\right.
\end{array}
\right.
\end{array}
\tag{11}
$$

Based on the crisp equivalent models (8) and (9), we can get the following model (12).

$$
\begin{array}{l}
\max \ (11x_1 + 6x_2 + 7x_3 + 2y_1 + y_2) + \Phi^{-1}(1 - \eta_1)\sqrt{x_1^2 + 4x_2^2 + 2x_3^2 + y_1^2 + y_2^2} \\
\quad +(1 - \zeta_1)(x_1 + 2x_2 + x_3 + y_1 + y_2) \\
\text{s.t.} \left\{
\begin{array}{l}
(2x_1 + 2x_2 + 4x_3 - y_1) + \Phi^{-1}(\gamma_{11})\sqrt{3x_1^2 + x_2^2 + x_3^2} \\
\quad -(1 - \delta_{11})(x_1 + x_2 + x_3) \leq 0 \\
(5x_1 + 3x_2 + 4x_3 - y_2) + \Phi^{-1}(\gamma_{12})\sqrt{x_1^2 + 3x_2^2 + x_3^2} \\
\quad -(1 - \delta_{12})(2x_1 + 2x_2 + x_3) \leq 0 \\
x_1, x_2, x_3 \geq 0 \\
\text{where } y \text{ solves:} \\
\max \ (4x_1 + x_2 + 6x_3 + 3y_1 + 2y_2) + \Phi^{-1}(1 - \eta_2)\sqrt{x_1^2 + x_2^2 + x_3^2 + 4y_1^2 + y_2^2} \\
\quad +(1 - \zeta_1)(x_1 + 2x_2 + 3x_3 + y_1 + y_2) \\
\text{s.t.} \left\{
\begin{array}{l}
(2x_1 + 2x_2 + 2x_3 + 2y_1 + y_2 - 500) \\
\quad +\Phi^{-1}(\gamma_{21})\sqrt{x_1^2 + x_2^2 + x_3^2 + y_1^2 + y_2^2 + 9} \\
\quad -(1 - \delta_{21})(x_1 + 0.5x_2 + x_3 + y_1 + y_2 + 50) \leq 0 \\
(3x_1 + 2x_2 + x_3 + y_1 + 2y_2 - 800) \\
\quad +\Phi^{-1}(\gamma_{22})\sqrt{x_1^2 + x_2^2 + x_3^2 + y_1^2 + y_2^2 + 9} \\
\quad -(1 - \delta_{22})(2x_1 + x_2 + x_3 + 0.5y_1 + y_2 + 100) \leq 0 \\
y_1, y_2 \geq 0.
\end{array}
\right.
\end{array}
\right.
\end{array}
\tag{12}
$$

In the following, we set $\eta_1 = \eta_2 = \zeta_1 = \zeta_2 = 0.85$, and $\gamma_{11} = \gamma_{12} = \gamma_{21} = \gamma_{22} = \delta_{11} = \delta_{12} = \delta_{21} = \delta_{22} = 0.9$, and we know $\Phi^{-1}(0.15) = -1.032$ and $\Phi^{-1}(0.9) = 1.281$. Then according to the interactive programming technique [13], we have:

$$\begin{aligned} H_1(x, y) = \ & 11.15x_1 + 6.3x_2 + 7.15x_3 + 2.15y_1 + 1.15y_2 \\ & -1.032\sqrt{x_1^2 + 4x_2^2 + 2x_3^2 + y_1^2 + y_2^2}, \end{aligned}$$

$$\begin{aligned} H_2(x, y) = \ & 4.15x_1 + 1.3x_2 + 6.45x_3 + 3.15y_1 + 2.15y_2 \\ & -1.032\sqrt{x_1^2 + x_2^2 + x_3^2 + 4y_1^2 + y_2^2} \end{aligned}$$

and

$$S = \left\{ (x, y) \geq 0 \;\middle|\; \begin{array}{l} 1.9x_1 + 1.9x_2 + 3.9x_3 - y_1 + 1.281\sqrt{3x_1^2 + x_2^2 + x_3^2} \leq 0 \\ 4.8x_1 + 2.8x_2 + 3.9x_3 - y_2 + 1.281\sqrt{x_1^2 + 3x_2^2 + x_3^2} \leq 0 \\ 1.9x_1 + 1.95x_2 + 1.9x_3 + 1.9y_1 + 0.9y_2 \\ \quad +1.281\sqrt{x_1^2 + x_2^2 + x_3^2 + y_1^2 + y_2^2 + 9} \leq 490 \\ 2.8x_1 + 1.9x_2 + 0.9x_3 + 0.95y_1 + 1.9y_2 \\ \quad +1.281\sqrt{x_1^2 + x_2^2 + x_3^2 + y_1^2 + y_2^2 + 9} \leq 790 \end{array} \right\}.$$

In order to get the value of $H_1^{\max}$, $H_1^{\min}$, $H_2^{\max}$, $H_2^{\min}$, we need to solve the following two models:

$$\begin{array}{l} \max \ H_1(x, y) \\ \text{s.t. } (x, y) \in S \end{array} \quad \text{and} \quad \begin{array}{l} \max \ H_2(x, y) \\ \text{s.t. } (x, y) \in S. \end{array}$$

After solving these two models, we can obtain that

$$\begin{aligned} & H_1^{\max} = 375.362, \ \ H_1^{\min} = 323.879, \\ & (x_1, x_2, x_3) = (18.45, 1.80, 0), \ \ (y_1, y_2) = (79.45, 117.56) \end{aligned}$$

and

$$\begin{aligned} & H_2^{\max} = 409.28, \ \ H_2^{\min} = 377.049, \\ & (x_1, x_2, x_3) = (3.73, 0, 15.75), \ \ (y_1, y_2) = (90.30, 103.92). \end{aligned}$$

Following the interactive programming method, we get the following model,

$$\max \ \lambda$$
$$\text{s.t.} \begin{cases} (H_1(x,y) - 323.879)/(375.362 - 323.879) \geq \lambda \\ (H_2(x,y) - 377.049)/(409.28 - 377.049) \geq \lambda \\ (x,y) \in S. \end{cases} \tag{13}$$

After solving Model (13), we get the following results:

$$\lambda = 0.711,\ F(x,y) = 349.74,\ f(x,y) = 399.96,$$
$$(x_1, x_2, x_3) = (12.11, 0, 8.48),\ (y_1, y_2) = (85.05, 110.13).$$

4 Conclusion

In this paper, we proposed a class of chance constrained bi-level multi-objective decision making model under random fuzzy environment. Then we propose transform it into an equivalent model which is easy to solve. Interactive programming technique is employed to combine the bi-level model to a single level model. Finally, we employ a numerical example to show the feasibility.

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A Consensus Based VIKOR Method Using the 2-Tuple Linguistic Model

Zhibin Wu, Kang Xu and Lin Zhong

Abstract Consensus plays a key role in group decision making where the participants in a group want to achieve some predefined degree of accordance. In this paper, based on the 2-tuple linguistic model, a consensus reaching process for multiple attribute group decision making (MAGDM) problem is introduced. Then a classical VIKOR method is extended based on the consensus process. Therefore, an intergraded MADGM approach combining the consensus process and VIKOR method is presented. Finally, a numerical example is illustrated to validate the practicality of the proposed approach.

Keywords Multiple attribute decision making (MADM) · The 2-tuple linguistic model · VIKOR · Group decision making

1 Introduction

In human decision making process, there are cases in which the information cannot be expressed precisely in a quantitative form but may be stated only in linguistic terms. For example, when attempting to qualify phenomena related to human perception, we are likely to use words in natural language instead of numerical values. (e.g. when evaluating the “comfort” or “design” of a car, terms like “bad”, “poor”, “tolerable”, “average”, or “good” can be used [12]). A more realistic measurement is to use linguistic assessments instead of numerical values [28]. Linguistic variables are very useful in situations where the decision making problems are too complex or ill-defined to be described properly using conventional quantitative expressions.

A fundamental aspect of group decision making (GDM) is the importance of looking for approaches to reach consensus, a focus which has attracted a great deal of attention and has become a major research topic in the GDM field. Consensus can be

Z. Wu (✉) · K. Xu · L. Zhong
Uncertainty Decision-making Laboratory, Business School, Sichuan University, Chengdu 610064, People’s Republic of China
e-mail: zbwu1982@163.com, zhibinwu@scu.edu.cn

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understood in various ways and in various contexts in GDM [3]. For example, it may refer to the multiple criteria approach, the model, the tools, the procedures or the way that the collective judgments are used to derive the final group preferences [1]. In this paper, consensus refers to the manner in which the group members achieve a minimum level of agreement on the group decision matrix. A large number of approaches have been developed to support the modeling for consensus reaching processes [2, 5–7, 18, 19, 24]. Cabrerizo et al. [4] and Herrera-Viedma et al. [10] presented an excellent overview of consensus models based on soft consensus measures in a fuzzy environment.

From the literature, there have been a few papers which have focused on consensus models in a MAGDM setting [9, 20, 21, 23, 27]. Fu and Yang [9] suggested a MAGDM group consensus model based on an evidential reasoning approach. Parreiras et al. [20] proposed a flexible MAGDM consensus scheme under linguistic assessments. To maximize the soft consensus index, an optimization procedure that searched for the weight of each decision maker's opinion was conducted. Parreiras et al. [21] further studied three consensus schemes based on fuzzy models. Roselló et al. considered group consensus in a multi-granular linguistic environment [23]. Xu et al. [27] proposed a consensus process under an uncertain linguistic setting.

The VIKOR method, which stands for VIse Kriterijumska Optimizacija i Kompromisno Resenje, was first purposed by Opricovic [14–16]. The VIKOR method has been extensively researched for a wide range of problems [25]. In this method, the ranking indexes are determined by considering both the maximum group utility and the minimum individual regret function for an opponent. The characteristic of this method is deriving a compromise solution as a form of robust analysis. However, the literature review reveals that although many papers had applied VIKOR method in GDM, few of them recognized the importance of consensus before applying the MADM method. Consensus process is an essential part in GDM. In order to apply VIKOR method to GDM case, it is necessary to include a consensus process in the GDM procedure. In this paper, we aim to develop a consensus and VIKOR integrated approach to solve MAGDM problems.

The rest of the paper is organized as follows. Section 2 reviews basic concepts of the 2-tuple fuzzy linguistic model. Section 3 introduces an automatic consensus reaching process to achieve a predefined consensus goal among a group. Section 4 presents the procedure of the consensus and VIKOR integrated approach. Section 5 gives an numerical example to illustrate the proposed method and Sect. 6 concludes the paper.

2 The 2-Tuple Linguistic Model

The 2-tuple fuzzy linguistic representation model proposed by Herrera and Martínez was introduced to conduct precise processes for computing with words (CW) when the linguistic term sets are symmetrically and uniformly distributed, and to improve several aspects of the ordinal fuzzy linguistic approach [11].

Definition 1 ([11]) Let β be the result of an aggregation of the position indices of a set of labels assessed in a linguistic term set $S = \{s_0, s_1, \ldots, s_{g-1}, s_g\}$, where g stands for the cardinality of S, i.e. the result of a symbolic aggregation operation. Let $i = \text{round}(\beta)$ and $\alpha = \beta - i$ be two values such that $i \in [0, g]$ and $\alpha \in [-0.5, 0.5)$. Then, α is called a *symbolic translation*, with round being the usual round operation.

This model defines a set of transformation functions to manage the linguistic information expressed by the linguistic 2-tuples.

Definition 2 ([11]) Let S be a linguistic term set and $\beta \in [0, g]$ a value representing the result of a symbolic aggregation operation, then the 2-tuple that expresses the equivalent information to β is obtained with the following transformation:

$$\begin{aligned}
&\triangle : [0, g] \rightarrow S \times [-0.5, 0.5), \\
&\triangle(\beta) = (s_i, \alpha) \;\; \text{with } i = \text{round}(\beta) \text{ and } \alpha = \beta - i,
\end{aligned}$$

where round$(\cdot)$ is the usual round operation, s_i has the closest index label to β, and α is the value of the symbolic translation. In addition, we have

$$\begin{aligned}
&\triangle^{-1} : S \times [-0.5, 0.5) \rightarrow [0, g], \\
&\triangle^{-1}(s_i, \alpha) = i + \alpha = \beta.
\end{aligned}$$

The operations and aggregation operators for linguistic 2-tuples can refer to [11]. In the following, the range for $\triangle$ is denoted as $\overline{S}$.

Note that the Herrera and Martínez model aims to deal with uniformly and symmetrically distributed linguistic term sets. However, it may occur that multi-granular linguistic terms and unbalanced terms are used. We can address these cases by generalizing the 2-tuple linguistic model to a general numerical scale [8].

3 Consensus Reaching Process

Based on the 2-tuple linguistic representation model, this section first defines a deviation measure and a consensus index, and then presents an algorithm to describe the consensus reaching process.

Suppose there are $n (n \geq 2)$ potential alternatives denoted by $X = \{X_1, X_2, \ldots, X_n\}$. Each alternative is evaluated with respect to a predefined attribute set $C = \{C_1, C_2, \ldots, C_m\}$. There are a group of experts $E = \{e_1, e_2, \ldots, e_t\} (t \geq 2)$. Assume $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_t)$ is the weight vector for the experts, where $\lambda_k \in (0, 1)$, $k = 1, 2, \ldots, t$, $\sum_{k=1}^{t} \lambda_k = 1$. Suppose that $R_k = (r_{ij}^{(k)})_{n \times m}$ is a linguistic decision matrix given by the expert $e_k \in E$, where $r_{ij}^{(k)} \in \overline{S}$ represents the performance of alternative X_i over the attribute $C_j \in C$. The problem in this paper is concerned with the ranking of the alternatives or the selection of the most desirable alternative(s) using the linguistic decision matrices R_k, $k = 1, 2, \ldots, t$.

3.1 Consensus Measure

There are two categories for computing consensus measures: the first is based on the distance to the collective preference and the second is based on the distance between the experts [18]. This paper follows the former definition for the consensus measure.

Definition 3 ([26]) Let $a_\alpha = (s_\alpha, x_\alpha)$ and $a_\beta = (s_\beta, x_\beta)$ be the two linguistic 2-tuples. The deviation measure between a_α and a_β is defined by:

$$d(a_\alpha, a_\beta) = \frac{\left|\Delta^{-1}(s_\alpha, x_\alpha) - \Delta^{-1}(s_\beta, x_\beta)\right|}{g}. \tag{1}$$

It is easy to verify that $0 \leq d(a_\alpha, a_\beta) \leq 1$.

Based on the deviation measure between the two linguistic 2-tuples, we introduce a similarity degree between the two linguistic decision matrices.

Definition 4 ([26]) Let $A = (a_{ij})_{n\times m}$ and $B = (b_{ij})_{n\times m}$ be the two linguistic decision matrices, where $a_{ij}, b_{ij} \in \overline{S}$. Then the similarity degree between A and B is defined as

$$SD(A, B) = \sqrt{\frac{1}{nm}\sum_{i=1}^{n}\sum_{j=1}^{m} d^2(a_{ij}, b_{ij})}. \tag{2}$$

The similarity degree is used to measure the closeness of two experts' preferences. It was found that the Euclidean distance functions helped the consensus process to converge faster than other distance functions [5]. The Euclidean distance is one of the most widely used distance measures, so here the Euclidean distance is used to define the similarity degree of the preferences between any two experts in the group.

Let $R_1, R_2, \ldots, R_t$ be t linguistic decision matrices provided by t experts, where $R_k = (r_{ij}^{(k)})_{n\times m}, r_{ij}^{(k)} \in \overline{S}$. Then the weighted combination $R = \lambda_1 R_1 \oplus \lambda_2 R_2 \oplus \cdots \oplus \lambda_t R_t$ is the group linguistic decision matrix $R = (r_{ij})_{n\times m}$, where $r_{ij} = \mathrm{LWAA}(r_{ij}^{(1)}, r_{ij}^{(2)}, \ldots, r_{ij}^{(t)}) = \Delta(\sum_{k=1}^{t} \Delta^{-1}(r_{ij}^{(k)}) \cdot \lambda_k)$.

Definition 5 ([26]) Let $R_k = (r_{ij}^{(k)})_{n\times m}$, $k = 1, 2, \ldots, t$ and $R = (r_{ij})_{n\times m}$ be t linguistic decision matrices and the group linguistic decision matrix, respectively. Then, based on the similarity degree between the two linguistic decision matrices, the group consensus index for R_k is defined by:

$$GCI(R_k) = 1 - SD(R_k, R) = 1 - \sqrt{\frac{1}{nm}\sum_{i=1}^{n}\sum_{j=1}^{m} d^2\big(r_{ij}^{(k)}, r_{ij}\big)}. \tag{3}$$

From Definition 5, it follows that $0 \leq GCI(R_k) \leq 1$. Given a threshold value $\overline{GCI}$, if $GCI(R_k) \geq \overline{GCI}$, then R_k is a linguistic decision matrix with an acceptable consensus level. The value $\overline{GCI}$ can be determined in advance by the decision makers. If $GCI(R_k) = 1$, then the kth expert e_k achieves the maximum consensus level. In this case, the preferences for e_k are the same as the group preferences. Otherwise, the larger the value of $GCI(R_k)$, the closer that expert is to the group.

3.2 Consensus Reaching Algorithm

Let $R_1, R_2, \ldots, R_t$ and R be t individual linguistic decision matrices and the group linguistic decision matrix, respectively. Without loss of generality, suppose that the preferences for e_p have the largest distance from the group preferences in this round. It is reasonable to assume that e_p is asked to adjust their preferences in the next round. In general, when some of the experts need to alter their preferences, they can do so freely. However, the effect of these preferences on the alternatives and the attributes are regarded as effective reassessments only when the consensus index is improved. It is useful to present a simple algorithm to guide this consensus process. The basic idea of the proposed consensus reaching process is that in each round, the group linguistic decision matrix is thought to be a good reference for the modification of the individual preferences. To reach a predefined consensus level, the following algorithm is designed.

Algorithm 1: Consensus reaching algorithm

Input: Individual linguistic decision matrices $R_1, R_2, \ldots, R_t$, the weight vector of the experts $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_t)^T$, the predefined threshold $\overline{GCI}$, the maximum number of iterative times $h_{\max} \geq 1$ and the parameter $0 < \gamma < 1$.

Output: Modified linguistic decision matrices $\overline{R_1}$, $\overline{R_2}$, ..., $\overline{R}_t$, $GCI(\overline{R}_k)$, $k = 1, 2, \ldots, t$, and the number of iterations h.

Step 1. Set $h = 0$ and $R_{k,0} = (r_{ij,0}^{(k)})_{n\times m} = (r_{ij}^{(k)})_{n\times m}$.

Step 2. Calculate the group linguistic decision matrix $R_h = (r_{ij,h})_{n\times m}$ corresponding to $R_{1,h}, R_{2,h}, \ldots, R_{t,h}$, where

$$r_{ij,h} = \text{LWAA}\left(r_{ij,h}^{(1)}, r_{ij,h}^{(2)}, \ldots, r_{ij,h}^{(t)}\right).$$

Step 3. Calculate the group consensus index $GCI(R_{k,h})$, $k = 1, 2, \ldots, t$ by using Definition 5. If $GCI(R_{k,h}) \geq \overline{GCI}$, $k = 1, 2, \ldots, t$ or $h \geq h_{\max}$, then go to Step 5; otherwise, go to the next step.

Step 4. Suppose that $GCI(R_{p,h}) = \min_k\{GCI(R_{k,h})\}$. Let $R_{k,h+1} = (r_{ij,h+1}^{(k)})_{n\times m}$, where

$$r_{ij,h+1}^{(k)} = \begin{cases} \gamma r_{ij,h}^{(k)} \oplus (1-\gamma) r_{ij,h}, & k = p \\ r_{ij,h}^{(k)}, & k \neq p. \end{cases} \tag{4}$$

Set $h = h + 1$ and go to Step 2. Note that the computation for $\gamma r_{ij,h}^{(k)} \oplus (1-\gamma) r_{ij,h}$ is given by:

$$\gamma r_{ij,h}^{(k)} \oplus (1-\gamma) r_{ij,h} = \triangle(\gamma \triangle^{-1}(r_{ij,h}^{(k)}) + (1-\gamma)\triangle^{-1}(r_{ij,h})).$$

Step 5. Let $\overline{R}_k = R_{k,h}$, for all $k = 1, 2, \ldots, t$. Output $\overline{R}_1, \overline{R}_2, \ldots, \overline{R}_t$, $GCI(\overline{R}_k)$, for all $k = 1, 2, \ldots, t$, and the number of iterations h.
Step 6. End.

A desirable property of the algorithm is that it can improve the consensus level of each individual in the group. When an individual who has the smallest value implemented the improving strategy, the individual will have a better value. To demonstrate that Algorithm 1 is convergent, the following two theorems are proposed. These two theorems can be proved similar to [26].

Theorem 1 *Let $R_1, R_2, \ldots, R_t$ and $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_t)^T$ be t linguistic decision matrices and the weight vector of the experts respectively. Let $R_{l,h}$ be the decision matrix sequences generated by Algorithm 1 for expert e_l. In the hth iteration, suppose that expert e_p has the minimum GCI value, then*

$$GCI(R_{p,h+1}) > GCI(R_{p,h}). \tag{5}$$

Theorem 1 guarantees that for expert e_p, the consensus level of this round is better than that of the last round. As mentioned, parameter γ controls the modification degree in every round. At the same time γ influences the process convergence rate.

Theorem 2 *Let $R_1, R_2, \ldots, R_t$ and $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_t)^T$ be t linguistic decision matrices and the weight vector of the experts, respectively. Let $R_{l,h}$ be the decision matrix sequences generated by Algorithm 1 for expert e_l. Then , we have*

$$\min_l \{GCI(R_{l,h+1})\} > \min_l \{GCI(R_{l,h})\}. \tag{6}$$

Theorem 2 concludes that the overall consensus level of the group in this round is better than that of the last round. Generally, after implementing the process finite times, the group achieves a predefined consensus level. When $h \to \infty$, it follows that, $SD(R_{k,h}, R_h) \to 0$, and $GCI(R_{k,h}, R_h) \to 1$, for $k = 1, 2, \ldots, t$.

4 The Extended VIKOR Method

The VIKOR technique is used to make a ranking list, give weights and provide a compromise solution, which is the achievable solution closest to the ideal. A compromise solution means an agreement established through mutual adjustment [17].

For the notations, see the second paragraph of Sect. 3. The procedure of the extended VIKOR can be described as follows:

Step 1. Construct the linguistic decision matrix. With respect to each alternative under each attribute, the decision makers express their preferences using linguistic terms based on their own background and expertise. Suppose that $R_k = (r_{ij}^{(k)})_{n\times m}$ is a linguistic decision matrix given by the decision maker $e_k \in E$, where $r_{ij}^{(k)} \in \overline{S}$ represents the performance of the alternative X_i over the attribute $C_j \in C$.

Step 2. Achieve the predefined consensus level. Algorithm 1 is used to complete the consensus reaching process. From the output of the algorithm, we obtain the modified individual linguistic decision matrices. For the notation simplicity, the modified linguistic decision matrices are still denoted as $R_k = (r_{ij}^{(k)})_{n\times m}$. Calculate the group linguistic decision matrix $R = (r_{ij})_{n\times m}$ corresponding to $R_1, R_2, \ldots, R_t$, where

$$r_{ij} = \mathrm{LWAA}(r_{ij}^{(1)}, r_{ij}^{(2)}, \ldots, r_{ij}^{(t)}).$$

Step 3. Determine the best f_j^+ and the worst f_j^- values of all attribute ratings. For benefit attributes,

$$f_j^+ = \max_i r_{ij},\ i = 1, 2, \ldots, n, \quad f_j^- = \min_i r_{ij},\ i = 1, 2, \ldots, n.$$

For cost attributes,

$$f_j^+ = \min_i r_{ij},\ i = 1, 2, \ldots, n, \quad f_j^- = \max_i r_{ij},\ i = 1, 2, \ldots, n.$$

Step 4. Calculate the values S_i and R_i as follows,

$$S_i = \sum_{j=1}^{m} w_j \frac{d(f_j^+, r_{ij})}{d(f_j^+, f_j^-)} = \sum_{j=1}^{m} w_j \frac{\Delta^{-1}(f_j^+) - \Delta^{-1}(r_{ij})}{\Delta^{-1}(f_j^+) - \Delta^{-1}(f_j^-)},\ i = 1, 2, \ldots, n, \tag{7}$$

$$R_i = \max_{j=1} w_j \frac{d(f_j^+, r_{ij})}{d(f_j^+, f_j^-)} = \max_{j=1} w_j \frac{\Delta^{-1}(f_j^+) - \Delta^{-1}(r_{ij})}{\Delta^{-1}(f_j^+) - \Delta^{-1}(f_j^-)},\ i = 1, 2, \ldots, n. \tag{8}$$

In this way, $S_i, R_i \in [0, 1], i = 1, 2, \ldots, n$.

Step 5. Calculate the values Q_i as follows,

$$Q_i = v\frac{S_i - S^-}{S^+ - S^-} + (1 - v)\frac{R_i - R^-}{R^+ - R^-},\ i = 1, 2, \ldots, n, \tag{9}$$

where $S^+ = \max_i S_i$, $S^- = \min_i S_i$, $R^+ = \max_i R_i$, $R^- = \min_i R_i$, and v is a weight for the strategy of "the majority of criteria" (or "the maximum group utility"), while $1 - v$ is the weight of the individual regret.

Step 6. Rank the alternatives by sorting Q_i, S_i, and R_i in ascending order. The results are three ranking lists X_Q, X_S, and X_R.

Step 7. Propose as a compromise solution the alternative $X^{(1)}$ which is the best ranked by the measure Q if the following two conditions are satisfied:

$Cond_1$. Acceptable advantage

$$Q(X^{(2)}) - Q(X^{(1)}) \geq DQ = \frac{1}{n-1}, \tag{10}$$

where $X^{(2)}$ is ranked the second position in X_Q. Note that n is the number of alternatives and the above equation shows the advantage rate of the alternative $X^{(1)}$ ranked first.

$Cond_2$. Acceptable stability in decision making. The alternative $X^{(1)}$ must also be the best ranked by X_S or/and X_R.

If one of the two conditions is not satisfied, then a set of compromise solutions is proposed. If the condition $Cond_1$ is not satisfied, then alternatives $X^{(1)}, X^{(2)}, \ldots, X^{(M)}$ are the compromise solutions. $X^{(M)}$ is determined according to

$$Q(X^{(M)}) - Q(X^{(1)}) < DQ = \frac{1}{n-1}, \tag{11}$$

for maximum M. If only the condition $Cond_2$ is not satisfied, then $X^{(1)}$ and $X^{(2)}$ are the compromise solutions.

5 Numerical Example

Consider the example which was discussed in [22, 27]. A city is planning to build a municipal library. One of the problems facing the city development commissioner is to determine what kind of air-conditioning system should be installed in the municipal library. The contractor offers five feasible alternatives (X_1, X_2, X_3, X_4, X_5), which might be adapted to the physical structure of the library. The offered air-conditioning system must take a decision according to the following four attribute: (1) C_1 is performance. (2) C_2 is maintainability. (3) C_3 is flexibility. (4) C_4 is safety.

The five possible alternatives $X_j (j = 1, 2, 3, 4, 5)$ are to be evaluated using the linguistic variables by three decision makers under the above four attributes. Consequently, the decision makers use the following linguistic term set to express their preferences on alternatives.

$$\begin{aligned} S = \{ & s_0 = \text{extremely poor},\ s_1 = \text{very poor},\ s_2 = \text{poor}, \\ & s_3 = \text{slightly poor},\ s_4 = \text{fair},\ s_5 = \text{slightly good}, \\ & s_6 = \text{good},\ s_7 = \text{very good},\ s_8 = \text{extremely good}\}. \end{aligned}$$

The proposed method is applied to solve this problem and the computational procedure is summarized in the following.

Step 1. Construct the linguistic decision matrix. The three decision matrices constructed by the decision makers, respectively, $R_k (k = 1, 2, 3)$ are listed in Tables 1, 2 and 3.

Step 2. Achieve the predefined consensus level. The initial group linguistic decision matrix, R_I, is given in Table 4.

The current consensus level is $GCI(R_1) = 0.9266, GCI(R_2) = 0.9092$, $GCI(R_3) = 0.9449$. If $\overline{GCI} = 0.9$, it can be seen that all linguistic decision matrices arrive at the predefined consensus level. We set $\overline{GCI} = 0.95$ to show how the algorithm works. Setting $\gamma = 0.95$, the algorithm terminated after 23 iterations. Overall, e_1 and e_2 modified their preferences 16 and 6 times, respectively. Since this is an automatic process, as a matter of fact, the decision makers need not to participate the consensus reaching process. The final consensus level is $GCI(R_1) = 0.9516, GCI(R_2) = 0.9506, GCI(R_3) = 0.9561$. The final group linguistic decision matrix, R_F, is shown in Table 5.

Step 3. Determine the best f_j^+ and the worst f_j^- values of all attribute ratings. Here all the attributes are benefit ones. It follows that:

$$f_1^+ = (s_4, 0.31),\ f_2^+ = (s_5, -0.10),\ f_3^+ = (s_5, 0.13),\ f_4^+ = (s_4, 0.43),$$
$$f_1^- = (s_2, 0.44),\ f_2^- = (s_2, 0.31),\ f_3^- = (s_3, -0.43),\ f_4^- = (s_3, -0.44).$$

Step 4. Calculate the values S_i and R_i. The results are as follows:

$$S_1 = 0.6260,\ S_2 = 0.3957,\ S_3 = 0.4034,\ S_4 = 0.4852,\ S_5 = 0.0733,$$
$$R_1 = 0.3056,\ R_2 = 0.3000,\ R_3 = 0.2000,\ R_4 = 0.4000,\ R_5 = 0.0458.$$

Step 5. Calculate the values Q_i. Setting $v = 0.5$, we have $Q_1 = 0.8668$, $Q_2 = 0.6505$, $Q_3 = 0.5163$, $Q_4 = 0.8726$, $Q_5 = 0$.

Table 1 Decision matrix R_1

	X_1	X_2	X_3	X_4	X_5
C_1	$(s_5, 0)$	$(s_3, 0)$	$(s_2, 0)$	$(s_5, 0)$	$(s_3, 0)$
C_2	$(s_4, 0)$	$(s_1, 0)$	$(s_3, 0)$	$(s_5, 0)$	$(s_6, 0)$
C_3	$(s_3, 0)$	$(s_5, 0)$	$(s_3, 0)$	$(s_6, 0)$	$(s_4, 0)$
C_4	$(s_3, 0)$	$(s_3, 0)$	$(s_4, 0)$	$(s_3, 0)$	$(s_4, 0)$

Table 2 Decision matrix R_2

	X_1	X_2	X_3	X_4	X_5
C_1	$(s_3, 0)$	$(s_5, 0)$	$(s_2, 0)$	$(s_5, 0)$	$(s_3, 0)$
C_2	$(s_2, 0)$	$(s_3, 0)$	$(s_5, 0)$	$(s_4, 0)$	$(s_5, 0)$
C_3	$(s_1, 0)$	$(s_3, 0)$	$(s_2, 0)$	$(s_4, 0)$	$(s_6, 0)$
C_4	$(s_3, 0)$	$(s_6, 0)$	$(s_3, 0)$	$(s_3, 0)$	$(s_6, 0)$

Table 3 Decision matrix R_3

	X_1	X_2	X_3	X_4	X_5
C_1	$(s_3, 0)$	$(s_5, 0)$	$(s_3, 0)$	$(s_3, 0)$	$(s_5, 0)$
C_2	$(s_4, 0)$	$(s_3, 0)$	$(s_5, 0)$	$(s_4, 0)$	$(s_4, 0)$
C_3	$(s_3, 0)$	$(s_5, 0)$	$(s_3, 0)$	$(s_5, 0)$	$(s_4, 0)$
C_4	$(s_3, 0)$	$(s_4, 0)$	$(s_5, 0)$	$(s_2, 0)$	$(s_4, 0)$

Table 4 The initial group linguistic decision matrix R_I

	X_1	X_2	X_3	X_4	X_5
C_1	$(s_4, -0.33)$	$(s_4, 0.33)$	$(s_2, 0.33)$	$(s_4, 0.33)$	$(s_4, -0.33)$
C_2	$(s_3, 0.33)$	$(s_2, 0.33)$	$(s_4, 0.33)$	$(s_4, 0.33)$	$(s_5, 0)$
C_3	$(s_2, 0.33)$	$(s_4, 0.33)$	$(s_3, -0.33)$	$(s_5, 0)$	$(s_5, -0.33)$
C_4	$(s_3, 0)$	$(s_4, 0.33)$	$(s_4, 0)$	$(s_3, -0.33)$	$(s_5, -0.33)$

Table 5 The final group linguistic decision matrix R_F

	X_1	X_2	X_3	X_4	X_5
C_1	$(s_4, -0.31)$	$(s_4, 0.31)$	$(s_2, 0.44)$	$(s_4, 0.12)$	$(s_4, -0.12)$
C_2	$(s_4, -0.43)$	$(s_2, 0.31)$	$(s_4, 0.31)$	$(s_4, 0.35)$	$(s_5, -0.10)$
C_3	$(s_3, -0.43)$	$(s_5, -0.43)$	$(s_3, -0.21)$	$(s_5, 0.13)$	$(s_4, 0.43)$
C_4	$(s_3, 0)$	$(s_4, 0.08)$	$(s_4, 0, 23)$	$(s_3, -0.44)$	$(s_4, 0.43)$

Step 6. Rank the alternatives by sorting Q_i, S_i, and R_i in ascending order. By R_i, we have $X_S = \{X_5 \succ X_2 \succ X_3 \succ X_4 \succ X_1\}$. By R_i, we have $X_R = \{X_5 \succ X_3 \succ X_2 \succ X_1 \succ X_4\}$. By Q_i, we have $X_Q = \{X_5 \succ X_3 \succ X_2 \succ X_1 \succ X_4\}$.
Step 7. Propose a compromise solution. Since

$$Q(X^{(2)}) - Q(X^{(1)}) = 0.5163 \geq DQ = \frac{1}{5-1} = 0.25.$$

Condition $Cond_1$ is satisfied. X_5 ranks the first by X_Q and X_5 is also the best ranked by X_S and X_R. Condition $Cond_2$ is satisfied. This suggests that X_5 is the best alternative.

6 Concluding Remarks

The VIKOR method has the advantage in handling MADM problems when facing with conflicting and incommensurable attributes. Consensus reaching process has the advantage of generating a solution acceptable to all the experts participating in a problem. This paper has presented a consensus process and VIKOR method integrated approach to solve MAGDM problems. Although we choose an automatic consensuses reaching process, other consensus process can also be selected. In the future work, the proposed integrated approach will be applied to other linguistic environments such as unbalanced linguistic scale and hesitant fuzzy linguistic information. Comparative study could also be considered to show the effects of different combinations.

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Value Analysis of Mobile Internet Users Based on Clustering

Dan Zhang, Yufeng Ma, Xiong Tao and Yue He

Abstract This paper divides the value of mobile internet users into two parts: direct value and promotion value. Thus the core users can be found by the value of users. Then analyze the value indexes which are weighted by maximum deviation. At last, in the experiment, use k-means clustering analysis to cluster the users and analyze the value of each cluster in order to find the core users as well as their characteristics. The results show that the high value users have preference in Operating System (OS) and it's more likely for the Apple users to buy the software and services. These results can be used as a business reference for marketing decision.

Keywords Mobile internet · User value · K-means clustering · Maximum deviation

1 Introduction

The mobile internet is the new Internet based on mobile communication technology and Internet technology which is composed by the traditional wide area network, local area network and all kinds of mobile terminals. In generally, the mobile Internet users refer to the users who regard the mobile phones as their mobile terminal. According to the China internet center, by the end of 2013, China's mobile internet users reached 500 million [4]. Such a huge market attracted operators, mobile phone manufacturers, operating system, application stores and traditional Internet content providers. To be sure, the core focus of the competition is the user. Knowing mobile phone users' value types is very important and that it improves efficiency and effectiveness of mobile phone websites [13]. Therefore, it is necessary to develop a comprehensive scientific analysis for the mobile internet users.

User analysis can provide a powerful decision support for the construction of information resources, and make it more reasonable and scientific [12]. User value analysis is an important part of user analysis. Through the analysis we can find

D. Zhang (✉) · Y. Ma · X. Tao · Y. He
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 809675863@qq.com

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that the core user. The core user refers to the most valuable user groups. Usually it indicates that the 20 % users who make the 80 % profit of enterprises [11]. For the mobile application developers who have limited resources, the discovering of the core user is a very important work.

Mobile internet as a new field has great relation with the traditional internet. Therefore, the previous studies of traditional literature in terms of internet user also have certain reference significance. Zehraoui and Kanawati [19] combined case-based reasoning theory with artificial neural networks to cluster and analyze the electronic commerce website user's behavior. In addition, they provided a scalable algorithm to handle the noise data. But the research is focused on the algorithm, slightly less than the actual commercial value. Kim [10] investigated, proposed, and tested a mobile user engagement model to explain mobile user engagement intention through user's motivations, perceived value and satisfaction. Lu [16] constructed the mobile commerce explorer framework, mined and predicted the trajectory of mobile users and purchase trend. Ahn [1] put forward an integrated scoring model that can analyze which types of customers are willing to use mobile value-added services (VAS). Chen [3] created the UMBPs mining method to study the behavior model of mobile users. Deng [5] investigated how older and middle-aged citizens adopted mobile health services based on the value attitude behavior model. Tamas [21] presented a flow model for the GPRS network users after a long-term observation and actual measurement. Chung-Chu and Jason [14] used Q methodology to categorize the mobile phone website users into four groups: online shopper, information seekers, recreation demanders, and easy users. The empirical results can provide decision support intelligence for the websites designers to increase mobile phone website users' satisfaction.

The research directions in China are mostly concentrated in the study of user behaviors. Although the significance of user value is mentioned, research about user value is quite fragmented and divergent [22]. Bose and Chen [2] used the clustering algorithm to discuss the behavior model of people who subscribe mobile service. They discovered that the imbalance between the mobile customer service, subscription service and income contribution. Li [18] studied customer value clustering classification based on customer profit contribution. Tan [20] through the establishment of customer experience value model to assess the value of Internet companies. While the shortage is the small number of the evaluation indexes. Gao [7] constructed the mobile user feature model with scenario analysis. Wang [17] used the empirical data of one telecom operator to present a method based on modeling for mobile internet user behavior analysis. Liu [15] proposed to study the visiting behaviors of mobile internet user through the user clicks stream data. Yang [24] built the structural equation model for user adoption behaviors based on the views of perceived benefits, costs and risks. Du [6] presented a dynamic analytical model for user value. Through the analysis of user session value and the using of an incremental computation method, it can reflect the dynamic user value. But the performance of the model still needs to be improved.

This paper uses k-means clustering data mining technology to analyze the mobile internet user data, makes a quantitative method to research the mobile internet user value and the general characteristics or rules of the core group of users. All above doing are to make a reference for business decision-making.

2 Related Theory

2.1 *K*-Means Clustering Algorithm

K-means algorithm is a commonly used clustering algorithm based on division, according to the similarity between the samples attributes values to group the samples. The basic idea is: the data set is divided into *k* clusters. Inside each cluster the samples are very similar, but different clusters of samples are very different [8]. *K*-means algorithm is an iterative algorithm. The initial *k* clusters are randomly classified. Then these clusters will be constantly updated and optimized in the update until a termination condition is reached.

The basic flow of *K*-means algorithm is as follows [23]:

(1) Randomly determine initial centroid.
(2) In each iteration, each sample is assigned to the nearest Euclidean distance cluster where the centroid locates.
(3) Decide the center of the new cluster, and regard the nearest Euclidean distance sample from the new center as the new centroid. Repeat the second step until termination condition is met.

Termination conditions:

(1) Reached the maximum number of iterations.
(2) After the update, the maximum centroid distance should less than the tolerance of difference in advance.

Anyone of these two conditions is satisfied, the algorithm terminates. The formula of Euclidean distance in algorithm is as follows:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_j - y_j)^2}. \tag{1}$$

This paper uses *k*-means clustering analysis to find the common characteristics of similar users and then analyzes the user value.

2.2 *Maximizing Deviation Method*

If an attribute value of each program is no difference from the perspective of sorting programs, the attribute will not work for the program to sort, and also make no sense in the multi-attribute decision. Therefore, if the attribute difference for each program is greater, the distinction of attribute in the program is greater. Certainly the more important properties, the attribute should be given greater weight [9]. So the optimization model can be constructed:

$$\begin{cases} \max V(w) = \sum_{j=1}^{m} \sum_{i=1}^{n} \sum_{i=1}^{n} \mid r_{ij} - r_{kj} \mid w_j \\ s.t. w_j \geq 0,\ j \in M,\ \sum_{j=1}^{m} {w_j}^2 = 1. \end{cases}$$

Construct Lagrange function to this model, the solution is:

$$w_j^* = \frac{\sum_{i=1}^{n} \sum_{i=1}^{n} \mid r_{ij} - r_{kj} \mid}{\sqrt{\sum_{j=1}^{m} \left[\sum_{i=1}^{n} \sum_{i=1}^{n} \mid r_{ij} - r_{kj} \mid \right]^2}}.$$

Then, normalize the weights of the units:

$$w_j = \frac{\sum_{i=1}^{n} \sum_{i=1}^{n} \mid r_{ij} - r_{kj} \mid}{\sum_{j=1}^{m} \sum_{i=1}^{n} \sum_{i=1}^{n} \mid r_{ij} - r_{kj} \mid},\ j \in M. \tag{2}$$

Using w_j obtained from the formula Eq. (2) can get the comprehensive evaluation value for each cluster.

3 Mobile Internet Users Value Model

Each user on the value of the enterprise is not the same. The same user will be in one or more aspects of the enterprise to generate value. According to the characteristics of mobile internet the user values may be divided into two parts: the direct value and promotional value [3].

1. The direct value

Direct value refers to the user's activity that directly bring the enterprise income or profits, such as buying the company's products or services, or to purchase value-added services on the basis of free use, as well as engage in mobile e-commerce activities. Users with high direct value can make enterprises have a relatively stable income. Direct value is reflected in the willingness to buy products and services in the mobile e-commerce activities.

2. Promotional value

Unlike traditional industries, the Internet (including traditional Internet and mobile internet) users even use enterprise's products freely; it is possible to allow enterprises to get income or resources from third parties in the form of advertising or obtaining investment.

Generally speaking, two values will all be reflected on the user, but the proportion is different. The total value of the user can use Eq. (3):

$$V = V_1 + V_2, \tag{3}$$

$$V_1 = \sum_{j=1}^{2} w_{1j} \times p_{1j}, \tag{4}$$

$$V_2 = \sum_{j=1}^{2} w_{2j} \times p_{2j}. \tag{5}$$

In Eq. (3), V represents the total value of the user. V_1, V_2 respectively represent the direct value and promotion value.

4 Experimental Analysis of Mobile Internet Users

The data of this paper come from the questionnaire. The survey uses random sampling method. The time span is from August 21, 2011 to September 13, 2011. Because young people are the main population of mobile internet, the main object of this questionnaire is young people under 30 years old, mainly university students. 300 questionnaires in total were distributed, 278 were collected. At last, 256 copies are effective.

4.1 User Background Analysis

The User background information of this questionnaire includes gender, age and monthly expenditure. Using the SPSS software, statistical information obtained about the sample of gender, age, and total monthly expenses is as shown in Table 1.

See from Table 1, the gender of sample, age and financial status are accorded with the normal distribution. That shows that the selected samples have a good representation of the target population.

Table 1 User background information

Sample	Value	Frequency	Percentage (%)
Gender	Man	124	48.44
	Woman	132	51.56
Age	≤18	94	36.72
	18–22	128	50.00
	23–30	32	12.50
	≥31	2	0.78
Monthly expenditure	500	24	9.38
	500–1500	168	65.63
	1500–3000	44	17.19
	≥3000	20	7.81

4.2 User Value Analysis

This paper uses K-means clustering method with clementine 11.1 software, and combines the user value model to make a quantitative analysis of user value.

Unlike classification problems, there are no universal standards to evaluate the clustering results objectively. This paper uses the most satisfying criteria to determine the number of clusters. And the paper finds that when the cluster number is 5, the clustering result is the most satisfied, which embodied as: the average distance for sample to centroid is satisfactory. There are obvious different performances on the five key indicators. This can be find below. Table 2 shows the basic statistical information of all types:

In the above table, the samples number of minimum class is 20, the proportion of 7.81 %. There are no small sample classes below 3 % (Table 3).

1. User direct value

Through the statistics and analysis of indexes for various kinds of online shopping and buying intention, this paper finds that the categories are obviously different. For the first category, although the number that willing to use mobile online shopping is small, the proportion for mobile products and services to purchase is the highest. The second category people is willing to develop online shopping, while 30 % of the

Table 2 Clustering situation

	First class	Second class	Third class	Fourth class	Fifth class
Sample size	70	34	52	80	20
Percentage (%)	27.34	13.28	20.31	31.25	7.81
Average distance	2.12	2.17	2.15	2.11	2.16

Table 3 Basic information

	First class	Second class	Third class	Fourth class	Fifth class
Gender	77 % man	No difference	No difference	82.5 % woman	No difference
Age group	18-22 (51 %)	18–22 (53 %)	23–30 (57 %)	23–30 (75 %)	18–22 (50 %)
The proportion of intelligent machines	51 %	53 %	96 %	13 %	90 %
Mobile brands	Nokia (69 %)	Nokia (47 %)	Nokia (54 %)	Nokia (55 %)	Apple (60 %)
Attitude to operating system	71 % important	100 % very important	54 % very important	70 % important	90 % very important

Table 4 Indicators of direct value

	First class	Second class	Third class	Fourth class	Fifth class
The proportion willing to try online shopping	9 %	71 %	42 %	60 %	50 %
Purchase intention	77 % have	41 % have 29 % uncertainty	23 % have 58 % uncertainty	82 % uncertainty	40 % have 60 % uncertainty

people will not buy mobile products or services. The specific situation is as shown in the Table 4.

2. User promotional value

Each category has significant difference on the index of promotion value. The Fifth class spends the most of time on Internet, and also has the highest attention proportion on recommended links to Webpage. The second category uses more mobile applications and games (merger referred to as APP) (Table 5).

Table 5 Indicators of promotional value

	First class	Second class	Third class	Fourth class	Fifth class
Time online (h)	$51\,\% \le 0.5$	$0.5 \le 82\,\% \le 3$	$0.5 \le 54\,\% \le 1$	$63\,\% \le 0.5$	$90\,\% \ge 0.5$ $40\,\% \ge 3$
Website visit	11 %	53 %	31 %	25 %	50 %
Attention to recommended links	35 %	58 %	38 %	70 %	90 %
App use	31 %	70 %	62 %	38 %	60 %

The Eq. (2) can calculate the weights of time online, internet width, APP using width, recommended web links, online shopping situation and willingness to buy APP these six indicators. There are as follows: $W = (0.1, 0.1, 0.1, 0.2, 0.2, 0.3)^T$.

According to the ranks of all clustering performance on indicators, the indicators of the first to fifth respectively are with the value of: 10, 7, 5, 3, 1. The results can be obtained as shown in Table 6.

From Table 4, the top user value up to 10, the minimum is 1. According to Eq. (2), the Eq. (3) and Eq. (4), the last value of all as shown in Table 7.

1. The first class

There are 27.35 % of the people belonging to the first category. Boys accounted for the vast majority. Although nearly half of the people spend more than half an hour a day, and have high interest in applications and games, the breadth of the Internet is not enough. Some people also has cautious attitude on online shopping.

2. The second class

There are 13.28 % of the people belonging to the second category. Mobile operating system is an important factor when this kind of user selects the cell phone. This category all indicators are excellent, especially for online shopping and willingness to use the width of the APP.

Table 6 Index value of each cluster

	Index	Weight	First class	Second class	Third class	Fourth class	Fifth class
Promotional value	Time online	0.1	3	7	5	1	10
	Internet width	0.1	1	10	5	3	7
	APP width	0.1	1	10	7	3	5
	Web links	0.2	1	5	3	7	10
Direct value	Online shopping	0.2	1	10	3	7	5
	APP purchase	0.3	10	5	3	1	7

Table 7 Value of each cluster

	First class	Second class	Third class	Fourth class	Fifth class
Promotional value	0.7	3.7	2.3	2.1	4.2
Direct value	3.2	3.5	1.5	1.7	3.1
Total value	3.9	7.2	3.8	3.8	7.3

3. The third class

There are 20.31 % of the people belonging to the third category. The proportion of intelligent machines and browser using are the highest, but the direct value is the lowest.

4. The fourth class

There are 31.25 % of the people belonging to this category. Such kind of people's notable feature is that girls account for the majority of users, reaching 82.5 %. At the same time, there are the largest groups of non-intelligent machine.

5. The fifth class

The fifth type is the least of the crowd, only 7.81 %. But Apple mobile phone users are basically inside this class. They have a fairly good acceptance and purchase intention.

Direct value and promotional value of the third class and fourth class are in the middle. The total ratio of these two types is 51.56 %. In other words, they are the main users of mobile internet. The second and fifth category have higher direct value and promotional value. The sum of two kinds of proportion is 21.1 %. So people in second and fifth class are relatively core users of mobile Internet. Their common feature is high awareness of mobile operating systems, and they always spend more than half an hour online every day.

5 Conclusion

This paper proposes the user analysis method, user value analysis model and the calculation methods to quantify the value of the user. The user values are divided into direct value and promotional value. What's more, the data mining technology was used to study the mobile Internet users. Experimental results show that:

(1) People in second and fifth class have a special preference of mobile operating system users. They are the ultimate core user groups. Hence, whether mobile service provider or hardware manufacturers will find that the operating system is a factor that must be considered when locating the target user group.
(2) Through the study of first class users, this paper finds that the user who may use Internet rarely is likely to bring direct profits to the enterprise. In this regard, the company's products or services should be able to attract the user eyes for the first time. The company should take advantage of the limited opportunities for recommended products or services.
(3) Apple's mobile phone users in general can bring direct profits to the enterprise. The reason is that the price they can accept is relatively high. So Apple's mobile phone users are generally high-end users. Companies should strive for them industriously.

Due to resource constraints, the paper takes the questionnaire survey as the data source. Consequently, the sample size is slightly not enough. Meanwhile, the user behavior of mobile internet is very important information for company. That can help enterprise to make further excavation on mobile internet user behavior analysis.

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Advertising Information Content of Web Forums and Message Boards Official Posts in China National 5A Rated Tourism Attractions

Shimin Yin, Yongge Niu and Wei Li

Abstract Taking the 7 years official posts on web forums and message boards (from the January 1st, 2007 to December 31th, 2013) of China National 5A Rated Tourism Attractions as the study object, this study carried out a content analysis on the posts with the Resnik and Stern ad information classification criteria. Results found that the web forum and message board are unique and effective interactive media, ad information cues that each official post contained are significantly more than those in magazine, TV and web banner ads.

Keywords Web forum · Message board · Tourist products · Content analysis

1 Introduction

Internet has become the most important interactive media. In the United States, Internet advertising revenues surpassed those of cable television [1]. Information transmission on Internet is totally different from on TV, magazine, newspaper and other traditional media. The advantage of information transmission lies in two-way communication, information sender and recipient are both convenient in information transmission, mining and feedback.

The advantage of ad information transmission on Internet interactive media (such as forum and message board) mainly embodied in following aspects. First, forum is such a platform built around a topic/theme, users are topic participants, and forum ads can easily reach target audience, and users are actively involved in ad information transmission. Second, the discussion around a particular topic/theme is interactive, official posts with advertising nature both offer information and communication themes, which make it much easier to get feedback from users and adjust the ad information content. Third, flexible operation of ad posts can not only rely on

S. Yin · Y. Niu (✉) · W. Li
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: niuyongge@gmail.com

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administrators and moderators but also on paid posters. Fourth, audience accept ads information easily because of the undetectable transmission.

Functions of message boards are slightly different acceding to different settings. The overall information dissemination characteristics are similar to web forums, but the differences as follows: first, communication may or may not be around a topic/theme; second, information dissemination may be two way or may also be one-way.

National 5A Rated Tourism Attractions are the highest level tourism attractions in China, and the selection need to consider 12 aspects, including successively traffic, region, safety, sanitation, post and telegraph service, shopping, operation, environment protection, accommodation capacity, satisfaction [2].

This study mainly to explore the structure of official post ad information cues on web forums and message boards, the time period change of ad information cues, and the difference between ads of tourism products on forum and message board with ads of other product categories on other media.

2 Literature Review

Insufficient specific purchase information to facilitate consumer's comparison leads to unwise purchase decision. Resnik and Stern [3] deem that informative ads depend on offering information cues for consumers to make wise choices from many options. Stern and Resnik [4] offers an operational explain that an ad can be consider informative when found at least 1 of 14 types of information cue, then follower scholars could start extensional studies in the basis of their criteria.

Advertising information cues influenced by many factors: such as media type, product category, cultural difference, advertising feature, time development and other factors.

Media Type: Abernethy and Franke [5] meta-analysis shows that media is the most important factor influencing information cue amount. Stern and Resnik [4] found printed ads information clues were higher than TV ads. Healey and Kassarjian [6] found average number of information cues of each ad in magazines was 3.78, significantly higher than Resnik and Stern [3] findings of 0.67 in TVs.

Product Category: Product category also affects ad information cues. Resnik and Stern [7] found average number of information cues of each institutional ad was 1.13, next was toy and transit ad, the lowest was 0.57 of food ad. Abernethy and Franke [5] found durable goods ad contained more cues than ad of durables consumer goods, because consumers would be involved in higher risks associated with currency and functions. Choi et al. [8] found high involvement product ad contained more information cues than low involvement product ads.

Cultural Difference: many scholars compared advertising information content between Eastern and Western cultures. Some found that ads in East Asian cultures contained more information than those in Western cultures [7, 9, 10], while some results are reversed [11, 12]. Some scholars explored the underlying reasons of the differences, Liang and Cherian [13] investigated how analytic and holistic thinking influence American and Chinese consumers' responses toward ads using different types and amounts of information.

Even in English cultures, ad information content have differences in different countries. Laczniak found 92 % of the US magazine ads were informative while 83 % British magazine ads were informative [14]. Dowling found 74 % of Australian television ads were informative [15]. Weinberger and Spotts compared information cues of US and British TV ad, found both the proportion of informative ads and amount of each ad cues that in US were significantly higher than in UK [16].

Time Development: Weinberger and Spotts found 65.3 % of commercial television ads from the summer of 1985 to the end of the year were informative and each ad contains an average of 1.05 cues [16], significantly higher than Resnik and Stern early measured data (49.2 % and 0.67) [3]. Resnik and Stern explained the trend with economic development and consumer education improvement, consumer consciousness and behavior became more and more rational, thus ads offered more product related information [3].

Özsoy carried out the content analysis of Turkish newspaper ads from 1880s to 1960s with Stern and Resnik criteria, found that Turkish newspaper ads generally contain a large amount of information and a significant decrease on the number of multiple cues from late Ottoman to 1960s. These changes revealed economic and cultural environment's influence on demand and supply mechanism in a specific period [17].

While there are no related empirical studies on tourism products and new media of web forums and message boards, we expected the results can increase the knowledge in the field of advertising information analysis.

3 Study Object

This study is based on China National Tourism Administration (CNTA) as of December 19th, 2013 certification of 175 national 5A Rated Tourism Attractions as study object. As of December 31th, 2013, 170 of total 175 National 5A Rated Tourism Attractions have official websites, and there are 19 web forums and message boards with advertising information of official posts (see Table 1). Once a post found any 1 information cue of 14 types of advertising information is judged to be advertising post basis on Resnik and Stern ad information classification criteria.

Among the 19 websites, there are 4 tourist attractions post through message board. Message board and forum have certain difference in transmission information. Forum is two-way communication in form of theme/topic classification, but differences of message board according to the website setting, information transmission can be one-way and can also be two-way, but not in form of theme/topic classification.

Official posts are those posts can represent tourist attraction website official claims. We take administrator posts, moderator posts, super moderator posts, forum announcements, top posts, digest posts as the sampling frame (top posts and digest

Table 1 Tourist attraction websites with official posts

Tourist attractions	Communication platform	Official post	Advertising post
Nanping Wuyi Mountain Scenic Area	Message board	1	1
Lianzhou Underground River Scenic Area	Forum	296	110
Hengyang Nanyue Henshan Mountain Tourist Area	Forum	919	422
Nanjing Fuzimiao Qinghuai Scenic Area	Forum	16	2
Mount Taishan Scenic Area	Forum	27	14
Jixi Longchuan Scenic Area	Forum	15	11
Sanming Taining Tourist Spot	Forum	46	13
Hainan Yanoda Rainforest Tourist Area	Forum	6	4
Hainan Boundary Islet Tourist Attraction	Forum	685	85
Xinan Longtan Valley Scenic Area	Forum	3	3
Heihe Wudalianchi Scenic Area	Forum	61	37
Shennongjia Tourist Area	Message board	27	24
Wuxi Turtle-head Peninsula Scenic Spot	Forum	24	3
Ancient City of Taierzhuang	Forum	44	8
Huanglong Scenic and Historic Interest Area	Forum	14	2
Wenzhou Yandang Mountain Scenery Tourism Area	Message board	5	5
Kaihua Root Palace Tourist Area of the Buddhist Culture	Message Board	807	166
Zepu Jinhu Yang National Forest Park	Forum	14	4
Hengdian World Studios	Forum	259	110
Total	19	3269	1024

posts may submitted by forum members, but must be recommended by the administrators and moderators). Finally, we selected 1024 official posts with a nature of advertising from the 19 websites for analysis (see Table 2). In addition, according to post forms (text, image and mixed), we divided them into three categories: text post, image post and mixed post.

Table 2 The official advertising information posts distribution matrix

	Administrator	Super moderator	Moderator	Member	Total
Announcement	4	1	1	1	7
Top post	7	2	1	3	13
Digest post	4	1	1	17	23
Others	242	171	568	0	981
Total	257	175	571	21	1024

3.1 Method

1. Coding Design

Resnik and Stern developed 14 types of ad information cues and clearly defined each type. Following large number of empirical studies confirmed the criteria with high reliability and validity. The rules can be as an objective and quantitative evaluation of ad information and conduct comparison across different media, product categories, regions [5]. The criteria is highly abstract and suitable for a wide range of product categories.

In order to improve the applicability, we have a correspondence interpretation of the criteria based on the features of tourism products follow Resnik and Stern original intention (see Table 3). Once a post found any 1 information cue of 14 types of advertising information is judged to be advertising post.

2. Coding Reliability

Perreault and Leigh reliability measurement formula is adopted to test the coding reliability, the data reliability is 0.965 on average. The distribution range of information categories is from 0.89 to 1.00, all higher than Kassarjian recommended minimum value of 0.85 [6].

3.2 Result

1. Overall Data

Among the 170 official websites of National 5A Rated Tourism Attraction, 4 web forums inform closed (Harbin Sun Island Scenic Area, Wuxi Lingshan Buddhist Scenic Spot, Wujiang Tongli Town Scenic Area and Shangrao Sanqing Mountain Scenic Area), 1 informs deleted (Shiyan Wudang Mountain Scenic Area), 1 informs offline (Xi'an Huaqing Pool Scenic Area), there are 50 websites with web forums in total.

But among the 50 web forums, 14 forums cannot open the links, 3 inform updating, 1 links to microblog (see Table 4). Therefore, there 32 tourism attraction websites developed with forum function and operated normally, account for 64 % of the total

Table 3 Adverting information cue criteria

Information type	Correspondence interpretation
1. Price-value	A. What does the tourism product cost?
	B. What is the value-retention capability?
	C. What is the need-satisfaction capability/price?
2. Quality	What are the characteristics of tourism product distinguish it from competitors based on objective evaluation?
3. Performance	A. What does the tourism product do?
	B. How well does it do compared with alternative purchases?
4. Components or contents	A. What is the tourist attraction composed of?
	B. What ingredients does it contain?
	C. What ancillary items are included with the tourist attraction?
5. Availability	A. Through which agencies or way can come to the tourist attraction?
	B. How to buy the tickets?
	C. When is the right time come to the tourist attraction for pleasure?
6. Special offers	What limited-time, non-price deals are available with a particular purchase?
7. Taste	Is evidence provide the taste of particular tourism product could perceived by potential customers (advertiser opinion is inadequate)?
8. Nutrition	Are objective characteristics or differences concerning the nutritional content of the tourism product provided?
9. Packaging or shape	A. What package is the tourism product available in which makes it more desirable than alternatives?
	B. What special shape/scene is the tourism product/service available in?
10. Guarantees or warranties	What post-purchase ticket and during-consuming assurances accompany the tourism/service?
11. Safety	What safety features are available on a particular tourism product compared to alternatives?
12. Independent research	Are results of research gathered by an "independent" research firm presented?
13. Company research	Are data gathered by a company to compare its product with a competitor's presented?
14. New ideas	A. Is a totally new concept introduced in the official post?
	B. Are the advantages of the new concept/way presented?

websites with web forums (32/50), 18.82 % of the total websites (32/170). Among the 32 websites, 15 forums posted official posts, account for 46.88 % of the normal operating forums (15/32) and 8.82 % of the total websites (15/170).

There are 48 message boards in use except 2 (Zhenbeibu China West Film Studio, Badong Shennong Stream Boat Tracker Culture Tourist Area) closed. There are 5 websites (Tianshan Tianchi Scenic Area, Heihe Wudalianchi Scenic Area, Hainan Yanoda Rainfrost Tourist Area, Wuyuan Jiangwan Scenic Spot, Yingshang Bali River

Table 4 Non-functional web forums

Status	Tourist attractions
Links Error	Yantai Penglai Pavilion Scenic Area
	Foshan Xiqiao Mountain Scenic Area
	Turpan Turpan Putaogou Scenic Area
	Qinghai Lake Scenic Area
	Summer Palace
	Anshun Dragon Palace Cave Scenic Spot
	Sanya Nanshan Cultural Tourism Zone
	Laishui Ye-San-Po Scenic Area
	Yaoshan-Zhongyuan Buddha Scenic Area
	Ji'an Jinggangshan Mountain Scenic Area
	Chengdu Qingcheng Mountain-Dujiangyan Scenic Area
	Tianjin Panshan Mountain Scenic Area
	The Yellow Emperor (Huangdi) Mausoleum Scenic Area
	Jiaozuo (Yuntai Mountain-Shennong Mountain-Qingtian River) Scenic Area
Updating	Leshan Grand Buddha Scenic Area
	Yili Xinyuan Nalati Scenic Area
	Luofu Mountain National Scenic Area
Link to Microblog	Chengde Mountain Resort and the Surrounding Temples Scenic Area

Scenic Area) both have forums and message boards, but none of them have official post on both platforms. There are 4 message boards have official posts, account for 8.89 % of the normal operating message boards (4/45) and 2.35 % of the total websites (15/170). This shows appeal of posting official posts on message board is much lower than on forums.

Among the 19 communication platforms (including web forums and message boards), There are 16 platforms have more than 7 official posts, means that there 94 % of the total websites post more than 1 official post each year (16/170). This shows most of the scenic attractions haven't realized the marketing role of web forums and message boards.

There are 31.32 % of the official posts which contain one or more advertising information cues (1024/3269). The percentage of post informative ads is lower than web banner ads (68.30 %) [8], Australian television advertising (74 %) [15] and Chinese magazine advertising (100 %) [7].

But the number of information cue on each ad is 11.15 significantly higher than that of Choi et al. [8] about the ads of magazines (2.45), TVs (1.95) and web banner ads (0.88). Official posts on forums and message boards are highly informative, mainly result from web post pages can combine texts, images, videos, audios and other interactive forms. And viewer's choice based on their own intentions, lead to the browsing behavior interacts with strong motivation and high involvement.

2. Compared with Classic Study

Resnik and Stern measured ads on the mainstream TV media in the United States, the ads covered wide range product categories, which including food, enterprise organizations, family and personal care products, cleaning supplies, toys, vehicles and other products [3].

While we focus on informative ads of tourism products on web forums and message boards. Compared with the classic study (Non-tourism products, television), the differences are on the three aspects: product categories, media platforms and time span. In spite of this, we can also find particularity and universality of ad information cues by comparison (see Table 5).

Resnik and Stern shows the most frequent 3 types of ad information cues are Performance, Components or Contents and Price-Value, while the most frequent 3 types of tourism product ad information cues are Packaging or Shape, Quality and Taste. There are 6 information cues (Packaging or Shape, Quality, Taste, Availability, Independent Research, Special Offers) shows increase trend, other 8 cues have no obvious changes.

Table 5 Information cue proportion between classic study and this study

Information cue	Resnik and stern ($N = 378$)	This study ($N = 1024$)	Z-value
Price-Value	8.7	10.06	0.79
Quality	2.4	25.20	14.54[a]
Performance	17.7	7.81	−4.63
Components or Contents	17.5	14.06	−1.54
Availability	1.3	13.18	9.84[a]
Special Offers	1.9	4.30	2.54[b]
Taste	5.3	25.88	11.50[a]
Nutrition	4.5	6.25	1.34
Packaging or Shape	1.3	85.94	68.66[a]
Guarantees/Warranties	0.3	0.29	−0.03
Safety	0.3	0.29	−0.03
Independent Research	0.8	5.66	5.68[a]
Company Research	2.6	0.68	−2.24
New Ideas	3.2	1.56	−1.67
Total	4.8	14.4	6.13[a]

[a] $p < 0.001$
[b] $p < 0.01$

Table 6 Advertising information cues change over time

Information cues	2007.Q1–2010.Q2 ($N = 447$)	2010.Q3–2013.Q4 ($N = 577$)	Z-value
Price-Value	5.3	13.69	4.71[a]
Quality	25.28	25.13	−0.05
Performance	5.37	9.71	2.66[b]
Components or Contents	10.51	16.81	2.96[b]
Availability	10.96	14.90	1.88
Special Offers	5.15	3.64	−1.16
Taste	24.16	27.21	1.11
Nutrition	8.72	4.33	−2.78
Packaging or Shape	88.59	83.88	−2.19
Guarantees/Warranties	0.00	0.52	1.74
Safety	0.00	0.52	1.74
Independent Research	6.04	5.37	−0.46
Company Research	0.89	0.52	−0.69
New Ideas	1.57	1.56	−0.01
Total	13.75	14.84	0.50

[a] $p < 0.001$
[b] $p < 0.01$

3. Advertising Information Cues Change Over Time

We also analyzes the information cue changes over time. The analysis operate as follows: time is divided into two periods, the first stage is for the first quarter of 2007 to the second quarter of 2010 and the second stage is for the third quarter of 2010 to the fourth quarter of 2013 (see Table 6).

Z test shows average number of 3 cues (Price-Value, Components or Contents, Performance) in two periods is typically increased, while average number of 7 cues (New Ideas, Quality, Independent Research, Company Research, Special Offers, Packaging or Shape, Nutrition) is decreased, other cues have no significant changes.

Results revealed that the administrators realized the marketing role of web forums and message boards: offering a clear price and value information of the tourism products to stimulate the price-sensitive consumers to purchase and providing detailed information on quality and performance of tourism products to help consumers to make purchase decision on high involvement condition.

4 Conclusions, Management Implication and Research Prospects

4.1 Conclusions

Empirical study on ad information of National 5A Rated Tourism Attractions can precisely draw conclusions as follows:

First, official posts on web forums and message boards are with advertising nature. The number of information cues on average are obviously higher than that on magazines, TV and web banner ads. Web forums and message boards are more targeted, controllable and interactive than traditional media to answer to the claims from the consumer's perspective. They can carry more information because of its multimedia transition, low-cost and interaction.

Second, most managers of the national 5A Rated Tourism Attractions did not realize the marketing role of web forums and message boards. The proportion of the websites contain official posts is quite small (0.93 %), and the webmaster of the tourism attractions did not make full use of the platforms to post ad posts, reply questions and guide public opinions.

Third, the consciousness of using message boards is far below that of forums. There are 15 websites with forum ads, account for 46.88 % of normal operational websites (15/32) and 8.82 % total websites (15/170). While there only 4 websites using message board post ads, which account for 8.89 % normal operational websites (4/45) and 2.35 % total websites (4/170).

Fourth, the most 3 types of tourism ad information cue are Packaging or Shape, Quality and Taste, means that compared with other product categories, tourism product has its unique features in advertising transmission. Different cues have different roles in persuading purchase decision. The evidence shows that forums and message boards can fully display advertising information cues, and tourism product advertising is in preference for the physical evidences.

Fifth, results of ad information cues changing over time reveal that scenic managers have verified the ad propagation effects. As highly involved products, tourism product ads can help consumers make better purchase decision by offering clear and detailed information of price, performance and components.

4.2 Management Implication and Research Prospects

This study revealed that the forums and message boards are effective adverting interactive media. Tourists can refer to relevant information when making purchase decisions. Thus scenic managers should fully use these media, and exposing targeted advertising posts according to the demand of potential tourists. Those websites without forum and message board should be and managed.

Most of forums and message boards of the tourism attractions are leaving unused, so specialized management organizations of forums and message boards are needed. Meanwhile, specific official advertising posts should be developed and released according to different consumer groups and different time periods to make sure establishing a wide range of interactive relationship with tourists.

Though this study carried out in accordance with the norms and procedures of content analysis strictly, it inevitably has some limitations because of research purposes, and also indicate the future research:

Resnik and Stern is an objective criteria for ad information content analysis, but can only analyze whether the ad contains information cues, but cannot provide consumer subjective views. Future research should measure and analyze consumer response to advertising information cues.

This study confirmed web forums and message boards are effective interactive media. Future research could analyze advertising information content of tourism products on magazines, newspapers, televisions, radios and other media and explore differences between them.

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Research on Urban Public Transport Status and Countermeasure of Yinzhou District in Ningbo City

Chunyan Du, Min Xiao and Xizhao Zhou

Abstract The contradiction between supply and demand of urban traffic is increasingly intensified, and has become a major bottleneck restricting social and economic development. And public transport has a positive role in saving road resources, improving the traffic environment, so, achieving sustainable and priority development of urban public transport has become an inevitable trend. On the basis of investigation of transport infrastructure and transit status quo in Yinzhou District, this paper analyzed the existing problems, put forward the corresponding countermeasures, and advocated for an assurance system of public transport sustainable and priority development.

Keywords Public transport status · Yinzhou District in Ningbo City · Assurance system

1 Introduction

Yinzhou District in Ningbo City, the largest municipal area, occupies 1380.54 km and has a population of more than 77 million. Its geographical location is so special. Particularly it approaches Ningbo City. The district center is near Ningbo downtown, and the region within the jurisdiction surrounds Ningbo City from three directions and has become a highly urbanized southern new town of Ningbo City. With the continuous economic and social development and the gradual growth of population, transportation problems in the region have become increasingly prominent, and it is particularly important to solve the corresponding problem [1]. In addition, from the comprehensive perspective, geography of Yinzhou District and Ningbo City is intertwined, which has proposed higher requirements for corresponding public traffic system objectively.

C. Du · M. Xiao (✉) · X. Zhou
School of Economics and Management, Shanghai Maritime University,
Shanghai 201306, People's Republic of China
e-mail: minxiao@shmtu.edu.cn

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At present, studies concerning Ningbo City are focused on three respects, namely regional strategic development, resource environment, and economy and culture. Through comparative research and making reference of the construction and development model three-district-linkage in Shanghai, Wang [2] summarized and concluded the connotations and results of the three-district-linkage model in Ningbo and proposed suggestions for its future development. You [3] found that mudflat shellfish in Ningbo is excessive in glant Pacific oysters, which should arouse the attention of relevant departments. By studying geographical names in Ningbo, Ding [4] understood the unique ancient topography of Ningbo and explored the history and culture of salt industry's development. Literature on public transport is rare, and is mainly concerned about monographic research such as the attractiveness of public transportation [5] and the ticketing system. It is not systematic enough and research about Yinzhou District is even missing. This paper hopes to make up for gaps in this area. This paper first analyzes the transportation infrastructure and public transport situation of Yinzhou District in Ningbo City, identifies existing problems and proposes corresponding solutions, in the hope of providing corresponding references for the development of public transportation in Yinzhou District in Ningbo City.

2 Analysis of Transportation Infrastructure in Yinzhou District

In recent years, transportation infrastructure in Yinzhou District has been continuously improved. By the end of 2011, the mileage of this district has reached 1870 km. There were118 km of expressway, 151 km of first-class highway, 227 km of secondary roads, 294 km of tertiary roads, and 1080 Km of fourth-class roads, which basically formed an extensive road network with expressway as the framework, national and provincial roads as the main lines and crisscrossed county and country highways as the branch lines. 2007–2011 Yinzhou District road network and each grade of road mileage and changes are displayed in Table 1.

With the rapid development of social economy of Yinzhou District, there is still a wide gap compared with the rapidly growing traffic in the area although

Table 1 Yinzhou District road network odometer over the years (Unit: km)

Years	Mileage	Free way	First class highway	Secondary road	Tertiary highway	Fourth class road
2007	1672	98	91	234	279	970
2008	1717	98	95	237	285	1002
2009	1742	98	97	242	284	1021
2010	1802	99	103	240	297	1063
2011	1870	118	151	227	294	1080

regional transport infrastructure has also been dramatically developed. Especially, cross-district channels and old towns fail to adapt to the future growth of motor vehicle, resulting in short supply of road traffic in Yinzhou, as well as restricting the long-term development of motor vehicle traffic in the area. Therefore, it has been an inevitable trend in Yinzhou District to optimize the public transport facilities, plan bus lines and efficiently use road resources.

3 Analysis of Public Transport Situation in Yinzhou District

1. Analysis of Public Transport Supply

Currently, there are 1455 various buses, 178 operating lines, 12488 daily total runs, 355,400 passengers/day of carrying capacity and 97 % all-region bus coverage in 4 bus companies in Yinzhou District. The bus lines are mainly divided into two categories: urban bus routes and urban and rural bus routes, which are mainly concentrated on the Yinxian Avenue, Youngor Avenue, Xiaying Avenue and Tiantong north Road, etc., and the spatial distribution is basically reasonable.

The urban bus lines operated by Ningbo Public Transpotation Corporation and Ningbo Gongyun Group Co., Ltd, start from the main point of traffic zone and enter into Ningbo downtown through Tiantong Road, Qianhu Road, Youngor Avenue, etc. The urban and rural bus routes operated by Ningbo Urban and Rural Public Transport Co., Ltd and Ningbo Dongfang Bus Service Co., Ltd, mainly start from the district jurisdiction towns and enter into Ningbo Downtown through the main public concentration areas.

2. Analysis of Public Traffic Demand

Public transport demand is analyzed from three perspectives: bus travel feature, bus passenger flow distribution, and subjective passenger demand, with the purpose of fully understanding the travel time, time distribution of bus passengers, and travel features, while grasping the overall ratings and comments of current bus service, so as to provide a basis to develop appropriate countermeasures. Data in this section come mainly from public transport survey.

The survey objects were local residents in Yinzhou District (living in the city for a long time without being away for a long time) or foreign residents that worked in Yinzhou District and do not leave for a long time prior to the survey. 1000 paper questionnaires were distributed, and 889 were retrieved, with paper-based questionnaire effectiveness of 96.3 %. 200 electronic questionnaires were distributed and 179 were retrieved, with electronic questionnaires effectiveness of 97.2 %. There were a total of 1068 people surveyed. The survey content encompasses multiple aspects, including bus travel reason, age levels, and satisfaction. Single topic selection is given priority to, complemented with the right amount of subjective questions.

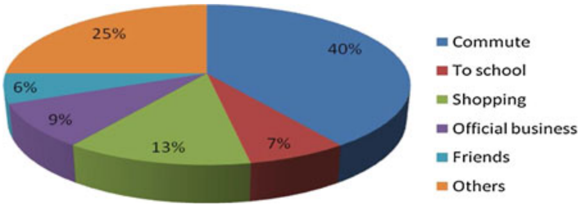

Fig. 1 Bus passengers travel purpose

(1) Characteristics of bus travel

From Fig. 1, passengers travelling to work and joining in other activities by bus on weekdays, which account for more than half of the travelling proportion, and shopping and business account for about 20 % of the travelling proportion. Friends' sharing is only about 6 %, which may be a result of survey data in peak periods.

Figure 2 shows that traveling passengers are mostly aged from 20 to 30, and with the increase of age, fewer people tend to travel by bus. This phenomenon conforms to the rule.

Figure 3 shows that the main reason for travelers to choose public transport is "convenience", signifying that "convenience" is the primary factor of bus travel for travelers. The second is price, which is also the important factor that affects travelers' choice.

(2) Time distribution of passenger flow

The numbers of daily bus passengers are different on weekdays and weekends. Here the results of the survey data provided by Ningbo Urban And Rural Public Transportation Co., Ltd. are analyzed, as seen in Table 2 and Fig. 4.

Flow of bus passengers can be seen from Fig. 4 for saddle type distribution. Monday and Friday are the largest, normal weekdays (Tuesday to Thursday) are relatively

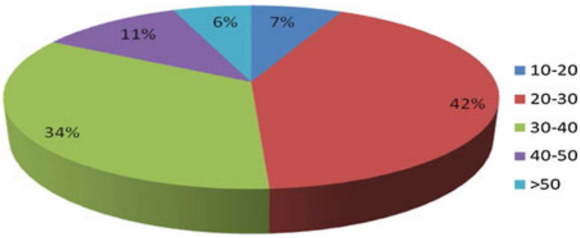

Fig. 2 The proportion of transit passengers of all ages

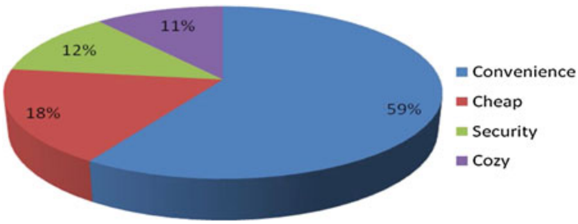

Fig. 3 The reason of bus travel

Table 2 Passenger scale of one week (Unit: Ten thousand)

Date	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Passenger volume	3.05	3.28	2.77	2.53	2.74	3.12	2.98

Source Statistical Yearbook 2012, Yinzhou District

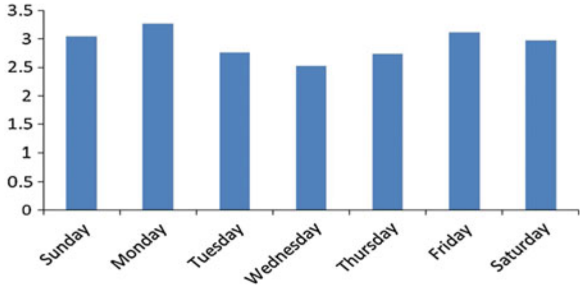

Fig. 4 Distribution of passengers

small. It has something to do with residents to and from work on Mondays, and to travel for shopping, entertainment and other factors on Friday.

(3) Analysis of passengers' subjective demand

Passengers' subjective demand refers to the use of bus travelers' subjective demand for buses. This article mainly analyzes the results of the survey about overall evaluation of the bus passengers and the problems of the current bus.

From Fig. 5, bus passengers currently highly evaluate public transport in Yinzhou District. Nearly one-third of bus passengers give an overall assessment as "excellent", while more than half of the passengers consider bus overall rating "good" and only 1 % of the passengers consider bus overall assessment as "poor" (Fig. 6).

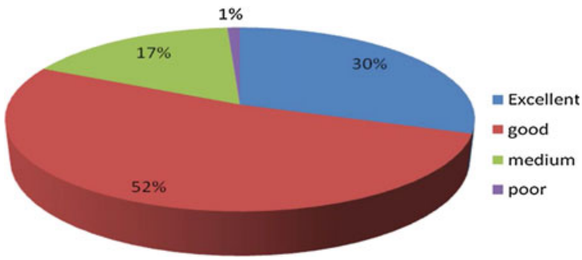

Fig. 5 Overall rating for public transport

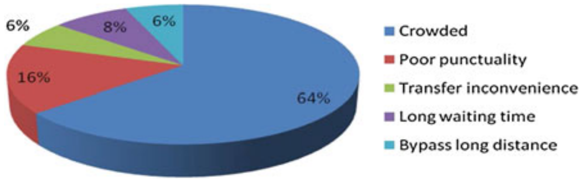

Fig. 6 Bus problems considered by passengers

Table 3 Evaluation system of bus service level

Index	Result	High	Higher	Medium	Low
Public transportation network density	1.12 [a]	>3.5	2.5~3.5	1.0~2.5	<1.0
Bus ownership	16.02[b]	>10	8.3~10	6.1~8.3	<6.1
The proportion of bus travel	12 %	>40	30~40	15~30	<15
Public transportation network coverage (300 m radius)	50 %[c]	>70	60~70	50~60	<50
Non-linear coefficient of bus lines	1.67	<1.2	1.2~1.7	1.7~2.0	>2.0
Bus traffic punctuality rate	86 %	>95	85~95	50~85	<50
Bus load factor (Consider only comfort)	45 %	<50	50~80	80~110	>110

[a] $\frac{km}{km^2}$
[b] Veh/ten thousand people
[c] (New Town)

Among current problems in the bus, 64 % of the passengers think the main problem is traffic congestion; 16 % of the passengers believe the main problem is the poor punctuality; 8 % of the passengers consider the main problem as long waiting time; 6 % of the passengers think long detouring distance and transfer inconvenience are the major problems.

Since the survey data derive from the peak periods, over half of the comments are focused on traffic congestion. At the same time, due to peak periods, the saturation is very large, congestion is serious, so punctuality is affected. Waiting time and punctuality are closely related, but are not exactly the same. In general, in terms of punctuality, besides waiting time, passengers also perceived the bus travel time, so passengers that felt waiting for a long time were slightly lower than those with poor punctuality. The proportion of passengers who have to transfer is small, so there are not many passengers feeling transfer inconvenient. Passengers usually evaluate public transportation services from the perspective of travel time, and seldom pay attention to distance, so the number of passengers who feel long destouring distance is not large.

3. Analysis of Public Transport Services

According to Table 3, we get the following conclusions: Yinzhou District has a higher rate of direct bus lines, but the line bypass is serious. Line mileage, one-way travel time is too long overall. Transfer is not convenient and passengers' waiting time is long. The bus running state is lack of effective supervision.

4 Problems and Solutions

Based on the analysis of the above survey results, the main problems of the public transport system in Yinzhou District can be summarized as follows:

(1) Subject to the existing road network structure, the bus service is not balanced. Part of the road line repetition coefficient is too high, such as Yinxian Avenue.

Because it is currently the only east-west road running through the new city, in addition to a number of bus lines, all transit vehicles (including trucks) also pass through the road, causing severe congestion and intensified road damage.

(2) There is a lack of facilities in public transportation hub sites, and it is difficult to match the regional characteristics. Because now Yinzhou District has not formed public transport hubs completely, most of the bus lines are just to communicate with the urban areas in Ningbo, making it difficult to play a guiding role to its reasonable development.

(3) At present, bus lines through Yinzhou District are operated respectively by Ningbo Public Transpotation Corporation, Ningbo Urban and Rural Public Transport Co., Ltd, Ningbo Dongfang Bus Service Co., Ltd and Ningbo Gongyun Group Co., Ltd. It is urgent to reform the management system and business model, in order to fully integrate and use existing resources to improve operational efficiency.

Aiming at these problems, countermeasures are put forward as follows:

(1) Further improve the rationality of public transportation network coverage and the layout of the bus lines, extend the bus lines to the blank road.
(2) Improve the quality of public transport services; timely and effectively control the increment of motorcycles and the increase in cars through managing traffic demand; ensure the healthy development of public transport and smoothness of urban road traffic.
(3) Reasonably plan bus routes to reduce linear coefficients of bus lines, reduce bus bypass, and take measures like giving priority to buses to reduce vehicle delay.
(4) Reasonably plan bus stops, shorten the passenger transfer distance; increase the frequency of bus services in the morning and evening peak periods to shorten the waiting time of passengers.
(5) Improve the level of transit service; scientifically plan the network. Under the premise of protecting the smooth road traffic and passenger comfort degree, coordinate the relationship between public transport capacity supply and traffic demand; improve the vehicle load rate.
(6) Rely on the terminals; construct a new passenger transit hub; realize centralized access between township lines and new city lines, well converge with other passenger modes, together constitute a urban transport system with clear-cut labor division, proportional coordination, complementary advantages and advanced operation.
(7) At the stage of cultivating passenger market, the government should give appropriate subsidies to bus companies according to the circuit operation.
(8) Comprehensively cover intelligent transportation systems; realize transit vehicle real-time monitoring and dynamic scheduling.
(9) The size of the bus and stop fields should be balanced within the scope of Ningbo city bus system, and obey the city bus system.
(10) Improve the public transport operation mode to achieve the combination of bus lines operation mode and area operation model.

5 Build Sustainable and Preferential Development Public Transport Security System

The optimization of the public transport system is a system engineering issue and needs to take into account the soft and hard environments of the public transport system, thereby achieving organic combination [6]. These initiatives in this paper mainly focus on building a good hardware environment for public transport in Yinzhou in Ningbo. While pursuing the improvement of the hard environment, the soft environment for the urban public transport system is an important influence. This paper has pointed out that the soft environment is sustainable and preferential development public transport security system.

1. Sustainable Public Transport Security System

Protecting the environment is the foundation of sustainable social and economic development. A beautiful environment can better enhance the city competitiveness, promote the city's taste and improve the quality of life of urban residents. The current status of the urban environment influence in Yinzhou District in Ningbo City has the following two main traffic characteristics:

(1) Motor vehicle emissions in Yinzhou District have become the main source of atmospheric pollution;
(2) Individual transportation is developing rapidly. Thus, to develop public transport and enhance the attractiveness of public transportation can inhibit the development of individual traffic speed, ease traffic congestion and reduce emissions.

In addition, in order to reduce the influence of public transportation on the environment of Yinzhou District in Ningbo. The following measures targeted at buses should be taken:

(1) Encourage the use of clean energy buses.
(2) Transform the existing bus, make sure that all the bus exhaust emissions reach standards.
(3) Strengthen the monitoring of public transport vehicles, resolutely eliminate vehicles with poor shape, large noise and high fuel consumption.

2. Preferential Development of Public Transport Security System

Bus priority refers to the government gives the city bus more favorable conditions for from economic, administration, legal, technical development, so that the city buses have a prior status different from many modes of transportation [7]. They are mainly reflected in to minimize the impact of traffic congestion on public transport vehicles, ensure punctuality, save travel time, increase the attractiveness of bus travel, achieve a virtuous cycle of transportation structures, ease traffic conflicts and improve urban traffic environment.

1. Government macro management

(1) Guide benign competition

The situation of traffic congestion is becoming increasingly serious. Vigorously develop public transportation as an important measure to ease road supply and demand contradiction, so that the public transportation industry can develop rapidly. Objectively, it proposes a challenge to government's macro-control ability. The government should meet the demand of urban public traffic and improve the city traffic environment, take into account the interests of the public transport enterprises and strengthen macro-control, thereby forming a virtuous and orderly competitive situation among Ningbo Public Transpotation Corporation, Ningbo Urban And Rural Public Transport Co., Ltd, Ningbo Dongfang Bus Service Co., Ltd and Ningbo Gongyun Group Co., Ltd.

(2) Reform the present situation of the bus system

Yinzhou District Government should insist on separating government functions from enterprise management to realize the separation of ownership and management rights, give priority to the bus enterprise autonomy in regard to personnel and equipment, create good external conditions for the public transportation enterprise reform, prompt public transport enterprises to unceasingly perfect in market competitions, construct the modern enterprise system, and enhance the benefit of the public transportation enterprises and service level, in order to gradually reduce and eliminate operating losses.

2. Fiscal policies

(1) Investment policies

Public welfare of buses decides the poor public transport investment performance, long capital recovery period and low attraction of capital, and therefore public transport infrastructure has long been invested by the government. While the long-term development of the bus needs to realize the diversification of investment to public transportation, namely centering on government investment, bank credit is complementary and social capital and foreign capital utilization should be raised actively [8]. The following breakthroughs can be considered: The government fiscal interest discount loans to the bank. On the basis of the shareholding system reform, issuing shares to raise funds, to revitalize the assets of the bus companies. In addition, select some benefits guaranteed projects to attract foreign investment for joint operation.

(2) Subsidy policy

On taxes, Yinzhou District Government employs the reduction and exemption policies, such as using preferential policies for oil that runs buses. In chargeable places such as roads, tunnels, bridges, implement free policy for buses and exempt vehicles' purchase tax, etc.

(3) Fare policy

Yinzhou District suffers from losses permitted by policy due to the government's social functions. At present, in order to achieve public welfare, Yinzhou District should still adopt a policy of low bus fares. Fare adjustment should be based on the monthly average transportation costs for a percentage of the monthly average gross income, set up the annual fine-tuning fares natural adjustment mechanism according to the average wage growth, and gradually break even small profit. For social vulnerable groups, such as the elderly population, low income earners, the disabled, etc., give proper care on the fare mechanism.

3. City planning and construction

Highlight the priority of public transportation in Yinzhou District's regional planning and comprehensive transportation planning. Ensure the land for public transport facilities; provide the necessary infrastructure for public transport development. Bus station construction should be based on bus operation and residents' travel requirements. Passenger terminals can organize urban traffic truly, balance distribution of passenger flow and realize the function of transportation conversion.

4. Bus operation management

The urban public transport system is a timing, lane and random service system. According to the change of the passenger flow, flow time and space distribution, the system can operate properly and maximize the benefits depending not only on road conditions and traffic flow, more importantly based on vehicle operation monitoring and operation information management. Therefore, it is necessary to use advanced public transport system for intelligent management.

The primary purpose of the advanced public transportation system is to convey users with reliable information. People can select travelling ways according to the information. Hence, the transportation system is market-oriented and should realize functions in terms of public transport management, provision of public transport information and maintenance of the public transportation safety.

6 Conclusion

In today when supply of road transport resources falls short of demand, the policy of "bus priority" can achieve intensive use of resources and effectively alleviate traffic conflicts. However, various existing problems hamper the implementation of this policy. On the basis of analyzing the current situation of Yinzhou District, this paper proposes a series of measures and promotes the sustainable and preferential developed public transport security system, which has important reference value. Although many aspects are involved, they are only to a point. A macro vision is put forward and specific implementation measures need further research.

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Analysis on Asymmetry and Trends Forecasting of Chinese Macroeconomic Fluctuations

Hong Wang and Yonggan Zhao

Abstract This paper studies economic operation characteristics and interactions of major indexes reflecting macroeconomic operation by using Markov Regime-Switching Model, and also verifies asymmetry among the various synthetic components in economic cycling. That is to say that there are some differences in interactions among these major macroeconomic variables under different macroeconomic operation environments ("good", "general" and "poor"). Therefore, the government should apply different control measures to different economic operations in the future. Our study has showed that Markov regime-switching model with 3-regime is suitable for forecast and prediction on macroeconomic variables in sample period and beyond sample period.

Keywords Economic fluctuation · Asymmetry · Trend forecast · Markov regime-switching model

1 Introduction

The practice of economic growth and cycling theory has proved that it is very difficult to achieve and keep steady and sustainable economic growth in a long term. The repeated fluctuations and tortuous development is the trajectory of economic growth and development. Economic fluctuation is periodic and asymmetric, and there are different behaviors in economic expansion and contraction period.

The traditional method usually used in economic fluctuation is time series analysis, such as autoregressive model (AR) and Auto Regressive moving average Model. Linear time series models are very popular since they have been incorporated into software package in statistics and econometrics. Although these models are very

H. Wang (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: wanghong_scu@scu.edu.cn

Y. Zhao
Rowe School of Business, Dalhousie University, Halifax, Canada

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successful, they cannot analyze more nonlinear dynamic models, such as economic fluctuation's asymmetry and volatility clustering. Markov Regime-Switching Model is one of the most popular nonlinear time series models. Its advantage is to divide invisible macroeconomic operation situation into several independent regimes. By this analysis method, we can capture more complicated dynamic models and their analysis results will be much better than that of general linear forecast.

The classical research of economic cycle asymmetry is Markov Regime-Switching Models with 2-state by Hamilton [6]. After researching American GNP data post World War II, he confirmed that American economic had periodical changes from active growth to passive growth. Sichel [10, 11] established economic cycle model with 3-state (recession phase, recovery phase with rapid growth and steady growth after recovery). Kontolemis [7] analyzed business cycle of the U.S. with a Vector-Markov-Switching Model. Guidolin [5] found Markov model's prediction effect is much better than that of other linear Asset price models after comparing several forecast models. Girardi and Alessandro [4] showed that survey expectations contain relevant information about business cycle developments in the euro area using a dynamic multivariate system. Xu et al. [12] obtained periodic components reflecting China's economic cycling fluctuation and distinguished two sorts of asymmetry of economic, deep asymmetry and steep asymmetry through peeling China's major macroeconomic variables log series by HP filtering and time trends to eliminate technology. Chen and Liu [1] applied Markov's research on auto regression of mean and variance transfer to study asymmetry and persistence of fluctuations in the economic cycle. Chen [2] analyzed the asymmetric effect of financial instability on China's economy using a specific Markov-Switching Auto-regression model MSIAH M-ARX P. Empirical results show that Chinese financial system has cyclical instability and the effect of financial instability on economy is asymmetric with regard to different regimes of economic growth. Different from foreign scholars, Chinese scholars' studies are focused on proving existence and persistence, correlation, volatility and other characteristics of China's economic asymmetry phenomenon. They mainly used single economic indicator to analyze, such as GDP or monetary supply growth rate and domestic product growth rate. About the number of regimes, they only marked they absorbed the idea of economic growth 3-regime system, and no explanation about reason and basis.

Economic cycle is a comprehensive result of multiple factors' combined action. It is very one-sided to reflect fluctuation and asymmetry of economic cycle only by using individual or a few indicators. Economic cycle also has a variety of synthetic ingredients with asymmetry [8]. Based on above considerations, seven indexes are selected to study interaction and asymmetry of synthetic ingredients in economic cycling. These indexes include macroeconomic climate index, producer price index, consumer price index, monetary supply, exchange rate, Shanghai securities composite index and Treasury bond index.

2 Index Selection, Model Design and Sample Choice

1. Index selection and model design
In researches of economic cycle, Lucas [9] thought that we should pay attention to linkage effect of macroeconomic variables, such as product and consume investment and employment. Diebold and Rudebusch [3] suggested that we should consider two aspects, the first is economic variables' linkage effect and the second is economic situation persistence while designing economic cycle model. In present researches of asymmetry of macroeconomic fluctuation, some single indexes, like GNP, GDP or a few indexes like monetary supply growth rate and domestic output growth rate, will be mainly used. In our opinion, when studying economic cycle, we need not only to study and verify asymmetric cycle form with 'slow-up steep-down', but also to study operation characteristics and interaction relationship of some major macro economic factors under different economic situations in the future. Based on above considerations, we choose 7 indicators in 3-category to reflect the status of macro economy. The first category includes indicators that reflect overall state economy, such as Macroeconomic Climate Index, Consumer Price Index (CPI), RMB exchange rate, stock index and Government Bond Index. The second includes indicators that reflect the attitude of central bank to the future state of economy, like monetary supply, interest rate. And the third reflects the characteristics of samples of manufacturing industry, such as Producer Price Index (PPI). In the end, we select the following indicators, Macroeconomic Climate Index, PPI, CPI, monetary supply, RMB exchange rate, the Shanghai Composite Index and the Government Bond Index.

Assuming at time t, vector M_t represents macroeconomic condition, and then all macroeconomic indicators can be predicted by Markov-Switching Vector Auto regression Model, which is written as:

$$M_t = \alpha_{s_t} + \beta_{s_t} M_{t-1} + \varepsilon_{s_t}. \tag{1}$$

In Eq. (1), M_{t-1} is the matrix of macroeconomic state at time $t-1$; α_{s_t} and β_{s_t} are state-dependent coefficient matrix; ε_{s_t} is the state-dependent random terms,ε_{s_t}. Assuming that macroeconomics has k kinds of states, and the future state of macro economy subject to the requirement of Markov chain, and then the matrix of transition probability including different states is as follows:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1K} \\ p_{21} & p_{22} & \cdots & p_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ p_{K1} & p_{K2} & \cdots & p_{KK} \end{bmatrix}. \tag{2}$$

In this matrix, $p_{ij} = P\left[S_t = j | S_{t-1} = i\right]$ represents the probability of macroeconomic states with from state i at time $t-1$ to state j at time $t, i, j \in K$.

2. Sample selection
In this paper, the range of macroeconomic data sample is from Dec 31st, 2001 to Sep 30th, 2012. Forecast interval of Out-of-sample is from Oct 1st, 2012 to Dec 31st, 2012.

3 Macroeconomic State Predicted Result and Analysis

1. Selection of macroeconomic operation state number
As the above, we select 7 indexes to reflect macroeconomic operation status from different perspectives. In Eq. (2), the number K of macroeconomic state is related to the accuracy of parameters in the model. If K is bigger and bigger, it shows the classification of macroeconomic state is more detailed. The prediction of the model may be better, but the parameters of the model will also increase rapidly. The increase of parameters may affect the accuracy of parameter estimation.

In many models, the basic judgment criteria of model selection are not complexity but forecast accuracy. Based on this principle, we use Bayesian Information Criterion (BIC) as the basis of macroeconomic state number selection in this article. Use relative small number of BIC as classification number selection. Among them

$$BIC = -2\ln\left(L\,|K, \varphi\left(K\right)\right) + f\left(K, \varphi\left(K\right)\right)\ln\left(N\right). \tag{3}$$

In Eq. (3), L is the likelihood function under K kinds of macroeconomic states; $\varphi(K) = \{a_{s_t}, b_{s_t}, \sum_{s_t}, P\}$ is estimated parameters; $f(K, \varphi(K))$s number of parameters in model; N is the sample number of observation data.

When the value of K is 1, we don't need to divide macroeconomic into different statuses to analyze; when K is 2, the macroeconomic status may be classified "good" and "bad" statuses; when K is 3, we can divide into three conditions, "good" and "general" and "bad". The results of calculated BIC are shown in Table 1. When K is 3, BIC value is the smallest. Therefore, we divide macroeconomic fluctuations into three statuses, "good", "general" and "bad" in the follow-up study.

2. Transition probability matrix of macroeconomic status transition
Under three statuses of macroeconomic, Regime 1, Regime 2, Regime 3, Markov state transition probability matrix related to Eq. (1) is as follows:

$$P = \begin{bmatrix} 0.7500 & 0.0000 & 0.2500 \\ 0.0413 & 0.1944 & 0.7643 \\ 0.0187 & 0.6757 & 0.3056 \end{bmatrix}. \tag{4}$$

Table 1 Calculated BIC under different macroeconomic status values

K	1	2	3	4	5
BIC	3.40E+03	3.40E+03	2.44E+03	2.92E+03	3.03E+03

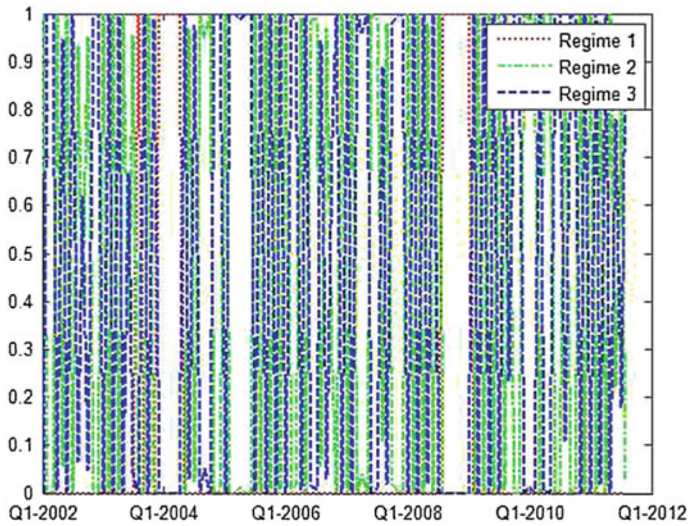

Fig. 1 Posterior probability of three different regimes

Posterior probabilities of macroeconomic status at different point of time are shown in Fig. 1. As seen in Fig. 1, from December 31, 2001 to September 30, 2011, macro economy fluctuated almost between Regime2 and Regime3, only three short periods (September in 2003, January, 2004 to May, 2004, September, 2008 to February, 2009) is in Regime 1 status. Contrast Chinese macroeconomic operation situation in the same period, we can see Chinese economy was under high speed development, and GDP surpassed Japan in 2009 to become the world's second. During the process of high speed development, China experienced the shock of "SARS" in 2003 and financial crisis in 2008. If we use "good, general, bad" to define macroeconomic status, we can conclude Regime 1 is the "bad" status. Besides, after twice Regime 1 status, macro economy transit into Regime 3 at posterior probability of 1, then fluctuated between Regime 2 and Regime 3, but before entering Regime 1, two kinds of performances are a little different. The first time is from Regime 3 to Regime 1, the second is from Regime 2 to Regime 1. In general, economic upturn is from "bad" back to "general", and then to "good". Economic state may change slowly from "good" to "general", and then to "bad", or may change directly from "good" to "bad". Therefore, we can conclude Regime 3 is macroeconomic status of "general", and Regime 2 is macroeconomic status of "good".

3. Macro factors relation model and significance analysis

Under the three statuses, macro factors relation model and significance analysis are shown in Tables 2, 3 and 4.

Data listed in Tables 2, 3 and 4 are influence coefficients between macroeconomic indexes of this period to macroeconomic indexes of next period. For example, 0.8573 at the first line of the second column in Table 2 indicates if macro economy is under Regime 1 next period, influence coefficient of current economic climate index to

Table 2 Macro factors relation models and significance level under Regime 1

Macro factors	Intercept	M1	M2	M3	M4	M5	M6	M7
Relation models								
M1	0.2278	0.8573	−0.0830	−0.0194	−0.0055	0.0518	−0.0244	0.0543
M2	0.7070	0.4734	1.4517	−0.9683	−0.0331	0.1816	0.0585	−0.3443
M3	0.4090	0.1860	0.1510	0.6474	−0.0789	0.0185	0.0134	−0.137
M4	−0.8676	1.5678	−2.7545	4.4383	−0.3178	−1.0188	−0.1666	1.8296
M5	−1.9052	1.2969	−1.3762	2.1541	−0.1431	−0.3113	0.1227	0.6397
M6	−1.6733	4.8628	−6.2035	9.0606	−0.5924	0.2985	−0.7634	1.1896
M7	−2.7055	−1.1567	0.3197	0.1604	0.1282	−0.0692	0.0442	−0.2391
Significance level								
M1	0.003	0.0000	0.0009	0.3695	0.1422	0.0000	0.0000	0.0000
M2	0.0005	0.0000	0.0000	0.0000	0.0068	0.0000	0.0000	0.0000
M3	0.0389	0.0752	0.0207	0.0000	0.0000	0.2366	0.0889	0.0000
M4	0.3731	0.1475	0.0007	0.0097	0.0295	0.0003	0.0734	0.0000
M5	0.1092	0.0667	0.0027	0.0246	0.0701	0.0356	0.032	0.0015
M6	0.2002	0.0000	0.0000	0.0000	0.0000	0.0891	0.0000	0.0000
M7	0.0000	0.0002	0.0432	0.3486	0.0002	0.1434	0.0386	0.0017

Note *M1* economic climate index; *M2* PPI; *M3* CPI; *M4* monetary supply; *M5* RMB exchange rate against the euro; *M6* SSE; *M7* Government Bond Index

Table 3 Macro factors relation models and significance level under Regime 1

Macro factors	Intercept	M1	M2	M3	M4	M5	M6	M7
Relation models								
M1	−0.0858	0.6235	−0.0673	0.1094	0.0133	0.0488	−0.0064	−0.0189
M2	−0.2301	0.9714	0.9952	0.0766	0.0432	0.0492	−0.0193	−0.1813
M3	0.2798	−0.1981	−0.0903	1.0312	0.0235	−0.0067	−0.0373	−0.1080
M4	1.1856	1.8904	0.1644	−0.1561	−0.6838	−0.0741	−0.0230	−1.4652
M5	0.2005	−1.2176	−0.4836	0.4670	−0.0003	0.0125	0.1202	0.3261
M6	−0.2401	−1.4779	−0.3902	0.5639	0.1962	−0.1977	0.1004	−0.4194
Significance level								
M1	0.0482	0.0000	0.0000	0.0000	0.0016	0.0002	0.0567	0.3552
M2	0.0001	0.0000	0.0000	0.0003	0.0000	0.0009	0.0000	0.0012
M3	0.0032	0.0646	0.0001	0.0000	0.0044	0.4014	0.0000	0.1422
M4	0.0187	0.0047	0.1119	0.2269	0.0000	0.3092	0.3022	0.0046
M5	0.3204	0.0134	0.0000	0.0016	0.4965	0.4556	0.0002	0.2211
M6	0.4307	0.2000	0.1161	0.1316	0.0515	0.2911	0.1748	0.3787
M7	0.0000	0.4416	0.0469	0.0071	0.0132	0.0574	0.1277	0.0156

Note *M1* economic climate index; *M2* PPI; *M3* CPI; *M4* monetary supply; *M5* RMB exchange rate against the euro; *M6* SSE; *M7* Government Bond Index

Table 4 Macro factors relation models and significance level under Regime 1

Macro factors	Intercept	M1	M2	M3	M4	M5	M6	M7
Relation models								
M1	0.3662	−0.0033	−0.0874	0.0046	0.0095	−0.0161	0.0032	0.0535
M2	−0.0980	1.0791	0.8925	0.1755	0.0022	0.0105	−0.0063	0.2437
M3	0.2805	0.2823	0.0081	0.9434	0.0068	−0.0266	0.0113	−0.1863
M4	2.6726	3.1533	0.2998	−0.3024	0.59	−0.2348	−0.0188	0.6407
M5	1.4709	0.4676	0.1334	−0.2001	0.0918	−0.0372	0.0280	−1.3341
M6	5.5258	1.0402	−0.2565	−1.3662	0.069	−0.5834	0.0782	−1.9967
M7	0.0493	0.0161	0.0423	−0.0386	0.0055	0.0234	−0.0119	0.8087
Significance level								
M1	0.0000	0.4842	0.0000	0.4123	0.0533	0.0946	0.2212	0.1720
M2	0.2011	0.0000	0.0000	0.0000	0.4322	0.3469	0.2438	0.0233
M3	0.0000	0.0040	0.3240	0.0000	0.1817	0.0448	0.0186	0.0051
M4	0.0003	0.0043	0.0678	0.1546	0.0000	0.0921	0.3788	0.2156
M5	0.0000	0.1453	0.0363	0.0346	0.0017	0.2845	0.1065	0.0000
M6	0.0000	0.2694	0.1833	0.0006	0.2816	0.0100	0.1817	0.0417
M7	0.2268	0.4367	0.0065	0.0624	0.2214	0.0590	0.0107	0.0000

Note *M1* economic climate index; *M2* PPI; *M3* CPI; *M4* monetary supply; *M5* RMB exchange rate against the euro; *M6* SSE; *M7* Government Bond Index

the next period economic climate index is 0.8573. Similarly, influence coefficient of current economic climate index to the next period PPI is 0.4734. From Table 2 to Table 4, there are differences among these coefficients reflecting economy performance from different perspectives. Taken together, these relations are presented as follows:

(1) Under different macroeconomic statuses in the future, although there are differences between influence coefficients of these indexes, the direction is the same. For example, under Regime 1, Regime 2 or Regime 3, impact of the current economic climate index (M1) to the future industrial producer price index (PPI) (M2) is positively correlated (influence coefficients are 0.4734,0.9714 and 1.0791) and have passed the test of significance (significance level are 0.0000 under three status). It shows that, regardless of what status the future macroeconomic is, the rise of current economic climate index will lead to the rise of future industrial producer price index (PPI); the falling of current economic climate index may lead to decline of future industrial producer price index (PPI). RMB exchange rate (M5) and industrial producer price index (PPI) (M2) have the same correlation, both positively correlated under three statuses, the influence coefficients are 0.1816, 0.0492 and 0.0105. This suggests that under three-status, the current RMB exchange rate appreciation (devaluation) will lead to rise of industrial producers state price index under this kind of status in next period; Similarly, the current RMB exchange rate decline (RMB appreciation) will lead to decline of industrial producers price index under this kind of status under the

state's price index decreased, and this relation Regime 1 and Regime 2 significant (significance level of 0.0000 and 0.0009, respectively) , in Regime 3 not significant (significance level of 0.3469).

(2) Under different macroeconomic statuses in the future, the directions of influence coefficients between indexes are not the same, and such relations exist widely. It shows that there are differences in different times among various ingredients in economic cycle, and it is asymmetrical. Such as relations between monetary supply (M4) and economic climate index (M1), PPI (M2), CPI (M3) and the Shanghai Composite Index (M6). When Macro economy in next period is Regime 2 ("good") and Regime 3 ("General"), the influence coefficients of monetary supply (M4) on economic climate index (M1), PPI (M2), CPI (M3) and the Shanghai Composite Index (M6) are positive, indicating that when the future macroeconomic status are "good" or "general", the rise of monetary supply will lead to the rise of economic climate index (M1), PPI (M2), CPI (M3) and the Shanghai Composite Index (M6). And the relation is significant when significance level of Regime 2 is higher than Regime 3. On the contrary, when macro economy in the next period is Regime 1 ("bad"), influence coefficients of monetary supply (M4) on the economic climate index (M1), PPI (M2), CPI (M3) and the Shanghai Composite Index (M6) are negative. It proves when the status of macro economy in the future is "bad", the increase of monetary supply will not lead to the rise of economic climate index , PPI, CPI and stock price, and this relation is significant, even much more significant (significance level of 0.0000). Comprehending above relations, we can draw the following conclusions: when macro economy performs well in the future, the increase of monetary supply will help enhance the level of economic booming, with the corresponding PPI, CPI rising, and the stock market also rising. But when the economic status is poor, the increase of monetary supply cannot stimulate economic recovery. Instead, it will lead to government debt burden, excess market liquidity, delaying economic recovery in the future.

Similarly, when economic status in next period are Regime 1 ("bad") and Regime 2 ("good"), the influence coefficient of current RMB exchange rate on economic climate index in next period is positive, and can pass significance testing (significance level is 0.0000 and 0.0002). This suggests that whether economic status is "good" or "bad", the rise of exchange rise (means depreciation of Renminbi) will help enhance future economic climate index. However, when the future economic status is Regime 3, influence coefficient of current RMB exchange rate on economic climate index in next period is negative, and the relation is not very significant (significance level of 0.0946).

From relation model of macroeconomic factors in sample period, in different sections of economic cycle, macroeconomic indexes behave differently. This approves macro economy is asymmetric from another side, and also provides theoretical basis for macroeconomic regulation. Macroeconomic regulation requires different policies based on different economic statuses, otherwise regulation targets and actual results may diverge.

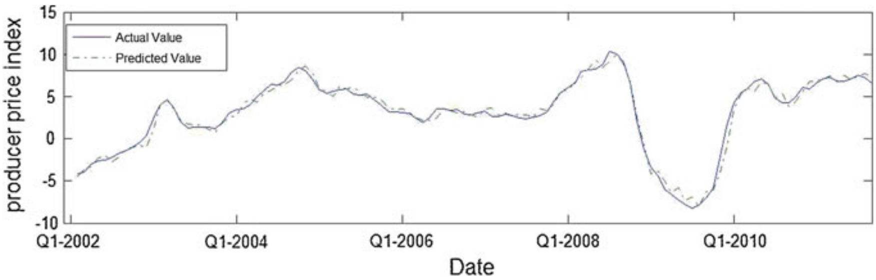

Fig. 2 Predicted value and actual value of economic climate indexes

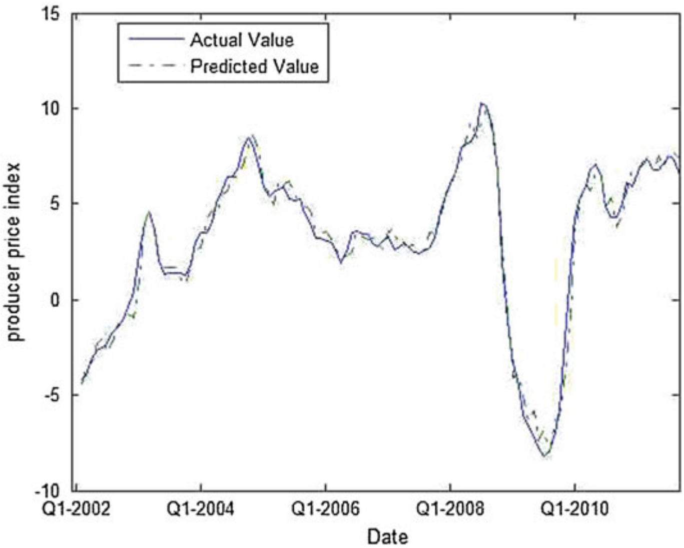

Fig. 3 Predicted value and actual value of the producer price index

4. Trend-forecasting analysis of macroeconomic indexes in sample period
(1) Comparison of macroeconomic indexes predicted value and actual value

The comparison between macroeconomic indexes trend forecasting and actual value in sample period is listed in Figs. 2, 3, 4, 5, 6, 7, and 8.

From Figs. 2, 3, 4, 5, 6, 7, and 8, differences between predicted value and actual value of economic climate index, PPI (M2), CPI (M3), monetary supply (M4) and government bond index (M7) are small, and it proves prediction is very good. The prediction of turning-point and trend of RMB exchange rate (M5) and the Shanghai Composite Index (M6) is better and time cycle is relatively accurate. Only the highest-point and lowest-point have a little prediction deviation.

(2) Prediction accuracy rate analysis of macroeconomic fluctuations in positive and negative directions

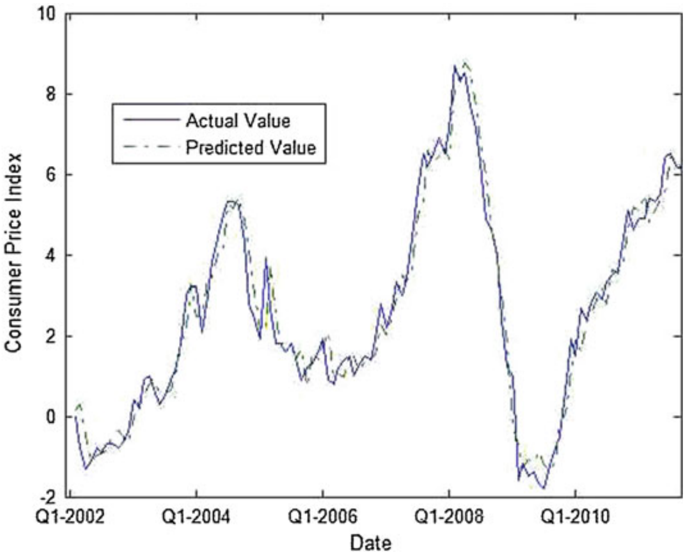

Fig. 4 Predicted value and actual value of consumer price index

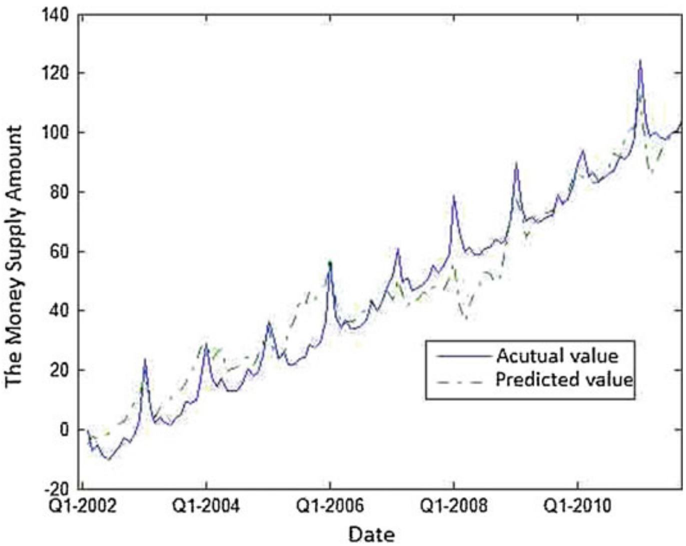

Fig. 5 Predicted value and actual value of monetary supply amount

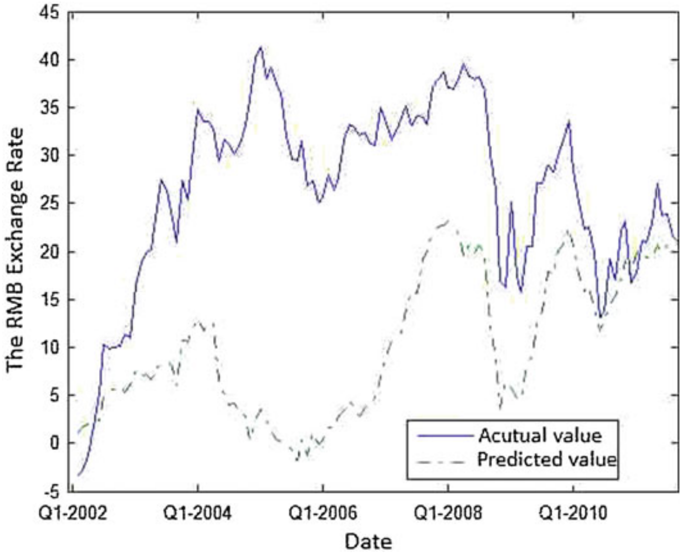

Fig. 6 Predicted value and actual value of RMB exchange rate

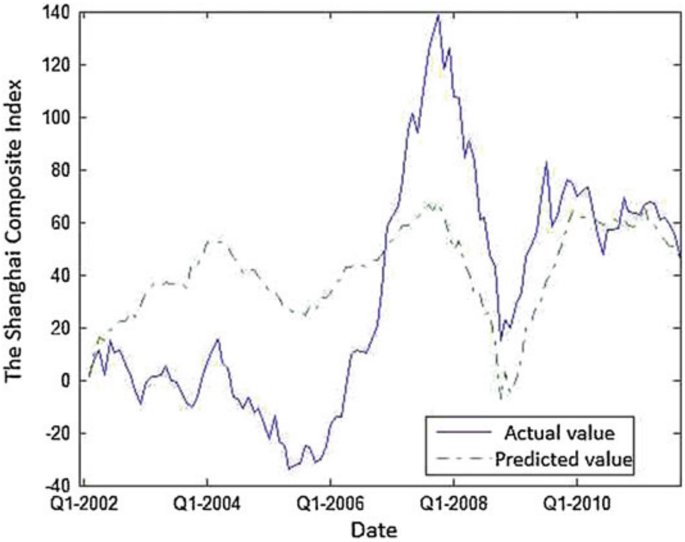

Fig. 7 Predicted value and actual value of Shanghai composite index

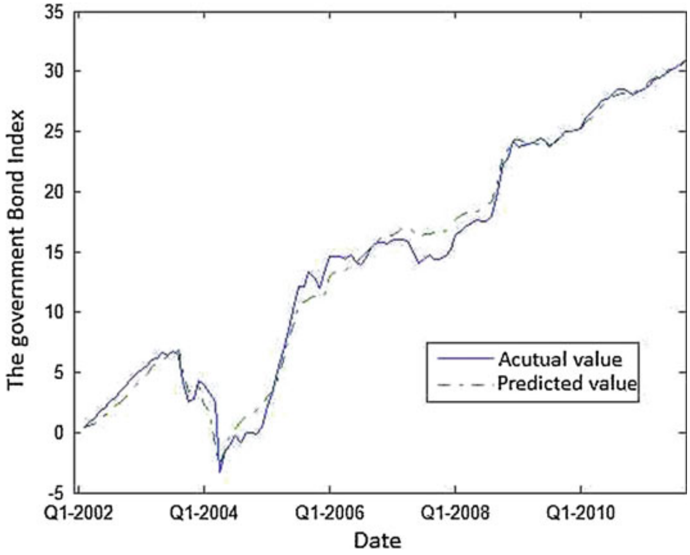

Fig. 8 Predicted value and actual value of government bond index

Table 5 Calculated BIC under different macroeconomic status values

	M1	M2	M3	M4	M5	M6	M7
Accuracy rate	0.75	0.98	0.97	0.73	0.73	0.7	0.81

Note The accuracy rate is the correctness of predicted value's positive and negative direction compared to the actual value

Positive and negative accuracy of various macroeconomic indexes predicted and actual value in sample period is shown in Table 5.

As seen in Table 5, the accuracy on PPI (M2) and CPI (M3) is the highest, respectively 98 % and 97 %, and the accuracy on the Shanghai Stock index is the lowest, only 70 %. The accuracy rate of predicted value's positive and negative direction is higher than 70 %. The overall prediction is good.

3. Analysis of prediction effect in sample period
Compared prediction value and actual value, and prediction accuracy of positive and negative direction, differences of prediction and actual value between economic climate index (M1), PPI (M2), CPI (M3), monetary supply (M4) and bond index (M7) is small, prediction is very good. The prediction and actual value (Figs. 6 and 7) and trend of RMB exchange rate (M5) and the Shanghai Composite index (M6) all are relatively accurate; the time cycle is also very accurate. But prediction of the highest point and lowest point has some deviations. Reasons for this as follows:

(1) China's exchange rate system had experienced a changing process from the "fixed" to floating, from"unified administration" to "market regulation", from "a single dollar peg" to "reference to a basket of currencies". During this process,

Table 6 Forecast accuracy statistics of out-of-sample macroeconomic indexes

	M1	M2	M3	M4	M5	M6	M7
Accuracy rate	0.33	0.92	1	0.75	0.5	0.33	0.92

Note: The accuracy rate is the correctness of predicted value of positive and negative direction compared to the real value.

exchange rate is not fully priced by market, even since July 21, 2005, China began to implement managed floating rate system based on market supply and demand and with reference to a basket of currencies. This “managed” floating rate system is not completely affected by market factors. Therefore, the methods used in this paper to predict the highest and lowest point of RMB exchange rate have some deviations in a certain degree, but the overall effects are acceptable, especially in the latter part of the sample period, the differences have been reducing.

(2) Prediction deviation in Shanghai securities index. Its primary reason is that there are deviations in basic condition of our economy and the stock market performance. Since more than 10 years, Chinese economy is in upward cycle, GDP growth keeping high speed at about 9 %. Until 2010, GDP ranked the second in the world. The analysis of macroeconomic state in this paper also verifies that in the sample period, China’s macro economy mainly runs in the “good” and “general”state. However, in the meantime, the Shanghai index trend did not play economic “barometer” role. Shanghai Composite Index in 2000, 31 December closed at 2073 points, in October 2007 after reaching at 6124.04 points, closed at 2199 points by the end of 2011, and in September 2012 fell below 2000 points, the index went back to the origin.

5. Out-of-sample forecasting result and analysis
Out-of-sample, predicted value accuracy rate of each macroeconomic index is shown in Table 6. Compare with sample prediction accuracy rate in Table 5, we can see that the prediction accuracy of economic climate index (M1), the RMB exchange rate (M5) and Shanghai Composite Index (M6) drops more; prediction accuracy rate of PPI (M2), CPI (M3), monetary supply (M4) and bond index (M7) decreased less, even rising The overall forecasting effects are better.

4 Conclusion

This paper uses Markov state transition model with 3-zone system to predict and analyze macroeconomic fluctuations and the interactions between macroeconomic variables under different economic statuses. The results show that under different macroeconomic states (“good”, “general” and “poor”) in the future, there are many differences in interactions between key macroeconomic variables. For example, when future macroeconomic performance state is “good”, increase of monetary supply will help to enhance the level of economic booming, with the corresponding PPI, CPI rising, and the stock market also rising. But when future state of economy is “poor”, increase of monetary supply will not stimulate economic recovery, but will lead to government debt burden, excess market liquidity and slow economic recovery in the future. Therefore, government should take different regulations based on differences in estimation of future economic performance status. Meanwhile, the predicted results of this paper indicate, Markov state transition model is very suitable for predicting macroeconomic status, main macroeconomic variable’s trend and turning points, and can be used as an alternative method for macroeconomic forecasting.

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Harnessing and Boosting University Brand in the Age of Big Data

Yu Liao

Abstract Institutions of higher learning will undergo dramatic changes in their teachings and ways of using data in the age of big data, from which new opportunities will emerge. By exploring the laws behind the data, universities can forecast the future, as well as enable the teachers, students and administrators to upgrade their teaching, learning and administrative capabilities, eventually harnessing their brand image and boosting their reputation in the real sense.

Keywords Big data · University brand · Harnessing and boosting

1 Introduction

Big data poses a gigantic challenge to the development of institutions of higher education. With the right tools and strategies however, big data can also offer incredibly rich resources that can be leveraged to improve student retention, adjust the curricula structure and support the students, teachers and administrators in numerous ways. It therefore presents an opportunity for universities to realign their brand strategies as well.

The information systems owned by universities are major producers of data. According to the latest report from the McKinsey Global Institute, the database of one information system in the U.S. Department of Education surged to 269 P bytes (1 P bytes equals 1 billion M bytes) in year 2009 alone [7]. Thanks to such a massive scale, the system was rated one of the year's top 10 big data producers in all America. Universities with populations of 10,000 or more people abound in China, where large amounts of data are being generated from the student identities, course selections, scores, book borrowings, internet visits, forums, microblogging and meal cards among other sources and activities, not to mention the equipments, computers

Y. Liao (✉)
President's Office Reception Institute, Sichuan University,
Chengdu 610065, People's Republic of China
e-mail: liaoyu1029@scu.edu.cn

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and books. The information systems in institutions of higher learning are thus often colossal, and after years of buildup, would result in the big data as we know. The big data of higher-learning institutions has highly distinct academic and scientific values that can alter the ways we teach and learn. Big data can help with academic administration, assist in scientific research with calculations of massive data, and aid the student enlistment and degree management programs besides other applications. In an age when information carries immense values, the students and faculties can both benefit from the big data technology [15].

2 Researches in China and Abroad

Research by the international data analysis company IDC shows that digital universities created or collected 2.25×10 bits of data in 2007 alone, and estimates that such data will grow by 60 % each year, hence the advent of the age of big data. Institutions of higher education are therefore facing the challenge of big data now. Starting with the effective leverage of information technology and the administration and decision-making mechanisms in the institutions of higher learning, this essay herein will explore how to utilize the massive existing data generated by the university information systems in an effective manner and enhance the universities' administrative efficiency and decision-making capacity.

Sang [5] believed that there are two key factors with regard to the prospects of applying big data analysis in universities, and that it is extremely important to closely integrate the business and technology dimensions. Business need is the objective of all data analysis. To analyze data, one first needs to know what to analyze, and only with the need can universities perform data analysis with a target and discover the deeper values of data to facilitate their decision-making. Secondly, data analysis has high requirements for technical professionals who are required to not only master the technology but also familiarize with the campus network operations.

Zhang et al. [14] thought that campuses are now swimming in a constantly expanding ocean of data. Big data has two distinctively different application layers in higher education nowadays: the first layer regarding big data as the achievements of scientific research institutes engaged in collecting, managing and organizing wide ranges of structural and nonstructural data, and the second layer viewing big data as the resource for predictive analysis.

Darren Catalano, a business intelligence expert at the University of Maryland University College (UMUC) [10] noted: "Our existing systems have already produced tons of data. It is only now that we begin to pay attention to these data". The key to big data is the application of better analytical know how in large datasets.

Xu [11] believed that with the advent of the age of big data in China, universities are generating huge amounts of data in their daily operations. Originating from different levels and categories, these data are mostly focused on serving and administrating the faculty and students.

3 Key Factors for Harnessing and Boosting University Brand in the Age of Big Data

3.1 *Building Intelligent University Brand in the Age of Big Data*

Compared to digital campuses, intelligent campuses feature more integration. With the supports of intelligent sensor technology, IOT (Internet of Things) technology, mobile internet technology, big data technology and cloud computing technology, the physical and virtual dimensions of campuses have become increasingly inseparable, and the activities of the faculty and students are already confined on an intelligent campus where the physical space is fused with the digital dimensions as indicated in Fig. 1.

To realize the fusion between physical and digital space, universities need to establish intelligent campus information support platform that is anchored on big data as the core, and with intelligent sensing as the nerve ending, mobile internet as the nerve network, intelligent applications as the support and adaptive personalized user interactions as the target, in order to realize the intelligent application of the

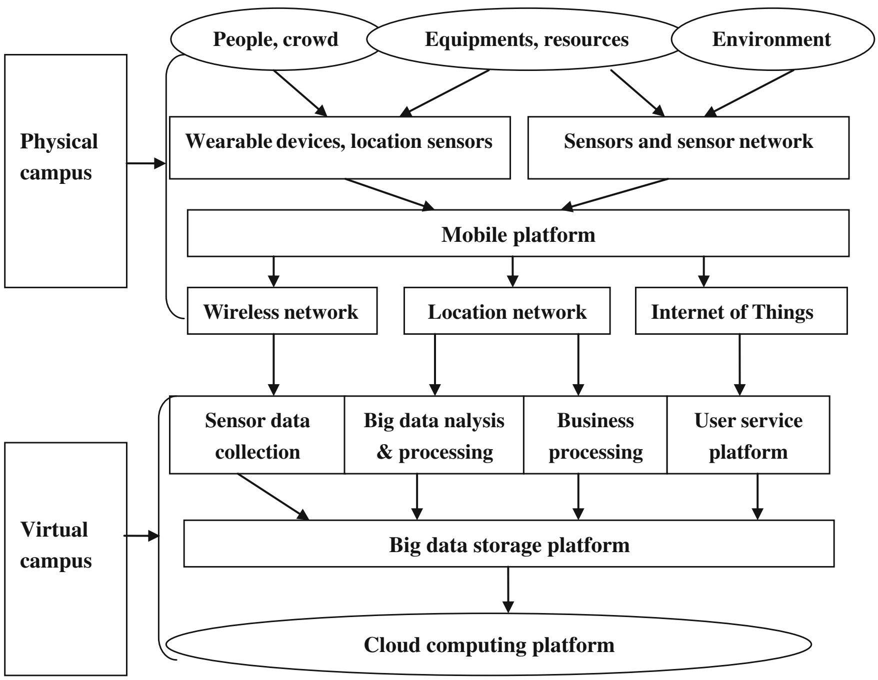


Fig. 1 Intelligent campus of integrated physical and digital dimensions

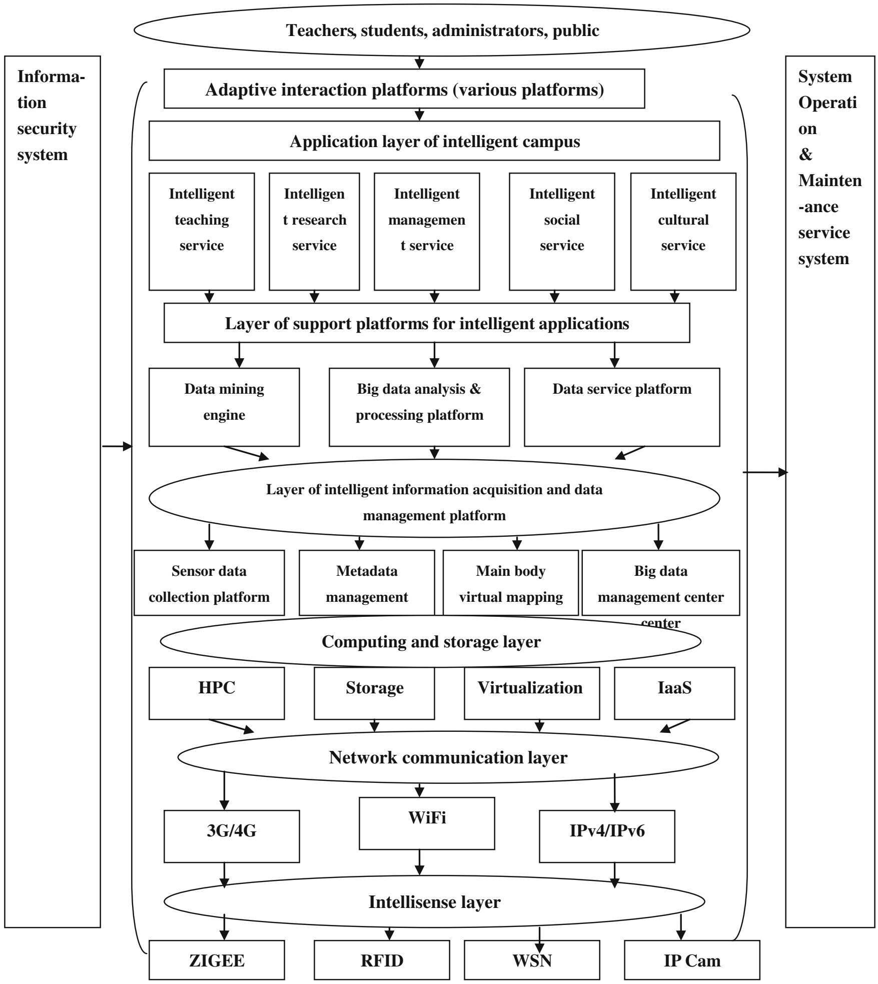


Fig. 2 Architecture of the intelligent campus system in universities

various tasks on campus. Below is a diagram of the architecture of the intelligent campus system in universities (Fig. 2).

1. The intelligent sensing layer
Using various sensing technologies to collect different data in real-time manner and achieve full knowledge of the status of faculty and student activities, operational status of the devices and the interactive status between the learning and living environment, the intelligent sensing layer provides the material foundation for the collection of mass data for intelligent campuses;

2. The network communication layer
Employing both wired and wireless network technology to promptly transmit the various data, and realize access anywhere anytime, full high-speed interconnectivity and application at will, the network communication layer lays a network foundation of ubiquitous broadband availability for intelligent campuses;

3. The big data layer
As the core part of intelligent campuses, the big data layer consists of physical platform for data storage and computation and the platform for information collection and data management, therefore creating a solid data foundation for intelligent campuses;

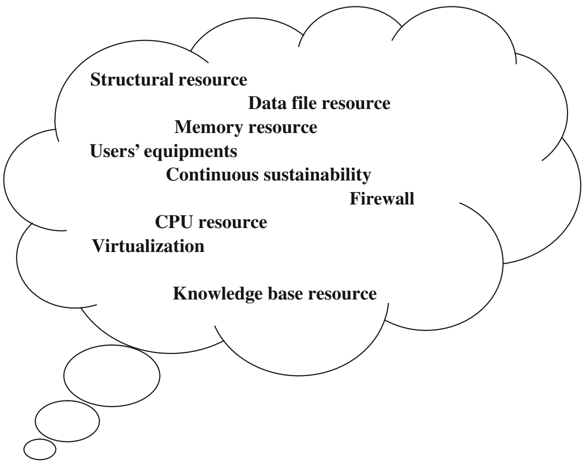
4. The application layer
Comprised of all kinds of information program applications for an intelligent campus such as the teaching, research, administration and service applications, the application layer is the key force allowing intelligent campuses to work.

3.2 Building Mobile Learning Platforms in Universities in the Age of Big Data

Mobile learning platforms are built in the big data era in order to break down the existing limitations to mobile learning in universities. This platform supports universities to offer different learning methods for different learning environments, and realize knowledge accumulation and sharing through the cloud system (Refer to Fig. 3).

In the client model (Fig. 4), the resource data of the knowledge base is distributed to different users in the way of education streams, where legitimate clients are allowed to access and share the resource data after certification and licensing.

Fig. 3 Basic architecture of cloud model and resources



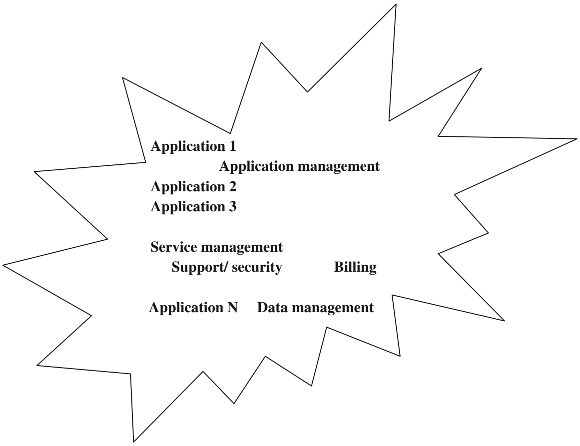


Fig. 4 Basic architecture of client model and layers

1. Fragmentized and personalized learning
As an application of the cloud computing technology in the field of education, this system can automatically analyze the contents that learners wish to study and present a list of the contents, or the users can manually search for the contents they wish to study, without the need of local downloading and with no limitation of time or space.

2. Functions of mobile learning
Featuring rich learning resources, this cloud platform for mobile learning provides one-stop learning services comprised of learning, Q&A, testing and interactive functions [1], intelligently tracks and analyzes the students' learning records, and offers prompt feedbacks through emails. The platform can also enable parents to look at their children's credit reports and performances on campus among other information, thus achieving home-school information communication (Refer to Fig. 5).

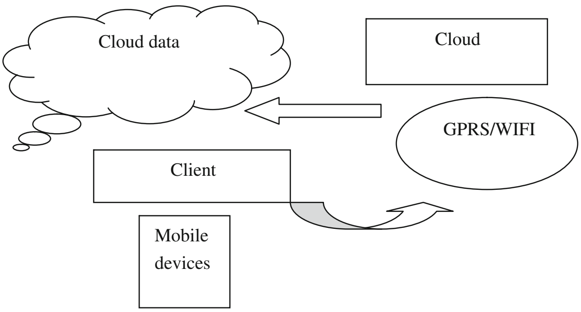


Fig. 5 Mobile learning process based on cloud computing

3.3 Application of Big Data Concept in Job Placement of University Students

Mainly focused on the complete data aggregation of relative groups or targets, big data application in this sphere is using identification, collection, storage, analysis, mining and related technologies to purify and simplify the "new oil of the future" that big data is known as, and employing visualization technology to form a "complete closed loop of data consolidation, analysis, mining and presentation" to help the employment staff better utilize the data to identify, solve and predict problems.

The big data-based job placement system shall be incorporated of: the basic information system of the employers, basic information system of the graduates, the system for analysis of the job market, the system for analysis of the graduates' job searches, graduate assistance system, system for tracking and service of graduated students, and job warning system which together collect, sort out, store and use the job related data (Refer to Fig. 6: Model of the Big Data-based Job Placement System).

3.4 Trends of University Curriculum Development in the Age of Big Data

Publishers may undergo the three stages as below to implement their big data program for university curricula as designed with three levels of difficulty: easy, medium and difficult, in accordance with the cycle of and challenge for implementing big data programs:

Step 1. An operational stage focusing on paperback products, and at the same time, exploring the new business model for digital products, as illustrated in Fig. 7.

Main jobs of the publishers at this stage: renovating and consolidating the existing database platforms, building standardized criteria for collection of data, establishing

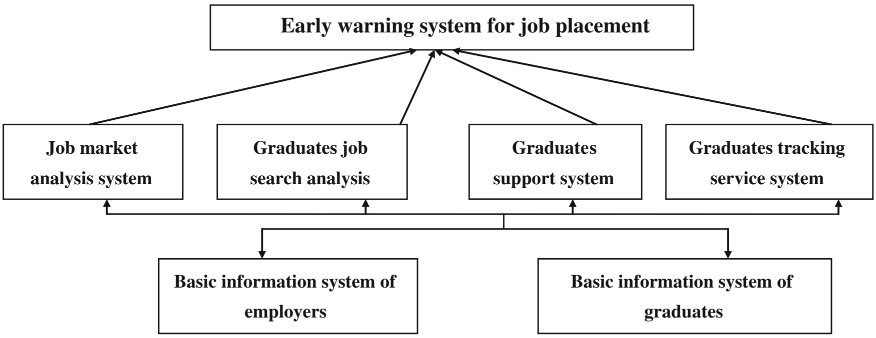


Fig. 6 Model of job placement system based on big data

Fig. 7 Stage of traditional business model

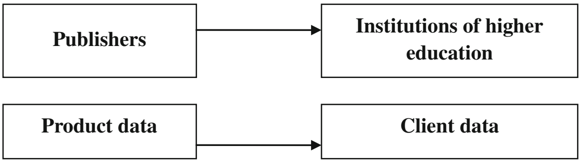


Fig. 8 Transitional stage from traditional business model to the data model

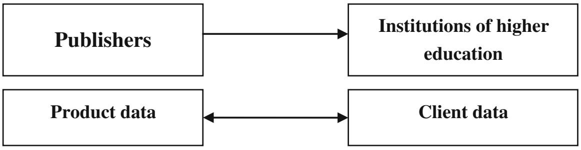
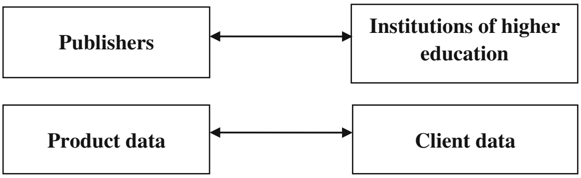


Fig. 9 Stage of new business model in the age of big data



database of user information, and further streamlining the data utilization procedures so as to provide physical supports and momentum for the research and development of current programs and promotion of market [8].

Step 2. A stage emphasizing both paperback curriculum products and digital products, as suggested in Fig. 8.

Main responsibilities of the publishers at this stage: establishing the primary big data mindset in the R&D and marketing campaigns through the building of systematic data platform, establishment of supporting work mechanisms and systems and development of talents.

Step 3. A stage when the business model centered on digital products emerges, as indicated in Fig. 9.

Main tasks of the publishers at this stage: as data utilization enters the stage of in-depth mining, publishers shall design their overall strategies with big data as one of their core competitive edges, while employing capital and administrative means to further consolidate external data and industry resources.

3.5 Information Literacy of University Teachers in the Age of Big Data

(1) Have the ability to use various methods or new technologies for searches (such as the InfoSoft system for innovative reporting service) to understand the research focuses and development trends of their specific disciplines;

(2) Know how to use the information aggregation and RSS function of the information retrieval system to follow the research trends of concerned subjects, and can use reference management software (such as Endnote, Mendeley, Zotero, Refwork, Noteexpress and Notefirst) to manage the reference information and other citation information read or obtained;
(3) Be able to use bibliometric analysis tools to update knowledge of the changing lifecycles of technologies and products; and know about the emerging forms and methods of academic publications in their respective fields such as blogging, information aggregation, open access to journals and free access to online research database.

4 Influences of Key Factors for University Branding in the Age of Big Data on University Brand

We conducted a cluster analysis based on the importance and attractiveness of the various factors for university branding, and found that university students show distinct variations in their perception of the importance of 4 choice influencing factors: educational quality, development of learning platforms, employment prospects and teachers capability.

In this research, we introduced the concept of "key factors for university branding in the age of big data". Wu et al. [9] pointed out that choice of a product is influenced both by personal factors such as needs, interests and values, and product factors like brand differentiations. Tu and Tu [6] also suggested that product dimensions impact both brand preferences and perceived product differences.

4.1 Design of This Research

For the study of the variables affecting student choice of university brand, we made reference to the research method used by He [4], "Study of Preferences of Chinese Consumers for Product Benefits". First, we invited 10 university students to form a focus group and interview "why I chose this university brand", and then studied relevant researches to develop 12 initial variables of influencing factors for brand choice. Afterwards, we asked the randomly selected 10 students to independently rate the importance of the 12 initial variables. Based on the ratings and the consultation with 3 teachers of marketing discipline, we deleted 4 very unimportant variables and attained the 8 initial variables influencing university brand choice, as illustrated in Table 1.

Table 1 Initial variables for brand choice of universities

Code	Variables	Code	Variables
X1	Quality of education	X5	Reputation of universities
X2	Learning platforms	X6	University ranking
X3	Faculty	X7	Employment prospects
X4	Scientific research capability	X8	Tuition

4.2 Design and Distribution of Questionnaires

The questionnaires are divided into 3 parts: questions regarding demographic variables such as age and gender for the first part, questions gauging the 8 initial variables impacting brand choice for the second part and questions measuring the key factors for university branding in the age of big data for the third part. We used the P1A model proposed by Trazzieri [2] which comprises of two dimensions, attractiveness and importance, along with 6 questions [3]. We used the linkert scale with ratings of 1 to 7, 1 meaning very unimportant and 7 very important. We distributed 300 copies of questionnaires on campuses and recovered 204 effective samples, 68 % of the total, which is 10 times that of the measurement variables and meets the requirements for data analysis (Table 2).

Table 2 Respondents' demographics

Demographic	Variables	Samples	Effective samples
Gender			
Male	91	44	44
Female	113	56	100
Age			
18–21 years old	2	1	1
22–25 years old	185	91	92
25–29 years old	15	7	99
More than 30 years old	2	1	10
Record of formal schooling			
Freshmen	36	18	18
Undergraduate students	111	54	72
Graduate students	44	22	94
Doctoral students	13	6	100

4.3 Validity and Reliability of the Questionnaires

In this essay, we used SPSS 17.0 for data analysis and the C ranach's Alpha [12] coefficients of the initial variable part of brand impacting factors in the questionnaires are 0.802 and 0.819 respectively, which is in the range of 0.7 and 0.9, suggesting the survey tool is reliable and has a good internal consistency. Meanwhile, except for the tuition (C0.440) and scientific research capability (C0.481), the communality of all remaining items is higher than 0.5, which indicates that the questionnaire has excellent structural validity. According to the previous qualitative study and the actual situations of university students, reputation and teaching quality are two important factors influencing students' university brand choice and are therefore retained.

4.4 Measurement and Comparison of Influencing Factors for Students' Brand Choice Under Different Conditions

Firstly, we performed a factorial analysis of the dimension items in university branding in the age of big data, conducted a varimax rotation and intercepted data with latent root bigger than 1. The results show that 6 measured variables in the questionnaires are explained by 2 factors, and the cumulative contribution rate is 74.177 % [13].

As shown in Table 3, the first 4 items constitute the "attractiveness" factor, while the last 2 items form the "importance" factor. Secondly, based on the results of factor analysis, we adopted the k-means clustering method for fast clustering of the 204 samples and discovered via comparative analysis that both classification methods are viable.

Findings from cluster analysis: the mean value of category 1 is negative in terms of both the importance factor and attractiveness factor, while that of category 2 is positive, which suggests that category 1 exerts little dimensional influence on university branding, whereas category 2 has strong dimensional impacts on university branding in the age of big data (Table 4).

Table 3 Results from analysis of university brand factors

	Factor	
	1	2
The quality of teaching	0.886	
Employment prospects	0.843	
Scientific research capability	0.813	
Discipline development	0.674	
Faculty		0.895
Intelligent campus development		0.846

Table 4 Results from cluster analysis

	Clustering		
	1	2	Sum
"Importance" factor	−0.5984	0.49154	
"Attractiveness" factor	−0.66069	0.54271	
Quantity of samples	96	112	204
Proportions	47 %	53 %	100 %

5 Conclusions

The research indicates that there are notable differences among university students in their perception of the importance of brand influencing factors such as "teaching quality", "reputation", "scientific research capability" and "faculty", and students attach more values to these factors in the age of big data. We have discovered that in comparison to university students of different eras, the students in the era of big data are influenced by more factors in their choice of university brand. On one hand, this validates the assertion of other scholars that "the different dimensions of university branding in the age of big data influence the perception of product properties and brand preferences". On the other, it fully suggests that university students are willing to receive more product knowledge and brand information in the age of big data. There are two key factors regarding the prospects of applying big data analysis in universities. Firstly, it is extremely important to closely integrate the business and technology. Business need is the objective of all data analysis. To analyze data, one first needs to know what to analyze, and only with the need can universities perform data analysis with a target and find the deeper values of data to facilitate their decision-making. Secondly, data analysis has high requests for technical professionals who are required to not only master the technology but also familiarize with the campus network operations. Although big data sees prospects for extensive applications in universities, it is undeniable that there are still issues needing to be further corrected and probed at the current stage.The branding of institutions of higher education in the age of big data shall therefore be oriented to the developments of different aspects, and universities shall enhance their administration and decision-making to better harness and boost their brand in this era of big data.

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The Research of E-Commerce Enterprises' Price Game: Empirical Studies in China

Yong Huang, Jian Liu, Ronghua Zhu, Lili Jiang and Lingxi Song

Abstract With the rapid development of Internet in China, network economy, especially e-commerce enterprises, plays an increasingly important role in the overall situation of economy. However, excessive and vicious competition among enterprises in the network market occurs frequently, resulting in tremendous waste of resources, lack of fairness and some other consequences. Through focusing on the some typical B2C and O2O cases in China, this paper analyzes the competition behavior and strategy choices of e-commerce enterprises in the market with game model. It focuses on two common e-commerce price games in China, and explores the possibility of market self-regulation. Finally, suggestions are provided to perfect the regulation of the government, which might be good for the healthy development of network economy.

Keywords E-commerce enterprises · Repeated game · Price competition

1 Introduction

Network economy and e-commerce have become a major driving force to promote the development of the world with advances in computer and Internet technology. Although the Internet formally entered China until the 1990s, the growth rate of network economy in China was amazing in the past 20 years. Nowadays, the network economy and e-commerce enterprises have become an integral part of the overall situation of economy. The data of Chinese Electronic Commerce Research Center shows that Chinese e-commerce market scale reached 10.2 trillion yuan at the end of 2013, which has an increase of 29.9 % than last year. Specifically, B2B e-commerce market transaction amounted to 8.2 trillion yuan, which has an increase of 31.2 % over last year, and online retail market deal size reached 1.8851 trillion yuan, up 42.8 % from last year [3]. Chinese e-commerce giants such as Alibaba and Jingdong have

Y. Huang · J. Liu (✉) · R. Zhu · L. Jiang · L. Song
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 925341539@qq.com

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appeared in NASDAQ one after another in 2014, which demonstrated the world's recognition of Chinese e-commerce development.

However, Chinese network economy is still in an immature stage and a lot of problems arise in the development process. For example, the competition of Taxi APP began in February 2014. Although it was welcomed by many young people due to convenience and low price, those who do not use taxi software, such as the elders and the children, might not enjoy it, because they often can't take a taxi when they need to use it. In the price war of e-commerce enterprises in August 2012, some e-commerce enterprises announced the lowest price policy to consumers in the beginning, but consumers were disappointed, and discovered that the types of discounted commodities were limited and most of discounted products were out of stock. The excessive and mendacious price competition indicates that Chinese e-commerce enterprises have serious homogeneity and are lack of innovation in the mode of business competition.

Price war is a competition means for e-commerce enterprises to consolidate their monopoly position and gain profit. This competitive mode, which consumes much capital, can weaken competitors of the same level, annihilate small competitors and prevent the potential entrants, improving market access barriers. However, for its waste of resources and damage of trust in the market, the price war is not a very reasonable competition mode.

The remainder of the paper is organized as follows. Section 2 introduces related researches. Section 3 uses repeated game model consisting of the prisoner's dilemma theory to analyze two common e-commerce price games in China, and explores the possibility of market self-regulation. The game model is tested by two instances of e-commerce price war happening in China recently in Sect. 3.4. Finally we conclude in Sect. 4 and provide recommendations for further research on this theme.

2 Related Literature

With the rapid development of network economy, scholars abroad worked a lot on the behavior of the e-commerce participants. Dube et al. [5] presented a general framework for modeling the competitive equilibrium across two enterprises, within which they studied pricing choices and analyzed the decision to outsource IT capability. Zhao et al. [15] examined the pricing behavior of online retailers (e-tailers) in Chinese e-commerce markets using statistical methods. Cai et al. [1] evaluated the impact of price discount contracts and pricing schemes on the dual-channel supply chain competition from supplier Stackelberg, retailer Stackelberg, and Nash game theoretic perspectives, concluded that the scenarios with price discount contracts could outperform the non-contract scenarios. Yang et al. [14] analyzed the imbalance between e-commerce and logistics service by using factor sub-game perfect Nash equilibrium as a tool from the view of system and linked up the bargaining process between sellers and express enterprise involved in service engineering during online shopping with discount factor. Huang et al. [7] proposed a Stackelberg game model by considering the two suppliers as the leaders and the e-retailer as the follower, assisting the channel members in getting an equilibrium relationship in a competitive environment. Lu an Liu [8] examined two types of Stackelberg pricing games and one type of Nash pricing game in a dual-channel distribution system, in which a supplier sold a common product through conventional (physical retailer) and e-commerce (e-tailers) channels.

While researchers abroad focused their attention on the behavior of the participants in the network economy, domestic scholars became interested in various economic phenomena emerged when e-commerce enterprises participating in the market competition in recent years. Game theory was often used by the researchers to carry out their research. Cai and Zhang [2] analyzed price competition between EB (Electronic Business) retailer and traditional retailer by using game theory model to find Nash equilibrium of price competition. Tang and Fu [11] analyzed the problem of credit in C2C e-commerce using game theory. Ma and Song [9] established a dynamic evolutionary game model between large populations based on evolutionary theory to develop the quality of transaction and promoted the e-commerce development in a healthy way. Xie et al. [13] constructed a static model for individual and a dynamic model for group decision to explore the reasons of choosing the mode for survival and development. Miao and Li [10] established complete information static game and repeated game to explore the key factors affecting the healthy development of C2C market, and proposed some suggestions to promote the harmonious development of C2C e-commerce market. Wang [12] discussed on the issues of "used car" and "lemons", constructed a simple game model and three-phase sub-Nash game model to analyze the above problems.

We can see from previous studies that the game theory was widely used in the analysis of the network economy. The paper also takes advantage of game theory as a tool, but when compared with the above works, the innovations of our research are as follows. First, the paper analyzes the process of e-commerce enterprises' price competition with repeated game model. Second, the study uses actual Chinese price competition examples of B2C and O2O to inspect the reliability of the proposed model. Third, the paper provides some suggestions for government in managing price competition of e-commerce enterprises.

3 Theoretical Foundations and Models Analysis

3.1 The Basic Theory

1. The Prisoner's Dilemma Model

The prisoner's dilemma game model proposed by Davis and Maschler [4] reveals the contradiction between individual rationality and collective rationality. Its content is that supposing A and B are two criminals, they are caught after committing a crime together. For each suspect, the police give policy: both confess, each of them will be sentenced eight years. One of them confess, and the other does not, the confession will be released immediately, the dishonest person will be sentenced 10 years; if both of them do not confess, due to lack of evidence, each will be sentenced one year only. For A, though he doesn't know how to choose, he knows that no matter what the choice of B is, "honest" is always his best choice. Obviously, according to the asymmetry, B will also choose "honest", the result is that both of them will be sentenced to eight years.

2. The Repeated Game
Repeated game proposed by Espinosa and Rhee [6] is that the same structure game repeats many times over a period of time. The one-off game is called "stage game". Repeated game is the dynamic game, it can be complete or incomplete information. When the game only goes one time, every participant is only concerned with one-time payment; if the game is repeated many times, participants may be willing to sacrifice immediate benefits and choose different equilibrium strategies which can bring them long-term benefits.

Trigger strategy has an important influence on the result in a repeated game. If one participant takes uncooperative strategies, the other also take uncooperative strategy immediately and may never take cooperative strategy. It is also known as ruthless strategy.

3.2 Basic Assumptions and Strategy Set of the Model

The price competition among Chinese e-commerce enterprises is always there, and it is continuous. In order to make the model easy to understand, the price game is divided into several phases. Firstly, the paper analyzes a one-off game situation, and then expands it to a multi-stage game, or called repeated game. The basic assumptions and strategies of the model are as followed:

(1) Assuming that only two enterprises A and B compete in the market, their products can be substituted. In the competition, they have found the optimal product price p_0 which can bring them biggest profits when they cooperate.
(2) Assuming that the total demand of market $Q = q_1 + q_2$, and q_1, q_2 are the sales of enterprise A and B. In order to make analysis easy to understand, we assume that demand q has a linear relationship with the price p, $q(p) = a - bp, a > 0, b > 0$.
(3) Assuming that when one of A and B cuts a unit in price, the increasing quantity of sale, $\triangle x = x_1 + x_2$. Here x_1 is loss of competitor, and x_2 is increment of the entire market demand. The x_1 and x_2 depend on sensitivity of the consumers to price change. We introduce β to measure x_1 $(0 \le \beta \le 1)$. That is to say, if A cut 1 unit in price, B will lose $100 \times \beta$ percent of its sales. As for x_2, we only need to know that $x_2 \ge 0$.
(4) Assuming that A and B have the same product cost c. So if R is the profit of the whole market, it is a function of price p, $R = Q(p - c)$.

(5) Strategy set of the players. Since player A and B are symmetrical, they have same strategy set $\{L, S\}$. L is a strategy that the players reduce product price, and S is to stable product price.

3.3 Analyzing the Game Model

1. Single Stage Game Model
When the two enterprises have a one-off price competition, it forms a typical prisoner's dilemma. Analysis of this game is as follows:

(1) If A and B both adopt cooperation strategy. Due to $q(p) = a - bp$ and $R = (a - bp)(p - c)$, so when $p = (b + ac)/2b$, R is the biggest. At this time, A and B have the same sales q_3, $q_3 = (b - ac)/4$, thus, they have the same profits R_0.

$$R_0 = (p - c)q_3 = \frac{(a - bc)^2}{8b}. \tag{1}$$

(2) If B adopts co-operation strategy and A does not adopt cooperation strategy at the same time, then A will reduce product price to get as more sale as possible. Assuming that A cut the price by one unit. So the profit of A at this time is W_1, and $W_1 = (p - 1 - c)(\Delta x + q_3) = [x_2 + (1 + \beta)q_3] = (R_0 - q_3)(1 + \beta) + (p - 1 - c)x_2$, then,

$$W_1 = (R_0 - q_{AB})(1 + \beta) + (p - 1 - c)x_2. \tag{2}$$

The profit of B is W_2,

$$W_2 = (p - c)(1 - \beta)q_3. \tag{3}$$

(3) If A and B both do not cooperate and assuming that they cut their product price by a unit. At this time, the new sale of A and B is equal. It is q_4, then $q_4 = a - b(p - 1)$. The profit of A and B is M, $M = q_4(p - c - 1)$.
(4) If $\beta \geq [q_3 - x_2(p - c - 1)]/(R_0 - q_3)$, then $W_1 > R_0$. Since $x_2 \geq 0$, when $\beta \geq 1/(p - c - 1)$, $W_1 > R_0$. Due to assumptions (1), $R_0 > M$. In e-commerce, the product can be replaced easily, and transfer cost is reduced greatly, so the value of β is close to 1. Thus, W_2 is close to 0. So, $W_1 > R_0 > M > W_2$.

For the game above, we make their payoff matrix.

From the matrix, we can know that (L, L) is the Nash equilibrium of this game, so A and B will not choose cooperation. However, the price war of e-commerce enterprises will not end by one-off game, it is a process. To analyze this process well, the paper use repeated game theory (Table 1).

Table 1 Payoff matrix of A and B

		A	
		L	S
B	L	(M, M)	(W_1, W_2)
	S	(W_2, W_1)	(R_0, R_0)

2. Repeated Game Model

The duration of the price war can be long or short, and this process is composed of single stage game with similar structure. The repeated game has the same Nash equilibrium with its stage game, because its single stage game is the Prisoner's dilemma game. In addition, branches in each stage will adopt the Nash equilibrium strategy. At this time, the price game can be divided into two forms.

The first kind of repeated price game is quite simple. Before time t, suppose company A and B have chosen to take stable pricing strategy S; but A begins to adopt strategy L_0 at time t, and reduce product price. From analysis of the single stage game, we know that B will follow A and cut product price at time $t + 1$, and make its price equal to A's. After that, the two companies will continue their price competition.

The paper shows A and B's game process in Table 2 and A and B's process of reducing product price in Fig. 1. In Fig. 1, for the simplicity of the description, we assume that the initial market price is 100 yuan.

From Table 2, we know, at time t, for A takes the strategy L_0 and B still take strategy S, A's profit increases suddenly. But after B follows at time $t + 1$, the benefit of A reduces drastically. Finally, both A and B will take strategy L_0, and their proceeds were less than their proceeds before time t. If this goes for a long time, both A and B's proceeds will be greatly damaged.

To illustrate this point, the study compares their discounted value of long-term benefits. Since money has time and chance cost, there is a discount coefficient δ, which is used by the enterprise to estimate the future income. For comparing easily, we assume that R_i represents A's profit of time i $(i = 0, 1, 2, \ldots)$. When two enterprises choose to cooperate, A's long-term profit is,

$$R_0 + \delta R_0 + \delta^2 R_0 + \delta^3 R_0 + \delta^4 R_0 + \cdots = \frac{R_0}{1-\delta}. \tag{4}$$

Table 2 The gambling process of A and B

Period of time	1	2	3	$\cdots$	$t-1$	t	$t+1$	$t+2$	$t+3$	$\cdots$
Strategy of A	S	S	S	$\cdots$	S	L_0	L_0	L_0	L_0	$\cdots$
Strategy of B	S	S	S	$\cdots$	S	S	L_0	L_0	L_0	$\cdots$
Earnings of A	R_0	R_0	R_0	$\cdots$	R_0	W_1	M	M	M	$\cdots$
Earnings of B	R_0	R_0	R_0	$\cdots$	R_0	W_1	M	M	M	$\cdots$

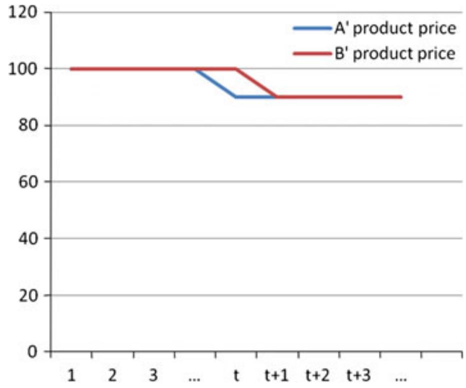

Fig. 1 The graph of A and B product price

Table 3 The gambling process of A and B

Period of time	1	2	3	$\cdots$	$t-1$	t	$t+1$	$t+2$	$t+3$	$\cdots$
Strategy of A	S	S	S	$\cdots$	S	L_0	L_0	L_2	L_2	$\cdots$
Strategy of B	S	S	S	$\cdots$	S	S	L_1	L_1	L_3	$\cdots$
Earnings of A	R_0	R_0	R_0	$\cdots$	R_0	W_1	W_4	W_5	W_8	$\cdots$
Earnings of A	R_0	R_0	R_0	$\cdots$	R_0	W_2	W_3	W_6	W_7	$\cdots$

In the same way, when A and B do not choose to cooperate with each other, the long-term profit of A is $M/(1-\delta)$. Clearly, $R_0/(1-\delta) \gg M/(1-\delta)$.

Assuming that the two companies both focus on long-term benefits, so when they realize that this game is infinitely repeated prisoner's dilemma game, they will avoid lose-lose, and strive for cooperation. So if the value of δ is big enough, A and B will cooperate as soon as possible.

The second kind of repeated price game is special. Before time t, suppose company A and B have chosen to take stable pricing strategy S; but A begins to adopt strategy L_0 at time t, and reduce product price. From analysis of the single stage game, we know that B will follow A and cut product price at time $t+1$, but different from the first kind of repeated game, at this point, the enterprise B is not willing to follow A's reduction, but to revenge A, and to take strategy L_1 which make B's product price lower than A's. At this moment, A's gain is W_3, and B's earnings is W_4. Of course, after the benefit of A is cut, A will take strategy L_2 at time $t+2$. The above strategy is the trigger strategy of the repeated game.

The paper shows A and B game process in Table 3 and A and B process of reducing product price in Fig. 2. In Fig. 2, for the simplicity of the description, we assume that the initial market price is 100 yuan.

In the long term, the benefits of A and B will be far less than the original benefits. According to assumption 1 and $R = -bp^2 + (a+bc)p - ac$ and $b > 0$, R has a maximum. Assuming the maximum is R_{max} and the product price is p_0 at this moment. So whether price p rises or falls, the total market profit will be reduced.

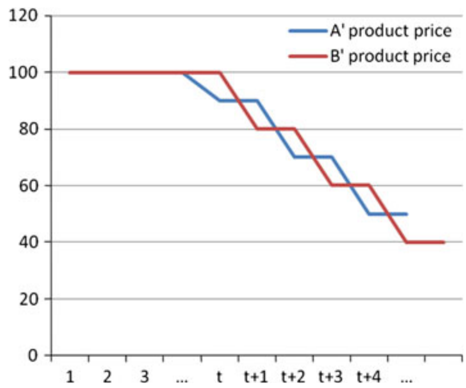

Fig. 2 The graph of A and B product price

The greater the deviation of p and p_0 is,the smaller the total market profits R is. From the above analysis we can get the following relations, $R_{\max} > W_1 + W_2 > W_3 + W_4 > \cdots > W_{2n-1} + W_{2n} > \cdots, n = 1, 2, \ldots$. And vice versa.

With the increase of game, the size of A and B profits are alternating. Though the profits of A and B is lower and lower, they will not change their strategies until they are losing. There are a lot of disadvantages in this kind of price game.

3.4 *Empirical Analysis*

Here, two examples of Chinese e-commerce price war happening in recent years will be analyzed by using the theory and models mentioned above.

1. Example 1

The first kind of repeated price game is mainly product price war of online mall. The price war of Jingdong and Suning happening in August 2012 is a good example. Just as the analysis above mentioned, before Jingdong first began to take the strategy of cutting price L_0, Jingdong and Suning were both willing to sell the product at a high price. However, Jingdong took the strategy L_0 on August 15, 2012. The time corresponds to the time t in Table 2. Suning knew the fact that if it still took the strategy of maintaining price S, its benefit would suffer a lot. So Suning announced that it would take the strategy of cutting price L_0 and remain its product price same with Jingdong's at the time $t+1$. Keeping the game in a certain time, the competitive behavior made their benefits less than before. Therefore, they knew if they continued to do it, they would both suffer from it. About five days later, they reached cooperation consciously, which had them restore the product price at same time.

This shows that due to the pursuit of long-term interests, the e-commerce enterprises in the first kind of repeated price war can return to the rational without outside interference, but it may be a long time process.

2. Example 2
The price game of O2O product mostly corresponds to the second kind repeat price game. For example, the game of taxi APP began in February 2014. Before Alibaba first began to announce that people can take a taxi at a discount by using its taxi APP, which can be looked as taking the strategy of cutting price L_0, Alibaba and Tencent were both willing to have people taking a taxi at a high price. However, in order to get more benefits, Alibaba began to cut its product price. After that, the interest of Tencent was damaged, so Tencent followed to cut its product price, and made its price lower than Alibaba's. The interest of Alibaba was damaged at this time. Therefore, Alibaba did the same thing, too. The price of taking a taxi became lower and lower. Just as the analysis above mentioned, we can see the time when Alibaba cut its product price as the time t in Table 3, and the two enterprises took a lower price than the price of opposite. Keep doing it, ultimately, the two enterprises didn't stop the game until they lost.

This means that the e-commerce enterprises in the second kind repeated price war can not return to the rational without outside interference, and they need the power of the third party intervention.

4 Conclusions and Future Research Recommendation

Due to the great homogeneity among Chinese e-commerce enterprises and the absence of external regulation, it is easy for Chinese e-commerce enterprises to fall into price war. In some cases, it is difficult for them to get rid of the dilemma only relying on market regulation, which means that it requires the power of the third party intervention.

The government can undertake the responsibility. For example, when the first kind price war appears in the market for a long time, the government can increase in the discount rate, and promote the e-commerce enterprises return to a rational way as soon as possible. What's more, the government can use administrative, legal and economic means to prevent the emergence of second kind of price war or to stop it. Finally, the government can also encourage enterprises to pursuit innovation and technology competition instead of price competition. Thus the market competition behavior of e-commerce enterprises can be regulated, and once the market problems take place, they can be solved in time.

This paper analyzed the drawbacks of the price competition of e-commerce enterprises in network economy, and analyzed the possibility of market self-regulation. We also provide suggestions for perfecting the government regulation, which might be good for the healthy development of network economy. For the simplicity of the empirical analysis, we only analyzed two players in the game. However, Baidu carried huge sums of money into taxi software market recently, which will undoubtedly set off a storm and change the game situation. For the multi game like this, the research scope will be expanded in the future.

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System Concept-Based Integrated Model and Application for Enterprise Performance Management

Yanting Yuan

Abstract Based on the latest performance management theory and case studies, this paper proposed a relatively complete enterprise performance management system according to logical thinking of questions raising, analyzing and solving and the actual specific state-owned enterprises (SOE). Researches of performance management theories, methods and applications were firstly reviewed. Through questionnaires, interviews, etc., the problems and causes of enterprise performance management currently were analyzed and summarized, and reasonable and effective solutions were then given. Then, the current four comparative advanced performance management were analyzed and compared. Last, based on the target management theory framework, drawing on the key performance indicators and 360-degree performance management thinking methods, a comprehensive model of performance management was built. The idea, the building processes and functions of the model were also explained.

Keywords Performance management · Integrated model · Factor analysis · Performance improvement

1 Realistic Background of Enterprise Performance Management

As a modern management tool, performance management has become a driving force for sustained growth and development. In China, a considerable number of enterprises have not built a scientific enterprise performance management system yet,

Y. Yuan (✉)
School of Management, Southwest University for Nationalities,
Chengdu 610064, People's Republic of China
e-mail: Yuan_yt@126.com

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which is consistent with their specific circumstances and China situation. Therefore, theorists and domestic enterprises pay great attention on effective performance management system establishment. With the rapid development of knowledge economy and the growing of global competition, our enterprise business managements are facing severe challenges. Though theorists have advocated systematic, comprehensive and integrated performance management, some enterprises have not yet applied the performance management in the practical application of Chinese enterprises. Some enterprises have adopted partly performance management methods, but they wrongly implement performance appraisal instead of performance management, ignoring the development of staff, and ultimately the capacity for sustainable development of enterprises is limited.

2 Overview on Performance Management Research

For the study of the performance researches, the West began earlier, and they believe that performance mainly works in two aspects: output and behavior [3, 8]. Therefore, two kinds of performance theories are formed. One is the performance output theory, which advocates a results-oriented performance appraisal. Its main representatives are Locke, Latham, Pritchard, Kane, Bernardin, Rodgers, Hunter, etc. Bernardine and other researchers learned from Kane earlier studies [4, 5, 9], and they defined performance as the output record produced by a particular production function or activity within a specific period of time. The sum of job performance is equivalent to the performance sum (or average) of the key or essential job functions. Functions should be concerned with the work being carried out, instead of human characteristics. The base of Pritchard's measure productivity and improvement system theory is that product is the expected activity or target to be completed in the organization and product is the manifestation of performance. However, the view that performance is equivalent to the completion situation of tasks, targets, the results and outputs has been challenged by many theorists, especially the psychologists. Therefore, another performance theory has gradually been formed, that is Performance Behavior Theory. Its main representatives are Murphy, Ilgen, Schneider, Mohrman, Campell, etc. This theory holds that the performance something is made by people or the system, rather than the outputs or results. Murphy also defined it clearly that performance is the actions relative to targets set for the organization or individuals. Following this theory, performance is made to quantify things, focus on the behavior, not the results (Fig. 1).

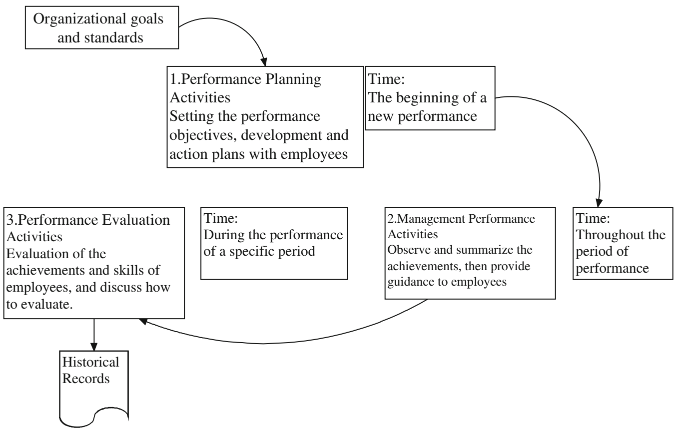

Fig. 1 Performance management cycle of McAFee and Champagen

3 Performance Management Problems in Domestic Corporate

1. Performance Assessment Irregularities

Performance management is a systematic project throughout the enterprise, and should be carried out at any time. As a key part of the performance appraisal, however, performance management should be carried out for a fixed period. Enterprise performance indicators assessment task usually requires a shorter cycle in order that people who work on the assessment is more clear and impressive about the output records of the being accessed. Contextual performance indicators are suitable for a relatively long period of assessment [2], for example half a year or one year, because these indicators are relative stable need longer to conclude. As different performance indicators require different appraisal cycle, some companies implement performance appraisal arbitrarily and the performance appraisal cycle is not fixed, resulting in the failure formation of performance management system in the hearts of the staff and weakening the role of performance management.

2. Lack of Performance Management Training

Training performance management includes performance management, performance purpose, meaning, methods, functions, processes, skills, etc. [1, 3]. The main purpose of the training is to enhance employees and managers' awareness and understanding on performance management, and eliminate misunderstanding and resentment. However, in fact, both the managers and employees are lack of Performance Management related training. Lack of performance management related training, for the supervisors, they can't properly understand the meaning and methods of performance management and guide the performance management work from a whole perspective difficultly, resulting in the a bias between the performance management process likely; for the employees, they also can't understand the importance of the assessment and essentials, become discontent for their managers easily, and thus the examination results do not reflect the real situation, resulting in conflicts between employees and managers and affecting directly the smooth development of performance management.

3. Lack of Communication Links in Performance Management Process
In some companies, as managers control the performance management process and neither guide subordinates to achieve the stated performance goals nor take corrective and corrective actions to reduce the deviations and missing subordinates. Besides, they cannot guide the employees timely when in need and maintain the necessary information by keeping in communicating with subordinates actively. What is worse, the employees have no opportunity to join in the management. They are unaware of their performance objectives and assessment criteria and do not understand the basis for the assessment and incentives and have no opportunity to express their views and to solve the problems. However, the real performance management should allow communication anytime and anywhere so that managers and employees continue to enhance and improve the performance in the process.

4 Integrated Performance Management Modelling

1. Performance Management Model Based on the Traditional Performance Concept
Many scholars have proposed corresponding employee performance management models based on traditional concept of performance, of which the most comprehensive and influential model is proposed by Campbell et al. in 1993. Campbell's model explained two main problems: performance analysis of the performance determinants and performance ingredients classification.

Although there are many factors affecting human performance, Campbell et al. [3] believed that there only three key factors that ultimately can affect the performance. They are: (1) know what to do-declarative knowledge, i.e. knowledge of facts and things. (2) know how to do-procedural knowledge and skills. (3) to be or not-motivation- defined as the choice behaviors.

2. Performance Management Model Based on System Theory
For the system perspective, the work performance level is decided by two interdependent factors: the employee's personal characteristics and work environment, including teamwork, and is a function of individual and team performance and environmental performance, completely different from the traditional performance decided by individuals. Certainly, the purpose for the performance management of the knowledge workers is also different from the reward and punishment in traditional performance management. The performance management of the knowledge workers focused on system resources and expertise purposeful use in order to maximize organizational capacity and enhance individual performance. Therefore, though tra-

ditional performance management model has certain advantages, it can't be applied to a knowledge-based employee performance management and needs re-building. Combined with the characteristics of knowledge workers, the nature of work and the working mechanism, learning from the advantages of traditional performance management model, this paper builds a new model for the knowledge-based employee performance management, as shown in Fig. 2, based on previous performance analysis of knowledge workers.

As shown in Fig. 2, the basic idea of employee performance management model is derived from systems theory: input-transfer-output, including three main parts, i.e. factors affecting performance, performance determinants and performance output. Factors affecting performance and performance determinants determine the knowledge worker performance output, and the performance output is the outcome of the knowledge workers performance. At the same time, the performance output of each component in turn has appropriate feedback on the performance factors and determinants. Thus, the performance management system has the ability to repeat and form the cycle of investment.

According to the former performance model, companies together with employees can analyze the knowledge-based employee performance achievements to find the disadvantages from three aspects: the task performance [6], the relationship performance and the deferred performance. Then corresponding improvement measures can be taken to improve the performance. In addition to knowledge workers own factors affecting the performance, situational factors should be taken into consideration as well. Therefore, situational factors should be considered when improving the performance of knowledge workers. We believe that we can take measures such as work content, emotional or spiritual employees and material incentives to improve knowledge workers performance.

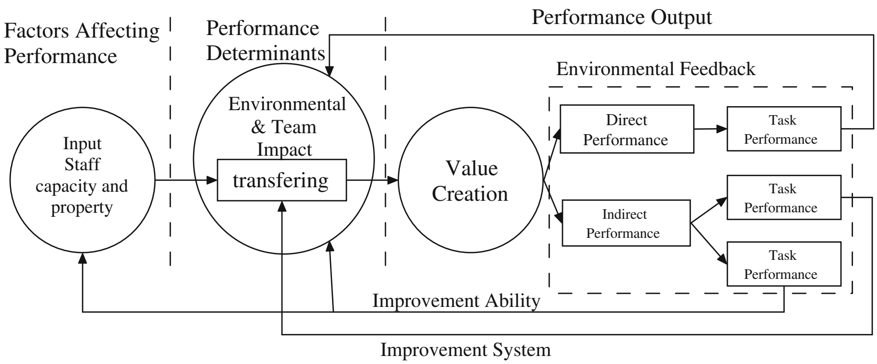

Fig. 2 Performance management model based on system theory

5 Empirical Analysis of Employee Performance Management Factors

In order to find suitable employees motivator of employee performance management factors and take appropriate incentives, the empirical analysis is done as follows to make some constructions to solving this problems.

5.1 Questionnaire Design, Data Sources

According to the characteristics of employees, nature work, workers behavior, and corporate expectations for employee behavior, employee incentives and satisfaction questionnaires are designed by seeking some human resource management experts and high-tech enterprises in human resource executives' opinions based on previous research and survey achievements. Questionnaires are first conducted in a small area for pre-trial, and the response is good. Besides, the reliability and validity test was passed and questionnaires were further refined.

Six furniture typical enterprises of the significance in Chengdu and Beijing were chosen, and workers in these enterprises were required to fill these questionnaires. 249 valid questionnaires were returned after total of 270 questionnaires released, and the recovery rate reached 92.3 %. Five levels (very unimportant, relative unimportant, common, relative important, very important) measures were used to evaluate the problems in the questionnaires [7]. The basic statistical information of staff participated in the survey are as shown in Table 1.

5.2 Analytical Methods

Factor analysis was implied to the data got from the questionnaires. Factor analysis begins from the correlation between multiple original indicators to find a limited number of unobservable latent variables, which are then used to explain the correlation between the original indicators. Suppose there are n samples, m observation indicators $X_1, X_2, \ldots, X_m$. The potential decisive factors: common factors $F_1, F_2, \ldots, F_q$ ($q \leq m$) can be found to explain the relative relationship among original indicators. The model is shown in Eq. (1) as follows. Suppose X_i are standardized data for

Table 1 Statistical information of staff participated in the survey

Project	Gender		Age				Education	
	Male	Female	<23	23–30	31–40	>40	College	Undergraduate
Percent	73	26	3.9	51.3	30.3	15	26.4	73.6

simplicity.

$$\left\{\begin{array}{l} X_1 = a_{11}F_1 + a_{12}F_2 + \cdots a_{1q}F_q + e_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \cdots a_{2q}F_q + e_2 \\ \vdots \\ X_m = a_{m1}F_1 + a_{m2}F_2 + \cdots a_{mq}F_q + e_m \end{array}\right\}. \tag{1}$$

Let

$$X = \left\{\begin{array}{l} X_1 \\ X_2 \\ \vdots \\ X_m \end{array}\right\}, A = \left\{\begin{array}{llll} a_{11} & a_{12} & \cdots & a_{1q} \\ a_{21} & a_{22} & \cdots & a_{2q} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mq} \end{array}\right\}, F = \left\{\begin{array}{l} F_1 \\ F_2 \\ \vdots \\ F_m \end{array}\right\}, e = \left\{\begin{array}{l} e_1 \\ e_2 \\ \vdots \\ e_m \end{array}\right\}. \tag{2}$$

Then Eq. (1) can be rewritten as:

$$\underset{m\times 1}{X} = \underset{m\times q}{A}\,\underset{q\times 1}{F} + \underset{m\times 1}{e}. \tag{3}$$

And the explanation are as:

(1) The mean of X_i is 0, and its variance is 1 ($\overline{X_i} = 0, s_i^2 = 1$). The mean and variance of F_i are the same as X_i ($\overline{F_j} = 0, S_F^2 = 1$). The mean of special factor e_i is 0 and its variance is Q_i^2 ($\overline{e_i} = 0, s_e^2 = \sigma_i^2$).
(2) The correlation coefficient between the common factors is 0, i.e. $r_{F_i,F_j} = 0$. So it is the same with the special factor e_i, i.e. $r_{e_i,e_j} = 0$. The correlation coefficient among the common factors and the special factor is also 0, i.e. $r_{F_i,e_j} = 0$.

In other words, the covariance matrix $\sum_x$ of original indicator vector X and $\sum_F$ (or the correlation coefficient matrix) of Common Unit vectors. The covariance matrix $\sum_e$ of is a diagonal matrix as follows.

$$\sum_x = R_x = I_{m\times m} \sum_F = R_F = I_{q\times q} \sum_e = \begin{pmatrix} \sigma_1^2 & & \\ & \sigma_2^2 & \\ & & \sigma_m^2 \end{pmatrix}. \tag{4}$$

5.3 Results and Analysis

Cronbach was utilized to measure reliability. According to the requirements of psychometric, the reliability is 0.7 or more can be accepted. The reliability analysis of knowledge worker performance improvement incentives in this survey are as: Cronbach Alpha = 0.950, the number of questionnaires N of Items = 26, as shown

Table 2 KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy	0.943
Bartlett's test of sphericity approx. Chi-square	3332.598
df	349
Sig.	0

in Table 2. It is obviously that the reliability is more than 0.7. So the measurement results is reliable.

As shown in Table 2, the Bartlett test results reject the assumption that each variable is independent, i.e. there is a strong correlation between the variables. The statistics of KMO is 0.934, more than 0.7, indicating there is a strong correlation between variables. Therefore, applying the factor analysis in data processing is feasible.

Specifically, the four factors are: factor 1 named achievements and development dimension includes eight factors, factor 2 named welfare income dimension include 4 factors, factor 3 named job autonomy dimension include three factors, and factor 4 named respect and participating dimension include four factors.

From the previous analysis, we can know that for performance improvement of knowledge workers, the incentive factor is nearly consistent to the incentive effect satisfaction factor, but their first two factors' priorities are a little different. The index of achievements and development, welfare and income, working independently and respect are significant for the performance improvement and incentives satisfaction of knowledge workers, which is useful for the implementation of incentives mechanism for knowledge worker performance improvement. According to this results, the incentive mechanism will do a very good effect for knowledge workers incentive as long as the incentive mechanism design is reasonable, thereby laying a solid foundation for improving their performance.

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ISHM-Oriented Sensor Optimization Selection for Aircraft Engine System

Yusheng Wang, Xiaoling Song and Li Zhang

Abstract For an aircraft engine system, it is vital to monitor its health condition using different types of sensors. Selecting a minimal subset of sensors that are the most informative yet cost-effective determines the performance of health monitoring. Integrated system health management (ISHM), a systematic approach to improve the safety and reliability of certain system, can be conducted in sensor selection procedure for the aircraft engine. In this paper, an ISHM-oriented sensor optimization selection model was developed to actively select required sensors. A numerical example is presented to apply the sensor selection approach to an aircraft gas turbine engine. The results demonstrate that the proposed model and algorithm are effective and feasible, and can guide sensor selection for aircraft engine system very well.

Keywords Sensor optimization selection · ISHM · Aircraft engine

1 Introduction

The aircraft engine (AE) is the heart of the aircraft and the health condition of AE directly affects the safety and reliability of the aircraft [1]. To monitor the health condition of AE, a large number of sensors of varying types may be mounted on or inside the engine to sense various physical parameters and monitor the operational and environmental conditions. In order to efficiently provide information to a decision-maker, it is important to avoid unnecessary or unproductive sensor actions. Thus, we must actively select a subset of sensors that are the most informative yet cost-effective.

Integrated system health management (ISHM) is a more comprehensive system, which consists of real-time monitoring, condition assessment, fault diagnosis, prognosis, and appropriate decision making [2]. In recent years, researches on ISHM for AE have been conducted as a means of providing advance warning of failures,

Y. Wang (✉) · X. Song · L. Zhang
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: wys028@yeah.net

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extending system life, and diagnosing intermittent failures [3]. As the foundation of ISHM, health monitoring is crucial to monitor the health condition by sensors and provide condition information to other functions of ISHM, i.e., fault diagnostics [4], prognostics [5], etc. Moreover, sensor selection is the premise of health monitoring and how to select a subset of sensors determines the performance and efficiency of health monitoring [6]. Therefore, sensors should be selected based on ISHM requirements. Many researchers have paid attention to ISHM-oriented sensor selection problem in recent years. Niranjan et al. [7] proposed a new algorithm based on the use of a Bayesian framework for sensor selection with application to on-board fault diagnostics. Yang et al. [8] proposed a sensor selection model by considering the impacts of sensor actual attributes on fault detectability, with application to a stable tracking servo platform. Lyu et al. [9] developed a novel approach for sensor selection based on physical model and sensitivity analysis with application to health monitoring of helicopter transmission systems. And there is rare specific current research on AE system sensor selection, nor considering ISHM requirements.

In this paper, an ISHM-oriented sensor optimization selection model is developed in this paper. This model, which takes sensor cost as optimization objectives simultaneously, and takes ISHM requirements as constraints, aims to select a minimal subset of sensors that are the most informative yet cost-effective. The remainder of this paper is organized as follows. Section 2 presents the conceptual ISHM architecture for AE. Section 3 outlines the procedure of modeling, constructs ISHM-oriented sensor sensor selection model, and the corresponding genetic algorithm. In Sect. 4, a numerical example is conducted to apply the proposed model and algorithm to an aircraft gas turbine engine. Finally, this paper ends with conclusions and proposals for future research in Sect. 5.

2 ISHM Architecture for AE

Due to the system complexity, the inevitable uncertainty, and the large number of parameters of sensors data, ISHM for AE system is a tough task, and it should be realized in parallel with system design [10]. The conceptual ISHM architecture for AE system can be represented by Fig. 1.

The conceptual ISHM architecture incorporates the functions of sensor selection, condition monitoring, health assessment, fault diagnostics, prognostics and maintenance decision support [11]. There are many types of sensors (e.g., temperature sensors, pressure sensors, vibration sensors, proximity sensors, and position sensors, etc.) to monitor AE's health condition [12]. However, considering the factors of cost and monitoring performance, it is necessary to select a minimal sensor subset. The condition monitoring module includes the selected sensors and appropriate signal conditioning circuitry. The signal conditioning circuitry receives the sensor signal from the selected sensors. Then the data preprocess step is used to fuse the data information and extract more valuable information from the monitoring sensor data. The health assessment module receives and fuses sensor data information,

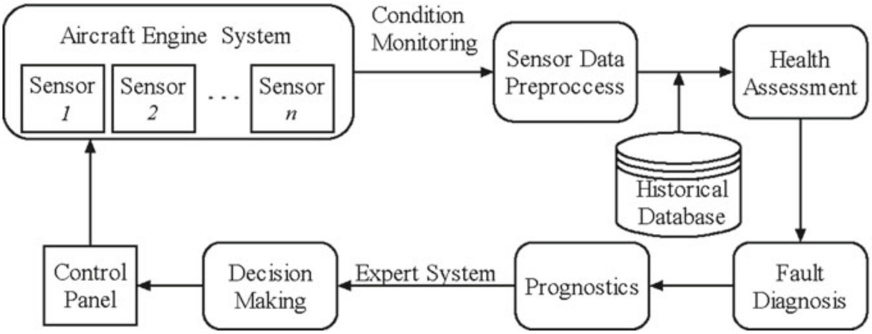

Fig. 1 The conceptual ISHM architecture for AE system

then assesses the health condition of AE combined with historical data. The fault diagnosis module aims to complete AE's symptom detection, fault diagnosis, fault positioning and sorting. The prognostic module receives the data information from the fault diagnosis module to estimate AE's health trends. It generally consists of three parts, namely, fault prognostics, condition prognostics and remaining useful life (RUL) prognostics. Finally, the human computer interface fuses the information from the prognostic module, then makes decisions and feeds back the information to the control panel to adjust AE system.

In the conceptual ISHM architecture, sensor selection plays a fundamental role. The more sensors we use, the more information we can obtain. However, every act of information gathering incurs the cost of utilizing those sensors, e.g., computational cost, operation cost, etc. In order to efficiently provide information to a decision-maker, it is important to avoid unnecessary or unproductive sensor actions. Thus, we must actively select a subset of sensors that are the most informative yet cost-effective. In order to reduce the total cost of AE system and enhance the performance of sensors, this paper proposed an ISHM-oriented sensor optimization selection model, which takes the ISHM requirements into account in parallel with system design.

3 Sensor Optimization Selection Modelling for AE

3.1 The Sensor System of AE

Given the complete sensor set used for selection is $S = \{s_1, s_2, \ldots, s_n\}$, and the corresponding sensor failure rate vector is $F_s = [r_1, r_2, \ldots, r_n]$. Sensor selection situation vector is $Q = [q_1, q_2, \ldots, q_n]$, where $q_j (1 \leq j \leq n)$ denotes the number of the selected sensor s_j. Given there are m fault modes in the system, the fault mode set is $F = \{f_1, f_2, \ldots, f_m\}$, and the corresponding occurring rate vector is $\lambda = [\lambda_1, \lambda_2, \ldots, \lambda_m]$. In this paper, only the evolutionary fault is considered.

A matrix $D = [d_{ij}], i = 1, 2, \ldots, m; j = 1, 2, \ldots, n$ is used to denote dependency between faults and sensors. The rows of D correspond to fault modes, and the columns correspond to sensors. If sensor s_j can detect fault f_i, the element $d_{ij} = 1$; otherwise, $d_{ij} = 0$.

The fault-sensor dependency matrix just roughly describes the simple matched relationship between fault mode set and sensor set. For example, $d_{ij} = 1$ means that sensor s_j can detect fault f_i with probability 1 when fault f_i occurs. In the actual system, due to the sensor itself reliability and the complex environmental factors, a sensor relating to a fault may not mean that the fault can be detected by the sensor with probability 1. Sensor fault detectability is dependent on many factors, such as signal to noise rate (SNR), sensor sensitivity, sensor timely detection rate, etc. According to [13], the fault detectability of sensor s_j to fault f_i can be formulated by:

$$\rho_{ij} = \begin{cases} (1 + e^{-10(V_{ij}-0.5)})^{-1}(1 + e^{-(N_j-0.5)})^{-1}\left(1 - \frac{T_{ij}}{F_{ij}}\right)^{0.5}\left(\frac{Y_{ij}}{F_{ij}}\right)^{0.2}, & T_{ij} < F_{ij} \\ 0, & T_{ij} \geq F_{ij}, \end{cases} \tag{1}$$

where V_{ij} denotes detection sensitivity of sensor s_j to fault f_i, N_j denotes the SNR of sensor s_j, T_{ij} denotes the time span between the initiation of fault f_i (potential failure) and the detection of the fault by the sensor s_j, F_{ij} denotes the duration between the initiation of the fault f_i and the time when the failure occurs, and Y_{ij} denotes the symptom duration time span of sensor s_j to fault f_i.

ρ_{ij} denotes the effective detectability of sensor s_j to fault f_i when the fault f_i occurs. From Eq. (1), we have $0 \leq \rho_{ij} \leq 1$. In addition, T_{ij}, F_{ij} and Y_{ij} can be obtained by fault simulation or fault propagation timing analysis method.

3.2 ISHM-Oriented Sensor Optimization Selection Model

1. Objective function

For large complex systems, the number of sensors need to install is very large, thus sensor-configuration cost is a factor must be considered. In general, sensor-configuration cost mainly includes purchase and installation cost. For simplicity, we assume that the sensor-configuration cost of sensor s_j is c_j. Then the total sensor-configuration cost can be formulated by Eq. (2):

$$C_M = \sum_{j=1}^{n} c_j q_j. \tag{2}$$

In addition, sensor-usage cost must be considered. Sensor-usage cost may include many factors, such as communication, bandwidth and risk-to-sensor. The major energy consumption of a sensor is the communication energy. For simplicity, only the communication energy is considered in this paper. The communication energy consists of two components: the sensing energy and the transmission energy. The sensing energy consumed by the sensor s_j while sensing 1 bit of data is denoted by E_j^s, and the transmit energy consumed by sensor s_j while transmitting 1 bit of data is denoted by E_j^t. The total sensor-usage cost of selected sensors could be formulated by Eq. (3):

$$C_E = \sum_{j=1}^{n} \delta(E_j^s + E_j^t)q_j, \tag{3}$$

where δ denotes the coefficient of energy cost.

Therefore, the total costs of selected sensors can be represented by:

$$C = C_M + C_E = \sum_{j=1}^{n} c_j q_j + \sum_{j=1}^{n} \delta(E_j^s + E_j^t)q_j. \tag{4}$$

2. Constraints

Due to a variety of uncertainties in complex aerospace system, many factors must be taken into account when dealing with the sensor optimization selection problem. Firstly, ISHM requires that the selected sensors can detect all the system fault modes, namely, for each kind of fault f_i, there is at least one sensor to detect it. The mathematical description is shown in Eq. (5):

$$\sum_{j=1}^{n} q_j d_{ij} \rho_{ij} > 0, \quad i = 1, 2, \ldots, m, \tag{5}$$

where q_j denotes the number of the selected sensor s_j, d_{ij} denotes the correlation relationship between sensor set and fault mode set. ρ_{ij} denotes the effective detectability of sensor s_j to fault f_i when the fault f_i occurs.

In addition, the PHM system has certain requirements for testability indexes. The main testability indexes are fault detection rate (FDR), fault isolatable rate (FIR) and false-alarm probability (FAP). FDR is the ratio of the number of faults detected correctly by sensors to the total number of system faults during the stated time span. FIR is the ratio of the number of faults isolated correctly to no more than the stated replaceable units by sensors during the stated time span to the number of the detected faults during the same time span. FAP is the probability of false alarm when the fault is detected by mistake. Considering the impact of sensor attributes on detectability and predictability, FDR, FIR and FAP can be formulated by Eqs. (6)–(8).

$$FDR = \frac{\sum_{i=1}^{m} \lambda_i \left(1 - \prod_{j=1}^{n} r_j^{q_j d_{ij} \rho_{ij}}\right)}{\sum_{i=1}^{m} \lambda_i}, \tag{6}$$

$$FIR = \frac{\sum_{i=1}^{m} \lambda_i \prod_{j=1}^{n} (1 - r_j^{q_j d_{ij} \rho ij})}{\sum_{i=1}^{m} \lambda_i \left(1 - \prod_{j=1}^{n} r_j^{q_j d_{ij} \rho_{ij}}\right)}, \tag{7}$$

$$FAP = \frac{\sum_{i=1}^{m} \left[(1 - \lambda_i) \prod_{j=1}^{n} r_j^{q_j d_{ij} \rho ij}\right]}{\sum_{i=1}^{m} \left[\lambda_i \left(1 - \prod_{j=1}^{n} r_j^{q_j d_{ij} \rho_{ij}}\right)\right] + \sum_{i=1}^{m} \left[(1 - \lambda_i) \prod_{j=1}^{n} r_j^{q_j d_{ij} \rho_{ij}}\right]}, \tag{8}$$

where λ_i denotes the occurring rate of fault f_i, r_j denotes the failure rate of sensor s_j. λ_i and r_j can be obtained by analyzing large amount of historical data or based on experience.

The sensor optimization selection model must satisfy the constraints (5) and (8), meanwhile, make the objective function (2) to obtain the minimum value. From the above, the mathematical model for the sensor selection problem as shown in the following.

$$\min C = \sum_{j=1}^{n} c_j q_j + \sum_{j=1}^{n} \delta (E_j^s + E_j^t) q_j$$
$$s.t. \begin{cases} \sum_{j=1}^{n} q_j d_{ij} \rho_{ij} > 0 \\ FDR \geq \phi_{FD} \\ FIR \geq \phi_{FI} \\ FAP \leq \phi_{FA} \\ c_j > 0 \\ l_j \geq 0 \\ 0 \leq \lambda_i, r_j \leq 1 \\ 0 \leq \rho_{ij} \leq 1 \\ d_{ij} = 0 \text{ or } 1 \\ 0 \leq q_j \leq X_j \text{ and } q_j \text{ is integer} \\ \alpha_j, \beta_j, \gamma_j > 0 \\ 0 \leq \phi_{FI}, \phi_{FA} \leq 1 \\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n, \end{cases} \tag{9}$$

where X_j denotes the upper limit of q_j. ϕ_{FD}, ϕ_{FI} and ϕ_{FA} are constants, which represent the ISHM testability requirements that AE system must satisfy.

3.3 Genetic Algorithm for Sensor Optimization Selection

The constructed sensor selection model is a combination optimization problem and is of nonlinearity property. It is a typical NP-hard problem. Many literatures proposed the corresponding solutions, such as the greedy algorithm, particle swarm optimization (PSO), and genetic algorithm (GA). Due to GA has stronger global searching ability and is more suited to solve discrete optimization problems, GA is used in this paper to solve the constructed sensor optimization selection model.

GA is search and optimization algorithms based on the mechanics of natural genetics. In GA, a population is made up of individuals that represent the candidate solutions to the given problem. The fitness of each individual is calculated from the perspective of the objective function. The near optimality solutions can be obtained through stochastic genetic operators, namely, selection, crossover and mutation. The steps of GA for sensor optimization selection are as follows.

Step 1. Chromosome encoding. First of all, the solution in the solution space must be encoded into the form of binary system, namely, the chromosome. The chromosome stands for an individual solution.
Step 2. The population and parameter initialization, including population size $N_{popsize}$, genetic crossover probability p_c, genetic mutation probability p_m and max iterative number $I_{\max}$. The initialization population, which consists of N chromosome, are randomly generated.
Step 3. Decoding and fitness evaluation. Decode the chromosomes and calculate their fitness. Define fitness function:

$$f(k) = \frac{1}{\sum_{j=1}^{n} c_j q_j + \sum_{j=1}^{n} \delta(E_j^s + E_j^t) q_j}. \tag{10}$$

Justify whether the iterative number satisfies the max iterative number $I_{\max}$. If true, output the optimal objective values and the corresponding optimal solutions, and end the program; otherwise, go to Step 3.
Step 4. Select individuals using roulette wheel selection method based on individual fitness.
Step 5. Execute crossover operation with probability p_c.
Step 6. Execute mutation operation with probability p_m.
Step 7. The new generation of population is generated by the crossover and mutation operation. Return to Step 3.

4 A Numerical Example

In this section, the proposed ISHM-oriented sensor optimization selection model is applied to an aircraft gas turbine engine. The aircraft gas turbine engine has a built-in control system, which consists of a fan-speed controller, and a set of regulators and limiters. The latter include three high-limit regulators, engine-pressure ratio, and high-pressure turbine (HPT) [14]. Different quantity and type of sensors are installed in the components of the engine to monitor the AE's health condition. Figure 2 shows the main components of the aircraft gas turbine engine.

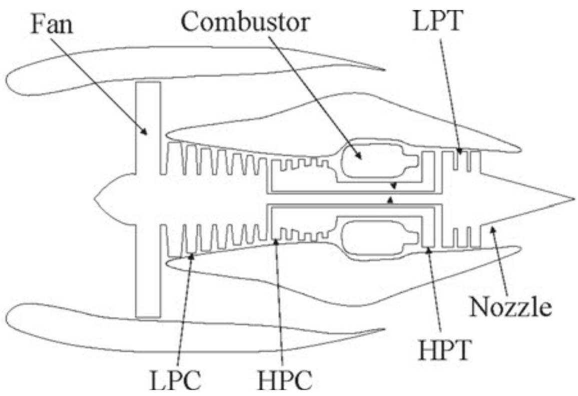

Fig. 2 Simplified diagram for the aircraft gas turbine engine

The available sensors information and the fault mode information of the aircraft gas turbine engine are listed in Tables 1 and 2 respectively. Sensors information in Table 1 come from specification when purchasing them. The data of λ_i in Table 2 are obtained by training a large number of historical data. Because of the limited space for the paper to be printed, the historical data are not listed.

By analyzing historical data, and comparing with similar system knowledge, the fault-sensor dependency matrix of the aircraft gas turbine engine can be obtained combined with FMMEA, as shown in Table 3.

According to Eq. (1), by training a large number of historical data, we obtained the sensors' fault detectability ρ_{ij}, as shown in Table 4.

In order to satisfy ISHM requirements, the required testability indexes are under the following conditions: FDR is no less than 0.98, FIR is no less than 0.95, FAR is no more than 0.01. In addition, to avoid unnecessary or redundancy sensors, we set the upper limit of each type of sensor, $X_j = 7$. Then, the ISHM-oriented sensor optimization selection model for the aircraft gas turbine engine is built as followings:

Table 1 The available sensors information

No.	Sensor symbol	r_j	c_j	E_j^s	E_j^t
s_1	Vibration sensor TZDM22-50	0.84	57.9	187.26	693.45
s_2	Current detection sensor ACS712ELC-05B	1.18	18.5	165.16	762.35
s_3	Optical-electricity sensor E3JK-R4M1	1.22	17.1	203.46	646.80
s_4	Temperature sensor AF3005	1.15	41.8	162.76	635.09
s_5	Rate gyroscope sensor CS-ARS-12A	1.28	84.3	169.07	819.14
s_6	Pressure sensor CS-PT1100A	1.40	41.8	147.88	766.97
s_7	Revolution speed transducer TR-2211	0.83	51.4	129.40	732.38
s_8	Oil level sensor FKLT	1.20	63.4	240.11	866.20
s_9	Burner fuel-air ratio Sensor MQ-2	0.70	48.3	112.21	643.83

Note r_j denotes failure rate of sensor s_j, its unit is 10^{-3}; c_j denotes the sensor-configuration cost of sensor s_j, its unit is dollar; E_j^s denotes the energy expended in sensing and encoding 1 bit of data by sensor s_j, its unit is nJ/bit; E_j^t denotes the electronics energy expended in transmitting 1 bit of data by sensor s_j, its unit is also nJ/bit

Table 2 Failure modes and fault occurring rate

No.	Failure mode	$\lambda_i/10^{-3}$
f_1	Failure in the fuel control system	2.96
f_2	Malfunction in combustor components	4.91
f_3	Too low rotary speed of rotor	3.85
f_4	Crack or fracture in turbine blade or fan	1.24
f_5	The whole engine vibrated terribly	1.17
f_6	Malfunction in lubrication system	3.09
f_7	Fatigue wear in gearbox	1.39

$$\begin{cases} \min C = \sum_{j=1}^{9} c_j q_j + \sum_{j=1}^{9} \delta(E_j^s + E_j^t) q_j \\ s.t. \begin{cases} \sum_{j=1}^{9} q_j d_{ij} \rho_{ij} > 0 \\ FDR \geq 0.98 \\ FIR \geq 0.95 \\ FAP \leq 0.01 \\ 0 \leq q_j \leq 7 \text{ and } q_j \text{ is integer} \\ i = 1, 2, \ldots, 7;\ j = 1, 2, \ldots, 9. \end{cases} \end{cases} \tag{11}$$

Table 3 Fault-sensor dependency matrix of AE system

Fault	Sensor								
	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9
f_1	0	0	0	0	0	0	0	1	1
f_2	0	0	0	1	0	0	0	0	0
f_3	0	1	0	0	1	0	1	0	0
f_4	0	0	0	0	0	1	0	0	0
f_5	1	0	0	0	0	0	0	0	0
f_6	0	0	0	1	0	0	0	1	0
f_7	1	0	1	0	1	0	1	0	0

Table 4 Sensors' fault detectability ρ_{ij}

Fault	Sensor								
	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9
f_1	0	0	0	0	0	0	0	0.92	0.83
f_2	0	0	0	0.88	0	0	0	0	0
f_3	0	0.85	0	0	0.96	0	0.62	0	0
f_4	0	0	0	0	0	0.91	0	0	0
f_5	0.95	0	0	0	0	0	0	0	0
f_6	0	0	0	0.82	0	0	0	0.84	0
f_7	0.86	0	0.65	0	0.91	0	0.85	0	0

Table 5 Sensor selection scheme for the aircraft gas turbine engine

Sensor	s_1	s_2	s_4	s_5	s_6	s_8
Number	3	1	2	1	4	3

A GA is used to solve model (11), and the parameters are set as $N_{\text{popsize}} = 30$, $p_c = 0.6$, $p_m = 0.1$, $I_{\max} = 100$. The optimization results are shown in Table 5. The total sensor configuration cost is 717.5 dollars, and the total sensor-usage cost is 13131.88 nJ.

In order to verify the performance of selected sensors, we collected large amounts of sensor data from these sensors starting work to failure. These sensor data are plotted in Fig. 3.

From Fig. 3, we can see that selected sensors with continuous values exhibit a monotonic trend of system degradation. In general, only those continuous-value sensors with a consistent trend can work well. If sensors have inconsistent end-life trends, it is hard to find trace of system degradation. Therefore, the selected sensors can not only satisfy ISHM requirements with lower cost, but also have a better performance with a consistent trend of system degradation. The analytical results

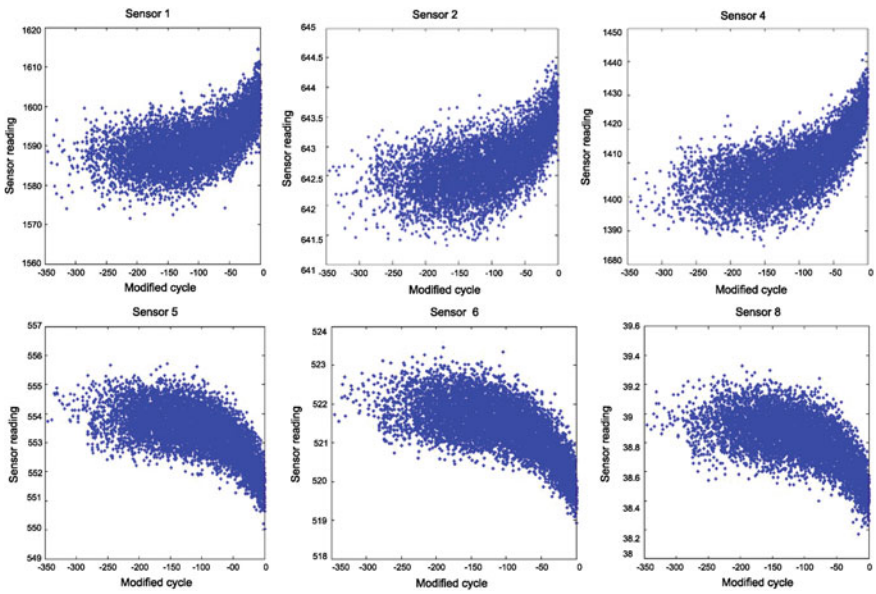

Fig. 3 Selected sensors with consistent degradation pattern

show that the proposed model can guide sensor selection and optimization for AE system very well.

5 Conclusion

ISHM-oriented sensor selection can improve the quality and efficiency of health monitoring. In this paper, we first reviewed ISHM conceptual architecture for AE, and analyzed ISHM requirements for sensor selection. Then we built ISHM-oriented sensor selection model. Then, we proposed a GA to solve the model. In the numerical example, the proposed model and algorithm were applied to an aircraft gas turbine engine. The analytical results show that the proposed model can guide sensor selection and optimization for AE system very well. In the future, we plan to investigate more complex models which considering more objective functions and more constraints, and improve the intelligence algorithm to assist in selecting optimal sensors in order to monitor the health condition of certain system.

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Collaborating in Horizontal Networks of Interprovincial Agreements in Pan Pearl River Delta

Jie Ma, Liming Suo and Wei Chen

Abstract This paper employed a network approach to investigating the inter-jurisdictional networks formed within the Pan Pearl River Delta (PPRD). We examined the overlapping participation of PPRD members in interlocal agreements of environmental protection, tourism, transportation, S&T and culture, migrant labor, public health, and trade. The PPRD members are found to build extensive regional networks to address issues of regional concerns. Although regional economic integration was the initial focus, more collaborative efforts have been devoted to tackle the concerns of minimizing negative externalities brought by rapid social and economic progress. Geographic proximity and resource complementarity play key roles in determining members' scale and scope of cooperation with each other. The Province of Guangdong occupied the most central positions in all the PPRD networks.

1 Introduction

China's phenomenal economic performance has largely been attributed to a competitive environment in which local governments compete with each other to attract business investment, resources and talents. Recently attention has turned to the efforts that involve collaboration among multiple jurisdictions at the regional level. Local governments increasingly confront policy problems that span the boundaries of individual geographic jurisdictions. The need to work together has clustered them into several large regional collaborative zones to address positive and negative inter-jurisdictional externalities caused by rapid social and economic growth.

J. Ma (✉) · W. Chen
School of Management and Economics,
University of Electronic Science and Technology of China,
Chengdu 610054, People's Republic of China
e-mail: maj@uestc.edu.cn

L. Suo
School of Political Science and Public Administration,
University of Electronic Science and Technology of China,
Chengdu 610054, People's Republic of China

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China's major regional collaborative zones formed include the Beijing-Tianjin-Hebei Metropolitan Region, the Yangtze River Delta, the Pan Pearl River Delta and the Mid-China region [14]. Despite the fanfare of media coverage, how these regional collaborative zones work is still understudied. The purpose of this paper is to examine one type of regional collaborative mechanism-interlocal agreements (ILAs) from a network perspective. ILAs are formal and informal arrangements (joint planning, joint policy initiatives, joint programs, contracts, etc.) where one local government collaborates with another or in which multiple jurisdictions pool their resources for joint problem solving, better coordination and more innovation. Scholars and researchers also recognize that multiple local governments that participated in multiple interlocal agreements became regional-level networked governance structures [3, 9]. A regional network of jurisdictions connected through interlocal agreements are manifestations of regional collaborative governance.

This paper proceeds in four sections. The first section is a survey of literature on regional governance. In the second section, we present the Pan Pearl River Delta (PPRD) as a case study of regional cooperation through interlocal agreements. We will analyze a data set of 191 ILAs co-participated by eleven jurisdictions to examine what policy issues these ILAs intend to address. We will answer the questions: What is the scope of interlocal agreements in PPRD? Are they used more in one type of policy domain than another?

2 The Road to Regional Networked Governance

Research on China's regional governance also started with a vertical dimension. The earlier studies have focused on the utility of administrative and fiscal decentralization in sustaining the economic reforms in terms of central-local relationships [7]. The development of China's central-local interaction was touted by political economists as a model of "Market-Preserving Federalism" [5] in which the central government incentivized local governments to undertake reforms, generate more revenues and allocate resources to meet their own needs. At the horizontal level, the reform unleashed the entrepreneurial spirit of local governments, fuelling the rapid growth of local economies, a market-oriented scenario that would be favored by polycentrists.

Over time, when neither centralized authority nor market solution works, China's local governments began to recognize that a decision or action of one government affects the actions of others. According to a survey of local officials, such a recognition of interdependency led to more horizontal and collaborative approaches when two or more local governments seek to create a desirable outcome through coordination or cooperation, rather than competition [6]. Accordingly, Chinese scholars call for a shift of scholarly interests toward regional governance [12]. Collaboration between local governments is believed to be one of the policy instruments to address policy problems of regional significance, particularly for the purposes of economic integration, industrial restructuring and joint planning, and trans-jurisdictional problems and regional public goods [13]. Yet once local governments participate in regional collaboration, it usually has a bandwagon effect-other local governments are also eager to participate for the fear of being left out [8]. Interlocal or intergovernmental agreements have been treated as institutional innovation in regional governance and therefore have received a lot of attention. According to Yang's study [11], on the basis of different participating actors, these agreements can be classified along the three dimensions: vertical, horizontal and cross-jurisdictional.

3 Interlocal Agreements in Pan Pearl River Delta

The Pan Pearl River Delta (PPRD), also known as "9 + 2", was initially suggested in July 2003 by Zhang Dejiang, the Party Secretary of Guangdong and a member of Politburo, as a development strategy of fostering an integral regional economy [15]. The case of PPRD regional cooperation provides us with a unique laboratory for the study of ILAs from a network perspective on the three grounds. First, as one of China's four major regional cooperative zones, the "9 + 2" area spans across China's four geographic areas-eastern, southern, central and southwestern parts, covering nine coastal and inland provinces of Fujian, Jiangxi, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Yunnan and Guizhou and the two special administrative regions (SARs) of Hong Kong and Macau. Although member provinces are mostly contiguous and located in the Pearl River Basin, it embraces one fifth of China's total territory and 55 % of the mainland coastline.

Second, the PPRD carries a third of China's population and contributes 36 % to China's GDP. It is a very vibrant regional economy with an average growth rate of 10.8 , 0.7 % higher than the national average of 10.1 %. Except for Hainan, Hong Kong and Macau, the GDP growth rates of other "9 + 2" members are all above the national average. Third, statistics also suggest that the PPRD is also marked by huge variations in economic performance. The nine provinces and two regions are categorized into four different development levels [4]. While Hong Kong and Macau are considered as the two wealthiest members, Guangxi, Yunnan and Guizhou are treated as three "underdeveloped" provinces . In between, Guangdong and Fujian are two "developed" provinces. Hainan, Hunan, Jiangxi and Sichuan are four "developing" members.

To examine the scope of PPRD's regional cooperation, we compiled a dataset of 191 interlocal agreements participated by nine mainland provinces and two SARs over the time period of eleven years. These are publicly available data published by www.pprd.org.cn. We grouped them into seven areas of policy issues: environmental protection, tourism development, transportation infrastructure, science/technological/cultural collaboration (STC), migrant labor, public health, and trade development. These policy issues that involve positive and negative externalities are clearly trans-jurisdictional in nature.

4 Pan Pearl River Delta as Regional Networks

To explore the PPRD regional governance from a network perspective, we turned to the two-mode network analysis of the "9 + 2" interprovincial networks, defined as the set of relationships among provinces and SARs created by their common participation on agreements. Most social network analyses involve one-mode networks that consist of a single set of actors. The "9 + 2" regional networks we studied are two-mode, consisting of one set of actors and one set of events. Such networks of actors tied to each other through their participation in common events, and common events linked through multiple memberships of actors, are also referred to as affiliation networks [10].

We employed UCINET, analytical software for network analysis [1] to create seven two-mode affiliation networks, one for each policy area, that linked individual "9 + 2" members based on their joint participation on agreements.

4.1 Network Cohesiveness

To what extent the collaboration developed among the "9 + 2" members is cohesive? Do their connections vary across different policy issue networks? To answer these two questions, we look at one network metric-density, measuring the degree to which a network is connected. In binary one-mode networks, network density is the number of ties in a network, expressed as a proportion of the maximum possible number of ties. In valued one-mode projection of two-model networks, the network density is calculated as the average value of tie strength across all ties. By using measure of density, we could determine the degree of shared participation of interlocal agreements that existed among the PPRD members. The larger the density score, the more cohesive the network is. In Table 1, we present the network density values of jurisdiction-to-jurisdiction and agreement-to-agreement networks in seven policy issues.

Table 1 Densities of networks in seven policy areas

Inter-jurisdictional networks (co-participation)			
Environment (14.84)	S&T and culture (13.52)	Migrant labor (12.15)	Transportation (11.60)
Tourism (11.31)	Trade (2.98)	Public health (2.73)	
Inter-agreement networks (co-membership)			
Migrant labor (4.92)	Transportation (3.51)	S&T and culture (3.47)	Environment (2.96)
Public health (2.6)	Tourism (2.12)	Trade (1.21)	

For the inter-jurisdictional networks, the largest group (environment) still topped the list in Table 1 with a density score of 14.84, indicating that the policy issue of environmental protection sees the most connected and cohesive networking ties among 11 jurisdictions. The group of tourism development agreements also accounts for the largest share of total agreements. Yet the jurisdiction-to-jurisdiction network on policy issue of tourism only ranks fifth with a density score of 11.31. In other words, the average number of tourism agreements that the PPRD jurisdictions co-participated is around 11. The third largest group of S&T and culture agreements upgraded to the second place in terms of density. It is the network of migrant labor policy issue that has the largest gains, moving from the fifth up to the third in network density ranking. The rankings for trade and public health policy networks remain unchanged.

The results of inter-agreement networks are different. The largest number of co-membership is seen in the area of migrant labor. For any pair of agreements, on average there are five overlapping PPRD members. S&T and Culture moved down to the third place with a density score of 3.47. The environmental group further moved from the first place to the fourth one. The rankings of two groups upgraded with the transportation group from the fourth to the second and public health group from the bottom to the fifth. Another two groups downgraded their rankings with tourism from the fifth to the sixth and trade from the sixth to the bottom.

4.2 Network Visualization

To ascertain the extent to which there were overlapping participations of multiple agreements among the PPRD members, we used Net-Draw, a network visualization function embedded in UCINET to visually display the structural configuration of inter-jurisdictional network in seven policy areas. In each figure, the symbols of a square represent jurisdictions. To better visually represent the network structure, we deliberately placed provinces and SARs into the diagram layout that is consistent with their administrative boundaries and geographic locations. The lines connecting squares refer to their joint participation of agreements. Also note that some lines are thicker and some are thinner. The sizes of lines indicate the strength of connections and are in proportion to the number of agreements they have in common. The thicker lines represent more agreements and the thinners lines less agreements. As we illustrate each of the figures below, one of the strengths of network visualization is that it can reveal both loose and tight structures [2].

The inter-jurisdictional network connected through collaborative agreements in environmental protection is shown in Fig. 1. The six provinces of Yunan, Guizhou, Hunan, Jiangxi, Guangdong and Guangxi are found to form a tight substructure in the center of the PPRD, primarily because of their geographic proximity. The structural configuration looks like one where a square, consisting of four immediately neighboring provinces (Guizhou, Hunan, Guangdong and Guangxi) is embedded in a large trapezoid (Yunan, Guizhou, Hunan, Jiangxi, Guangdong and Guangxi). The network

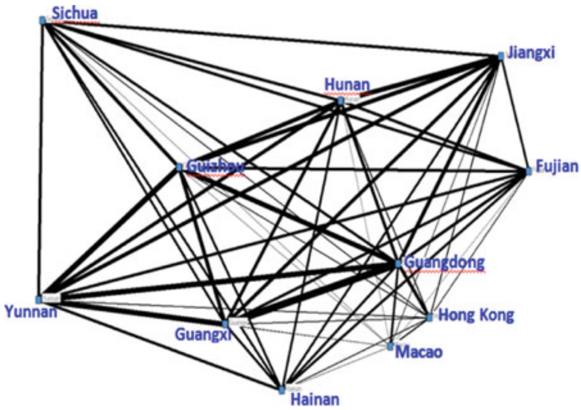


Fig. 1 Network structure in environmental protection

structural configurations of transportation infrastructure and trade look very similar to that of environmental protection. This is perhaps because geographic proximity is a key determinant in fostering inter-jurisdictional collaboration for addressing the issues of environmental protection, transportation infrastructure and trade development.

Figure 2 depicts inter-jurisdictional network formed through collaborative agreements in S&T and cultural collaboration. There are fairly extensive amounts of agreement shared among the PPRD members. Yet the strength of ties varies. As the sizes of lines indicate, mainland provinces have much stronger relationships with each other than their interactions with Hong Kong and Macau. There are two subnetworks: all the mainland members tightly connected as one block and Pearl River Delta (Guangdong, Hong Kong and Macau) as the other block. It is Guangdong as a coastal province that plays a bridging role between mainland members, Hong Kong and Macau through S&T cultural collaboration. This structural pattern is consistent with the fact that the "9 + 2" members are in different economic development stages. It is hard for most developing and underdeveloped inland provinces to engage in

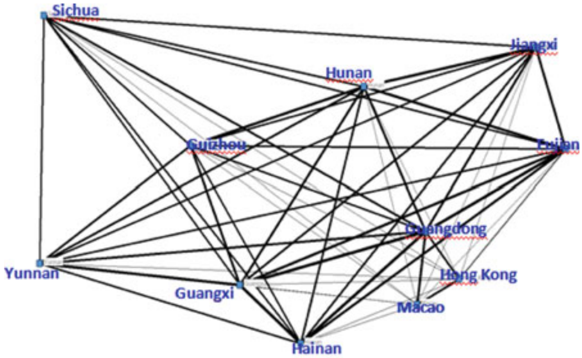
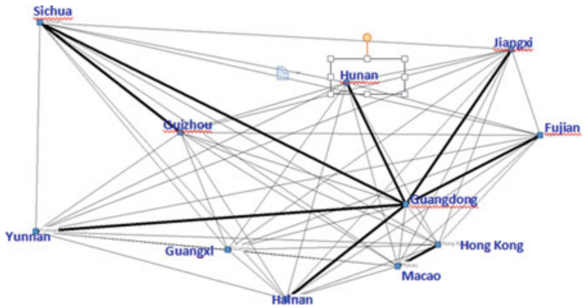


Fig. 2 Network structure in S&T and culture

Fig. 3 Network structure in migrant labor



substantial scientific, technological and cultural exchanges with Hong Kong and Macau as the two most developed members.

The sociogram in Fig. 3 clearly demonstrates a pattern of workers migrating from underdeveloped and developing inland provinces to developed coastal areas. Cities in Guangdong Province have been destinations for workers migrating from poor inland provinces. What emerged is a star-like structure where strong ties radiated from Guangdong, situated as the hub, to the provinces of Sichuan, Yunnan, Hainan, Fujian, Jiangxi and Hunan at the rim. Although also being part of inland provinces, Guizhou and Guangxi had less extensive ties with Guangdong. It might be because these two provinces are overshadowed by Sichuan as the largest labor-exporting province. For pairs of Sichuan and Guizhou, and Hong Kong and Macau, they are geographically neighboring with each other and therefore each has witnessed extensive co-participation of agreements on labor and manpower. However, an examining of agreements suggests a difference.

We also found inter-jurisdictional network in the policy issue of tourism development. The three provinces of Guangdong, Jiangxi and Fujian developed a strong triangle among themselves and Guangdong also built a strong tie with Guangxi. The sociogram in the public health area demonstrates a fairly strong and equally distributed degree of interconnectedness among geographically close mainland provinces. What is worth noting is that Guangdong, Hong Kong and Macau are so connected to each other that they developed an "iron triangle" with very thick lines connecting them. The closure of the triangle is usually an indicator of a strong and bonding network structural configuration. Across all the seven networks, Hong Kong and Macau as two special administrative regions, under the institutional arrangement of "one country and two systems", were usually loosely connected to most mainland provinces. Their connections with mainland were primarily through Guangdong.

5 Concluding Discussion

As network analysis can be a powerful analytic tool in researching governance, this paper contributes to the literature about China's regional governance, empirically and conceptually, using an analysis of inter-jurisdictional networks of nine provinces and two special administrative regions, connected through interlocal agreements within the Pan Pearl River Delta. We draw three implications and one caveat of our findings for theory and practice. First, local governments in China have been always criticized for diversion of scarce public resources to economic development and diverted attention away from environmental and social concerns [15]. Even in regional cooperation, the primary focus has always been on the issues related to local economic development. Yet the results of our analysis suggest a different story. Our network analysis reveals that on average, the PPRD members have the highest co-participation of agreements and the interlocal agreements have the highest co-memberships of the "9 + 2" members on policy issues of environmental protection, S&T and culture, and migrant labor, suggesting that local governments have begun to assume the role they are supposed to play-providing public goods and services, as opposed to simply pursuing economic growth.

Second, the visualization of the PPRD network structures provides us with some clues on what may drive the PPRD members' participation of regional cooperation. The "9 + 2" is intended to serve as an informal partnership in which its members participate on a voluntary basis and are free to pursue strategies on which they agree. In the absence of a centralized decision-making authority, geographic proximity and resource complementarity seem to determine the PPRD members' commitment to work with each other.

Third, the central positions of Guangdong in all the networks, identified by our analysis, illustrate its leading roles in the PPRD regional governance. Being cognizant of its prominence, the leadership in Guangdong should not only take initiatives in addressing key regional issues, but also be careful not to compromise other PPRD members' autonomy.

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Empirical Study On the Influencing Factors of the Public Security Perception Under Vital Emergent Events

Jing Yang and Qiuxia Li

Abstract The public security perception is seriously threatened due to an outbreak of a vital emergent event which is usually generated by the interaction between objective crisis and human's psychological crisis. Through literature reviews, the main influencing factors of it can be summarized as follows: the hypothesis of crisis events, the responsive capability of the government and media, the individual ability of processing emergency and the emergency psychology-behaviors of the group. In this research, four hundred samples, who had suffered from the "4·20 Earthquake" in Ya'an, were investigated with questionnaires. As examined, these four major factors can not only present high degree of polymerization which has been verified by Exploratory Factor Analysis (EFA), but also explain how the public security perception is changing that has been tested through Structural Equation Modeling (SEM). The explaining power of four factors can be described in this descending order: the emergency psychology-behaviors of the group, the responsive capability of the government and media, the hypothesis of crisis events and the individual ability of processing emergency.

Keywords Vital emergent events · Public security perception · Influencing factors

1 Introduction

One crisis event can often be overlaid by objective crisis and subjective perception from people. The subjective perception often does much more harm to people than that of the objective crisis. For example, American society had been deeply affected by the "9.11" terrorism event for about ten years and the fear has continued existing until the present day. When a crisis event happens, the loss of public security

J. Yang (✉) · Q. Li
School of Political Science and Public Administration,
University of Electronic Science and Technology of China,
Chengdu 610054, People's Republic of China
e-mail: yangjin3720@sina.com

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perception will be the greatest threat to common people. They are anxious about many incidents leading to small losses, but they do not pay more attention to these potential lethal risks. Why does this happen? Why does the same type of emergent events have different influence on different areas of the world? Why do the public, who are far away from the spot, have inferior public security perception? These questions indicate that both subjective and objective conditions play a great part in shaping public security perception.

This paper designs a model for influencing factors of public security perception on the basis of the questionnaire survey and the structural equation model analysis. Through careful analysis of these available data and accurate measurement of the effect degree, this paper provides a scientific foundation for building public security perception by making scientific plans and reducing unhealthy emotions of common people under vital emergent events.

2 Concept Definition and Literature Review

1. Definition of Public Security Perception

In this paper, public security perception refers to the sense of certainty, the perceived control and the attributive feeling, all of which are experienced by the general public in the society based on domestic and foreign research results. Firstly, the sense of certainty refers that the public gain sufficient, accurate, on-time and comprehensive information from the mainstream channels, so they can form the definitive understanding and experience about why and how the public crisis has developed under vital emergent events. Secondly, the perceived control refers that people improve their self-efficacy of crisis management after they obtain a complete understanding about the public crisis and an effective evaluation of the social assistance system as well as their own ability. Thirdly, the attributive feeling refers that the public form some subjective experience like safety, warmth and trustiness because of other community members' concern under the pressure of public crisis.

2. Domestic and Foreign Literature Review

The public security perception is a critical issue in the crisis management circle. Researches about it can be divided into two phases according to findings of the research abroad. First, the authors studied it from the perspective of crisis management. The Bounded Rationality Theory of Simon regarded individual rationality as bounded rationality on account of individual limited memories, thoughts and computing power under constraint conditions [15]. In a result, scholars of crisis such as Covello, Sandman thought that most of common people were irrational to participate in the formulation of a crisis policy in case they screwed it up. Moreover people's irrationality leaded to the decrease sense of the public security perception and the increase sense of panic [1]. Dougla, [3] and some other scientists constructed a DAD crisis-management which referred to decide, announce and defend, and proposed that creating public security perception demanded a process that elites expressed science and technology information to general public. Second, the authors introduced Risk Perception Theory and researched public security perception from the aspect of crisis communication. In 1984, as American Businessmen Union Carbide caused an industrial contamination accident and delayed the release of information, panic came into being. Then, many scholars introspected on this incident. Covello [2] found that the authority and the public had dramatically different understandings on risks so that the public showed no confidence in the authority's risk management, and people faced with panic and a weak sense of security at last. Slovic [17] offered over ten influencing factors of public risk perception to explore causes . Kahneman [7] advanced the Prospect Theory in which evolved availability, representativeness and anchoring effect as explanatory variables for the deviation of public risk perception and the loss of sense of security. Seeger [14] absorbed these theories and put forward Two-way Crisis Communication Model, trying to eliminate cognitive differences and regulate public security perception. Health considered the public as a principal part constructing risk knowledge and focused on the function of public participation which contributed to using the framework of crisis governance to rebuild crisis communication's value and goals [4]. What Renn's expedition further discovered was that trust was an intermediary condition of creating the public security perception under public participation [12]. Slovic [16] revealed that the trust and credibility were built slowly but could be lost almost instantly.

In our country studies of public security perception had achieved important progresses with the help of overseas research though it started relatively late. Firstly, the author analyzed influencing factors of public security perception. By means of the Prospect Theory Sun [18] built a research model about panic perception of the individual from there perspectives: the events own features, the individual characteristics and the social factors. Li [9] discovered the law of Psychological Typhoon Eye which said that the nearer the earthquake zone where more emergency measures had been provided, the more security people got by analyzing the earthquake in Wenchuan where emergency measures had great impact on the public security perception. Li [10] measured the level of public security perception from three aspects of safety needs, belonging needs and some certainty in perceived control after researching victims of earthquake in Wenchuan. By using the Risk Perception Theory, Zhang and Wei [21] recognized that factors such as the transmission channel, the individual, the group could enlarge the influence of public crisis. Hereby, they established an influence model of hypothesized experience of information transmission on social psychology. Secondly, the authors discussed the intervention of public security perception. After the outbreak of SARS, Xie [19] defined public rationality whose prerequisite is the public security perception obtaining by crisis communication. Zhang [21] presented that an effective supply of information was able to strengthen the public security perception of human beings and then constructed a supply mechanism of governmental information from three dimensions: the risk attitude, the risk cognition and the governmental credit. Wei [20] approved that the crisis spreading ignoring influences of common people's subjective perception might destroy the public security perception which could be regulated through directing and classifying communication contents, encoding modes and channel choices.

3 The Hypothesis of Public Security Perception

1. The Influencing Model of Public Security Perception
On the basis of literature reviews and analysis of government's practices of serious emergencies in our country, we extract four major influencing factors: the crisis events, the response capacity of the government and media, the responsive ability of individuals and the emergent psychology-behaviors of the group, as shown in the Fig. 1.

2. Research Hypothesis
Hugh Barr [11] put forward the idea of risk management and believed that the compound crisis both brought up physical injury and psychological harm from his analysis of the Great East Japan Earthquake/Tsunami hitting in the northeast of Japan on March 11th, 2011. Thus I make several assumptions as follows:
Hypothesis 1. (H1) The level of public security perception has a negative relationship with the cleft type, the influence scope and the number of casualties under vital emergent events. The more seriously the crisis has developed, the more anxiety there will be.

DeFleur [13], an American communication expert, advanced the Media Dependency Theory which indicated that people were eager to know the facts of matters from the government and media when the society had been greatly changed with unknown situations. Furthermore, they became more dependent. Consequently, giving a contemporaneous warning as well as an objective and fair report of the crisis by the government and media were favorable to reassure common people and prevent situations from becoming more serious. Thus I make several assumptions as follows:
Hypothesis 2. (H2) There is a positive correlativity between the government and media's responsive capability and the public security perception in the emergent events. The more quickly, more sincerely, even more effectively do the government and the media replay to a crisis, the more safety the public will feel.

The FPC model which means familiarity, predictability, and capability, was developed by Robert Heath who assumed that individual capacity and familiarity were kernel variables for an effective response to the crisis [5]. If individuals had higher

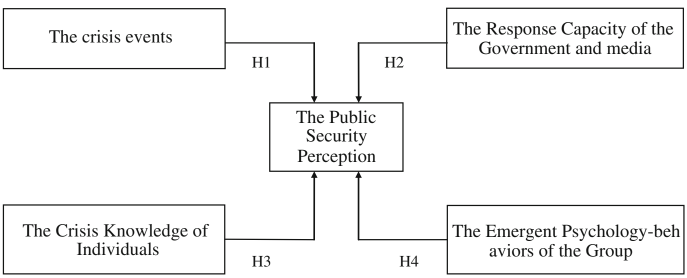

Fig. 1 Influencing model of public security perception under vital emergent events

ability and became more familiar with the crisis, they could deal with the critical challenge better.

Huang and Gao [6] pointed out that public emergencies would produce individual stress reactions and individual differences. The difference was originated from cognitive factors, emotional factors and individual personality characteristics. Thus I make several assumptions as follows:

Hypothesis 3. (H3) The level of public security perception is closely related to the knowledge of crisis, the risk preference and the psychological quality of individuals. The stronger ability about risk-resisting of individuals, the safer it is to the public.

According to the theory of Herd Behavior, a tested scientific theory, individual performances were directly affected by actions of surrounding population, in other words, behavior selections were likely made more for the ease of imitation and reliance on others than for any valuable information. What's more, the conformity will arise in the end. Thus I make several assumptions as follows:

Hypothesis 4. (H4) The positive correlation is observed between the Herd Behavior and the public security perception. The more stable behaviors of the group hold in psychology, the more stable the public security perception will be.

4 Research Methods and Tools

1. Measurement Scales

The study employed questionnaire survey as one methodology to collect data. The author investigated residents of Ya'an suffered from the "4.20 earthquake". The questionnaire could be classified into two parts. The first part was a measurement of the public security perception reconstructing from A. Maslow's "security-insecurity questionnaire". The second part is about questionnaires on four influencing factors. In the analysis of factors and projects, 23 items were chosen to compose the final scale, which is rated by using five-point scale and examined by five experts.

2. Descriptive Statistical Analysis

Totally 400 questionnaires were sent out, among which 385 questionnaires were received, for a response rate of 96.3 %. A total of 368 able responses were received out of an eligible sample of 400, representing a 95.6 % response rate.

3. Descriptive Statistical Analysis

Maslow's "security-insecurity questionnaire" was used in the first part of the questionnaire. The second part investigated these samples through internal consistency analysis, as shown in Table 1. Results showed good internal consistency (the Cronbach alpha was 0.82).

4. Exploratory Factor Analysis

By exploring factor analysis, we analyzed these samples with SPSS, as shown in Table 2.

The results showed that items of the questionnaire had a great convergence on these four hypothesis elements.

Table 1 The result of internal consistency analysis

Reliability statistics		
Cronbach's alpha	Cronbach's alpha based on standardized items	Items
0.820	0.829	19

Table 2 The result of exploratory factor analysis

Rotated component matrix				
	Components			
	1	2	3	4
V5			0.832	
V6			0.841	
V7			0.758	
V8	0.756			
V9	0.778			
V10	0.723			
V11	0.730			
V12	0.742			
V13	0.713			
V14	0.540			
V15				0.415
V16				0.838
V17				0.837
V18		0.605		0.335
V19		0.733		
V20		0.704		
V21		0.551		
V22		0.744		
V23		536		0.306

Extraction method: Principal component analysis; Varimax with Kaiser normalization; a. Rotation Converged in 5 Iterations

5 Conclusion

The model was tested with the software of Analysis of Moment Structure (AMOS) and all indexes were up to the expectant targets. Therefore, the model had powerful interpreting ability, as shown in Fig. 2.

As it turned out, there was a unique negative correlation between the influences of crisis events and the public security perception. However, the other three factors had a positive effect on the public security perception, which could verify the above four assumptions. These findings also suggested that the emergent psychology-behaviors

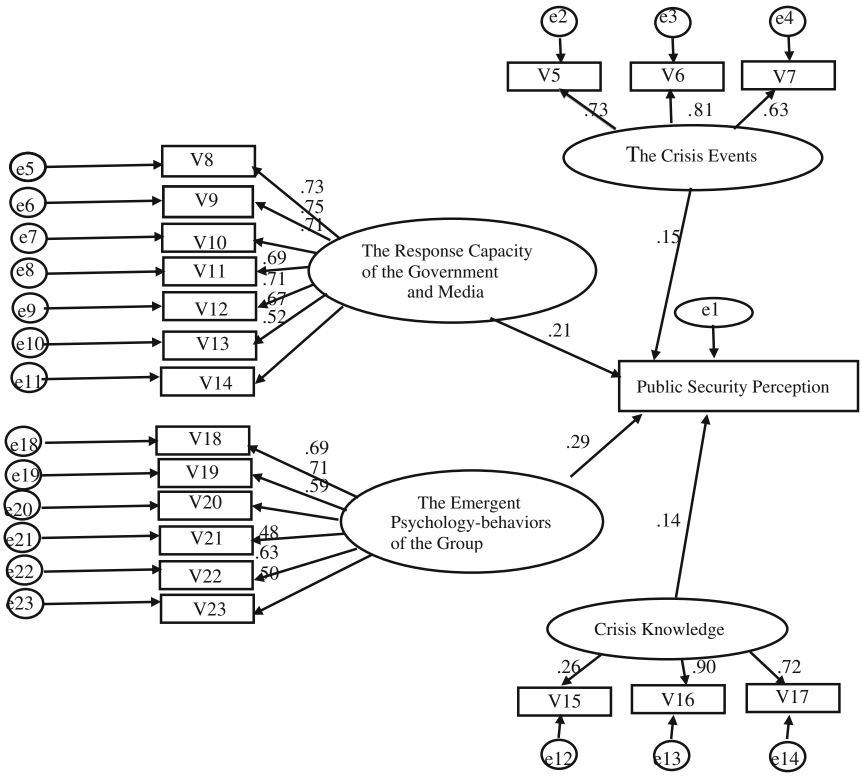

Fig. 2 The model of the public security perception

of the group had the greatest effect on the public security perception, followed by the response capacity of the government and media, and the next came to be the responsive abilities of individual based on values of all measuring factors.

6 Discussion

The study suggests that once a serious emergency occur, the psychological status and the reaction behaviors of the group have a most tremendous impact on the sense of security. In a word, emergent psychology-behaviors of the group have a great impact on the public security perception under vital emergent events. With different social background, the risk tolerance of social culture, the affinity-diaphaneity relationship, the level of social education, and the consciousness of crisis countermeasures, all of which are caused by social, historical and cultural factors, will affect the status of public security perception under a crisis. How to strengthen crisis education of the whole society to enhance people's ability to perform rationally and orderly is the top priority of constructing public security perception in a risk society.

The common herds regard the government and media as a symbol of common power and a main channel to obtain crisis information under the pressure of a crisis. So they play an important role in constructing public security perception. The roles can be affected by the trust between the public and the government and media. Common herds' judgment about danger and fear is strongly coupled to their confidence for public institutions. The less confidence, the more fear and panic the public will have [11]. The government should adopt an active attitude towards controlling the state of serious emergencies effectively and develop good trusted relationship with the public. The trust for the government capacity will not only help the government to deal with emergent events effectively, but also enhance the public security perception after disasters. The media shall truthfully and timely disclose information as required by the principle of news reporting and inform disposition most concerned by common people.

The cleft type, the influence scope and the number of casualties, to a certain extent, are not conducive to the public security perception. Therefore, it is important to cope with crisis objectively and to recover the public security perception fleetly. Besides, the knowledge of crisis, the risk preference and the psychological quality of individuals can partially explain the variation degree of public security perception. On the whole, these four factors have different explaining power of the public security perception under vital emergent events. To what degree the serious emergency affected healthy people depends on the individual personality, the urgent incident and the social environment [8]. Under the stress of critical incidents, indications of emergency response of the group like public security perception are affected by the interaction of the social individuals, the crisis event and the social environment.

Eventually, the present study needs to be explored in depth. On one hand, the four factors need to be further subdivided into smaller elements and the influence of these approaches for the public security perception need a further study. On the other hand the sense of certainty, the perceived control and the attributive feeling are there structural elements of the public security perception. Then how the four major factors act on these structural factors shall be analyzed in depth too.

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R&D Project Portfolio Selection in a Bi-Level Investment Environment: A Case Study from a Research Institute in China

Jun Gang, Ruijia Hu, Ti Wu, Yan Tu, Chun Feng and Yang Li

Abstract This paper focuses on a R&D project portfolio selection problem in a bi-level organization. In the organization, the considered project portfolio can be supported by two levels of funds, that is company fund and department funds. Thereinto, company fund can support all projects while department funds only support projects from a specified department. Hence, in contrast to prior studies, two levels of budget constraints are considered in project selection. To solve this problem, a multi-objective mixed integer programming model which considers three objectives (i.e., maximization of average comprehensive evaluated score, maximization of total expected profit and minimization of average project risk) is proposed. Finally, a practical R&D project selection case from a research institute in Western China is discussed, and the efficiency of the proposed model is evaluated.

Keywords R&D project · Portfolio selection · Multiple-objective · Mixed integer programming

1 Introduction

R&D project selection is a normal problem for most of companies and laboratories. The essence of this problem is to allocate scare resources such as fund, equipment, manpower during multiple competing projects so as to maximize the companies' benefit. The original research on R&D project selection can be found in Markowitz's paper "Portfolio selection" in 1952 [6]. After that, Centron [3] and Baker [1] discussed on how to evaluate and select R&D projects using quantitative methods and

J. Gang (✉) · T. Wu · C. Feng · Y. Li
Sichuan Institute of Building Research, Chengdu 610081, People's Republic of China
e-mail: gangjun@aliyun.com

R. Hu
School of Economy & Trade, Hunan University, Changsha 410079, People's Republic of China

Y. Tu
Business School, Sichuan University, Chengdu 610064, People's Republic of China

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mathematical model. In R&D project selection, two types of methods are mainly used. One is the multi-criteria evaluation technology, and the another is mathematical programming method. For example, the applicability of the Least Squares Monte Carlo (LSM) in valuing R&D investment opportunities was showed [8]. Coffin and Taylor considered a project selection with multiple criterion including investment income, resource constraints, project budget, project time limit, complete probability and so on [4]. Moreover, the risk of over-investment in enterprise development was also considered as one of the evaluation criterion in some researches [7]. Fang etc. carried out the comprehensive study for R&D project portfolio selection, and established a mixed integer programming model. In the model, the uncertainty was considered, and a stochastic programming model was used to analyze the risk of investment [5]. Later, the research of R&D project evaluation and selection problem was expanded to a new field, where the candidate projects are correlative with each other. To deal with this problem, Bhattacharyya et al. [2] set up a fuzzy multi-objective decision model with three objectives, including lowest cost, minimum risk and maximum profits.

The above researches have made significant contributions on the development of the R&D portfolio selection optimization methods, however, they didn't consider the portfolio selection in a bi-level organization, therefore, two levels of budget constraints weren't taken into account. In this paper, a multi-objective mixed integer programming model which considers three objectives (i.e., maximization of average comprehensive evaluated score, maximization of total expected profit and minimization of average project risk) is proposed, with consideration of the two levels of Q&R funds (i.e., company fund and department funds).

The reminder of this paper can be structured as follows. A detailed description of the R&D project portfolio selection problem in a bi-level investment environment is presented in Sect. 2. In Sect. 3, the model for the R&D project portfolio selection problem is formulated. A case study is then discussed in Sect. 4 to verify the optimization method proposed in this paper. And the conclusion remarks are given in Sect. 5.

2 Problem Statement

The problem considered in this paper is a R&D project portfolio selection problem in a bi-level organization. In the R&D management of bi-level organization, there are two levels of managers and two levels of science &technology funds to support R&D projects. The science &technology funds are composed of company R&D fund and department R&D fund. Each R&D project can apply for sponsoring from both the company fund and department funds. But each department fund only supports the R&D projects from the same department. In practice, the management process is shown as Fig. 1. First, applicants submit project applications to department managers.

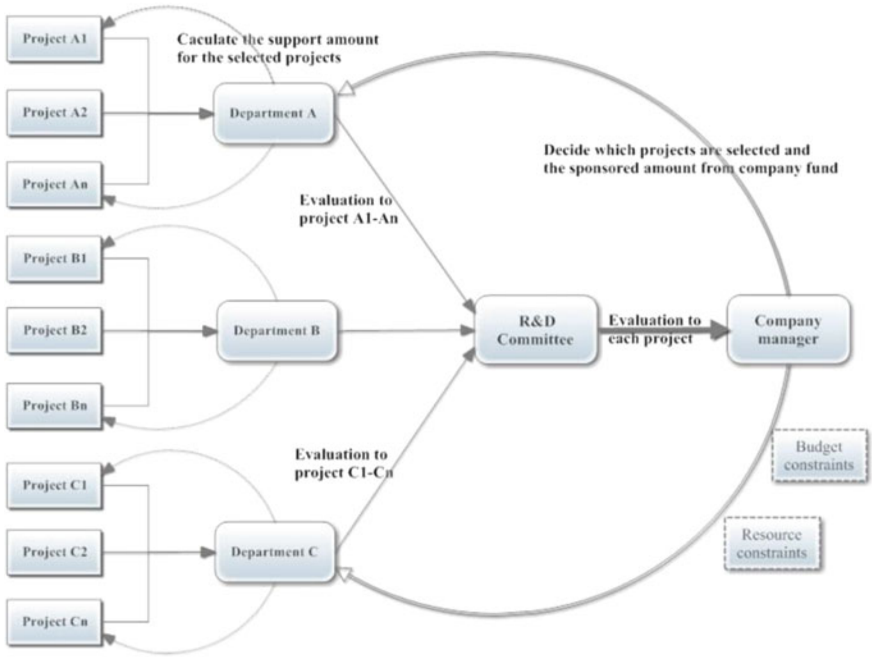

Fig. 1 The management process of R&D project in bi-level organization

Then department managers decide whether or not agree the applications based on comprehensive evaluation. The approved projects are passed to R&D committee for further evaluation. The R&D committee will examine and approve the projects including the technical feasibility, innovation, project execution, budget, potential profit, project risk, etc. Through the evaluation, each project can get a comprehensive score, then the company manager decides which project should be selected based on the evaluated results.

In this paper, it is assumed that the comprehensive evaluation has been carried out. Hence, the main problem the decision maker faces is how to decide the project portfolio selection. In addition, due to the existence of two levels of O&R funds, the decision maker has also to decide the allocation of funds to maximize the profit. In this situation, two decision variables are included in the problem: a binary integer variable to describe the project selection and a continuous variable to describe the allocation of funds. Of course, one latent assumption is to use the department fund preferentially. In the process of decision-making, two levels of budget constraints and some resource constraints must be considered.

3 Modelling

In this section, the modelling process of the considered portfolio selection problem is given.

3.1 Assumptions and Notations

Before constructing the model in this paper, the following assumptions are adopted:

(1) The income and demands for each project are clear.
(2) All project applications are submitted at the same time.
(3) There are no new project applications in a project evaluation cycle.
(4) The company fund and department funds are managed by a same manager.

The following symbols are used in this paper:

Indices

i index of department, $i \in \Psi = \{1, 2, \ldots, I\}$,
j index of project, $j \in \Phi = \{1, 2, \ldots, J\}$,
k index of resource, $k \in \Phi = \{1, 2, \ldots, K\}$

Parameters

TB total R&D budget from company investment,
Tb_i total R&D budget of department i,
B_{ij} Total budget of project j in department i,
S_{ij} evaluated score of project j in department i,
V_{ij} expected outcome of project j in department i,
r_{ij} expected risk of implementing project j in department i,
R_{ijk} amount of resources of type k required for implementation of project j in department i,
$\bar{R}_k$ total amount of available resource k,
c_k unit use cost of resource k

Decision Variables

$$x_{ij} \begin{cases} 1, & \text{if project } j \text{ in department } i \text{ is selected,} \\ 0, & \text{otherwise,} \end{cases}$$

y_{ij} the funded amount of project j in department i from company fund

3.2 Objective Functions

In the R&D project selection problem, there are three objectives (i.e., Maximization of average comprehensive evaluated score, Maximization of total expected profit, Minimization of average project risk) under three kinds of constraint conditions: budget constraint, resource constraint, logicality conditions. The detailed description are given as follows.

3.3 Maximization of Average Comprehensive Evaluated Score

Before project selection, managers always have to evaluate every project and give them scores. The score for each project is often obtained by a comprehensive assessment to multiple factors such as potential benefits, scientific and technological merit, project execution and intellectual property rights. Hence, the score reflects a integrated performance for each project, and the decision makers often tend to select the project portfolio with bigger evaluated score. In this paper, we assume that all projects have been evaluated and got a specific score in the range of 0–100. The objective function can be stated as follows:

$$\max F_1 = \sum_{i=1}^{I} \sum_{j=1}^{J} S_{ij} x_{ij} \Big/ \sum_{i=1}^{I} \sum_{j=1}^{J} x_{ij}. \tag{1}$$

1. Maximization of Total Expected Profit

For most of enterprises, the essence aim of research and development for new production and new technology is to gain profit. Hence, to maximize the total expected profit is often considered as an individual objective function in the enterprises' R&D project selection model. The total expected outcome is the sum of the expected profit of all the projects, which can be modelled as the following equation:

$$\max F_2 = \sum_{i=1}^{I} \sum_{j=1}^{J} V_{ij} x_{ij}. \tag{2}$$

2. Minimization of Average Project Risk

Minimization of risk will decrease the chance of failure of the projects and therefore often as an objective in the decision-making of R&D project portfolio selection. Similar to outcome, the expected risk for each project is also assumed to have been evaluated. In this paper, risk scores for each project were subjectively scored within the interval [0, 1], where 0 represents no risk, and 1 represents the maximum possible risk for a project. The total expected risk which is the sum of the expected risk of all the projects can be stated as Eq. (3).

$$\min F_3 = \sum_{i=1}^{I}\sum_{j=1}^{J} r_{ij}x_{ij} \Bigg/ \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij}. \tag{3}$$

3.4 Constraint Conditions

In the considered model, three types of constraints must be considered, including budget constraints, resource constraints and logicality conditions.

1. Budget Constraint
The considered project selection is a portfolio selection problem. The total budget of selected project portfolio can not exceed the total R&D projects budget for whole company which includes two levels of funds: the company R&D fund and the department R&D fund. Hence, the budget constraints are also divided into two types of constraints. First, for each department, the total budget of selected projects can not exceed its total R&D budget. Then, for whole company, the total funding can not exceed the company R&D budget. The two constraints can be modelled as Eqs. (4) and (5).

$$\sum_{j=1}^{J}(B_{ij} - y_{ij})x_{ij} \le Tb_i, \forall i = 1, 2, \ldots, I, \tag{4}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} y_{ij}x_{ij} \le TB. \tag{5}$$

2. Resource Constraint
Except the budget constraints, resource constraint is also usually considered in project selection because of the limitation of resources. For each type of resource, the total demanded quantity for selected projects can not exceed its available amount.

$$\sum_{i=1}^{I}\sum_{j=1}^{J} R_{ijk}x_{ij} \le \bar{R}_k, \forall k = 1, 2, \ldots, K. \tag{6}$$

3. Logicality Conditions
For each project, the funded amount y_{ij} from company fund can not exceed its total budget B_{ij}. Moreover, if a project is not selected, then its funded amount should be equal to 0. In addition, the decision variable x_{ij} can only take value either 0 or 1.

Hence, we have following constraints.

$$0 \leq y_{ij} \leq B_{ij}x_{ij},\ x_{ij} \in \{0, 1\},\ \forall i = 1, 2, \ldots, I;\ j = 1, 2, \ldots, J. \tag{7}$$

From the descriptions above, based on the objectives of expected outcome maximization (1), expected risk minimization (2) and expected cost minimization (3) by synthesizing department budget constraints (4), company budget constraint (5), resource constraints (6) and logicality conditions (7), we can obtain the R&D project portfolio selection model as following:

$$\begin{cases} \max F_1 = \sum_{i=1}^{I}\sum_{j=1}^{J} S_{ij}x_{ij} / \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij} \\ \max F_2 = \sum_{i=1}^{I}\sum_{j=1}^{J} V_{ij}x_{ij} \\ \min F_3 = \sum_{i=1}^{I}\sum_{j=1}^{J} r_{ij}x_{ij} / \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij} \\ \text{s.t.} \begin{cases} \sum_{i=1}^{I}\sum_{j=1}^{J} y_{ij}x_{ij} \leq TB \\ \sum_{j=1}^{J} (B_{ij} - y_{ij})x_{ij} \leq Tb_i,\ \forall i = 1, 2, \ldots, I \\ \sum_{i=1}^{I}\sum_{j=1}^{J} R_{ijk}x_{ij} \leq \bar{R}_k,\ \forall k = 1, 2, \ldots, K \\ 0 \leq y_{ij} \leq B_{ij}x_{ij},\ \forall i = 1, 2, \ldots, I;\ j = 1, 2, \ldots, J \\ x_{ij} \in \{0, 1\},\ \forall i = 1, 2, \ldots, I;\ j = 1, 2, \ldots, J. \end{cases} \end{cases} \tag{8}$$

4 Case Study

In the following, a practical example from a research institute in western China is introduced to demonstrate the complete modelling and solving process.

4.1 Presentation of Case Problem

X research institute is one of the largest comprehensive research institutes in western China, which was founded in 1954, and was restructured as a state-owned enterprise from an administrative institution in 2001. To adapt to the market competition environment, X research institute paid great attention to new technology research and development, and took out a good deal of capitals to support R&D projects. The R&D fund is made up of two parts: one is from the department income (two percent of the department income) and another is from company income (fifteen percent

Table 1 Parameters for 37 candidate projects from 8 departments

Department	No.	Budges	Scores	Profit	Risk	Required resources							
						258	240	700	380	360	400	784	366
						$R1$	$R2$	$R3$	$R4$	$R5$	$R6$	$R7$	R8
A	A-01	240	88	367	0.50	87	0	0	0	0	0	0	0
	A-02	120	76	234	0.33	86	0	0	0	0	0	0	0
	A-03	200	87	369	0.38	138	0	0	0	0	0	0	0
B	B-01	150	82	238	0.12	0	60	0	0	0	0	0	0
	B-02	160	85	260	0.36	0	80	0	0	0	0	0	0
	B-03	170	79	250	0.35	0	92	0	0	0	0	0	0
	B-04	220	88	325	0.48	0	98	0	0	0	0	0	0
C	C-01	120	92	164	0.21	0	0	70	0	0	0	0	0
	C-02	170	83	277	0.54	0	0	60	0	0	0	0	0
	C-03	150	87	291	0.53	0	0	80	0	0	0	0	0
	C-04	100	82	191	0.15	0	0	60	0	0	0	0	0
	C-05	160	85	210	0.34	0	0	120	0	0	0	0	0
	C-06	100	76	130	0.17	0	0	96	0	0	0	0	0
	C-07	250	81	343	0.43	0	0	200	0	0	0	0	0
	C-08	190	91	192	0.65	0	0	170	0	0	0	0	0
	C-09	280	92	411	0.44	0	0	200	0	0	0	0	0
D	D-01	160	84	219	0.38	0	0	0	120	0	0	0	0
	D-02	100	73	159	0.23	0	0	0	80	0	0	0	0
	D-03	200	81	360	0.20	0	0	0	110	0	0	0	0
	D-04	260	87	4178	0.59	0	0	0	100	0	0	0	0
E	E-01	240	83	417	0.12	0	0	0	0	168	0	0	0
	E-02	230	74	420	0.62	0	0	0	0	170	0	0	0
F	F-01	250	89	392	0.48	0	0	0	0	0	140	0	0
	F-02	360	93	654	0.38	0	0	0	0	0	260	0	0
	F-03	100	85	136	0.48	0	0	0	0	0	48	0	0
G	G-01	120	75	168	0.46	0	0	0	0	0	0	66	0
	G-02	100	71	199	0.32	0	0	0	0	0	0	72	0
	G-03	400	71	749	0.12	0	0	0	0	0	0	320	0
	G-04	100	90	139	0.38	0	0	0	0	0	0	40	0
	G-05	300	91	586	0.21	0	0	0	0	0	0	240	0
	G-06	100	87	124	0.37	0	0	0	0	0	0	40	0
	G-07	150	81	191	0.42	0	0	0	0	0	0	80	0
	G-08	200	94	352	0.56	0	0	0	0	0	0	138	0
	G-09	200	95	380	0.45	0	0	0	0	0	0	120	0
H	H-01	350	90	560	0.03	0	0	0	0	0	0	0	240
	H-02	170	78	213	0	0	0	0	0	0	0	0	110
	H-03	300	80	183	0	0	0	0	0	0	0		220

Table 2 A solution of model (8)

Objective values		Department	No.	Sources of funding	
				Department	Company
Weight-sum	14.6	A	A-02	80	40
			A-03	200	0
		B	B-01	150	0
			B-02	160	0
			B-04	10	210
F1	85	C	C-01	120	0
			C-02	30	140
			C-03	150	0
			C-04	100	0
			C-05	0	160
			C-06	0	100
			C-09	280	0
F2	8340	D	D-02	100	0
			D-03	200	0
			D-04	0	260
		E	E-01	240	0
		F	F-01	0	250
			F-02	290	70
F3	0.31	G	G-03	0	400
			G-05	300	0
			G-08	120	80
			G-09	200	0
		H	H-01	270	80
			H-02	0	170

of the gross profit). The department funds can only be used to sponsor the R&D projects from the same department, while the company fund can be used to sponsor all projects from different departments.

In 2013, the total R&D funds had increased to five million yuan, including company R&D fund of two million yuan and department R&D fund of three million yuan. The R&D fund for eight departments are 280, 320, 680, 300, 240, 290, 620 and 270 thousand yuan. At the same time, after a primary selection, 37 projects from 8 different departments were approved to apply for the funds. The basic information of these projects is stated in Table 1. Now the problem the company manager faces is how to decide the project portfolio from 37 projects to gain maximal outcome with minimal risk. In addition, due to the human resource-intensive of R&D projects and shortage of manpower in X research institute, the decision maker must also consider the manpower constraints in project selection.

4.2 Results and Discussion

As we known, Eq. (8) is a multi-objective model. In practice, it is often difficult for decision maker to search for all Pareto-optimal solutions for the multiple objectives. Instead, they tend to transform multi-objective model into single-objective model with weight-sum operation. In the case, the weights for the three objectives in the model are set as 0.3, 0.4, 03 respectively, and the parameters S_{ij}, V_{ij} and r_{ij} are standardized in the range of [0, 1], then a solution of model (8) can be found as shown in Table 2. It can be seen that 24 projects from 37 candidates are selected with weight-sum objective value of 14.6, average composite score of 85, total investment profit of 8.34 million yuan and average risk of 0.31. We can also see that different departments obtain different evaluated results. For example, both department C and G have 9 candidate projects. However, only 4 projects from department G are selected department while 7 project from department C are selected. Based on the selected project portfolio, we can calculate the fund allocation among 8 departments as shown in Fig. 2. It indicates that department G planned to apply more fund than other departments while department C actually obtained the bigger support than department G not only from the total authorized amount but also the rate of the authorized amount and applied amount. It is easy to come into a conclusion that department C is paying more attention to R&D projects.

To analyse the relationship between the project selection and objectives, we also carry out a comparison among three single models. The results are shown in Table 3. It can be seen that, different project portfolios are selected while considering different objectives. If we only consider the first objective (i.e., maximization of average evaluated score), then 24 projects will be selected with high average score, low profit

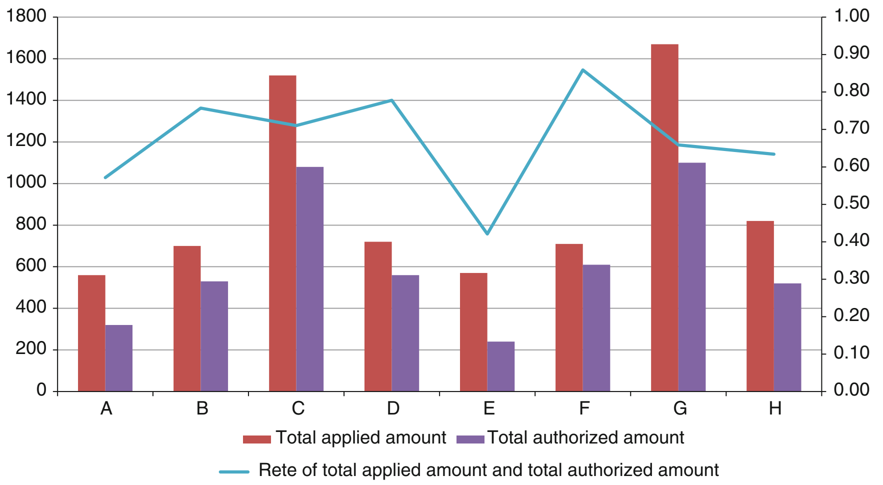

Fig. 2 Results of fund allocation among eight departments

Table 3 Relationship between objective functions and project portfolio

Objective	Objective values			Department	Selected project	Fund from company
	F_1	F_2	F_3			
F_1	87.75	7896	0.38	A	A-01, A-03	160
				B	B-01, B-02, B-04	210
				C	C-01, C-02, C-03, C-05, C-08, C-09	390
				D	D-01, D-03, D-04	320
				E	E-01	0
				F	F-01, F-02	320
				G	G-04, G-05, G-06, G-07, G-08, G-09	430
				H	H-01	80
F_2	84.00	8440	0.33	A	A-02, A-03	160
				B	B-01, B-02, B-04	210
				C	C-01, C-02, C-03, C-04, C-05, C-06, C-09	400
				D	D-02, D-03, D-04	260
				E	E-01, E-02	230
				F	F-01, F-02	320
				G	G-02, G-03, G-05, G-06, G-09	480
				H	H-03	30
F_3	83.00	7808	0.30	A	A-02, A-03	40
				B	B-01, B-02, B-03	160
				C	C-01, C-02, C-03, C-04, C-05, C-06, C-07	370
				D	D-01, D-02, D-03	160
				E	E-01	0
				F	F-01, F-02	320
				G	G-02, G-03, G-04, G-05, G-06, G-07	530
				H	H-01, H-02	250

and high average risk. We can also get similar results while considering the other two objectives. In addition, it should be noted that some projects are always selected regardless of what objective is considered, such as project A-02, B-01, B-02, C-01, C-02, C-03, C-05, C-09, D-02, D-03, E-01, F-01, F-02, G-05, G-06. Hence, these projects should be paid more attentions to than other project in decision-making.

5 Conclusion Remarks

This paper presented a multi-objective mixed integer programming model which considers three objectives (i.e., maximization of average comprehensive evaluated score, maximization of total expected profit and minimization of average project risk) to deal with the portfolio selection problem which considers two levels of funds (i.e., company fund and department funds). The model was then applied in a practical case study in a research institute in wester China to verify the practicality and efficiency of the proposed model and solving process.

The future research will focus on the hybrid uncertain environment and the study on bi-level programming of the portfolio selection problem.

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Wind Power Energy Pakistan Economical Renewable Power Resource

Asif Kamran, Syed Nayyer Ali and Fehmida Raufi

Abstract Pakistan today faces a severe energy crisis with a shortfall of approximately up to 5000 megawatts. Limited fossil fuel reserves increases the dependence on import of fossil fuels, particularly oil on a large scale. Moreover, too much reliance on imported oil is critical from energy security point of view along with the burden on a poor economy of Pakistan coupled with the demand of rural population which represents the major size of the population waiting to be connected to the national electricity grid. The study is based on the descriptive research; data is gathered from different institutions and stake holders namely Pakistan Meteorological Department and Pakistan Council of Renewable Energy Technologies responsible for collecting wind data and identifying wind corridors in different parts of Pakistan. To attract investment in the wind power sector which is relatively new in Pakistan the state has to provide investment and production incentives to the investors such as tax incentives and accelerated depreciation which lowers the cost of capital and motivates the investor to inject high capital. Disbursement of grants and aids to municipal and local corporations having limited resources and announcement of fiscal policy by the state lowering the interest rates on the lending and exempting customs duties on the equipment and wind turbines, eliminating or at least reducing the property tax on the land required for the wind farm.

Keywords Letter of intent (LOI) · National electric power and regulatory authority (NEPRA) · Alternative energy development board (AEDB) · Operation and maintenance (OM) · Internal rate of return (IRR) · Net present value (NPV) · Plant factor (PF)

A. Kamran (✉)
School of Management and Economics, University of Electronic Science and Technology of China, Chengdu 610054, People's Republic of China
e-mail: asifkamrankhan@gmail.com

S. Ali
General Studies Department, Yanbu Industrial College, Madinat, P.O. Box 30426, Yanbu Al Sinaiyah, Kingdom of Saudi Arabia

F. Raufi
Humanities Natural Sciences, Bahria University, Karachi 75260, Pakistan

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1 Introduction

Wind power is the application of wind energy to drive the wind turbines generating electricity mainly for the commercial purpose. Wind power is a renewable source of energy suitable for commercial operation; all of the available resource is availed as unlike fossil fuel wind energy is plentiful, renewable, clean and green house gases free [13]. Wind turbines are usually arranged in a group at a particular location known as wind farms, a large wind farm ranges from few dozen to several hundred wind turbines. The extended area consists of hundreds of square kilometers and the land lying between the turbines is used for agriculture purpose mainly a wind turbine may be located offshore taking the advantage of strong wind speed blowing over the surface of the sea, the turbines are connected with a medium voltage power collection system which is further transformed into high voltage to be connected to the high voltage power grid [6].

In the ancient times the wind power was used to propel sailboats and ships. The wind powered machines were used in Persia and later introduced to Romans however the practical windmills were built in ancient Afghanistan which was made up of sails covered with cloth material these windmills were used for grinding corn and draw up water [1]. In the 12th century A.D the windmills started appearing in Europe which was horizontal axis windmills; they became popular in Europe as unlike water mills they were not rendered inoperable by the freezing of the water in the winter season of Europe. By the 19th Century A.D there were about 2500 windmills in Denmark used for the mechanical work such as pumps and grinding mills and about Six million windmills were installed on American farm lands to operate irrigation pumps [9]. First windmill for electricity production was installed in Scotland which was used to charge the accumulators developed by Frenchman to power the lighting in the cottage thus making it the first house in the world to be powered by windmill and then later used to produce hydrogen. In the 20th Century the wind power became decentralized electrification, the forerunner of modern 3 blade horizontal axis turbine was installed in USSR. In Second World War, small wind generators were used on German U boats to recharge submarine batteries. In 1930s windmills were used on farms in the United States where the distribution system was not installed at that time. In 1941 the first mega size wind turbine was installed in Vermont, United States, in mid 70s and 80s in United States government worked with the industry to advance the technology and enable large commercial wind turbines [2].

In the beginning of 21st Century rising concerns over energy security, green house gases emission which led to global warming and depletion of fossil fuel led to the dependence on wind energy resources. The wind power industry began to expand at a robust rate of 30 % annually driven by the massive availability of wind resource and decreasing cost due to improved technology and management [7]. Global recession and inflation in the world economy during last 10 years mainly due to rising oil prices led to the shift from fossil fuel to natural gas but it has its own supply problem as the natural gas reserves are also depleting and wind power showed its potential for power generation. Advancement in wind energy technology led to the development of offshore which are limited to the water depth of 30 m utilizing fixed bottom technology.

2 Literature Review

This report summarizes the current conditions for business in the Pakistani Renewable Energy sector the recent power crises in Pakistan where the whole country is in the grip of power crisis with a shortage of around 5,000 MW, immediate investments in new hydroelectric or coal-fired power stations are not in sight as these projects require at least 7 to 8 years of operational time [12]. Pakistan has one of the highest energy prices in its region of about RS 6 per unit due to the international surge in oil prices. Daily load shedding is announced in advance, for Cities load shedding goes on for 3 to 4 h in winter and 8 to 10 h in summers, the situation sounds more intense in rural population as load shedding goes on far about half a day and in some cases more than 24 h. Market conditions for wind power in Pakistan are fertile as the estimated potential indentified by the reliable sources is nearly 50,000 MW sufficient to fulfill the long term energy needs. In rural population hundreds of wind power pumps and electricity generation turbines for micro generation have been installed providing electricity to nearly thousand homes houses in 18 remote villages [11].

This study has enabled to identify the potential areas where economically feasible wind farms can be established, the Potential areas covers 9700 sq. km in Sindh only, the AEDB in collaboration with USAID, has carried out Satellite survey of wind resource of the entire country, which would help to identify specific high-value areas for conducting specific on-site assessments and development, the technical support for wind projects developers includes civil engineering, infrastructure building (roads, foundations, grid connection), logistics, setting up an operation and maintenance (O&M) companies, financing and insurance [4]. The feed-in tariff provided by The Policy for Development of Renewable Energy for power Generation regulation states that companies having the signed LOI (Letter of Intent) with Government of Pakistan, are allowed to negotiate the final tariff with NEPRA. Taking all upfront costs into final calculation is challenging, since infrastructure is weak and no experiences are available at that present time, the implementation of the first wind turbines in Pakistan will have an impact on the replication and will give the necessary confidence for project developers and financiers. AEDB is considering indigenous manufacturing of wind Turbines which would play a part in creating job opportunities and poverty alleviation in the country. Karachi Shipyard, Pakistan Machine Tool Factory, Pakistan Steel Mills, State Engineering Corporation and several other companies were identified by AEDB.

The total amount of wind energy is considerably more than the present consumption of electricity from all sources, the potential wind energy of 72 TW can be commercially viable as compared to total power consumption of 15 TW from all sources. The strength of wind varies and an average value for a given location does not indicate the average output of wind turbine, making wind power more consistent requires existing technologies to be extended by grid energy storage and batteries. Wind energy is rapidly growing energy resource in the world [8]; today a global installed wind power capacity has surpassed the mark of 100,000 MW including onshore and offshore installations. In 2007 alone wind-power capacity had increased by a record 20,000 MW bringing the world total to 94,100 MW. Selection of wind turbine site is based on the economic feasibility of wind power; apart of wind itself other factors include availability of transmission lines, value of energy to be produced, and cost of land acquisition along with its environmental impact of operations. Wind and hydro electric power have negligible fuel cost and relatively low cost of maintenance; wind power benefits producers due to their low marginal cost, average per unit cost which incorporates construction cost of wind turbine, transmission facilities, borrowed funds and their costs averaged over a projected useful life of the equipment. The outcome of research identifies other fields of study having no relevance with the topic but is indirectly related to the subject matter because they are linked with the topic. Some forms of energies create costs that are neither paid by the producer nor by the consumer of the goods or services and the most significant the pollution which has social cost in the form of increased health expenses, reduction in the agricultural productivity and other environmental issues. The carbon dioxide is produced when fossil fuels are burned may impose further cost in the form of global warming, there must be a mechanism to add this cost as it indirectly affects the society in the form of wild habitat destruction and loss of scenery and tourism etc. [3]. The wind energy is the most competitive source of energy if the external cost is taken into account due to its minor environmental effects; wind power consumes no fuel and emits no air pollution, unlike fossil fuel its operation does not produce carbon dioxide, sulfur dioxide and mercury particles [5]. A study by the Irish national grid stated that producing electricity from wind energy reduces CO_2 ranging from 0.33 to 0.59 tons per unit of mega watt hours. However leaking lubricating oil or hydraulic fuel running down the turbine blades may be scattered over surrounding area may contaminate the drinking water area if that water area or reservoir is around.

Threats to the birds is often the main complaint against installing wind turbines but the fact sheet shows that there are less birds killed each year by other sources of energy which create pollution cause death of birds and other human activities such as hunting, high rise buildings, air and land traffic [10]. In some cases the wind turbines affects the wild life where the older design wind turbines are placed with lower hubs and tighter turbine blade spacing, the number of bats killed both onshore and offshore turbines exceeds over two thousand. Officials claim that wind farms can generate false signals for tornadoes as happen in Kansas, USA. Historical experience of noisy and visually intrusive wind turbines may create resistance on setting up land based wind farms, residents near wind farms complain about shadow flicker caused by turbine blades and intrusive sounds. Light pollution is also a cause of concern for residents near wind farms due to the requirement of aviation light on the wind turbine, these issues can be resolved by placing the wind turbines offshore at least 10 km from shore but some find the onshore wind farms as a source of attraction and others complain a cause of intrusion [13].

3 Statement of Problem

The present energy crises in Pakistan with a short fall of 5000 MW approximately in a peak summer season was due to the negligence of policy makers and regulators in Pakistan towards the alternate sources of energy. The demand for electricity continues to rise 10 % annually which creates further demand for fossil fuel; the dependence on fossil fuel raises the concern for energy security in case of a war situation or shortage of oil supply from the oil producing nations along with the burden on the foreign exchange of a country already facing economic crunch.

The problems which relates to the current crises are:

Policies, Institutions, Regulatory bodies, Financial and Technology
The power policies in Pakistan were traditionally focused on thermal production of electricity and the priority for renewable sources remains low although the acknowledgement for Renewable energy as an alternate source has prevailed in some policy documents but a meaningful development and incentives offered to the investors were still on the low priority, the institutional roles of the various organizations responsible for the development of renewable sources have often overlapped and varied over time is the cause of the lack of policy focus and priority towards renewable energy in the national energy planning process. Lack of knowledge about the potential of wind power and the technical knowledge required for establishing the necessary infrastructure and equipment required for the wind power generation, lack of fiscal and financial incentive necessary to attract the potential investors having necessary experience and knowledge in the wind energy production are causes for the development of wind energy at a snail pace.

4 Significance of Study

This study could benefit the electronic media greatly in making documentaries and creating awareness among general public, due to low literacy rate majority of people in Pakistan depends on electronic media as a source of information, through media people in isolated communities, small towns, suburbs and rural areas can get awareness of wind power benefits at the small scale or community level to get electricity for their homes and tube valves from wind energy. The other beneficiaries of this study are the local and foreign investors unaware of wind energy potential in Pakistan and its benefits of economic and financial nature, by studying this research the investors and entities in energy sector can get the idea about the opportunities and barriers in the energy market and can better formulate their business strategies, independent power producers can benefit in the decision making about the diversification of their assets to wind power. The institutions responsible for policy making and enforcing can review their policies towards wind energy and can offer better incentives to attract the investment in the renewable energy sources particularly wind energy and local production of wind turbines.

The scope of the thesis is geographically limited to Pakistan only; the data used in this descriptive research is obtained from the locations lie inside the frontiers of Pakistan, the analysis, processing and presentation is performed on the data which is obtained through the scientific observations on locations inside Pakistan and the recommendations, solutions and conclusions presented in this report are valid for Pakistan only.

Unlike thermal generation plants the capacity or production output varies in wind power depending on the inherent speed of wind, electricity generated from wind power can be highly variable at different time scales and seasons. Like other sources of energy wind power needs to be scheduled but predictability of wind plant output remains uncertain for short term periods which needs to be substituted by other renewable sources in case of non coincidence between the wind speed and electricity demand.

5 Research Design

Descriptive research is applied in the study to interpret and arrange the data in the understandable form, describing the observations and their analysis, Presentation and description of data in the form of tables, figures and charts. The descriptive research is applied to answer the problems of power crisis and to present renewable power resources. The descriptive study is applied to answer that who will going to form the policies necessary to boost the investment in the wind energy sector, what are the problems or limitations in implementing the wind energy program, how to remove the barriers in executing wind energy projects in Pakistan.

The respondents of the study are institutions, stake holders, regulatory bodies and investors.

(1) Pakistan Meteorological Department;
(2) National Electric Power Regulatory Authority;
(3) Pakistan Council of Renewable Energy Technologies;
(4) Private Investors;
(5) Private Power and Infrastructure Board.

The data gathered from these respondents was important in identifying the wind corridors. The data about the weather and climate of the wind corridors locations, to forecast the possibilities of natural disasters (storms, tornadoes and earthquake) from geophysical phenomenon, the regulatory bodies provide information about the formulation of policies related to safety standards, quality and supply to consumers and determining the power tariffs for generation and distribution of power. The council of renewable energy was helpful in providing the technical details and the necessary technological development done in the renewable energy sector particularly wind turbines. While a number of investors who have responded to Government's request for Letters of Interest some of them have been involved in wind energy tariff negotiations with regulatory bodies.

5.1 Research Instruments

The questionnaire had the questions enquiring about the problems faced by the developers, investors and other respondents in implementing and operating wind power on a commercial basis. Types of barriers faced by the developers in getting the sponsors and development of wind farms, meteorological survey of different locations necessary to gauge the wind speed and it's variation through the year. Tariff and policy formulation and the integration of wind power in the national energy planning along its transfer of technology.

Through internet surfing and extracting information from different information sites, internet was helpful in providing technical details necessary to locate the potential sites for developing wind farms. The online information was helpful in predicting the wind speeds throughout the year due to the presence of metro logical data of different locations of Pakistan, the internet was aiding in identifying the potential investors such as independent power producers, international and local engineering concerns developing wind power equipment and identification of marketing conditions for wind power and its potential power output in Pakistan.

One of the major sources of data gathered are newspaper articles and latest news covering seminars and programs related to wind energy sources. Special supplements were published by the news papers to educate the readers were helpful in getting the information necessary for research.

Special programs and documentaries on renewable energy resources were assisting in getting views from different government officials, bureaucrats, investors, Experts on wind energy resources and the representatives of those Independent power producers having stakes in the wind energy projects in Pakistan.

Primary data source of communication with the respondent is a questionnaire designed in an open ended questions and answers format to obtain the data. These questionnaires are posted on the email addresses of the institutions related to the wind energy projects in Pakistan; another source of primary data is the interview with the respondents through telephonic and face to face interviews. Secondary data was gathered through electronic sources of information such as internet, talk shows and renewable energy documentaries on television and the articles written in the newspapers related to the wind energy generation in Pakistan. Most of the data for the research is gathered through secondary data sources, the major dependence on the secondary sources of data was due to the scarcity of time, financial resources and the nature of topic as the wind energy is relatively new in Pakistan and there is limited awareness among the local officials and entities in Pakistan about the topic.

The data obtained from primary and secondary sources is interpreted into tabular form, the raw data gathered from questionnaires and electronic cum print sources of information such as internet, television, newspapers and magazines is transformed into tables presenting the data in percentages, frequency distribution and comparative or cross tabulation. The data is organized and analyzed in quantitative as well as qualitative manner and is presented not just in tabular form but in graphical methods of displaying data is also employed. Bar diagrams and line graphs are used in presenting

Table 1 Monthly mean, maximum and minimum wind speed of locations in m·s^{-13}

Months	Karachi	Ormara	Jiwani	Pasni
January	2.5	3.1	4.2	5.0
February	3.4	3.4	5.0	5.6
March	4.0	5.0	6.0	6.5
April	4.2	6.5	5.3	8.5
May	5.0	5.3	5.3	7.7
June	5.9	5.8	6.2	7.6
July	5.4	5.8	5.3	6.5
August	5.0	4.4	5.9	6.7
September	4.6	4.3	5.2	6.9
October	3.5	3.7	4.3	5.9
November	2.3	3.8	3.8	4.2
December	2.0	3.2	3.5	3.9
Maximum	5.9	6.5	6.2	8.5
Minimum	2.0	3.1	3.5	3.9
Average	3.98	4.525	5.0	6.25

the data in a more simple and understandable form, the employing of various tools of mathematical calculations, financial and statistical formulas aid in conducting analysis and forming final opinion on recommending wind power as the feasible source of renewable energy in Pakistan.

Presentation of Data. The assessment of wind power potential for four coastal locations of Karachi, Ormara, Jiwani and Pasni shows in Table 1 that the annual wind speed pattern in Karachi is on the lower side and Pasni and Jivani are observed to have the higher wind speeds.

Figure 1 shows the Wind speed for Karachi, Ormara and Jiwani are identical in some time periods or months such as in the months of February the wind speeds of Karachi and Ormara are identical, in May and November wind speeds of Ormara and Jiwani are identical. The months of peak temperature in Pakistan when the electricity

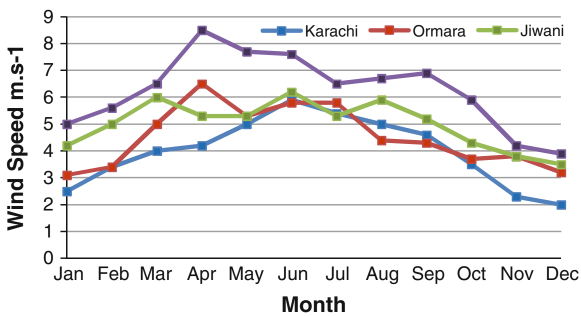

Fig. 1 Monthly wind speed for coastal locations of Pakistan

demand is at peak are April, May and June and these are the months showing correspondence with the maximum wind speeds of all four locations. Maximum wind speeds of Pasni and Ormara in the month of April is 8.5 and 6.5 $m \cdot s^{-1}$ respectively and maximum wind speeds of Karachi and Jiwani in the month of June is 5.9 and 6.2 $m \cdot s^{-1}$ respectively, the location of Jiwani is relatively stable in terms of wind speed and the most unstable is Pasni followed by Karachi and Ormara, the most preferable among these locations for wind generation is Jiwani followed by Ormara.

The development of institutional support is necessary for the effective implementation of renewable energy projects especially wind energy, the technological, financial environmental and metro logical awareness is necessary to frame the policies to develop the institutional support. The Pakistan council for renewable energy technology is placed under the ministry of science and technology responsible for the development of policy essential for wind energy resources and technology in the country, currently the institution is involved in the installation of micro wind turbine units on a community levels or on a test basis, the institution is responsible for establishing business links from the equipment suppliers and the producers and acquiring of technology. The Pakistan metro logical department operates under the Ministry of Science and Technology and is responsible for the collection and dissemination of weather and climatic data. The department is currently implementing a project on behalf of ministry for the collection of data to map the wind resource potential in the country, and is expected to set up more automated anemometry towers to collect relevant data, the ministry of environment implements the national conservation strategy.

The ministry of water and power which acts as a power sector planner and manager for power purchasing companies, generation and transmission companies, The Private Power and Infrastructure Board operates under the Ministry of Water and power provides facility to private investors in power generation, operates as a custodian of government policies related to private sector power generation and transmission, and is also responsible for handling all matters related to the implementation of these policies and act as a bridge among various federal and provincial agencies, the execution of implementation agreements with the independent power producers on the behalf of government and independent power producers who can build, own and operate power plants. The provincial and local governments must also be taken into confidence for the approval of projects from Pakistan council for renewable energy technology and Private power infrastructure board; there must be a mechanism to establish a regular coordination among the provincial and local governments and the PCRET and PPIB to establish projects in conformity with the developmental priorities. The NEPRA (National electric power and regulatory authority) regulates tariffs for the generation, transmission and distribution companies. It establishes the quality and operation safety standards for the independent power producers, private power infrastructure board along with the state owned distribution and transmission companies, approving investment programs for the utility companies and determining bulks and consumer energy tariffs. It is recommended that there must be a long term relationship among the ministries of Environment, Science and technology and Water and Power, the Functional Organization structure is essential in managing the

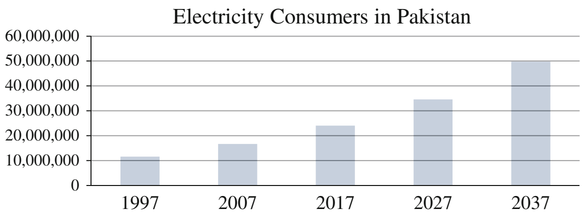

Fig. 2 Projected number of electricity consumers in Pakistan

Table 2 Projected number of electricity consumers in Pakistan

Year	Consumers	Growth rate %
1997	11, 605, 000	–
2007	16, 700, 000	43.903
2017	24, 031, 882	43.903
2027	34, 582, 718	43.903
2037	49, 765, 738	43.903

project coordination, the different ministries and the institutions working under their jurisdiction must coordinate and work like a single unit in implementing the wind energy projects in Pakistan.

Figure 2 shows the electricity consumption in Pakistan till 1997 to 2037.

The projected data in the Table 2 shows the constant growth rate of 44 % approximately each decade, from 2007 to 2017 expected number of consumers would be 24 million approximately, in 2027 the expected consumers will reach to 35 million approximately and 50 million consumers will be expected in 2037. This increasing trend of electricity consumers at 7.00 % (approx) annually shows the scope for power generation projects in the future.

Figure 3 shows financial model structure the project financing structure is based on capital outflows, which are further based on Debt and equity structure although it is likely that some grant support would be available to overcome financial barriers to the wind plant's construction, in the form of insurance, risk, and green tariff support. The project capital cost for each option has been divided into local and foreign components. It is assumed that the private sector equity portion would mainly fund the local cost component of the project costs, whereas the balance local costs would be met through local borrowing.

Cost of capital

The wind power projects capital cost is assumed to be raised through conventional sources of debt and private equity, the equity would be raised in local currency to cover the local costs of the project in part or whole.

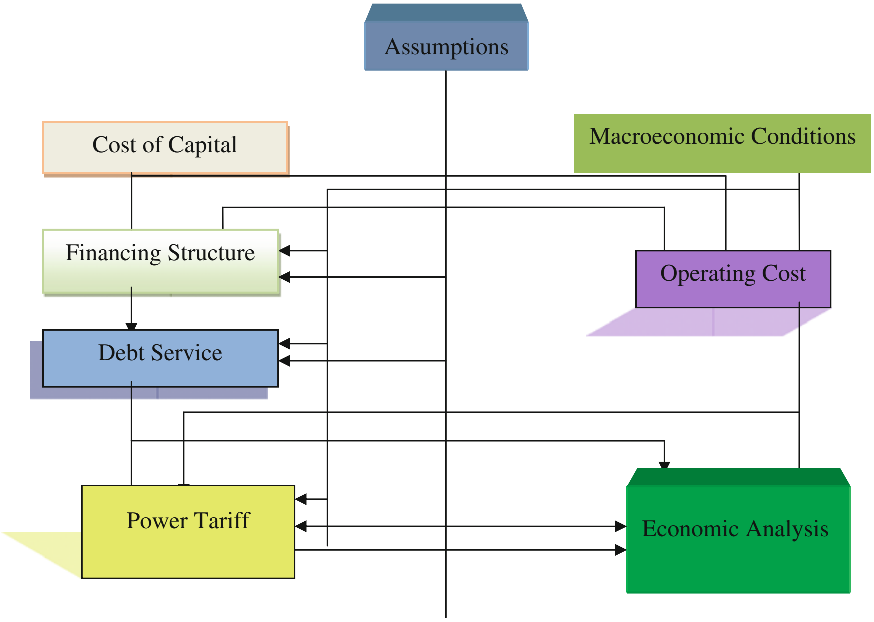

Fig. 3 Financial model structure

Table 3 Debt service

	Wind farm	Diesel plant
Installments		
per year	2	2
Repayment (years)	12	10
Interest rate	7.5 %	7.5 %

Debt service
Table 3 shows the financial model will assist in serving the local and foreign debts the debt service costs on an annual basis, the financial model also allows for payment of interest in each year of construction or to capitalize within the loan during the construction years, equal annual repayment of principal with interest paid on outstanding balance.

Operating costs
Table 4 shows the operating parameters for the projects have been worked out on a production capacity, energy generated, capital costs and operating expenditures, including fuel, operational and maintenance costs, the costs have been adjusted keeping in view the macroeconomic indices for equipment, fuel and other project inputs over the projected period project revenues have been also evaluated using an estimated tariff and the projects estimated operational capabilities.

Table 4 Comparative operational cost

	Wind farm	Diesel plant
Plant factor (at the output)	18 %	40 %
Projected life (years)	20	20
Salvage value	5.0 %	5.0 %
Land price (per acre)	20,000	35,000
Transportation	2.0 %	2.0 %
Contingencies	15 %	20 %
Decommissioning	2.0 %	2.5 %
Duties and other charges	10 %	15 %

Table 5 Financial data

Assumed year	2007
Debt/Equity	80 %
Return on equity	14 %
Variable cost	30 %
Income tax on thermal plants	43 %

Power tariff
Table 5 shows the bulk power purchase tariff for the project has been calculated keeping in view the fact That tariff must cover for all project costs as well as assure a reasonable return on equity the project costs for the wind farm are debt service requirements, including repayment of principal and interest, fixed and variable costs, return on equity, and decommissioning costs at the end of the project. However, in determining these costs certain credits, such as salvage value and environmental credits have been deducted from the costs in the respective years to arrive at a year-wise tariff rate for the project. Before setting the final tariff the net present value, internal rate of return and payback period must also be taken into account to make the project economically feasible.

Economic analysis
Certain financial and economic parameters, such as the internal rate of return (IRR), net Present value (NPV), and payback periods have been assessed in line with standard Economic analysis methodology Net annual cash flows have been projected from Initiation of the project's development to eventual decommissioning in arriving at the NPV, a discount rate equal to the weighted average rate of financing, including both Equity and debt, has been applied in Table 6.

Macroeconomic conditions
Table 7 shows the macroeconomic conditions include inflation, U.S. dollar inflation and the foreign exchange rate which affects the price of items to be imported from abroad. The crude oil prices play a vital role the prices of which are set by the OPEC

Table 6 Comparative economic analysis

	Wind farm	Diesel plant
Internal rate of return	11.85 %	7.9 %
Payback period (years)	9.02	9.85
Net present value@7.50 % (Rs)	519 Million	12.1 Million

Table 7 Inflation indices data

Inflation indices	2001–2010 (%)	2011–2020 (%)	2021–2030 (%)	2031–2040 (%)
Local inflation (average)	8.45	7.00	5.50	5.00
Dollar inflation (average)	2.09	2.40	2.40	2.50
Crude oil price (average)	2.94	0.00	(1.50)	(1.00)

nations, the transportation of equipment and plant from where it is produced to the site of their installation is done on the modes of transportation consuming crude oil.

Assumptions
The assumption is based on the financial and tariff evaluation which should covers the entire project life and a number of external cost parameters which are expected to change during the future period, these parameters are linked with basic macro-economic indicators that have a bearing on project costs, such as Pakistani inflation, US inflation, fuel prices, foreign exchange rates, etc. In order to accommodate such parametric variances over the project's life cycle, current projections have been obtained from appropriate and credible sources and factored into the financial modeling. Besides those economical factors the other factors of cost of capital which include cost of equity and annual repayment of principal along with its interest payment, these financial and economic factors affects the operating cost show the Table 8.

Table 8 Cash flow statement for economic analysis assumption

Cash flows (Rs. 000)	2008	2009–2013	2014–2016	2017	2018	2019–2028
Wind power	(782, 584)	(258, 628)	781, 030	254, 810	252, 154	2, 355, 291
Cumulative	(782, 584)	(1041, 212)	(260, 182)	5, 372	246, 782	2, 602, 073
Thermal power	(372, 587)	205, 093	106, 821	32, 951	32, 453	364, 370
Cumulative	(372, 587)	(167, 494)	(60, 673)	(27, 722)	4, 731	369, 101

Project Selection
On the basis of Internal Rate of Return wind power project is more feasible; in case of Payback Period the difference between thermal Plant and wind power is more or less similar is more suitable but the most authentic criteria followed by most of the financial managers is the project with the higher net present value is preferred as share holders will get more return and there will be more increase in their wealth.

6 Conclusion

There is a rising need for alternate and renewable sources of energy, especially in developing countries, whose progress and economic growth may strongly be linked to its development. With the ever increasing growth in energy consumption and rapidly depleting fossil fuel reserves, it is feared the world will soon exhaust its fossil fuel reserves. Pakistan is an energy deficient country and each year spends a large amount of its foreign exchange to import oil, to meet its energy requirements thus the need to develop alternate energy resources has become inevitable. The oldest and most widely used renewable energy resources are solar and wind, which have shown prospects and potential for efficient utilization. In the recent past, wind energy has emerged as clean, abundant, adorable, inexhaustible and environmentally caring source of energy. The worldwide attention with the development and availability of inexpensive technology that allow its easy conversion into useful energy wind energy has the advantage that it can be utilized independently, and deployed locally in rural and remote areas.

The coastal areas and mountains with high wind potential are considered most suitable for wind energy utilization. Therefore this study aims in investigating the prospects of harnessing the wind for energy generation the high wind speed is always available nearly all year round in the coastal and mountain regions of Pakistan.

6.1 Recommendation

To make the entire system of wind energy projects more efficient and productive by employing new techniques, devising policies and implementing reforms to make this field more attractive for the potential investors.

Tax incentives must be given to the investors to reduce the cost of investment through the savings in tax expenditures, investment tax incentives can be availed by investors paying corporate taxes on account of ongoing business operations. Investment tax incentives are redundant where exemptions from corporate taxes have already been granted, but new investors can avail this facility only during the expansion phase, provided that cash outflows associated with payment of corporate taxes exist.

It is allowed in a business to depreciate the value of its assets, such as equipment, plant and building in the financial statements; this depreciation can be deducted from the businesses yearly income taxes paid to the government. Usually, this reduction is based on the market value of the equipment and can only be depreciated at a certain, defined rate. However, allowing accelerated depreciation of wind equipment for example allowing 100 % depreciation of a wind turbine in the first year of operation will significantly lower the amount of income taxes paid during the initial stage of the project which can help ease the extra financial burden on wind developers which were experiencing due to the higher initial capital costs of a wind plant.

Direct cash payments can enhance the promotion of wind power, a direct cash payment for the installation of a wind energy system is beneficial to a potential developer who has a limited revenue base to fully take advantage of assistance, this type of incentive also helps both taxable and non-taxable entities such as a municipal or state owned utilities. In addition, grants provide an additional benefit to a private investor by reducing the total tax burden, since the grant portion of the equity usually is not taxed.

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Part IV
Risk Management

Estimation of Market Value of Compounding Bonds: An Innovative Technique

Husain Tahir Safdar and Muhammad Sabir Hazoor

Abstract This article aims to highlight an error in the prevailing present value (PV) approach with compounding for the bonds evaluation. Currently, compounding is used on both determinants i.e. coupon payments as well as maturity value without any sound argument. In line with value maximization principle, the investors should prefer compounding than non-compounding bonds due early payment of interest and higher market. But the prevailing approach as cited in different international books proves to be misleading. Investors of bond markets as well as academia were confused to use this erroneous approach around the globe. The study refutes to use compounding on both determinants with evidences from real life for the estimation of market value of bonds and offers an innovative technique to measure the market value of bonds which could be implemented immediately.

Keywords Bond evaluation · Interest payment · Innovative technique · Maturity value · Market value · Present value

1 Introduction

Fixed income securities and corporate bonds can play vital important role in financial stability, economic growth and economic recovery, particularly during the crisis. They contribute with key capital to companies motivating them to expand their horizon, offer employment, and create the opportunities with innovative goods and services. G20 as supranational bodies highlighted the important role of corporate bonds in financial markets in terms of long term financing. The European Bank for Reconstruction and Development (EBRD), International monetary fund (IMF) and Organization for Economic Co-Operation and development (OECD) have issued

H.T. Safdar (✉)
Banking & Finance Government College University, Faisalabad 38000, Pakistan
e-mail: safdartahir@gmail.com

M.S. Hazoor
Management & Admin Sciences Government College University, Faisalabad 38000, Pakistan

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research based diagnostic framework to boost up the development of corporate bond on local level.

Over the last decade, corporate bonds have become essential part of financial markets due to its increasing nature on wide span, especially for the real economy. It has almost tripled in size since 2000, reaching 49 trillion dollar in 2013 (IOSCO, 2014). This growth hindered in the stir of financial crisis as banks began deleveraging their balance sheets. However, the amount outstanding from non-financial companies has sustained to expand.

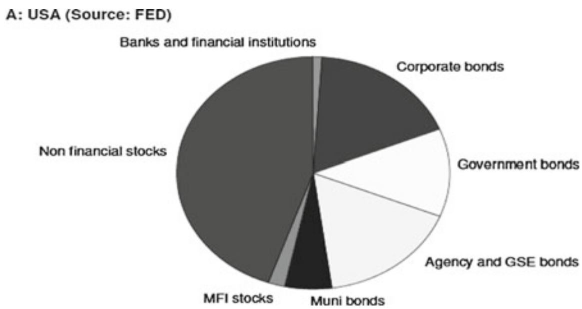
Corporate bond market brings borrowers and lenders together to incorporate market price through the interaction of supply and demand. It provides the opportunities to invest in diversified portfolios and control the risk factors of investors which ultimately increase the liquidity of financial markets. In this way, it becomes essential important in adjusting the market prices with respect to supply and demand and helps to set interest rate pattern in banking sectors. The market prices of bonds can impact the other decisions related to savings and investment decisions in corporate sectors. Thus, market price of bonds is an important determinant of investment as well as financing decisions.

In the developed countries, the bond markets are playing important role in their economies. In the United States (US), the corporate bond markets have the equal size as the financial markets of equity. In whole Europe, the capital of bond markets about two-thirds of the total capital of equity markets. There is notable difference found in contribution of financial bond market in US and Europe. In United States, most of the amounts of bonds are issued either by non-financial sectors or by government. But the bonds issued by government much lesser in amount than non-financial sectors. In Europe, the picture of bond markets is different. Most of the part of corporate bond markets is saturated by financial intermediaries issued bonds as well as by government issued bonds. In addition, other types of bonds like agency and municipal bonds are major components of financial market.

Figure 1 shows the chart of US stock market versus bond market capitalization for domestic firms from 1998 to 2012. All amounts nominal to gross domestic product (GDP) are taken end of each years.

The bond markets in Asia are growing rapidly in whole region as Asian borrowers tending from bank loans to long run debt financing. Due to global crisis in financial

Fig. 1 The US equity and corporate bond markets proportion in 2012



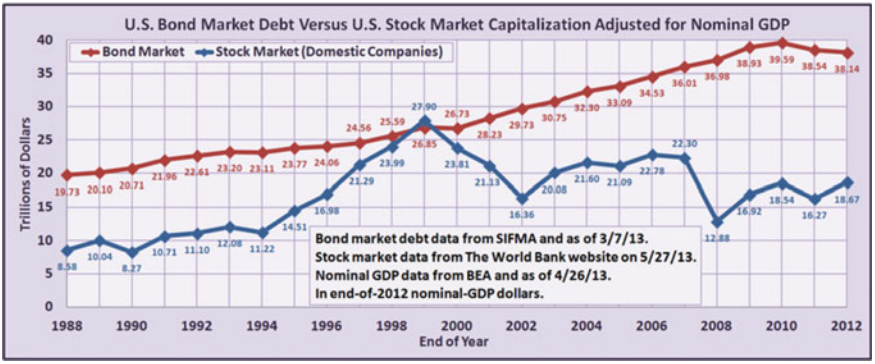


Fig. 2 US bond market to stock market

markets, the corporate businesses in Asia have increasing trend toward debt markets than stock markets for their funding needs. In this way, they control their risks. As a whole, the Asian bond markets show mixed picture. Some markets are on early stage while others on advanced and matured stage. Corporate bond markets in the countries like Singapore, Korea and Hong Kong are on advanced stage having high transactions rate and liquidity. While in India, China, Thailand and Indonesia, the corporate bond markets are on initial stage and a lot of development and advancement need to incorporate. Also, the term structure of bond markets reveals variation like currency, issuing volume and use of funds in different parts of the world (Fig. 2).

Objectives of Study
To test the validity regarding application of prevailing assumption of present value approach on value estimation of bonds in real market.

To introduce innovative and appropriate approach for bond evaluation.

2 Literature Review

Horne and Wachowicz [3] indicated in-appropriation of using compounding on maturity value (MV) in the fundamental of financial management, 13th edition. But he used compounding in maturity value (MV) on the base of this assumption compounding once taken, applies to all inflows. The current study provides the evidences that this assumption is misleading to investors. They may estimate the wrong price. Similarly, Brigham and Houston [2] also used compounding on maturity value in their book fundament of financial management. In line with Van Horne and Brigham, Brav and Maug [1–3] applied compounding on face value (maturity value) in their book global financial management. Endorsing the above cited authors, Brigham and Ehrhardt [2] applied compounding on maturity value in pricing bonds with different cash flows and compounding frequencies. Jones [4] described the same way for estimation of bond evaluation in the Chap. 7 of his book, investment analysis and management.

All above cited authors didn't mention the necessary reasons to take the assumptions compounding once taken, applies to all inflows. The current study tends to find out the consequence of this assumption on investors behaviors.

3 Methodology

The below mentioned formula generally is used to estimate the value (market price) of a bond with finite maturity for compounding more than once a year [3].

$$\text{Market price } = \sum_{1}^{n} \frac{Cn}{(1+i/m)^{mn}} + \frac{MV}{(1+i/m)^{mn}}, \quad (1)$$

where:

MV = Maturity value
C = Periodic interest payment (coupon rate)
N = Number of payments
I = required rate of return
M = compounding in a years (1, 2 and 4 for annually, semiannually and Quarterly respectively)

The discounting on maturity value is used in assumption, once taken, applies to all inflows (Van Horne). But this assumption may inappropriate in real world when investors evaluate bonds for the sale/purchase transactions. Sometime compounding on maturity payment overall decrease the value instead of increasing, as it eats up the benefits of early coupon rate payments. Therefore, the prevailing assumption and formula would be modified in order to estimate the market price of long-term securities with finite maturity. The below mentioned examples illustrate the phenomena conspicuously.

Illustration-1:
Suppose we have \$1000 face value a bond with 12 % coupon rate, three years to maturity. If the investor's required of return is 16 %, the bond value is calculated as: Table 1 shows the market price of annual payments (coupon) bond with finite maturity. In case of no compounding on coupon payments as well as maturity value the market price would be \$870.00 (Table 2).

Case 1 Compounding used on periodical payments (Cn) as well as Maturity value (MV).

Table 3 indicates the market price of quarterly compounding bond where discounting used on periodical payments of coupon rate as well on maturity value. In this case the market price would be \$859.70 below in both cases discussed above.

Table 1 Market value of bond (Annual coupon payments, no compounding)

End of the year	Coupon payments (C)	Value at maturity (MV)	Required rate (i)	Market price (P)
1	100		0.862	$86.20
2	100		0.743	$74.30
3	100	1000	0.645	$709.50
Total				$870.00

Table 2 Market value of semiannual bond (Compounding used in coupon payment as well as on maturity payments)

End of the year	Coupon payments (C)	Value at maturity (M)	Required rate (i)	Market price (P)
1	50		0.926	46.3
2	50		0.857	42.85
3	50		0.794	39.7
4	50		0.735	36.75
5	50		0.681	34.05
6	50	1000	0.63	661.5
Total				861.15

Table 3 Market value of quarterly compounding bond (Compounding used in maturity payment as well as on coupon payments)

End of the year	Coupon payments (C)	Value at maturity (M)	Required rate (i)	Market price (P)
1	25		0.962	24.05
2	25		0.925	23.13
3	25		0.889	22.22
4	25		0.855	21.38
5	25		0.822	20.55
6	25		0.79	19.75
7	25		0.76	19
8	25		0.731	18.27
9	25		0.703	17.58
10	25		0.676	16.9
11	25		0.65	16.25
12	25	1000	0.625	640.62
Total				859.7

Table 4 Market value of semiannual bond (Compounding used on coupon payments, not on maturity payment)

End of the year	Coupon payments (C)	Value at maturity (M)	Required rate (i)	Market price (P)
1	50	0.926	46.3	
2	50	0.857	42.85	
3	50	0.794	39.7	
4	50	0.735	36.75	
5	50	0.681	34.05	
6	50	0.63	31.5	
Compounding not used on maturity payment		1000	0.645	645
Total				876.15

Table 5 Market value of quarterly compounding bond (Compounding used on coupon payments, not on maturity payment)

End of the year	Coupon payments (C)	Value at maturity (M)	Required rate (i)	Market price (P)
1	25		0.962	24.05
2	25		0.925	23.13
3	25	1000	0.889	22.22
4	25		0.855	21.38
5	25		0.822	20.55
6	25		0.79	19.75
7	25		0.76	19
8	25		0.731	18.27
9	25		0.703	17.58
10	25		0.676	16.9
11	25		0.65	16.25
12	25		0.625	15.62
Compounding not used on maturity payment		1000	0.645	645
Total				879.7

Table 4 shows the market price of semiannual bond where compounding used on periodical payments of coupon rate but not on maturity value. In this case the market price would be $876.15 above the price where no compounding used ($870.00).

Case 2 Compounding used on periodical payments (Cn) but not used on Maturity value (MV).

Table 5 confirms the market price of quarterly compounding bond where compounding used on periodical payments of coupon rate but not on maturity value more than semiannual and annual bonds.

Table 6 Combine result of both cases

	Market value when compounding on maturity	Market value when no compounding on maturity
No compounding	$859.70	$879.70
Semiannually compounding	$861.15	$876.15
Quarterly compounding	$870.00	$870.00

4 Analysis Results

Table 6 confirms the decreasing trend in value of bond when compounding is used on periodical payments of coupon rate as well as on maturity value on the one hand. On the other hand, when compounding is used only on periodical payments, it shows increasing trend.

5 Conclusions

The compound discounting on maturity value (MV) eats up the benefits of early periodical payments that overall decrease the value. The current formula if applied estimates more value for annual periodical payment bond than the semiannual, quarterly compounding and so on, which seems to be inappropriate in the real world. Investors like more compounding bonds than less compounding in order to maximize their wealth. But the current formula shows less value. Therefore, the assumption, once taken, applies to all inflows seems to be inappropriate for estimation of market price of bond.

6 Recommendation

It is recommended to modify the current formula as under:

$$\text{Market price } = \sum_{1}^{n} \frac{Cn}{(1+i/m)^{mn}} + \frac{MV}{(1+i)^{n}}. \tag{2}$$

The compounding would be used only on periodical payments (Cn), not on maturity value (MV).

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Arbitrage Between More Than One Trading Post

Xin Liu

Abstract The idea of arbitrage lies in the heart of concept of equilibrium in economics and financial management. Such principles like Law of One Price are prevalent in economics and finance that the author tend to identify that no arbitrage exists at equilibrium. However, this argument and its consequence are fragile. In this paper, I attempt to show arbitrage equilibrium exists in a non-competitive context. I also attempt to explicit the role of elasticity of in the relation of arbitrage and equilibrium in non-Walrasian market. The central message of this paper is that outside the Walrasian framework, equilibrium and arbitrage can coexist even with frictionless markets. The existence of equilibria with multiple trading posts is determined by the number of agents in the market, or, by the size of the market. Another important result of this paper is, as the economy approaches the limit, the price in different markets becomes unity. I have also provided here a result relating arbitrage and efficiency, which showed that the presence of arbitrage activity in market transactions implies some inefficiency in the Pareto sense.

Keywords Arbitrage · Speculation · Walrasian equilibrium · Law of one price

1 Introduction

The idea of arbitrage, or rather the lack of it, lies in the heart of any concept of equilibrium in economics. The term arbitrage has been casually used in many different contexts where its formal definition varies. However, in general it refers to the possibility of advantageous trades at no cost. It is natural then that any economic equilibrium must be characterized by lack of arbitrage. Indeed, any situation allows for advantageous trades at no cost is not sustainable and thus cannot fulfill the definition of an economic equilibrium. No arbitrage arguments are prevalent in virtually

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X. Liu (✉)
School of Economics and Business Administration, Chongqing University,
Chongqing 400030, People's Republic of China
e-mail: liuxin@cqu.edu.cn

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every equilibrium model in economics and finance and underlie some of the most fundamental principles in economics and in finance. Principles such as the 'Law of One Price' in economic theory, the 'Purchasing Power Parity' in international trade, the 'Arbitrage Pricing' in finance are all consequences of arbitrage considerations. Such arguments are so prevalent in economics and finance that occasionally authors tend to identify no arbitrage with equilibrium situations.

In frictionless Walrasian (competitive) markets this requirement for lack of arbitrage has some very important consequences. First and foremost, it gives rise to the 'Law of One Price' principle. This principle states that, in a given system of markets, at equilibrium there must be a unique price that clears all markets for a commodity. Indeed, non-uniform prices in a particular commodity would leave room for arbitrage so they cannot be sustained as part of an equilibrium. Second, as a consequence of this, there can be no arbitrage activity at equilibrium (e.g. individuals simultaneously buying and selling the same item at a profit). This is natural since if such trades were possible scaling them up arbitrarily would lead to infinite profits. Third, it renders the market structure irrelevant in the description of equilibrium. This is because the 'Law of One Price' suggests that we may consolidate demands and supplies together into one market.

However, the argument that relates the lack of arbitrage with the 'Law of One Price' and its consequences is fragile. For example, if individuals are inhibited (by institutional or other considerations) from taking advantage of price differences then the 'Law of One Price' may very well fail. Such a case is demonstrated in [1] which demonstrates a kind of failure of the 'Law of One Price' because, due to liquidity constraints, individuals cannot take advantage of the resulting arbitrage opportunity. Imperfect information, transaction costs, search costs etc. have been cited as reasons for this failure. All these market frictions may inhibit individuals (directly or indirectly) from taking advantage of price spreads. In this way we have situations where traders cannot arbitrage price discrepancies, so the obvious failure of the 'Law of One Price' may be compatible with equilibrium. Those situations however should be distinguished from those where individuals are not inhibited (by institutional reasons or other frictions) from arbitraging price differences, but actually choose not to do so. In this way we have a more profound failure of the 'Law of one Price' at equilibrium. But how can it be possible that individuals may find it in their own interest to not arbitrage price differences? Conventional wisdom suggests that this is impossible. However, Koutsougeras [3, 4] had first demonstrated that in non Walrasian markets, i.e. markets where individual activities affect the formation of prices this is entirely possible.

Some recent work, including [3, 4], has pointed out that the relationship between no arbitrage and the 'Law of One Price' depends crucially on the price taking hypopaper. Indeed, the author has pointed out that outside the Walrasian context, the 'Law of One Price' may fail even if markets are frictionless. His contribution was basically to point out the critical role of the 'price taking' hypopaper for the prevalence of the 'Law of One Price' as a consequence of the no arbitrage principle. Indeed, it seems that economists have casually taken the 'Law of One Price' for granted irrespectively of the competitive conditions in markets. Some other profound consequences of this issue were demonstrated in a subsequent paper [5]. From the analysis in [3, 4] it is clear that an equilibrium may be compatible with some apparent arbitrage possibility, but it is less clear that equilibria may be compatible with some arbitrage activity, i.e., some agents simultaneously buying and selling the same objects at a profit. This possibility was demonstrated in a dramatic example in [5]. That example features a resourceless individual who buys and sells assets with the same returns at a profit, which he then spends on other assets. In this way this individual ends up with positive consumption in every contingency, i.e., with certainty. This is a striking departure from the Walrasian model of markets where the presence of resourceless individuals is inconsequential to the model. Besides demonstrating a possibility for equilibria with arbitrage activity the analysis there raises a number of conceptual issues. First, it demonstrates that, the structure of assets can never be 'complete' in the Walrasian sense. In other words even if the asset returns span the whole space the addition of assets changes the set of equilibria. Second, in defining an economy it is not possible to restrict attention to the set of agents with positive endowments. Indeed, in the Walrasian framework an economy is viewed as a distribution of characteristics over a set of individuals, but the support of that distribution can be restricted to the support of the endowment allocation, i.e., to the set of individuals which have a non zero endowment. But the example in Koutsougeras and Papadopoulos [5] suggest that this is no longer true.

We view this conclusion as very important because they suggest that some fundamental implications of the 'Law of One Price' are attached to the competitive framework. The fact that the 'Law of One Price' occurs in different guises in virtually every economic model motivates us to study this issue in more depth, and to further apply those ideas in stylized models. One should keep in mind that lack of price taking may occur for a number of reasons and is not merely a matter of 'small numbers'. Of course, that is the leading reason and it is the one that we will use in this paper as a basis for the lack of price taking by market participants. However, one may think of much more elaborate models where imperfect competition (or lack of price taking) occurs even though there is a large number of participants in markets. For example one may think that there is a continuum of agents but the trading process occurs via a small number of individuals (brokers) who process orders, a model often alluded to in finance. Another example is that of 'herding behavior' also popular with some strain of finance, where a very large number of market participants simply mimic the market actions of a few others. As a result the actions of those few influential individuals have effects on prices. There are therefore many different ways whereby lack of price taking may occur in a market. In what follows, we will stick with the finite number of traders model as it is the simplest framework for our purposes and leave it to the interested reader to see how the issues that we deal with arise in much more elaborate models.

In this paper we extend the conclusions of [3, 4] in a general model of exchange via non-Walrasian markets, i.e., markets where traders are not price takers but instead affect prevailing prices with their market activities. Our purpose is twofold: first, to demonstrate that the conclusions mentioned above do not depend on the context. Second in order to make transparent the reasons why the price-taking hypopaper is crucial for the validity of the 'Law of One Price'. [3] draws the above conclusion by demonstrating an equilibrium in a strategic market game, where commodities are exchanged simultaneously in two markets at different prices. It is further demonstrated that price disparities across markets converge to zero when the number of traders in markets tends to infinity. Hence, the conclusion that without price taking the 'Law of One Price' fails and it is restored as individuals become price takers. However, to a suspicious mind the conclusion may be related to the particular model that is used in that paper. We will demonstrate here that these ideas generalize in quite inclusive models of non-Walrasian markets.

The intuition for the conclusions of [3, 4], elementary as it is, it is not always readily grasped. Equilibria with non uniform prices across markets for a commodity seem odd, because they assign different values to the same commodity, according to which market it is traded in. In the absence of some friction, conventional wisdom would suggest that if prices were unequal then an individual would find it profitable to shift purchases (sales) from a more (less) expensive market to a less (more) expensive one. In this way prices in the two markets would change accordingly so that in equilibrium prices would be equal. However, in an imperfectly competitive set up this conventional wisdom fails. The reason is that in the imperfectly competitive context, shifts of orders across markets involve a 'price effect'. In this way infinitesimal 'shifts' of demands and supplies across markets may change prices in a way so that the net result is unfavourable to a consumer. The intuition of the example can be easily grasped in this way: if an agent reallocated a part of his demand from the expensive market to the cheaper one, the price in the expensive market would fall and at the same time the price in the cheaper one would rise. Therefore a higher price would have to be paid not only for the marginal unit but for all the units purchased from the cheaper post. Thus, the direct effect of shifting a part of the demand is followed by an adverse indirect effect due to the price change. If this price effect is severe enough the net effect can be unfavorable. It is evident from this discussion that since the total benefit depends not only on the quantities moved across markets but the movements of prices as well, which are of opposite direction) it is the relative elasticities across markets that are at work here in calculating the net benefit of such moves. It is our task here to formalize this discussion. We will provide a formula that makes the role of elasticities transparent in this argument.

Our paper proceeds as follows. In Chap. 2, we will present a model of an exchange economy. In Chap. 3, the equilibrium with the existence of arbitrage and the failure of Law of One Price will be demonstrated. We will discuss the incompatibility of arbitrage and efficiency in Chap. 4. In Chap. 5 we will observe how the economy converges when the size of the economy changes. We will show that as the size of the economy is sufficiently large, the arbitrage opportunity will vanish. Then a numerical example of equilibrium with price differences will be constructed in Chap. 7. Finally, we will have a short conclusion at the end of this paper.

2 Model

Consider a set H of agents and L commodity types available in the markets. The consumption set of each individual is identified with R_+^L, Each individual is characterised by an endowment $e^h \in R_+^L$, and preferences over consumption plans are summarized by a utility function $U^h : R^L \to R_+$. We assume that the utility function is twice continuously differentiable, concave and that indifference curves passing through the endowment do not intersect the axis. An economy is defined as $\varepsilon = \{(R^L, U^h, e^h) : h \in H\}$.

Let K_i be a positive integer denoting the number of markets for each commodity $i = 1, 2, 3, \ldots, L$. In this way, the vector characterizing the structure of the market game underlying this economy is $K = (K^i)_{i=1}^L$.

Let $S_h^{i,k}$ denote the set of signals available to individual h in the kth market for commodity i. These signals can be thought of as buy/sell orders or quoting prices and corresponding quantities to be exchanged. The strategy set of individual $h \in H$ is then as follows: $S_h = \Pi_{i=1}^L \Pi_{k=1}^{k^i} S_h^{i,k}$.

Since transactions of all commodities in this economy occur through markets, we proceed to formulate the mechanism via which those objects are priced and distributed. In other words we must model the idea that the signals that arrive in a market somehow collectively give rise to an outcome. In other words the market 'aggregates' the signals it receives to produce what is called a 'market outcome'. We would like to obtain a descriptive model that captures precisely how a market operates to produce an outcome. We will then proceed to define an equilibrium in a (system of) markets, i.e., which outcome is likely to occur from the optimizing behavior of individuals in the choice of their signals. This is in sharp contrast with the Walrasian (competitive) description of trade, where markets and their exact operation is not defined. Indeed, the Walrasian model only describes the economic environment and then directly defines what the equilibrium market outcomes will be, with out explaining the process via which those outcomes will be attained. In other words the Walrasian model describes what market activity will be observed at equilibrium but not out of equilibrium. It turns out that this is done for good reason as it has been shown that when price taking prevails, the description of the Walrasian model suffices in order to identify the equilibrium outcomes, i.e., all other issues and details of the functioning of markets can be 'swept under the rag'. But then again this fact requires proof and a justification, which is a formidable task. Our ideas here are inspired by this consideration as well.

Keeping those considerations in mind we proceed to describe the functioning of markets. Each market performs the following operation:

$$\pi : \prod_{h \in H} S_h^{i,k} \to R_+ \quad \text{(pricing)} \quad \varphi : S_h^{i,k} \times R_+ \to R \quad \text{(distribution)}.$$

That is to say, activities in each market are aggregated into a price vector. The net trades are calculated as a function of the activities of each individual and the price of the commodities in the trading posts, which captures the distribution of aggregate activity. Note that the mechanism is anonymous, and furthermore it does not depend on the object of exchange. The two functions performed by the market mechanism are not independent, i.e., the pair of mappings that describe the operation of a market should somehow be consistent. This is where the idea of 'market clearing' comes in. The two mappings that describe the functioning of a market should satisfy:

$$\sum_{h\in H} \phi\left(\xi_h^{i,k}, \pi(\xi^{i,k})\right) \equiv 0.$$

This condition requires that markets clear at all times (i.e., not only at equilibrium). The principle behind this requirement is that given a profile of signals, whatever exchanges take place at the prevailing prices are exactly feasible, i.e., nothing is left in the market. It might seem to the reader that this requirement already gives a neoclassical feature to the market description. However, this is not true. The above requirement only imposes that whatever is exchanged is indeed changing hands. It does not mean that there is no excess 'supply or demand'. The market outcome might involve assigning a net trade much less than what was signaled, e.g. returning some of the offers back to their owners. Given a set of markets, which operate as above, for a profile of signals $\xi \in \prod_{h\in H} S_h$, the budget of individual $h \in H$ is given by:

$$\sum_{i=1}^{L}\sum_{k=1}^{k^i} \pi(\xi^{i,k}) \times \varphi(\xi_h^{i,k}, \varsigma_{-h}^{i,k}) \leq 0. \tag{1}$$

In the model, bookkeeping of the agents is ensured by the budget constraint. They regulate the exchange of the individuals in following way:

$$\begin{array}{ll} z_h^i = \sum\limits_{k=1}^{k^i} \varphi(\xi_h^{i,k}, \xi^{i,k}) \qquad if \text{ (51.3) holds,} & \\ & \forall i = 1, 2, 3, \ldots, L, \\ z_h^i = \sum\limits_{k=1}^{k^i} \left[\varphi(\xi_h^{i,k}, \xi_{-h}^{i,k})\right]^- \text{ otherwise,} & \end{array}$$

where Z_h^i denotes the agent $h's$ net trade of commodity i. That is to say, individuals can only receive their assigned net trades when they can satisfy their budgets. Their purchases will be confiscated if they go bankrupt. Note that bookkeeping is not part of the functioning of the market, but rather an institutional matter. Each market is indeed unaware of the solvency of the participants in that market, so it has to take into account the signals of individuals who at the end of transactions are bankrupt. In absence of some punishment mechanism, nothing can guarantee that individuals will not misbehave by submitting totally arbitrary signals in the markets or involve in trades that they cannot honour. In order to ensure solvency, some mechanism is necessary which makes solvency be in the best interest of traders.

In the literature other ways of ensuring 'no bankruptcy' have appeared, all of which amount to the same thing. For instance a usual way of doing this is to add a 'penalty' to the utility function of individuals, which is proportional to the amount of default. We could have done the same here but we prefer the more intuitive penalty of confiscating purchases, since as it turns out the choice of the penalizing mechanism is largely a matter of taste rather than of essence.

Thus, for any given profile of signals to markets, each individual $h \in H$ ends up with consumption $x_h^i = e_h^i + z_h^i$.

In this way, each individual is faced with the following problem:

$$\text{Max}(U_h((e_h^i + z_h^i)_{i=1}^L)) : \xi_h \in S_h. \tag{2}$$

Now we have a generalized game where the set of players is H, the strategy sets are $(S_h)_{h \in H}$ and the payoffs are given by $P(\xi_h, \xi_{-h}) = U_h[(e_h^i + z_h^i)_{i=1}^L]$.

An equilibrium in the trading process can now be defined as a pure strategy Nash Equilibrium of this game. In other words a market equilibrium is a profile of strategies such that:

$$\xi_h \in \text{Arg max}\left\{U_h\left(\left(e_h^i + z_h^i\left(\zeta_h^i, \xi_{-h}^i\right)\right)_{i=1}^L\right) : \zeta_h \in S_h\right\}, \quad \forall h \in H.$$

Notice that due to the bankruptcy penalty, at equilibrium, Eq. (2) is equivalent to what follows:

$$\begin{aligned} &\underset{\varsigma_h \in S_h}{\text{Max}}\, U_h\left[(e_h + \sum_{k=1}^{k^i} \varphi(\xi_h^{i,k}, (\xi_h^{i,k}, \varsigma_{-h}^{i,k})))_{i=1}^L\right] \\ &s.t. \sum_{i=1}^L \sum_{k=1}^{k^i} \pi(\xi_h^{i,k}, (\xi_h^{i,k}, \varsigma_{-h}^{i,k}))\varphi(\xi_h^{i,k}, (\xi_h^{i,k}, \varsigma_{-h}^{i,k})) \le 0. \end{aligned} \tag{3}$$

3 Equilibrium

Such an equilibrium is characterised by the following necessary conditions for a solution to Eq. (3), for each $h \in H$:

$$\frac{\partial U_h}{\partial x_h^{i,k}} \times \frac{d\varphi}{d\varsigma_h^{i,k}}(\varsigma_h^{i,k}) = \lambda^k\left[\frac{d\pi}{d\varsigma_h^{i,k}}(\varsigma_h^{i,k})\varphi(\varsigma_h^{i,k}) + \frac{d\varphi}{d\varsigma_h^{i,k}}(\varsigma_h^{i,k}) \times \pi(\varsigma_h^{i,k})\right], \tag{4}$$

where λ^k is the Lagrange multipliers of the constraint. We assume that $\frac{d\varphi}{d\varsigma_h^{i,k}}(\varsigma_h^{i,k}) \neq 0$, which amounts to the mechanism being non-degenerate. In that case the above necessary condition can be written in the following way:

$$\frac{\partial U_h}{\partial x_h^i} = \lambda^k \left[\frac{\frac{d\pi}{d\varsigma_h^{i,k}}(\varsigma_h^{i,k}) \times \varphi(\varsigma_h^{i,k})}{\frac{d\varphi}{d\varsigma_h^{i,k}}(\varsigma_h^{i,k})} + \pi(\varsigma_h^{i,k}) \right], \tag{5}$$

when $\frac{d\pi}{d\varsigma_h^{i,k}} = 0$, which is the price-taking hypopaper, the first term on the right hand side vanishes. The above equation becomes the familiar Walrasian equilibrium condition property of competitive asset prices. On the other hand, $\frac{d\pi}{d\varsigma_h^{i,k}} \neq 0$ indicates imperfect competition.

According to the feasibility requirement of the distribution mechanism we have that:

$$\begin{aligned} \sum_{h\in H} \varphi(\xi_h^{i,k}) \equiv 0 \ \forall k, \forall i \Rightarrow \varphi(\xi_h^{i,k}) \equiv - \sum_{g\neq h\in H} \varphi(\xi_g^{i,k}) \\ \Rightarrow \frac{d\varphi}{d\xi_h^{i,k}}(\varsigma_h^{i,k}) = - \sum_{g\neq h\in H} \frac{d\varphi}{d\xi_h^{i,k}}(\xi_g^{i,k}). \end{aligned} \tag{6}$$

Furthermore, from the definition of distribution mechanism, we have that

$$\frac{d\varphi}{d\xi_h^{i,k}}(\xi_h^{i,k}) = - \sum_{g\neq h\in H} \left[\frac{d\varphi}{dp^{i,k}}(\xi_g^{i,k}) \times \frac{d\pi}{d\xi_h^{i,k}}(\xi^{i,k}) \right]. \tag{7}$$

We can define the elasticity of the excess demand that individual i is faced with in trading post k as:

$$\begin{aligned} \eta_h^{i,k} &= (-) \frac{\frac{d\pi}{d\xi_h^{i,k}}(\xi_h^{i,k})}{\frac{d\varphi}{d\xi_h^{i,k}}(\xi_h^{i,k})} \times \frac{\varphi(\xi_h^{i,k})}{\pi(\xi_h^{i,k})} = \frac{1}{\sum_{g\neq h\in H} \frac{\partial\varphi}{\partial p}(\xi_g^{i,k})} \times \frac{\varphi(\xi_h^{i,k})}{\pi(\xi_h^{i,k})} \\ &= (-) \frac{1}{\sum_{g\neq h\in H} \frac{\partial\varphi}{\partial p}(\xi_g^{i,k})} \times \frac{\sum_{g\neq h\in H} \varphi(\xi_g^{i,k})}{\pi(\xi_h^{i,k})}. \end{aligned} \tag{8}$$

Substitute Eqs. (6), (7) and the elasticity function (8) into (5), and then we can obtain:

$$\frac{\partial U_h}{\partial x_h^{i,k}} = \lambda^k [1 - (\eta_h^{i,k})] \times \pi(\varsigma_h^{i,k}).$$

And thus we can obtain:

$$\frac{\partial U_h / \partial x_h^i}{\partial U_h / \partial x_h^j} = \frac{(1 - (\eta_h^{i,k})) \times \pi(\varsigma_h^{j,t})}{(1 - (\eta_h^{j,t})) \times \pi(\varsigma_h^{i,k})}. \tag{9}$$

Note that when $i = j$, $t \neq k$, then the corresponding F.O.C. becomes:

$$1 = \frac{\pi({\varsigma_h}^{i,k})(1-\eta_h^{i,k})}{\pi({\varsigma_h}^{i,t})(1-\eta_h^{i,t})}. \tag{10}$$

That is to say, $\pi(\varsigma_h^{i,k}) = \pi(\varsigma_h^{i,t}) \Leftrightarrow \eta_h^{i,k} = \eta_h^{i,t}$, i.e., prices in different trading posts are equal to each other if and only if the elasticity terms in each trading post are the same.

From this heuristic analysis, we conclude that equilibrium prices in two markets may be unequal in as much as it is possible to have an equilibrium where $\eta_h^{i,k} \neq \eta_h^{i,t}$, for some individual $h \in H$.

Notice that if we were in a competitive environment where ${d\pi}\big/{d\xi_h^{i,k}} = 0$, then $\eta_h^{i,k} = \eta_h^{i,t} = \infty$. So a fortiori $\eta_h^{i,k} = \eta_h^{i,t}$, which reflects the Law of One Price which is prevalent in competitive markets. However, in an imperfectly competitive context we have the following possibilities:

Proposition 1 *Suppose that the market mechanism is monotonic, in the sense that* $\frac{\partial\varphi}{\partial\pi^{i,k}}(\xi^{i,k}) < 0, \forall \xi^{i,k} \in \Pi s_h^{i,k}{}_{h\in H}$. *If* $\xi \in \Pi_{h\in H} S_h$ *is a Nash Equilibrium where* $\varphi(\xi_h^{i,k}, \pi(\xi^{i,k})) \cdot \varphi(\xi_h^{i,t}, \pi(\xi^{i,t})) \leq 0$, *and* $| \varphi(\xi_h^{i,k}, \pi(\xi^{i,k})) | + | \varphi(\xi_h^{i,t}, \pi(\xi^{i,t})) | \neq 0$, *then* $p^{i,k} \neq p^{i,t}$. *In particular,* $\varphi(\xi_h^{i,k}, \pi(\varsigma^{i,k})) < 0 \Rightarrow p^{i,k} > p^{i,t}$.

A few comments are in order regarding Proposition 1:

First notice that in an equilibrium of the type described in this proposition, individual h is in fact involved in arbitrage activity: (s)he buys commodity i in one post and sells it in another. Also observe that very conveniently for our interpretation, the individual who is involved in arbitrage activity buys from the 'cheap' market ($z_h^{i,t} \geqslant 0$) and sells it in the 'expensive' market ($z_h^{i,k} < 0$).

Second, the above proposition suggests that in a strategic framework arbitrage activity never exhausts an arbitrage opportunity, i.e., the individual h in the above proposition is involved in arbitrage activity, but in the end outcome the arbitrage opportunity is not exhausted, we still have $p^{i,k} > p^{i,t}$. Here we witness an advantage of the nature of the strategic formulation of trade. The Walrasian framework concentrates on the end outcome so it is not capable of detecting arbitrage activities in market, which lead to the end outcome, i.e., the Walrasian framework concentrates on $\varphi(\xi_h^{i,k}) + \varphi(\xi_h^{i,t})$ and not the components $\varphi(\xi_h^{i,k})$, $\varphi(\xi_h^{i,t})$, so it cannot reveal to us anything about arbitrage activity.

It is also worthwhile to point out that the configuration of trades in the above proposition is excluded by the model in [1]. In that paper the authors use a model of 'bilateral oligopoly', where each individual owns exactly one commodity which can be sold in any market, but own no other commodity in order to simultaneously buy back some of it. In other words arbitrage activity is not allowed from the outset of the model. In that case they find that the Law of One Price prevails at equilibrium. Although that model is rather special in many respects, it seems to suggest that the conditions on net trades in the above proposition are necessary as well. However, there is no proof of this. Indeed, even in the special case of the Shapley-Shubik mechanism this cannot be deduced except in very special cases (buy or sell models).

The following Proposition 2 is an immediate conclusion of Proposition 1 above.

Proposition 2 *There is no equilibrium where for some pair of agents $h, g \in H$ and some pair of posts k and t for a commodity i, we have that:*

$$\varphi(\xi_h^{i,k}) \cdot \varphi(\xi_h^{i,t}) \leqslant 0, \left|\varphi(\xi_h^{i,k})\right| + \left|\varphi(\xi_h^{i,t})\right| \neq 0,$$
$$\phi(\xi_g^{i,k}) \cdot \phi(\xi_g^{i,t}) \leqslant 0, \left|\phi(\xi_g^{i,k})\right| + \left|\phi(\xi_g^{i,t})\right| \neq 0,$$
$$\phi(\xi_h^{i,k}) \cdot \phi(\xi_g^{i,k}) \leqslant 0, \left|\phi(\xi_h^{i,k})\right| + \left|\phi(\xi_g^{i,k})\right| \neq 0.$$

A conclusion seems to emerge from this proposition: the segmentation of economy into disjoint groups of individuals, who exchange one or more commodities among themselves in different markets, can never occur at equilibrium. That is to say, in equilibrium, given any group of individuals $S \subset H$ it is not possible to have an equilibrium where: $\sum_{h\in S} \phi(\xi_h^{i,k}) = 0$ and $\sum_{h\in H\setminus S} \phi(\xi_h^{i,t}) = 0$, provided of course that $\sum_{h\in S} \left|\phi(\xi_h^{i,k})\right| \neq 0$ and $\sum_{h\in H\setminus S} \left|\phi(\xi_h^{i,t})\right| \neq 0$.

4 Arbitrage and Efficiency

In what follows we will say that a mechanism (π, φ) allows for arbitrage if there are economies for which this mechanism results in equilibrium with unequal prices. We say that a mechanism is efficient if it results in Pareto efficient equilibria in any economy to which it is attached.

Proposition 3 *If a mechanism (π, φ) allows for arbitrage, then it is not efficient, i.e., equilibria with arbitrage are always inefficient. Equivalently, efficiency of a mechanism implies no arbitrage.*

The conclusion that we can draw from this proposition is that, the Pareto efficiency and arbitrage are not compatible with each other in the same economy. Lack of arbitrage opportunity is the characteristic of an efficient economy. Price differences between trading posts can never occur in an efficient economy. This result seems to justify the identification of no arbitrage equilibria with efficiency of the markets, which is popular in the finance literature. Indeed, often in finance no arbitrage is referred to as the ‘efficient markets hypopaper’, although many economists have pointed out that this causes confusion as the term efficiency might be confused with Pareto optimality. In particular economists are quick to point out that in incomplete markets equilibria are characterized by no arbitrage and yet they are (generically) inefficient (in the sense of being Pareto sub optimal). The above result suggests that indeed there is a relation between arbitrage and efficiency in the sense of Pareto optimality, at least for the complete markets case. When markets are incomplete efficiency is ruled out, but then again arbitrage is ruled out from the start in that model, so it is not clear that it is a fair example for the relationship between efficiency and arbitrage.

5 Asymptotic Price Distribution

Clearly, with a finite number of agents, equilibria are compatible with a non-uniform distribution of prices across markets for a commodity. We would be interested to study the asymptotic distribution of prices as the number of individuals increases. Intuitively, if the Law of One Price is to obtain somehow in a competitive economy, then it must be the case that price distributions converge (in some sense) to uniform ones.

Note that the Law of One Price is restored if and only if $\eta_h^{i,k} = \eta_h^{i,t}, \forall k, t, i, \forall h \in H$. This would be the case if in particular $\eta_h^{i,k} = \eta_h^{i,t} = 0, \forall k, t, \forall h \in H$. Thus, it is sufficient (but not necessary at this point), that along a sequence with an increasing number of agents $\eta_h^{i,k} \to 0, \forall k = 1, 2, 3 \ldots, k_i$.

Therefore, to obtain sufficient conditions so that the Law of One Price obtains in the limit we should look for conditions so that $\eta_h^{i,k} \to 0$ as $\#H \to \infty$. More generally, we would like to show $\frac{\eta_h^{i,k}}{\eta_h^{i,t}} \to 1$ as $\#H \to \infty$. A measurement of the dispersion of the price distribution d^i can be defined as follows:

$$d^i = \sup\left\{\frac{p^{i,k}}{p^{i,t}} - 1 : \quad k = 1, 2, \ldots, K_i\right\}$$
$$p^{i,t} = \min_{r=1,2,\ldots,T_i} \{p^{i,r} : r = 1, 2, \ldots, K_i\},$$

notice that $p^{i,t} = \min_{r=1,2,\ldots T_i} p^{i,r} \Rightarrow d^i \geqslant 0$.

Lemma 1

$$d^i \leqslant \frac{1}{\sum_{m\in H} \frac{\partial\varphi}{\partial\pi}(s_m^{i,k})} \times \frac{\frac{\varphi(s_h^{i,t})}{\pi(s_h^{i,t})} \times \sum\limits_{m\neq h} \frac{\partial\varphi}{\partial\pi}(s_m^{i,k}) - \frac{\varphi(s_h^{i,k})}{\pi(s_h^{i,k})} \times \sum\limits_{m\neq h} \frac{\partial\varphi}{\partial\pi}(s_m^{i,t})}{\sum\limits_{m\in H} \frac{\partial\varphi}{\partial\pi}(s_m^{i,t}) - \frac{\varphi(s_h^{i,t})}{\pi(s_h^{i,t})}},$$

let $\psi(K) = \min\left\{\frac{\partial\phi}{\partial\pi}(s_m^{i,k}) : h \in H\right\}$ *and* $\psi(T) = \max\left\{\frac{\partial\phi}{\partial\pi}(s_m^{i,t}) : h \in H\right\}$.

Theorem 1 *If* $\xi \in \prod_{h \in H} S_h$ *is a Nash Equilibrium, then*

$$d^i \leqslant \frac{1}{\#H \times \psi(K)} \times \frac{\frac{\varphi(s_h^{i,t})}{\pi(s_h^{i,t})} \times (\#H - 1) \times \psi(K) - \frac{\varphi(s_h^{i,k})}{\pi(s_h^{i,k})} \times (\#H - 1) \times \psi(T)}{\#H \times \psi(T) - \frac{\varphi(s_h^{i,t})}{\pi(s_h^{i,t})}}.$$

Proposition 4 $d^i \to 0$ *as* $\#H \to \infty$. *What we have done is to relate the number of agents* $\#H$ *with the measurement* d^i *that we define the prices' deviation from the uniform price. We got the expression with both* $\#H$ *and* d^i, *which shows that the value of* d^i *is negatively related with* $\#H$. *That is to say, as* $\#H$ *increases, the value of* d^i, *which is positive as defined, reduces. As* $\#H$ *goes to be infinity,* d^i *goes to zero.The implication of Proposition 4 is that, in the limit, when the number of the agents is infinite, the Law of One Price will hold.In other words, the Walrasian Equilibrium is compatible with the strategic market game equilibrium when the market is large enough.*

6 A Numeric Example

The example following features an equilibrium with two distinct positive prices for each commodity. In this way the idea of multiple trading posts becomes intuitive.

We have two purposes in constructing this example. Firstly, we show that the Law of One Price is not typical in the strategic market game. And secondly, we can see that the agents are optimizing their benefits by exploiting arbitrage opportunities. To demonstrate this, we have a characterization of the utility functions for which the proposed allocation is Nash equilibrium.

The example consists of three agents, $H = 1, 2, 3$. There are 3 commodities in the market, $L = 1, 2, 3$. And for each commodity, there are 2 trading posts. The consumption set of each agent is R_+^3.

The endowments are given as follows:

$$e_1 = \left(\frac{2955}{256}, \frac{111}{8}, \frac{2197}{256}\right), \quad e_2 = \left(\frac{111}{8}, \frac{2197}{256}, \frac{2955}{256}\right), \quad e_3 = \left(\frac{2197}{256}, \frac{2955}{256}, \frac{111}{8}\right).$$

We can get the following results with the substitution of values for bids and offers:

$$\text{Agent}(1): \frac{\partial u_1}{\partial x_1^1} = \frac{5}{2} \times \frac{\partial u_1}{\partial x_1^2} = \frac{5}{3} \times \frac{\partial u_1}{\partial x_1^3},$$
$$\text{Agent}(3): \frac{\partial u_3}{\partial x_3^1} = \frac{3}{5} \times \frac{\partial u_3}{\partial x_3^2} = \frac{3}{4} \times \frac{\partial u_3}{\partial x_3^3}.$$

By doing as above, we constructed a set of partial differential equations, which characterises the set of functions that solves our problem. And also, we now have a characterization of the family of utility functions for which the proposed allocation is a Nash equilibrium. Our example is robust enough to be shown in an informal with this fact. We have following utility functions:

$$u_1(x_1^1, x_1^2) = \log(x_1^1) + \frac{5}{2}\log(x_1^2) + \frac{5}{3}\log(x_1^3),$$
$$u_2(x_2^1, x_2^2) = \log(x_2^1) + \frac{4}{3}\log(x_2^2) + \frac{4}{5}\log(x_2^3),$$
$$u_3(x_3^1, x_3^2) = \log(x_3^1) + \frac{3}{5}\log(x_3^2) + \frac{3}{4}\log(x_3^3).$$

7 Conclusions

In this paper we have attempted to provide an analysis of the relationship between equilibrium and arbitrage in the non Walrasian context. We certainly are not original in conceiving these ideas, but we do claim to have extended those in a more general framework and thus demonstrate that the original results to this effect, presented in existing literature are not confined to the somewhat specific nature. In particular, we believe that the contribution of this paper has been to make explicit the crucial role of market elasticities in the relation of equilibrium and arbitrage in non Walrasian markets, which is alluded to in the arguments of the prototype papers in this area, but it cannot be made precise in the explicit model used in existing literature.

The central message of this line of research is that, outside the Walrasian framework, equilibrium and arbitrage can coexist even with frictionless markets. There are equilibria of games with multiple trading posts that cannot be captured by the market game with one trading post. Those are equilibria where the Law of One Price fails. The existence of such equilibria is decided by the number of agents in the market, or, by the size of the market. In other words, the appearance of such equilibria is entirely due to the finiteness of the number of agents in the economy. An important implication of this analysis is the relevance of the market structure in non Walrasian models of markets. This is often ignored in standard models of imperfectly competitive markets, notably in industrial organization.

Another important result of this paper is, as the economy approaches the limit, the price in different markets becomes uniform. So when the economy is large enough, or the number of the agents in the economy is large enough, the Law of One Price does not fail dramatically. We have also provided here a result that relates arbitrage and efficiency. We have showed that the presence of arbitrage activity in market transactions implies some inefficiency in the Pareto sense, something that is frequently alluded to but has never been made precise.

A couple of issues seem to arise from this result for further research. First, it would be interesting to see whether the opposite statement may hold in some way, i.e., whether a mechanism that does not allow for arbitrage is efficient (in the Pareto sense). Second, whether there is any relationship between approximate efficiency (as in [6]) and limited arbitrage. Indeed in this paper we did not address the efficiency issue extensively because in the context that we used efficiency is an exception rather than the rule. Besides, it is not clear what a fair comparison might be. First of all, it is not clear that every equilibrium with arbitrage is dominated by equilibria without arbitrage. Second, since either type of equilibria are inefficient such comparisons as 'more' or 'less' efficient are hard to even contemplate. Unfortunately the Pareto criterion only says whether or not an equilibrium is efficient but nothing beyond that.

Our results have some interesting application in related areas. Arbitrage is one of the focuses in the current literature on financial economics. [3] explains the nature of arbitrage in financial market and its convergence with strategic market games. In the paper, the authors showed that in imperfectly competitive markets a spread between the cost of a portfolio and its returns is compatible with equilibrium. And also examples of equilibria where agents hold a portfolio with zero cost and positive return can be obtained in that framework.

One interesting application of these ideas is international trade. The 'Law of One Price' appears there as the 'Purchasing Power Parity' principle, which is just as central to international trade as the no arbitrage principle is to finance. The Purchasing Power Parity principle has been the object of many scientific debates and its validity has been questioned in numerous theoretical as well as empirical studies in international trade. We believe that the ideas in this paper can be successfully applied in that framework. Given the generality of the model that we presented herein an extension to a general equilibrium model of international trade is feasible. We do not pretend to be the first to do this. Geanakoplos [2] unified international trade and finance in a single general equilibrium model, which included multiple commodities, multiple currencies, heterogeneous consumers in each country and multiple time periods. In this paper, the authors argue that international trade satisfies the Purchasing Power Parity. However, we intend to be original in demonstrating the failure of the Purchasing Power Parity principle in an imperfectly competitive model of international trade. The interested reader can certainly think of several stylised facts (that have been pointed out repeatedly) in the international trade literature, which give rise to imperfectly competitive features in international markets (for one there are only finitely many countries on the globe).

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Role of Web in an Online Setting: Consumers Perceived Risk Toward Online Purchase Intention

Muhammad Kashif Javed, Muhammad Nazam, Jamil Ahmad, Abid Hussain Nadeem and Talat Qadeer

Abstract Consumer trust plays an important role in any type of business deal specifically in an online setting. Though, there are hypothetical reasons to assume that the perceived risk acts as a fence to consumer trust. Likewise, existing literature suggest that consumers trust is a significant predictor of purchase intention. Therefore, this study aims at investigating the role of consumer trust in an online setting in the relationships among components of perceived risk (such as performance risk, online payment, and delivery risk) and purchase intention. Structural equation modeling (SEM) is used to test the hypothetical relationship in this context. While probing the total effect, the findings shown that performance, online payment, and delivery risks have a significant negative effect on purchase intention. This research also accomplishes that efforts, made by an online store, to diminish certain types of risk will first increase consumer trust, and then finally, increases consumers intention to purchase online. The managerial implications of the outcomes are also discussed.

Keywords Online setting · Perceived risk · Purchase intention · Consumer trust · Structural equation modeling

1 Introduction

Internet-based commerce has experienced explosive growth over the previous decade as consumers nowadays find it cheap as well as more appropriate to shop online. However, the change in the common way of shopping from offline (at store) to online commerce has caused customers to have doubts over subjects, such as online deception, private information leakage, inconsistency in product grade and quality, failed to delivery, and so on. Unluckily, there has been a increase in the number of

M.K. Javed (✉) · M. Nazam · J. Ahmad
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: mkjaved3@gmail.com

A. Nadeem · T. Qadeer
Islamia University, Bahawalpur, Pakistan

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cases that source consumers to have such concerns; for instance, the Internet Crime Complaint Center news that it has got 314,246 Internet deception complaints in 2012, which were 95,064 complaints in 2003 [12]. Consequently, consumers feel insecure about making purchases online. Consumers concerns over online buying are mutually termed as their perceived risk.

The effect of trust on perceived risk is value studying; the effect in the opposite way is similarly important, allowing insights into the possible of perceived risk such as an inhibitor of trust. Because, a consumer who perceives enormous risk regarding an online transaction is probable to foresee a countless potential of loss and therefore, places tiny trust in this settings. Agreeing to Pavlou [18], the main causes of the perceived risks whichever the technological uncertainty on the Internet setting or the behavioral uncertainty on the transaction companion.

In line for such kinds of uncertainty, the upsurge in worries above the perceived risk may damagingly affect trust. Such as, if a consumer who directs sensitive transaction data on the Internet is worried that his/her private information may slip out due to a lack of security; trust may decline [17]. In the same way, if the consumer senses that the online setting has the potential to revenue by behaving in an unscrupulous manner by captivating advantage of the distant, impersonal nature of online business, then it is not likely that the online setting will be trusted. Specifically, the additional likely it is for a hazard to occur, the smaller is the trust and the larger is the need to control the business deal [17].

Previous literature has also been focused on empirically investigating the influence of trust on perceived risk with slight attention keen to the influence of perceived risk on trust [2, 3, 6]. The current research is a step to filling that hole in existing research. It purposes at addressing the need to study the fascinating relationships amid perceived risk and purchase intention in an online (e-commerce) setting. To achieve the research objective, we recognized two research queries. (a) Does perceived risk perform as an inhibitor of purchase intention? (b) Does trust in an online setting mediate the relationship between purchase intention and perceived risk? We defined perceived risk into three different types based on the above literature, and empirically examined the effects of each dimension of perceived risk on purchase intention.

Hypothetically, it will pay attention to the existing body of literature by given that new insights into the role of consumer trust in an online setting in the relationships between perceived risk and purchase intention. Basically, the research will help online setting develop strategies to decrease the specific kinds of perceived risk originate to negative effect on trust, thus producing consumer trust in an online setting and eventually increasing online sales.

2 Theoretical Framework and Hypothesis

An individual perceives a condition as bearing risk if incoming this condition might lead to destructive consequences, and likewise if the individual is not competent to control the incidence of these concerns [15]. Therefore, the more destructive are the concerns and the less the individual can control the concerns, the advanced is the level of perceived risk. In this context of e-commerce, Cox and Rich [4] proposed perceived risk as the amount of risk perceived using a consumer in anticipating a specific purchase decision.

Trust refers to considering that the trustee will not damage to the trust and that negative significance will not occur. In the context of e-commerce, trust develops an even more important subject since exchange relationships are grounded on the objective nature of the Internet setup. In specific, consumers face the challenge of purchasing a service or product online from an unfamiliar seller; moreover, they cannot really see or touch the product. So, Trust plays a vital role in helping consumers overawed the perceptions of risk and uncertainty [16]. Meanwhile privacy and security concerns are main barriers to the online setting, without trust, customers will not provide vendors their personal information, containing credit card information and soon [10].

The existence of trust suggests the receiving of a sure degree of risk toward the loss when the expected consequence is positive. Whereas chooses to trust if the risk that he/she has to take in an acceptable range, trust or has no choice but to give it up making the trusting option in case the risk is probable to go beyond the limit. Consequently, the perceived risk can be a significant predictor of the trusting decision. Additional, a trusting choice will be completed if the subjective likelihood of an event of optimistic valence is advanced than the subjective likelihood of an incident of negative valence [5]. That is a trust or will not select to trust in circumstance risks are expected to be bigger than benefits. In the words of Olivero and Lunt [17], this concept is applied to the e-commerce setting. If a consumer links high risk using an online transaction, at that time level of trust in the online settings decreases and the need to switch the transaction increases.

Therefore, under situations where there are time stresses or a shortage of information or difficulties in governing the trustees behavior, uncertainty will be present. Risks in electronic commerce are presented by both the objective nature of the online environment and the uncertainty with the Internet for dealings [18]. Formerly, such uncertainty has two mechanisms: behavioral uncertainty as of the transaction partner and the environmental uncertainty as of the technical environment of online dealings [17]. So, Behavioral uncertainty happens as the Web vendor has the chance to act in an opportunistic manner, while environmental uncertainty happens due to the unpredictable features of the Internet setup.

Hypothesis Development
When consumers have trouble grasping the landscapes of products such as garments, shoes, and electronics solely from Website images, they could be easily worried that the products ordered might not be precisely as it seemed on the Website or might not perform up and doing to their expectations [8]. Strong perception of product performance risk will outcome in minimal trust in the online business. For example, an online consumer seeing purchasing such products as fresh vegetables, household items, or a cellphone often takes precautions to guarantee that the product under deliberation for online purchase meets his/her performance expectations. If the consumer

has certain doubts regarding these performance questions, he/she will put little trust in the online setting.

Hypothesis 1 Performance risk has a negative effect on consumer trust toward an online setting.

A risk element that can develop an important consideration in online setting is the perceived risk related with online payment. Several surveys have exposed that Internet users are increasingly worried about the possibility that their personal and credit card information may be apprehended, collected, and distorted by a hacker or even by online sellers without permission. These apprehensions will cause the customer to look for an alternative way of shopping (such as making purchases at a store). If a consumer is curiously concerned that his/her personal and financial information may come out due to the opportunity of a hacking case, he/she is likely to misplace trust in the online environment. For example, when consumers find that online shopping sites do not deliver minimum security, they are probable to doubt the dependability of the Website and even to select not to purchase online. As a consequence, we propose the subsequent hypotheses.

Hypothesis 2 Online payment risk has a negative effect on consumer trust toward an online setting.

While purchasing online, a shopper needs to intend for an order to arrive. The delivery containing the ordered product might be lost or delivered to an incorrect address or not in time if there is a shortage of business experience on the part of the courier company or a very slow courier services. Moreover, it is likely that the order reaches later than expected, if there is a backorder going on the ordered product [1]. In this situation, a consumer who has robust perception of delivery risk will likely lose concern in the online purchase. In conclusion, an online consumer who experienced several occurrences of wrong delivery and therefore perceives robust delivery risk will no longer trust the online setting, and probably intend not to purchase. It is also valid when the online shops outsource their delivery procedure to the third party service suppliers. With the greater level of perceived delivery risk, consumers can put less trust in the online purchasing, and consequently, may look for other substitutes to buy online from. Hence, we propose the following hypothesis:

Hypothesis 3 Delivery risk has a negative effect on consumer trust toward an online setting.

In the meantime, the causal relationship in the middle of trust and purchase intention has been also renowned by researchers. Jarvenpaa et al. [13] smeared the theory of reasoned action (TRA) to Web-based (online) shopping, and determined that a customers online purchase intentions are prejudiced by attitude, and attitude is exaggerated by consumer trust. In the same line, Heijden et al. [9] lead an empirical learning based on TRA, and stated a similar verdict; trust has an indirect influence on transaction intents through the approach as a mediator. In online business, trust in a matter partner represents behavioral views about the partner, also these views can change the consumers negotiating intentions for online transactions. Though, the majority of other connected studies [7, 20] deliver contrary research judgments indicating that trust has a direct influence on purchase intentions.

Hypothesis 4 Consumer trust has a direct and significant effect on purchase intention in an online setting.

3 Research Methodology

First and foremost, this research explained the data collection and sampling method. Afterwards, the procedure on how to improve the measures and model constructs were discussed. Finally, the subject of method bias was also explained.

3.1 Data Collection and Sample

The measures were hired from the related literature and improved to suit the study. Measures (3 items scale equally) of perceived risk such as performance, online payment, and delivery risk came from Cases [1], Jacoby and Kaplan [14]. The 3 items measure for consumer trust came from Pavlou [18], and Hongand Cho [11]. Finally, 3 items measure for online purchase intention came from Jarvenpaa et al. [13]. All items were measured at 7 point Likert scales, fastened by (1) strongly disagreed and (7) strongly agree.

Data were collected for the garments sector. The survey was managed online so we were capable to package the analysis in order to control the arrangement of questions; made sure that everybody was exposed and answered to all questions. The program did not let participants to complete the questionnaire more than once.

After erasing those who responded so fast we had 305 usable questionnaires; 46 % are female, 53.5 % are male, and 0.5 % did not disclose their gender. The largest age range in the sample is 18–26 (53 %), followed by 27–35 (27 %), and 20 % were over 35. About 80 % of respondents said that they bought from online sites once or multiple times during last month.

3.2 Results

Structural equation modeling (SEM) and LISREL (8.1) were used to test the hypothesized model (Fig. 1), the interpretation of outcomes does not proceed till the goodness of fit has been evaluated. However, after we released reasonable limitations on some correlations amongst the unique components of our CFA (Confirmatory Factor Analysis) model the normal global fit indexes (Chi-square, SRMR, RMSEA, CFI) testified a fairly good fit.

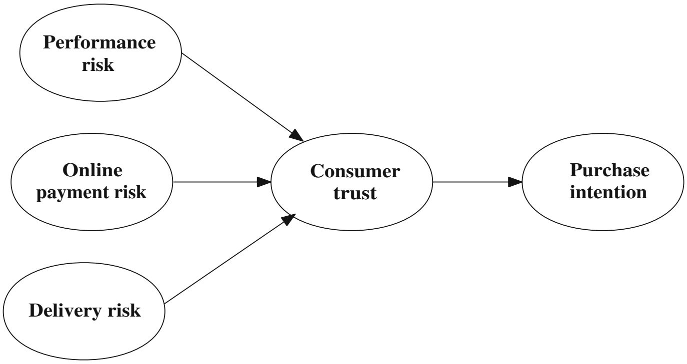

Fig. 1 Research model

The closing model-measurement and structural-produced $\chi^2(74) = 86.02$, 90 % confidence interval for RMSEA = (0.0338; 0.0286) with p value for test of close fit (RMSEA < 0.05) = 1.000; a comparative fit index (CFI) = 0.986 and standardized NNFI of 0.995 which shows a very good fit. No other indexes were less favorable.

Anyhow, our case involves reliability of the indicators and composites (Table 1), and a relatively stingy model. Certainly, we have made a more comprehensive diagnosis, containing whether the assessed values are reasonable and of the estimated sign,

Table 1 Results of the measurement model

	Factors	Standardized loadings
Performance Risk (PR)	PR1	0.77^m
	PR2	0.80 (10.75)
	PR3	0.75 (9.40)
Online Payment Risk (OPR)	OPR1	0.71^m
	OPR2	0.80 (8.4)
	OPR3	0.75 (9.2)
Delivery Risk (DR)	DR1	0.70^m
	DR2	0.78 (8.94)
	DR3	0.58 (9.29)
Consumer Trust (CR)	CR1	0.67^m
	CR2	0.34 (7.72)
	CR3	0.70 (10.94)
Purchase Intention (PI)	PI1	0.74^m
	PI2	0.81 (9.72)
	PI3	0.70 (10.94)

Goodness of fit statistics:
$\chi^2(69) = 89.58$, $p = 0.06$); RMSEA = 0.028, SRMR, $p = 0.032$, CFI = 0.974, NNFI = 0.952)
^{n} t values for the un-standardized answer are in parenthesis
^{m} Item fixed to scale

Table 2 Standardized regression weights

Hypothesis	Expected sign	Standard estimate	t value
H1: Performance Risk → Consumer trust	–	−0.12	−0.69
H2: O payment Risk → Consumer trust	–	−0.53	−3.21
H3: Delivery Risk → Consumer trust	–	−0.17	−0.71
H4: Consumer Trust → Purchase intention	+	0.18	0.71

Goodness of fit statistics ($\chi^2(74) = 86.02$, $p = 0.10$); RMSEA = 0.033, SRMR = 0.034, CFI = 0.986, NFI = 0.962, NNFI = 0.995).

whether the correlation residuals propose the adding of parameters, or whether the alteration indexes and the estimated parameter change leads to reasonable estimates. This is in line by way of a recent suggestion by Saris et al. [19] that recommended disbursing more attention to the recognition of misspecification mistakes (rather than concentrating solely on the fit indexes) and taking into explanation significance levels also power of the test. It has been stated, since our initial model directed to some misspecifications, rendering to the Saris et al. [19] process, we released a some justified constraints on uncorrelated exclusivity and as a result the model fits the data well.

The standardized regression weights (Table 2). designate that the relationships signified by all the hypotheses projected in this paper, that is hypothesis 1, hypothesis 2, hypothesis 3 and hypothesis 4 are supported. The results display that consumers perceived risk has a significant and negative relation with both consumer trust and purchase intention. Consumer trust has a positive and significant relation with purchase intention.

We would also like to remark that the correlations amongst our latent constructs were all negative and quite high because they are much less weakened by measurement error (Table 3). Nevertheless, even though the correlation of consumer perceived risk and purchase intention is not at all insignificant in our model, the estimation of the direct effect of perceived risk on trust is implausible. Additionally, this correlation is sufficiently reproduced just by the summation of the direct effects from consumer perceived risk through consumer trust as intervening (mediating) variables.

Table 3 Correlation matrix

	Performance risk	Payment risk	Delivery risk	Consumer's trust	Purchase intention
Performance risk	1.00				
Payment risk	−0.87	1.00			
Delivery risk	−0.96	−0.95	1.00		
Consumer's trust	0.86	0.90	0.89	1.00	
Purchase intention	0.52	0.65	0.84	0.58	1.000

4 Discussion and Conclusion

Existing research often reflects perceived risk as a uni-dimensional construct, and so, emphases on demonstrating that the perceived risk as a entire tends to inhibit consumer approach and transaction intents. On the conflicting, our results revealed that the effect of perceived risk on its significance were different contingent on the extents of the perceived risk. We likewise found three significant effects supporting H1, H2, and H3. It was confirmed that performance dimension of perceived risk and trust are in a very close, always together relationship, and this finding is constant with other study [17]. Meanwhile, it is motivating to note that the online payment, and delivery risk had a direct negative influence on consumers trust. It means consumer's also have reservations about delivery and payment risk, so need to improve the online payment and delivery process.

It has seen steady growth in garments sector sales as well as the total of online consumers. These changes have been determined in part by enhancements in the Web-based arrangement system and decrease in transaction costs. However, consumer perceptions of risks related with online purchases keep on great obstacles to the sustained growth of garments sector. In this setting, this study focused on examining the intriguing relationships between dimensions of consumers perceived risk, consumer trust, and their purchase intention.

While consumer trust in an online setting completely mediates the effect of perceived risk and has a positive effect on purchase intention i.e. higher consumer trust toward an online shop may cause a greater purchase intention. The findings have confirmed that while there is a negative relationship between perceived risk and consumer trust, but in this relationship consumer trust which is a mediated by perceived risk and purchase intention has also an opposite effect (in case of higher trust) in an online setting.

Our study makes scholarly and practical contributions by providing new understandings into the theoretical and practical relationships among consumers perceived risk, trust, and purchase intention. Different to current research, our study has found that some components of consumers perceived risk are an inhibitor of their trust. It was exposed that performance, payment, and delivery risks have a negative effect on consumer trust. It has also found that the relationships between these risks and purchase intention are mediated by trust in an online setting. The research also provides practical implications for managers of garments commerce. The role of consumer trust in the relationships concerning perceived risks and purchase intention proposes that an online setting can increase deals by first dropping the perceived risks, thus building consumer trust that then will purpose to improvement purchase intention.

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An Empirical Study on the Effect of Inflation Transmission

Haiyue Liu

Abstract This paper aimed to analyze the international transmission of inflation and explore the existence of inflation between U.S. and some representative countries before the outbreak of the global financial crisis. Therefore, 14 countries or regions (including developed countries, developing countries and less developed countries) were selected, such as U.S., China, Canada, Japan, etc. Their consumer price index (CPI) between 1990 and 2008 was analyzed. Through the co-integration test and the Granger causality test, the results revealed that the effects of the United States upon the inflation transmission to France, Italy and most of the developing countries were quite limited, but effective upon the inflation transmission to Japan , UK, Korea and China.

Keywords Inflation · Foreign direct investment (FDI) · CPI

1 Introduction

Under the background of economic globalization and economic integration, one nation is benefited from the open economic policy on one hand, and meanwhile experienced the side effects on the other during the gradual opening up. Among these possible side effects, "international transmission of inflation" is the one that significantly needs to be paid the widest attention. Generally speaking, inflation is considered to be a phenomenon of domestic economic imbalance. As for the causes of inflation, many researchers were limited to analyze it in a closed economy at first. After the outbreak of oil crisis in 1970s, it has been increasingly obvious that inflation can be spread from one nation to others through trade and investment channels. The price level in one nation became further affected by international import factors rather than purely depended on domestic factors. This issue is especially relevant also because most countries are small open economies, which are vulnerable to external shocks. Therefore, a good understanding of the international transmission

H. Liu (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: seamoon@scu.edu.cn

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of inflation provides valuable guidance for macro-economic policy makers in order to maintain economic growth and price stability.

This paper intends to analyze the total effect of inflation transmission between U.S. and other countries before the outbreak of financial crisis. It chooses 14 counties including U.S., China, Canada, Japan etc. grouping into three categories as developed countries, developing countries and undeveloped countries with heavy trade dependency on one commodity. It conducts the co-integration test and Granger causality test using yearly data from 1990–2008.

2 Literature Review and Hypothesis

2.1 Literature Review

The theory of transmission of inflation is always an issue that attracts attention and concerns. There are a lot of scholars trying to prove that inflation could be transmitted through certain channels. The Norwegian Mode on the imported inflation of a small open economy became widely acknowledged which proved that the inflation can be transmitted to another country firstly through trade departments and then to non-trade departments [1]. Later Mundell [9], Swoboda [9], Frenkel and Johnson [5], used monetary theories especially the variable of money supply to analyze the path of inflation transmission among countries. Branson combined the Philips curve and trade, linked the balance of payment and income together, proved the connection between domestic price and world price. Michael [4] and Kevin [10] found out that inflation could be transmitted from one country to another through complex channels including trade, exchange rate system, money and capital market.

As for the empirical research, quite a lot of scholars try to prove the effectiveness of these channels by taking developed countries and newly emerging industrial countries as samples. Jeong and Lee [6] took G7 countries as samples and tried to identify the major inflation-exporting country through co-integration test, they found out that U.S. is the major inflation-exporting country among G7. Cheng and Yuen [3] took Singapore and Hong Kong as inflation- recipient countries and try to identify how U.S. is transmitting inflation to these two, later they reached the conclusion that fixed exchange rate system could worsen the sensitivity to crisis for a small open economy. Boschen and Charles [7] used a pooled cross-country time series framework to study the factors associated with the start of 73 inflation episodes in OECD countries since 1960 and found that U.S. Inflation turned out to be a triggering event for simultaneous outbreaks of inflation across countries. Jian et al. [7] investigated the international transmission of inflation among G-7 countries using data-determined vector auto regression analysis, as advocated by Swanson and Granger [11]. They find that unexpected changes in U.S. inflation have large effects on inflation in other countries especially after 1990s. Joaquin [12] examined the effect of monetary shocks in the U.S., Japan and China on the Euro area. The results show that U.S. monetary aggregates have small effects on Euro area through testing on the variables over 1999–2011. Zuo [13] took an angle from the Quantitative-Ease (QE) monetary policy of U.S. Federal reserve and thinks QE is the major source of imported inflation in China in a way of direct investment and increased price of bulk stock.

Based on the literature review, the theoretical literatures are rich and acknowledged, while the empirical research is quite limited and controversial due to the complexity of transmission channels and sources. A lot of empirical test only focused on developed countries such as G7 or only tested one transmission channel such as trade. The effectiveness of each channel actually defers according to different economic variables such as exchange rate system, monetary policy, and trade dependency and so on. This paper tries to explain how the transmission effectiveness is different among different countries due to the different country groups they belong to in order to add some empirical value to the existing literature.

2.2 Hypothesis and Data

Hypothesis 1 U.S. is a major inflation-exporting country. The reasons are as follows:

Firstly, from the economic scale aspect, U.S. is the largest economy in the world. In 2008, the total U.S. GDP was 142 million dollars which means about 18.3 % of the global total. In contrast with 25.4 % in 2007, the ratio has decreased which still took up about 1/4 of the global GDP despite of the influence of financial crisis.

Secondly, from the trade aspect, U.S. takes a huge percentage in global trade market. In 2008, the total U.S. volume of the export and import was 3.46 trillion dollars which took up about 22 % of the global trade. U.S. was the third largest exporter with 1.29 trillion in total and the largest importer with 2.17 trillion in total All these figures show that U.S. plays an important role in global trade.

Thirdly, from the investment aspect, U.S. is the country that has the largest foreign direct investment (FDI) flow globally. In 2008, it topped the list as it took the FDI inflows of 316 billion and the outflow of 312 billion with the oversea M&A nearly took up about 1/3 of the global total; In 2007, US took 20 positions among the top 100 non-financial companies ranked by overseas assets in the world; In 2008, U.S. took 8 positions among the top 50 financial companies in the world including Citibank, Morgan Stanley and AIG etc.

Hypothesis 2 There are three types of countries in the world: developed countries, developing countries and countries with heavy trade dependency on one commodity.

During the research, we carefully choose the countries into the test which could belong to certain group with representative values. Countries are grouped as developed countries (U.S., Canada, U.K., France, Japan, Germany, Korea and Italy), developing countries or districts (China, Taiwan, India, Malaysia and Mexico), countries with heavy trade dependency on one commodity (Saudi Arabia). Among the developed countries, we chose two types, one of which is the type that closely follow the U.S. monetary policy and heavily rely on U.S. as bilateral trade is concerned such as Japan, Korea and Canada. Another type is the ones that belong to the European Union (EU) such as Germany, France and U.K.

Hypothesis 3 We take level of price changes as a variable to represent inflation, deflation is also considered. So it can be regarded as price shocks.

It is important to note that some countries or districts have once experienced a period of deflation like China from 1990 to 2008. However, either the international transmission of inflation or that of deflation is basically a kind of phenomenon that the price change in one nation causes the corresponding change in others. They are two sides of one coin. Based on this, the paper just studies the influence mechanism of U.S. price changes on these chosen countries or districts. Therefore, there is no special difference between inflation and deflation in this paper.

The CPI data of the countries are all from the International Trade Admission Database taking 2005 as the base year.

3 Unit Root Test of the Stationarity of Time Series (ADF Test)

ADF test was completed through the following three models:

$$\varDelta X_t = \delta X_{t-1} + \sum_{i-1}^{m} \beta_i \varDelta X_{t-i} + \varepsilon_t, \tag{1}$$

$$\varDelta X_t = \alpha + \delta X_{t-1} + \sum_{i-1}^{m} \beta_i \varDelta X_{t-i} + \varepsilon_t, \tag{2}$$

$$\varDelta X_t = \alpha + \beta t + \delta X_{t-1} + \sum_{i-1}^{m} \beta_i \varDelta X_{t-i} + \varepsilon_t . \tag{3}$$

In model (3), it is time variable which represents a certain trend that time series changes over time (if have). The main difference among the three models mainly refers to whether intercept or trend is included in the test equation. If null hypothesis 0: $\delta = 0$ during the test, it means it has a unit root and the time series is non-stationary consequently; while if the alternative hypothesis 1: $\delta < 0$, then the time series is stationary. Practically, the test starts from model (3), model (2) and then model (1). When the test refuses null hypothesis, the test can be stopped.

The sample data adopted in this paper are all time series data, therefore, the co-integration relationship between sampled data should be took into consideration when analyzing the possible influences of U.S. inflation rate on the price change in other countries. For this reason, ADF test will be used in this paper to conduct stationary test on time series. In consideration of the economic significance of variables, this paper will conduct unit root test on the natural logarithm of CPI levels in every country or region. The results of unit root test on each country's CPI natural logarithm level are shown in Table 1.

Table 1 ADF test results of countries' lnCPI and Δ lnCPI

	Testing variable	Types of model	Lag phase	ADF (P value)	Critical value ($\alpha = 5\,\%$)	LM (1)	LM (2)
U.S.	lnCPI	2	0	−3.580.0174	−3.04	0.15	3.53
Japan	lnCPI	1	0	−2.390.0200	−1.96	0.53	0.93
Canada	Δ lnCPI						
Germany	Δ lnCPI	3	1	−6.170.0008	−3.73	1.86	1.89
UK	lnCPI	1	0	−2.280.0258	−1.96	0.00	0.00
France	Δ lnCPI	1	0	−3.130.0038	−1.96	1.48	2.00
Italy	Δ lnCPI	1	0	−3.550.0014	−1.96	1.46	1.72
China	Δ lnCPI	3	3	−7.730.0001	−3.79	0.82	4.11
Korea	Δ lnCPI	3	1	−5.510.0056	−3.73	2.68	2.71
Mexico	Δ lnCPI	1	1	−4.040.0005	−1.96	0.34	1.38
India	Δ lnCPI	3	0	−6.300.0005	−3.71	3.55	3.67
Saudi Arabia	Δ lnCPI	3	0	−5.590.0018	−3.71	0.95	3.66
Malaysia	Δ lnCPI	1	0	−5.370.0000	−1.96	1.35	1.44
Taiwan	Δ lnCPI	1	0	−5.320.0000	−1.96	0.00	1.10

Notes The lag length is the value of m in testing model and provided automatically from the software under the condition of Schwarz Info criterion (SIC). And the critical value of significance level 5 % adopts the result took from the simulation experiment by MacKinnon [8]

The results of ADF test are showed as follows:

(1) When significance level was $\alpha = 5\,\%$, the ADF values of lnCPI in U.S., Japan and U.K. were all less than the corresponding critical value, which have been proved to have past the unit root test as well the Lagrange's multiplier test. It was shown that there was no serial correlation problem during modeling test and that the results were valid. lnCPI in U.S., Japan and UK was stationary during 1990 and 2008.
(2) When significance level was $\alpha = 5\,\%$, the price series in China and other ten countries was non-stationary. But their first-order difference series past ADF test, which meant that Δ lnCPI (first-order difference of lnCPI) of China and other ten countries was stationary during 1990 and 2008.

The price series in developed countries as U.S., Japan and U.K. was stationary while that in China, India and other six developing countries was non-stationary. The result was inconsistent with the fact that many empirical researches at home and abroad regarded the price series as non-stationary. The reason discussed in this paper was that the data adopted were annual ones of CPI in recent 20 years. By contrast, the price fluctuation in developed countries was rather gentle due to their comparatively stable economic system while the fluctuation in developing country was much more fluctuant. However, in sampled countries, the price in three EU countries as Germany, France and Italy was non-stationary and became stationary after first-order difference as well.

4 Granger Causality Tests Result

According to earlier study analysis, we found that the yearly CPI series in few developed countries like U.S., U.K. and Japan was stationary in recent 20 years while in the others was first-order integration series. It is important for us to further consider whether there are influences of stationary U.S. price change on the inflation of U.K. and Japan etc. Therefore, it is necessary to make tests against the cause and effect of inflation between U.S. and other countries.

Granger causality tests aim to uncover the fact that whether one-way or two-way relationships between two variables existed or not. The theory is listed as follows:

In terms of variable X and variable Y, Granger causality tests require the following regression:

$$Y_t = \sum_{i=1}^{m} \alpha_i X_{t-i} + \sum_{i=1}^{m} \beta_i Y_{t-i} + \mu_{1t}, \tag{4}$$

$$X_t = \sum_{i=1}^{m} \lambda_i Y_{t-i} + \sum_{i=1}^{m} \delta_i X_{t-i} + \mu_{2t}. \tag{5}$$

In the regression models, the fact whether the entire parameters before the lagged term of X and Y were zero was explained on the basis of Eqs. (4) and (5). According to this, it could be judged that the relationship between X and Y was one-way or two-way or zero. Moreover, Granger causality tests were completed with the help of controlled F. For example, as regards the hypothesis that X was not the Granger cause of Y, which meant the entire parameter before the lagged term of X in Eq. (4) was zero, the analyzing process can be divided into the following parts. The first step is to run regression including and excluding the lagged term of X respectively. Then the residual sum of squares of the former was recorded as RSSU and that of the latter as RSSR. Finally F-statistics can be calculated:

$$F = \frac{(RSS_R - RSS_U)/m}{RSS_U/n-k}. \tag{6}$$

In this formula, m is the number of the lagged term of X, n is the sample size and k is the number of the estimated parameter in unconstrained regression model involving possibly constant term and other variables.

If the calculated F is greater than the corresponding critical value $F_\alpha(m, n-k)$ which spread under the condition of given significant level of α , the original hypothesis can be refused. Thus, it can be judged that X is not the Granger cause of Y.

There is a precondition for the application of Granger causality tests which requires that the proving series should be stationary. And after testing, the lnCPI level of U.S., Japan and U.K. is actually stationary. Thus, the causality tests can be conducted to prove the impact of U.S. price shocks effect on the other counties or be the just opposite.

Table 2 The results of Granger causality tests

Null hypothesis	F-statistic	Prob
Japan does not Granger Cause U.S.	0.08791	0.7862
U.S. does not Granger Cause Japan	17.0160	0.0258
Canada does not Granger Cause U.S.	0.02682	0.8721
US does not Granger Cause Canada	0.09456	0.7627
UK does not Granger Cause U.S.	0.31887	0.5806
U.S. does not Granger Cause UK	3.43116	0.0838

Table 3 The results of Granger causality tests

Null hypothesis:	F-statistic	Prob
D (LChina) does not Granger Cause D (LU.S.)	8.39578	0.0231
D (LU.S.) does not Granger Cause D (LChina)	3.81319	0.0918
D (LItaly) does not Granger Cause D (LU.S.)	0.91678	0.3546
D (LU.S.) does not Granger Cause D (LItaly)	0.00551	0.9419
D (LGermany) does not Granger Cause D (LU.S.)	2.61984	0.1278
D (LU.S.) does not Granger Cause D (LGermany)	4.37353	0.0552
D (LFrance) does not Granger Cause D (LU.S.)	0.67291	0.4258
D (LU.S.) does not Granger Cause D (LFRANCE)	1.78620	0.2027
D (LMexico) does not Granger Cause D (LU.S.)	0.99373	0.3358
D (LU.S.) does not Granger Cause D (LMexico)	0.36341	0.5563
D (LIndia) does not Granger Cause D (LU.S.)	0.01823	0.8945
D (LU.S.) does not Granger Cause D (LIndia)	0.40330	0.5356
D (LKorea) does not Granger Cause D (LU.S.)	2.84247	0.1140
D (LU.S.) does not Granger Cause D (LKorea)	3.19667	0.0954
D (LMalaysia) does not Granger Cause D (LU.S.)	0.00040	0.9844
D (LU.S.) does not Granger Cause D (LMalaysia)	0.07520	0.7879
D (LSaudi) does not Granger Cause D (LU.S.)	0.98769	0.3766
D (LU.S.) does not Granger Cause D (LSaudi)	1.29018	0.3195
D (LTaiwan) does not Granger Cause D (LU.S.)	0.57008	0.4695
D (LU.S.) does not Granger Cause D (LTaiwan)	0.04838	0.8308

Eviews 7.0 is used to do Granger causality tests for U.S. CPI series based on the collected samples. Considering the sampled data are all annual data, we take the lag phase as 1 to do causality test. The results are listed as shown in Table 2.

In the view of the results of Granger causality tests, it can be found that U.S. inflation rate change is actually prior to Japan and its confidence coefficient can reach 97.42 % during the study of the transmission of inflation between U.S. and Japan. Similarly, when studying the transmission of inflation between U.S. and U.K., the results also support the fact that U.S. inflation rate change is truly the Granger cause of the price change in U.K.at 10 % significant level. It means that U.S. inflation rate change is prior to U.K. While surprisingly U.S. inflation does not have an imported pressure for Canada, the test refused the hypothesis that U.S. inflation does not Granger cause Canada's inflation (Table 3).

As the Granger causality tests need all the time series samples to be same order stationary. We further took the first order of logU.S. CPI and then run the tests with other countries' first order of logCPI to see if they have causality relationship with U.S. We choose 1 as the lag length according to the AIC. The test results are as follows:

The results show that U.S. inflation does Granger cause China, Germany and Korea at 10 % significant level. Other countries' price levels are found to be not very related with that of U.S.

5 Conclusions and Further Discussion

Currently many scholars have studied the international transmission of inflation and considered U.S. as the major inflation exporter. The total effect test of inflation in this paper also depended on the same consideration. The empirical results indicated that:

(1) For developed countries, the co-integration of the price level between U.S. and EU countries as France and Italy was rather worse; while the co-integration of the price level between U.S., Germany, Japan, Korea and also U.K. was evident.
(2) Among the developing countries, the price series of China, India, Mexico, etc. in the sample was non-stationary.

After taking the first-order of log U.S. CPI, we run the Granger causality test and find out that their co-integration with U.S. CPI was very weak except China. The results displayed that the influence of U.S. inflation on these developing countries were limited during 1990 and 2008. The conclusion so far was not completely consistent with the empirical results drew by other scholars. Thus, in this paper the reasons behind the conclusion will be discussed further in details:

First, inflation can be transmitted through price, money supply and balance of payments, and the effects are also restrained by countries' foreign exchange rate system, monetary policy and degree of opening-up. Therefore, it is reasonable that countries receive transmission of inflation to different degree. This paper excerpted a brief introduction of these sampled countries from WTO and IMF reports. It can be seen from the following table that the higher opening degree to FDI could be the

Table 4 Summary of indicators in sampled countries (2007)

Country	GDP (unit: 1 billion)	FDI inflow (unit: million dollars)	Opening degree	Exchange rate system	Inflation target system
China	3248.52	83521	0.026	Crawing peg	Yes
France	2515.24	157970	0.063	Independently floating	Yes
Germany	3259.21	50925	0.016	Independently floating	Yes
India	1089.94	22950	0.021	Managed floating with no predetermined path for the exchange rate	Yes
Italy	2067.68	40199	0.019	Independently floating	Yes
Japan	4345.95	22549	0.005	Independently floating	Yes
Korea	949.7	2628	0.003	Independently floating	Yes
Malaysia	164.98	8403	0.051	Managed floating with no predetermined path for the exchange rate	Yes
Mexico	886.44	24686	0.028	Independently floating	Yes
Saudi Arabia	374.46	5692	0.021	Conventional pegged arrangement	Yes
Taiwan	375.65	8161	0.022	Independently floating	Yes
UK	2755.92	233966	0.085	Independently floating	Yes
U.S.	13794	232839	0.017	Independently floating	Yes

Data resources collected from WTO and IMF relevant materials

reason for a country to receive more international transmission of inflation from U.S. (Table 4).

Secondly, to actively take part in regional economic integration can resolve one nation's external transmission of inflation in regional groups. For example, Germany, Italy and France are both members of EU who conduct united exchange rate system to the countries outside EU. And the economic and trade cooperation and communication between the regions are stronger. Moreover, EU now is the largest and superlative economic regional integration organization in the world. It will separate the transmission of internal and external inflation of some members due to trade substituting effect and trade diverting effect.

Thirdly, following monetary policy will aggravate the transmission of inflation between two countries. In the case of U.S. and Japan, it can be seen that the inflation in U.S. has a significant effect on that in Japan. One of the causes is that Japan's monetary authority always follows the FED monetary policy. And it has conducted financial liberalization and innovation since the middle of 1970s, which is helpful to maximize the effectiveness of monetary policy. The domestic price change in U.S. terrifically affects that in Japan. Therefore, it is fully obvious that Japan receives the imported inflation of U.S.

Fourthly, single pattern of trade will aggravate the transmission of inflation. If one nation excessively depends on others in trade field, its transmission of inflation will be more influenced obviously. It is not only shown in the geographical structure of trade, but in the product structure as well. It means that the trade based on one certain product will enlarge the transmission of inflation. For example, in 2008, Arab countries located in gulf area generally had a higher inflation rate. Specifically, the inflation rate in UAE, Saudi Arabia, Qatar and Kuwait was 12.9, 11.5, 15 and 9 % respectively while in 2007 these data were just 11.1, 4.1, 13.8 and 5.5 %. Consequently, it can be shown that the Arab countries has been greater influenced and suffered by the price shocks from oil importing country, main industrial countries and commodity exporting countries as well.

Fifthly, from the empirical results, U.S. exported inflation has limited impact on developing countries. Due to the non-stationary series of inflation rate in newly industrial countries and other developing countries, the co-integration does not fit well. But it does not mean that U.S. inflation has no influence on developing countries. As a matter of fact, on the contrary, it reflects the complexity, instability and model's limitation when time series data are tested in empirical study. Since most developing countries with poor economic system have prominent economic structure problems such as strict control of foreign exchange, less free exchange rate system, these problems all provide a place to receive the transmission of inflation from developed countries.

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Real Estate Project DCRM in Post-Earthquake Reconstruction Based on the Stochastic Game Model

Lu Gan, Jianqiang Tang and Gaomin Li

Abstract This paper synthesized the existing research results about dynamic customer relationship management (DCRM) and the salvage cost of lost customer. According to characteristics of the estate project in post-earthquake reconstruction, this paper proposes the DCRM with salvage cost to discuss the behavior of customer and company, thus establishes the two-stage model in view of the DCRM with salvage cost. And in this paper, the synthesis algorithm which was based on genetic algorithm (GA) was put forward in view of the model's solution.

Keywords Post-earthquake · DCRM · Salvage cost · Stochastic game · GA

1 Introduction

Since the 1990s, customer relationship management (CRM) has become a sustained hot spot of research in the marketing academia and business circles. Making one academic boom after another, research achievements in this field emerge in endlessly, till now, the research of customer relationship management has three different study aspects in the aggregate: customer perceptive value oriented, customer value oriented, customer perceptive value and customer value oriented (namely customer value interactive study). The research of CRM which is customer perceptive value oriented has plentiful study achievements, how to understand and cater to the needs of customers are the focus of research in this field. Customer value oriented CRM has made progress in the calculation of customer lifetime value (CLV) which is the core of research. The dynamic customer relationship management (DCRM) study which is customer value interactive oriented are the most lacking, current research results are mainly used in the direct mail industry, the win-win situation between the customer and the company is the core of the study [5, 8, 9, 11]. Of course, under the

L. Gan (✉), J. Tang and G. Li
College of Architecture and Urban-Rural Planning, Sichuan Agriculture University, Dujiangyan 611830, People's Republic of China
e-mail: ganlu_swe_1119@sina.cn

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premise form that now the company are widely considering developing the customer relationship, effective customer relationship management is effective techniques and methods to achieve this premise, and is worthy of in-depth study and discussion in this field.

Meanwhile, for the post-earthquake reconstruction of estate projects, which are pursuing the public benefits and economic benefits, in the customer relationship management, in addition to taking the maximum interests on the respect of customers and companies into account, the salvage cost of lost customers is a consideration aspect which can not be ignored, due to the special geographical features and regionalism. The salvage cost is also known as the cost for saving loss customers. It refers to the cost of salvage incurred in order to save the loss customers, including gifts, communication costs, labor fees, etc. As a market behavior, saving the customer needs rational, because some may be successful, and some may not; some are valuable, others are not worth [2, 7, 10].

DCRM with the salvage cost is a procedure, which obtains customers, identifies valuable customers through the DCRM and implements appropriate marketing mix strategies those are corresponding to transaction data of customers to retain customers, and ultimately achieve the maximized interests both of the company and the customer. That is based on customer value interaction studies (customer perceptive value and customer life cycle value) as the core of the discussion. The decision criteria of determining the upper limit of salvage cost, is on the basis of the customer value interaction studies (customer perceived value and customer life cycle value) which is seen as the primary indicators, and while consider the salvage cost that should be lower than the interests brought to the company by the increased customers because of salvage. Customer lifetime value is the primary index to measure the customer value, which has been used for a variety of occasions. But considering customer interactive value research and salvage cost are even more uncommon. Once confirmed as to save customers, the next step is to determine the upper limit of salvage cost. Because the cost it takes to save the loss of customers will directly reduce the company's earnings brought by the customer, therefore the salvage cost should be minimized [8, 9].

This paper has synthesized the existing research results of DCRM and the salvage cost of the loss customer, and put forward it, then, and also applied the stochastic game theory and dynamic programming theory to discuss, thereby establishing the two-stage model of dynamic customer relationship management with the salvage cost. Aiming at the solution of the model, the synthesis algorithm based on genetic algorithm (GA) was proposed. Among current studies, it is seldom to find out the study both considering the DCRM and the loss of customers to save the cost. In the paper, the established model can be used in the actual situation, and guide the company to put the DCRM into practice while considering the cost for saving the loss customer. It plays a significant role for the company to effectively analyze customer value, implement customer strategies and control the cost of the customer loss. Especially, it will be suit for real Estate Project in post-Earthquake to save public resource. The GA synthesis algorithm which targets on the model can be designed to facilitate effective and feasible management software, to reduce unnecessary burdens on managers and make management more feasible.

This article is organized as follows: Sect. 2.1, as the first stage of a two-stage model, according to the stochastic game theory and dynamic programming theory, respectively considered the behavior of customers and the company and discussed establishing a dynamic customer relationship management model. Section 2.2 is on the basis of results of the first stage of the model, as the second stage of a two-stage model, we discussed how to determine the upper limit of the salvage cost of the loss customer. Section 3 proposed synthesis algorithm, gave the specific implementation steps of the algorithm aiming at the GA-based two-stage model. Section 4 made a summary of the paper and pointed out the further discussion and in-depth orientation of the paper.

2 The Model of DCRM

2.1 The Description of the Model

1. The connotation of the DCRM

The so-called "dynamic" refers not only to consider the current interests when the company and the customer make the decision, must also consider the impact of current decisions in the future, reflecting the "forward-looking" dynamic characteristic of the company and the customer. When modeling the DCRM, taking the interests both of the company and customers into account, in order to achieve a win-win situation, not just considering the unilateral interests of the customer or the company. So that, the problem of DCRM also can transfer into a stochastic game between the company and its customers by comparing with the dispose of the similar problems according to the literature on the direct mail industry. The company chooses the marketing mix strategy for every customer of each state in each period (pricing, communication, marketing, etc.). And customers decide whether to buy or not in a given period of time, so a framework for a multi-stage repeated game is established, as Fig. 1 shows. The customer's decision is affected by the marketing activities of the company, and the state transfers between each stage. From the company's perspective, the customer's decision is the transition probability of the system, which is a random variable [5, 8, 9].

The application of stochastic game in the DCRM. Through the above analysis, DCRM has transformed into a problem that how to build the company and customer behavior models (in order to achieve their own goals), and how to solve the problem of the established model, under the framework of the multi-stage repeated stochastic game.

In this issue, the company and its customersas participants in the game, carry on a game with state probability transition. This process consists of multiple game stages. At the beginning of each stage, the game is under a particular state. Participants

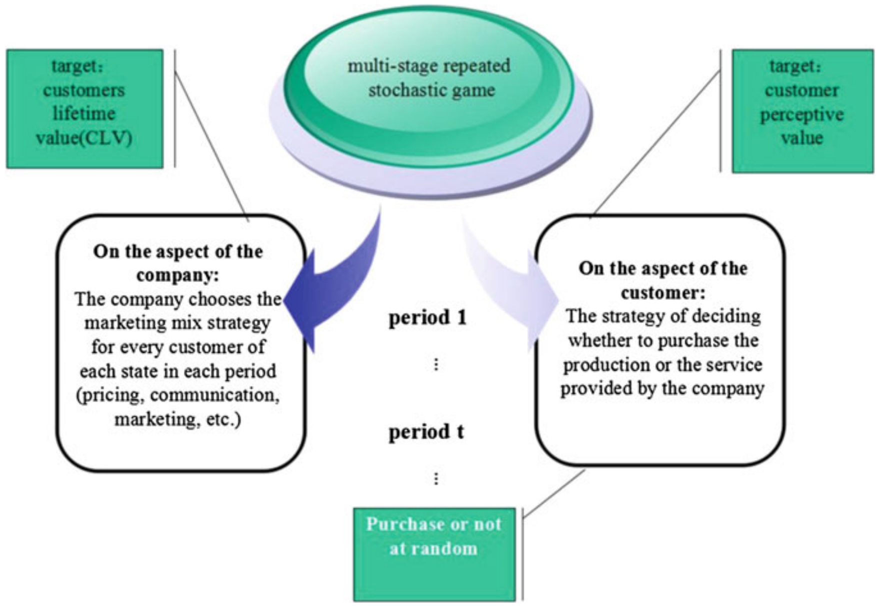

Fig. 1 Stochastic game in the DCRM

choose their own strategies and get paid determined by the current status and strategy decisions. Then the game moves to the next stage randomly according to the distribution of probability and the strategies of participants. In the new state of the stage, the strategy selection process is repeated, and then the game continues. The entire rewards of all the participants, obtained in the stochastic game, are calculated by the discounted value of the remuneration of various stages.

2. The DCRM with salvage cost

Calculate the expectation $E(V)$ of the customer's CLV in the situation of salvage, which is the customer's CLV when the salvage is successful and the mathematical expectation of CLV of the customer when the salvage is unsuccessful. And then, calculate the customer's CLV in the case of no-saving. Next compare the difference between the two values, the increase of the value is due to the salvage operation. The salvage operation itself pays the cost, and the cost should not exceed the increase in value due to salvage.

2.2 The Building of the Model

1. The model hypothesis

The purpose of model is to create a win-win situation for clients and the company.

- The information between clients and the company is complete.
- The company provides clients with one kind of product.
- The clients have "purchase or not", two strategies.

- The company's strategy takes the communication and price into account. Among them, communication has two strategies that are sending messages or not; price is mainly focused on giving clients price discount.
- Whether clients purchase or not is at random, the purchase total utility (the utility sum for the future of current utility and current behavior) should be larger than non-purchase total utility, when they choose to purchase. In another word, the probability of occurrence of this event is that of the fact that clients choose to purchase.
- Current clients discussed are certain for us to save. The purpose of the model is to settle down the upper limit of salvage cost.
- Salvage can get results in one period.
- Clients only can purchase one product at a time.
- During the purchase, there is no option of volume but whether to purchase or not for clients.

2. The state and transfer of stochastic game
In this paper, the model established under the framework of the multi-stage repeated stochastic game, for the stochastic game, to determine the state of the game at each stage and the transfer of states are the most important.

$r_{it} = (r_{it}, f_{it})$ is set to measure the state variables of each stage. Among them, the discussion is under the condition of the number period t and the number i customer. In terms of state variables $r_{it} = (r_{it}, f_{it})$, among them: r_{it} and f_{it} are variables to describe the customer status, which represent the loss time of customer and continuous purchasing times respectively. d_{it} is the strategy of customers, representing to purchase or not. r_{it} and f_{it} are defined as Eq. (1) [9]:

$$r_{it} = \begin{cases} 1 & \text{if } d_{it} = 1 \\ r_{it} + 1 & \text{if } d_{it} = 0, \end{cases} \qquad f_{it} = \begin{cases} f_{it} + 1 & \text{if } d_{it} = 1 \\ 1 & \text{if } d_{it} = 0. \end{cases} \tag{1}$$

The meaning of transformation of r_{it} and f_{it} is as Fig. 2 shows. When purchase and not purchase, r_{it} and f_{it} are changing according to Eq. (1).

The model of customer behavior. The target of the customer behavior is the customer perceived value. The customer's consumption condition can be described by using the customer's utility theory and according to their transaction data. And the various parameters can be determined by using appropriate method, thus obtaining the probability whether the customer will buy or not in different state space and different marketing mix strategy. DCRM is a kind of management process with very obvious dynamic characteristics. In this model, dynamic programming is used in DCRM as the effective method to solve the random dynamic optimization problem. In the building of the model, the parameters are to be determined.

To measure customer perceptive value, the purchase utility model of the customer [5] is given first as the following Eq. (2).

$$u_{it} = \alpha + \beta_m m_{it} + \beta_p p_{it} + \beta_{1r} r_{it} + \beta_{2r} r_{it}^2 + \beta_f \ln(f_{it}+) + \varepsilon_{it} = \bar{u}_{it} + \varepsilon_{it}. \tag{2}$$

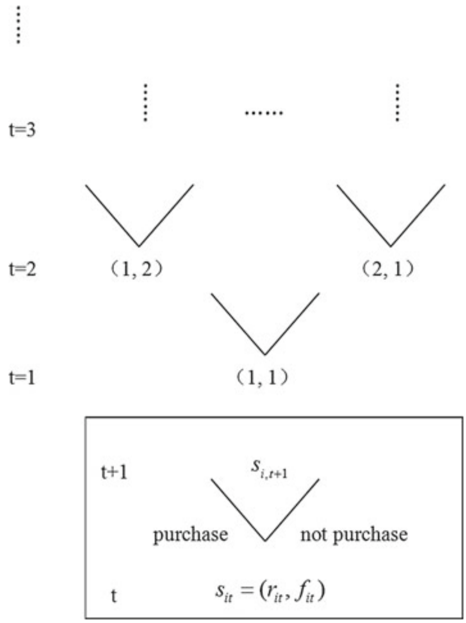

Fig. 2 Transformation of state variables on each stage

Among them: m_{it} and p_{it} stand for the company's marketing strategy. m_{it} represents the communication strategy of company for the customers (sending messages or not), which is defined as Eq. (3) [5]:

$$m_{it} = \begin{cases} 1 \text{ if sending messages to the number } i \text{ customer at the number } t \text{ period} \\ 0 \text{ otherwise.} \end{cases} \tag{3}$$

p_{it} is the price strategy of the company, namely the change rate of the price p_{it}, provided by the number i customer in the number t period, compared with the original price P_0, defined in Eq. (4) [5].

$$p_{it} = \frac{P_{it} - P_0}{P_0}. \tag{4}$$

ε_{it} is the term of stochastic error, which is obey the standard normal distribution. And a range of coefficients of related items, α and β need to be determined by using the global optimum algorithm in the local optimum.

Measuring the customer perceptive value should consider the utility sum for the future of customer current behavior, that is to say considering from the perspective of dynamic programming, so the perceptive value function of the customer i in the number t period can be defined as follows as Eq. (5) [5]:

$$V_{it}(s_{it}) = \begin{cases} \bar{u}_{it} + \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 1) + \varepsilon_{it}, & \text{if } d_{it} = 1 \\ \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 0), & \text{if } d_{it} = 0. \end{cases} \tag{5}$$

Among them, δ_ι is the discount factor of the company.

The probability of customers to buy products of the company, as follows as [5] in Eq. (6):

$$\begin{aligned} \text{Prob}_{it} &= (d_{it} = 1|s_{it}, m_{it}, p_{it}) \\ &= \text{Prob}(\bar{u}_{it} + \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 1)) + \varepsilon_{it} > \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 0) \\ &= \phi[\bar{u}_{it} + \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 1) - EV_{i,t+1}(s_{i,t+1}|d_{it} = 0)]. \end{aligned} \tag{6}$$

The expected value of the perceptive value function of the number customer in the number period is as follows as Eq. (7) [5]:

$$\begin{aligned} EV_{it}(s_{it}) = \; & \text{Prob}_{it}(d_{it} = 1|s_{it}, m_{it}, p_{it}) \times [\bar{u}_{it} + \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 1)] \\ & + \text{Prob}_{it}(d_{it} = 0|s_{it}, m_{it}, p_{it}) \times \delta_\iota EV_{i,t+1}(s_{i,t+1}|d_{it} = 0) \\ & + \phi[\delta_\iota(EV_{i,t+1}(s_{i,t+1}|d_{it} = 0) - EV_{i,t+1}(s_{i,t+1}|d_{it} = 1)) - \bar{u}_{it}] \end{aligned} \tag{7}$$

3. The model of company behavior

The target of the company behavior is the whole life-cycle value of the customer. Similarly, because DCRM is a kind of management process with obvious dynamic characteristics, in this model, dynamic programming is used in DCRM as the effective method to solve the random dynamic optimization problem.

The purchase decision of customer i brings the current profit to company in the period of t [5]:

$$\pi_{it}(s_{it}, m_{it}, p_{it}) = R(p_{it}) \times \text{Prob}_{it}(d_{it} = 1|s_{it}, m_{it}, p_{it}) - c \times m_{it}. \tag{8}$$

Among them, ι is the transmitting cost. $R(p_{it})$ represents the available profits which can be obtained when the company uses the price strategy, defined as Eq. (9). The gross profit rate relative to the original cost is $r_0 = \frac{P_0 - C}{P_0}$, $p_{it} = \frac{P_{it} - P_0}{P_0}$ [5], when r_0 is used as original cost.

$$R(p_{it}) = P_{it} - C = P_0 \times (p_{it} + r_0). \tag{9}$$

So from the dynamic perspective, the largest interests created by the number customer t from the number period, is as follows in Eq. (10) [5]:

$$\begin{aligned} CLV_{it}(s_{it}) = \; & \max_{m_{it}, p_{it}} \{\pi_{it}(s_{it}, m_{it}, p_{it})\} + \delta_\iota[\text{Prob}_{it}(d_{it} = 1|s_{it}, m_{it}, p_{it}) \\ & CLV_{i,t+1}(s_{i,t+1}|d_{it} = 1)] + \text{Prob}_{it}(d_{it} = 0|s_{it}, m_{it}, p_{it}) \\ & CLV_{i,t+1}(s_{i,t+1}|d_{it} = 1). \end{aligned} \tag{10}$$

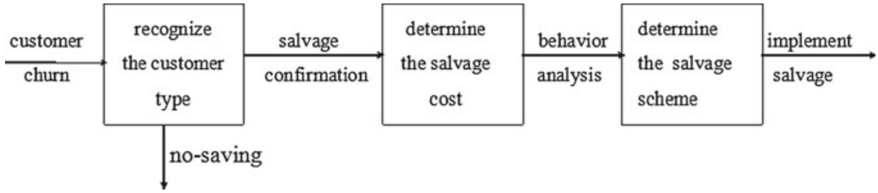

Fig. 3 Customer loss salvage model

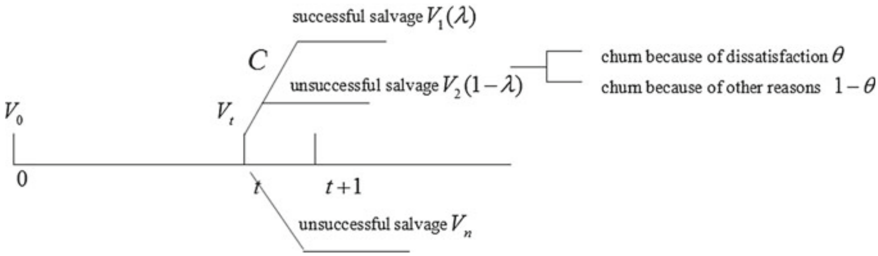

Fig. 4 Calculation process of salvage cost upper limit

4. The model of salvage cost upper limit
As one market behavior, to save customers needs rationality. Because some salvage may be successful, others will uncertainly succeed and some salvage is valuable, others have no value. The following customer loss salvage model (Fig. 3) reflects the whole rescue process in details as from customer churn to implement salvage [7].
5. The calculation process of salvage cost upper limit
According to hypothesis, the current customers which are discussed have been identified as having salvage needs. And then determine the salvage cost upper limit. The calculation process within time lag of salvage cost upper limit is shown in Fig. 4.

According to Fig. 4, the calculation steps of the upper limit of salvage cost are as follows.

The first step: Calculate the mathematic expectation $E(V)$ of the customer's CLV in the situation of salvage.

First, calculate the customer's CLV [5] when the salvage is successful.

$$V_1 = V_0 - \frac{C}{(1+i)^{t+1}}. \tag{11}$$

Among them, V_0 represents the initial value of the customer's CLV at the time of entering into the second stage of the two-stage model, namely the optimal CLV value obtained from the first-stage model.

And then calculate the customer's CLV namely V_2 [5] when the salvage is not successful.

$$V_2 = \left(v_t - \frac{C}{(1+i)^{t+1}}\right) \times (1-\theta) + \left(V_t - \frac{C}{(1+i)^{t+1}} r_2 V_0\right) \times \theta$$
$$= (\theta \times r_2 - \varphi(t)) \times V_0 - \frac{C}{(1+i)^{t+1}}. \tag{12}$$

Among them, r_2 represents spread cost system, indicating the effect on other customers if the salvage is failed because of the discontent of customers. And the effect will bring r_2 times as much as the loss of V_0.

Last, calculate the mathematic expectation $E(V)$ [5] of the customer's CLV in the situation of salvage.

$$E(V) = V_1\lambda + V_2(1+\lambda) = [\lambda - (r_a\theta - \varphi(t))(1-\lambda)]v_0 - \frac{C}{(1+i)^{t+1}}. \tag{13}$$

The second step: calculate the CLV [5] of the lost customer in the situation of no salvage.

$$V_n = -(r_a\theta - \varphi(t))V_0. \tag{14}$$

The third step: Determine the upper limit of salvage cost. If the salvage brings the increase of the customer's CLV, it will become the necessary condition of salvage. The expression will be $E(V) - V_0 > 0$. Considering this is only a minimum limit, but the actual cost should be less than the difference. The expression will be $C > E(V) - V_0$. The expression of salvage cost upper limit [5] is as follows.

$$C < \frac{1}{2}[(1-\varphi(t)) + r\theta_2]\lambda V_0(1+i)^{t+1}. \tag{15}$$

Therefore, the model of the second stage has been built. Based on the results of the first stage, the lost customer's salvage cost upper limit, namely C, can be determined, according to Eq. (15).

3 The Synthesis Algorithm Based on GA

The synthesis algorithm based on GA [1, 3, 4, 6] is put forward to adapt to the two-stage model established in this paper. Through GA algorithm, the undermined parameters in the customer relationship management model are determined. And then through the given convergence standard, the optimal customer perceived value, the optimal CLV value and the corresponding optimal marketing mix strategy can be obtained from the whole stochastic game and dynamic programming approach. The thoughts of the algorithm are as follows:

The customer purchasing data obtained by observing can be used as the solution of the dynamic optimization problem to conduct parameter evaluations and solve the multi-parameter evaluation problems in consumer utility modelin order to determine parameters of the model, and then, the purchasing probability of customers can be obtained.

Combining the dynamic characteristics of DCRM with the process of stochastic game between customers and companies, the solution method of should be used (and using the solving approach of stochastic game).

The synthesis algorithm based on GA is given to solve the problem of this complex process. The final target of solving this problem includes the optimal customer perceived value, the company's CLV and the optimal marketing mix strategy.

The specific steps of algorithm are as follows:

Step 0. Set initial values. $CLV_{i,t+1}(s_{i,t+1})$ and $EV_{i,t+1}(s_{i,t+1})$ are set to 0 for all the state variables. Set the convergence index greater than 0. The expression will be $\eta > 0$.

Step 1. The optimal value can be obtained by changing the parameter values in the whole parameter space. The algorithm to solve the multivariate, multi-peak and global optimization is needed right here. The GA algorithm is effective right here.

Step 2. The purchase probability, namely $\text{Prob}_{it}(d_{it} = 1|s_{it}, m_{it}, p_{it})$, of the company marketing mix strategy $D_{it}(m_{it}, p_{it})$ should be calculated separately when the number i customer is at the state of $s_{it}(m_{it}, p_{it})$.

Step 3. Calculate the perceived value function $V_{it}(s_{it})$ when the number $i$customer is at the state of $s_{it}(r_{it}, f_{it})$.

Step 4. Calculate the expectation-maximization $CLV_{it}(s_{it})$ of the number i customer and the corresponding optimal marketing mix strategy $D^*_{it}(s_{it})$.

Step 5. Calculate the customer perceptive value $EV_{it}(s_{it})$ by the optimal marketing mix strategy which is obtained by calculating, when the number i customer is at the state of s_{it}.

Step 6. Termination standard: let be $d_1 = EV_{i,t+1} - EV_{it}$ and $d_2 = CLV_{i,t+1} - CLV_{it}$, if $d_1' d_1 + d_2' d_2 < \eta$, then stop, Otherwise, $EV_{i,t+1} = EV_{it}$, $CLV_{i,t+1} = CLV_{it}$, then go back to step 1.

The above algorithm is convenient for companies to design effective and feasible management software, which can reduce the unnecessary burden for the manager and make the management more feasible.

4 Conclusions

In this paper we argued DCRM with salvage cost, which firstly considers the interests of both company and customers at the same time in order to make the optimal marketing mix strategy. Then, we considers the upper limit of salvage cost which is in order to prevent the customer loss. This issue originates from the practice of customer relationship management. The technology proposed to solve this issue comes from the academic frontier of international marketing field. The principle and technique of this method can also be used in various industries. Especially for the post-earthquake reconstruction estate projects, this method provides a feasible way to keep valuable customers for enterprises when many enterprises are trying to keep valuable customers for themselves. Finally, in this paper, the synthesis algorithm which was based on (GA) was put forward in view of the model's solution. Of course, the amount of money customers purchase each time with reward programs and practice application would also be taken into account in the future.

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The Visualization Research on Control Policy System of Social Risk of Large Engineering's Environment Pollution

Weiping Yu, Xu Zu, Yalan Liu and Renshu Zuo

Abstract From the perspective of large engineering construction life cycle, combined with the content analysis and word analysis, this research carries on the quantitative analysis from the two aspects control policy of large engineering environmental protection and social risk, builds the control policy system structure of social risk of large engineering environmental pollution. The proposed method makes contributions to management research methods in terms of control policy data collection and analysis. The research offers valuable advices and implications by which the government can perfect the existing control policy system and enterprises can maintain the corporate image.

Keywords Large engineering · Environment pollution · Social risk · Control policy · Content analysis · Word analysis

1 Introduction

In recent years, large engineering construction is in the ascendant in our country, catering to the development of Chinese industrialization, informationization, urbanization, agricultural modernization, but the characteristics, which are long construction period, large investment, complex design process and wide range, will also cause a lot of environment pollution problems in our country, and all kinds of social risk factors are in the intricate relationship. Social risks may bring huge negative impact on Chinese economy and society. Large engineering construction may adds pollution to the environment in the whole life cycle, thus it is important to face the social risk. A lot of examples can illustrate it: from Kunming, occurred in preparation for the large engineering construction, PX project cause local large-scale march; in large engineering construction implementation stage, the substation project of Guangzhou induced residents group disputes; in large engineering construction end stage,

W. Yu · X. Zu (✉) · Y. Liu · R. Zuo
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: 403008983@qq.com

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serious environmental pollution accident of Zijin Mining copper project in Fujian caused huge social cost [11]. With the strengthening of the public's risk awareness, the government and the enterprise urgently solve the problem that how to better control the social risk environment pollution in the whole life cycle of large engineering construction?

"Crisis" is the practical consequences of "risk". If risk society is into social crisis, it will cause the loss and disorder [5]. For two issues of environmental pollution and social risks in large engineering, a series of corresponding control policy which the government formulated effective ensure that a large engineering is constructed smoothly, the operation is carried out smoothly, and promote social and economic coordinated development. However, facing large scale and the complex structure of large engineering, which is the existing achievements or insufficient of relevant control policies of government? What about the control policy system of social risk of large engineering's environment pollution. These study contents are the innovations of the research which are not involved in previous studies.

Based on the whole life cycle theory of large engineering construction, integrated with the content analysis and word analysis, the research respectively combs environment protection and social risk control policy files of large engineering construction involves in whole life cycle, aiming to solve the above problem, and offers a quantitative analysis method for control policy data collection and analysis. The research also puts forward valuable references to improve the control policy system of social risk of large engineering environmental pollution for the government and better promote enterprises' image in the process of engineering construction.

2 Concept Definition

1. Large Engineering and Environmental Pollution
Large engineering is a major project, which has certain investment scale and is significantly related to people's livelihood. Large engineering has a major impact to some regions' political system, economic structure, social life and the ecological environment, easily leading to interest conflict of social public [5]. According to the engineering construction regulations, the whole life cycle of project is divided into five stages: the early stage of engineering construction, the construction preparation stage, the implementation stage of engineering construction, the project acceptance and maintenance stage, the end stage.

Environmental pollution, which leads to environmental pollution event, is the inevitable outcome of the large engineering construction. According to Chinese national standard (GB/T16705-1996), the environmental pollution is a outcome that the change of the physical, chemical and biological environment condition leads environmental system to be harmful to survival and development of human and other creatures. The large engineering construction can cause significant environmental pollution, often accompanying by a series of fines, damages and lawsuits. It could seriously injure the company's image and reputation [7]. From the perspective of the nature and the way, major environmental pollution events is mainly divided into pollution event caused the nuclear pollution, oil spills, abnormal discharge waste water and pollution event caused hazardous chemicals leakage, explosion, diffuse, and so on.

2. Social Risk
The concept of risk society, first proposed by Beck and Jorgensen [9], is closely combined with social risk and has the characteristics of uncertainty and loss. The essence of the social risk is the uncertainty of social loss. Social risk has broad sense and narrow sense. Broad social risk refers to any other than the risk of personal risk, including aspects of political, economic, cultural, financial and natural ecological environment, and so on; narrow social risk means that rebel social behavior of individuals or groups, which may cause social disorder or may cause social conflict, endangering social stability and social order [4].

Social risk in large engineering refers to the uncertainty that exists large impact on the social public, long duration, and easily leads to larger social conflict in large engineering projects construction implementation or operation stage [3]. The incentives of social risk in large engineering are very complex, mainly including the cognition of project risk, the judgment of subject and object in engineering, engineering subject's thinking, engineering activities in the natural, political, economic, technical factors and project risk management approach [6]. The research tries to find out the social risk factors of large engineering environmental pollution based on studying the relevant control policies of large project construction life cycle by content analysis in the Chinese context.

3 Research Methods

1. Content Analysis
Content analysis is a kind of quantitative and qualitative integrated research methods by which information can be objectively and systematically researched. According to the normative information content, content analysis can express in a form of orderly and quantitative symbol. Content analysis method is widely used, first applied in the field of journalism and communication, then in political science, psychology, social science, market research, library and information fields and so on [2]. The research shifts two aspects of environmental pollution and social risk policy content into quantitative data in the whole cycle of the large engineering construction by content analysis which can overcome the disadvantages and the subjectivity of the qualitative research, achieving more accurate analysis of policy content.

2. Co-Words Analysis
Co-words analysis is a method which includes the statistical analysis and cluster analysis of words in same article, revealing the relationship between vocabulary groups and showing the structure change of the subject and topic. Co-words analysis is first mentioned by the French literature metrologists in the late 1970

and its ideas derived from the concept of citation coupling in literature metrology [1]. After 40 years, co-words analysis has been widely used in many fields, such as artificial intelligence, scientific metrology, information science and information systems, and information retrieval, achieving important research results [8], but rarely applied in the field of policy research. The research studies on the control policy system of social risk of large engineering's environment pollution based on co-words analysis, hoping to realize more accurate analysis of the related policy system by the unique advantage of this method and identify the structure of control policy.

4 Research Process

4.1 Data Sources and Sample Selection

First of all, the research uses keywords, such as "environmental protection", "social risk", "policy", "risk" and "environment", to retrieve large engineering related policies relying on the public sites (Xinhua website, China website, etc.) and the authoritative department websites (the national government, the NDRC and EPA, etc.), then the research uses the related words, such as "risk assessment" "environmental impact assessment" to extensively search other policy files. Finally the research finds out 33 policy documents, including 20 environmental policy documents and 13 social risk policy documents. In order to guarantee the credibility of the policy research, 22 high correlation policy documents, including 12 environmental protection policy file, 10 social risk policy files, are eventually checked and ratified to be the study objects by two relevant professional Ph.D. students and three relevant professional masters.

4.2 Standardized Coding and Reliability Test

In order to better quantitative coding content of policy system, every member carefully reads contents of each policy, and masters the basic contents involved in the project construction phase, then respectively extracts key phrases of practical significance from the two aspects of environmental protection and social risk in each policy document by machine word segmentation software (first of all, to eliminate nonsense words, such as "help", "every", etc., secondly, to merge similar meaning words, such as "radioactive" and "radiation" into "radioactive", thirdly, to summarize meaning related words, such as "autonomous region" and "municipalities" summed up as "the region"), and classifies and statistical analyze word frequency of key phrases in control policy system. In order to follow the principle of keeping coding type perfect and exhausted as far as possible and keeping classification mutually exclusive and separate [12], two doctoral students independently filter the key phrasesaccording to the word frequency of key phrases in the form and policy content ,then they compare the results and verify creditability of results. Reliability test statistics formula is as follows:

$$A = \frac{2M}{N_1 + N_2},$$

M is the two coders' unanimous result numbers in the coding-mode decision process; N_1 and N_2 are the amount of two coders to their coding decisions.he research finds that consistence degree of key phrase' integration is 81 % in the environmental protection policy, key phrase' integrate consistence degree is 85 % in social risk policy. Based on Nunnaly's view, above 0.7 consistency shows that a previous study has enough credibility [12]. In order to guarantee the precision of the policy system research, the other two related professional teachers are invited to further amend the integration result of the key phrases, and the research ultimately determines 28 key phrases related policy system of environment protection and 34 key phrases related the social risk key phrases policy system, then the research refines to determine the analysis unit (the policy goals, the applicable objects and role means) based on the large engineering of environmental protection and social risk policy system structure.

Based on the existing analyzing unit, the research counts frequency for each keyword in the policy document. Keyword, which first appears in any policy file or appears several times in a policy file, is down to 1 time, then keywords are generated a word matrix (the datamn in the matrix is frequency of two key words of the m line and the n column in the same piece of policy document). The research respectively generates social network diagram in two aspects of environmental protection and social risk control policy system of large engineering construction and performs the center degree analysis by UCINET software which is used more by researchers [10].

5 Results and Discussion

1. The Corresponding Phase Analysis of Control Policy Content
According to regulations of engineering construction procedure in our country, large project life cycle is divided into five stages: the early stage of engineering construction, the construction preparation stage, the implementation stage of engineering construction, the project acceptance and maintenance stage, the end stage. The research statistic analyzes the project construction stages based on the high research value's policy content in the two aspects of environmental protection and social risk, as shown in Fig. 1.

As shown in Fig. 1, the environment protection policy mainly focuses on the construction preparation stage (10 times) which is mainly concentrated in the engineering, the implementation stage of engineering construction (6 times) and the project acceptance and maintenance stage (9 times), and the policy control content mainly concentrated in the engineering construction preparation stage and the project accep-

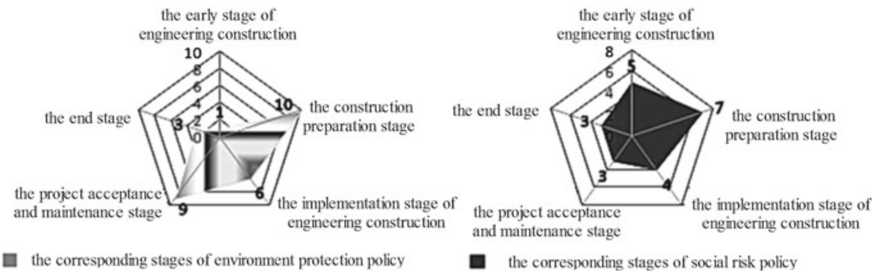

Fig. 1 The corresponding stages of control policy system of social risk of large engineering's environment pollution

tance and maintenance stage, but the policy control is weak and not conducive to control environmental pollution well in the early stage of engineering construction (1 time) and the end stage (3 times). Social risk policy control is balanced in five stages of project life cycle, but it mainly focuses on the construction preparation stage (7 times). The research finds that it has much relevance for the high cost and risk of large engineering construction.

2. Extracting Keywords

Through the extraction of keywords to the control policy system of social risk of large engineering's environment pollution, the research ultimately determines 28 key phrases related policy system of environment protection and 34 key phrases related policy system of social risk, then the research refines to determine the analysis unit (the policy goals, the applicable objects and role means), shown in Table 1.

Statistical results preliminary show that there is a focus of overlap in the three modules, not only focusing on environmental protection and the region situation, but also focusing on the mass line and the standardization of the work. From the point of the frequency of keywords, environmental protection (12 times) and report (12 times) have the highest frequency in the environmental protection policy, the state council (10 times) and the region (10 times) have the highest frequency in the social risk policy.

3. Map Network

The research statistic analyzes the frequency of every two key words appear in each policy file at the same time (if the documents appears many times, it still keep the same documents for 1 time), then compiles them into a common word matrix by EXCEL and processes them by of the NETDRAW software in UCINET software. In the end, the research respectively obtains policy network maps for two aspects of environmental protection and social risk, as shown in Figs. 2, 3.

In network map, the degree of two key words co-occurrence is positively related to thickness of network line and the high position is positively related to the keyword in the center of network map. In Fig. 2, "the state council" and "report" are close to the center position in the network map; In Fig. 3, "under the state council" and "regional" are close to the center of the network graph. Above of all, it illustrates the

Table 1 Keyword glossary of control policy system of social risk of large engineering's environment pollution

	The environmental policy keywords	
	Environmental protection (12 times)	Safety production (2 times)
	Normalize (4 times)	Standardization (2times)
Policy objective	Conservation of water and soil (4 times)	National economy (2 times)
	Scientificity (3 times)	
	The region (10 times)	Relevant departments (6 times)
Applicable object	Relevant units (10 times)	Responsible individual (3 times)
	The state council (8 times)	
	Report (12times)	Examination and approval authority (4 times)
	Environmental protection rules and regulations (9 times)	Business license (3 times)
	Environmental pollution (7 times)	Comprehensive utilization (3 times)
	Feasibility research (7 times)	Evaluation report (2 times)
Means	radioactivity (6 times)	Comprehensive treatment (2 times)
	Disciplinary sanction (6 times)	Database (2 times)
	Conservation area (5 times)	Hearing (2 times)
	Licensing regulations (4times)	Management procedure (2 times)
	The social risk policy keywords	
	Keywords	
	Environmental protection (5 times)	Rationality (3 times)
	Possibility (4 times)	People-oriented (2 times)
Policy objective	Feasibility (6 times)	Effectiveness (2 times)
	Normative (3 times)	Responsibility system (2 times)
	Legality (3times)	Facticity (2 times)
	The state council (10 times)	Responsible individual (8 times)
Applicable object	The region (10times)	Relevant units (5 times)
	Relevant departments (8times)	
	Mass character (6 times)	The risks (2 times)
	Coordination and adaption (4 times)	Evaluation report (2 times)
	Disciplinary sanction (4 times)	Coerciveness (2 times)
	Flammable and combustible (4 times)	Database (2 times)
	Radioactivity (3 times)	Business license (2 times)
Means	National economy (3 times)	Planning work (2 times)
	Technicist (3 times)	Comprehensiveness (2 times)
	Groupment (3times)	Law on safety in production (2 times)
	Environmental pollution (3 times)	Public emergency (2 times)
	Emergency security (3 times)	

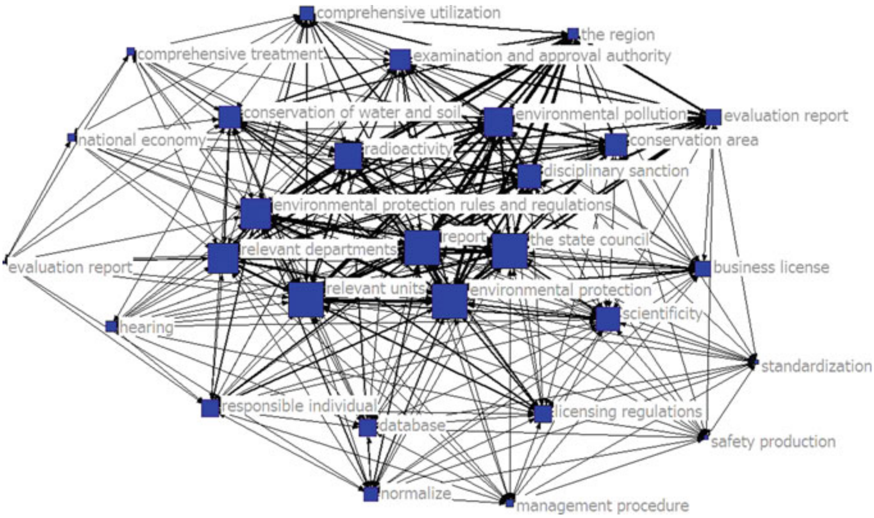

Fig. 2 The environmental policy keywords network map

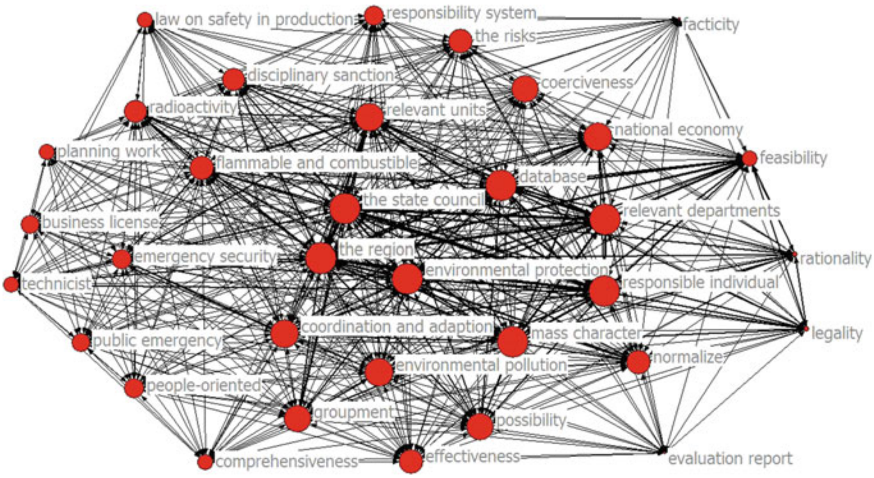

Fig. 3 The social risk policy keywords network map

control policy system of social risk of large engineering's environment pollution has important association with these keywords. In the network map, it can also analyze that other surrounding keywords are highly closed to the key words of center position and there is no isolated keywords as well, these illustrate that all keywords are formed a whole network to comprehensively control large project in control policy system of social risk of large engineering's environment pollution.

4. Point Degree of Center Degree Analysis

Point degree of center degree analysis is a common metric for representation of center nodes in social network analysis [8]. When a node is connected to many nodes, it represents that the node has an important position in the network. In order to get the main aspects of the control system, the research is through the Network Centrality-Degree path to respectively calculate the point degree of center degree of environmental protection policy and social risk policy by the UCINET software.

It can be seen from the Table 2, that "report" (the degree is 122.000, the nrm degree is 38.245) is located in the highest, suggesting that "report" plays an important role in the environmental protection policy, "environmental protection" and "unit", which stay at the second position, also plays an important role. Thus, it is concluded that in environmental policy, "environmental protection" is the main control objective and it needs relevant departments actively to carry out responsibilities, the statement of the project will have related reports. The research can analyze from the Table 3 that "the state council" and "the region" (the degree is 120.000, the nrm degree is 36.364) are both located in the highest position in the social risk policy." responsible individual", "relevant departments", "database" and "mass" stay at the second position, also occupying an important position. Thus, it concludes that the basic idea of social risk policy is the "state council" as the important work leadership, combined with the basic conditions of "the region" and cooperated with the relevant departments, which are responsible to each one, build information database and carry out the mass line.

Table 2 The environmental policy point degree of center degree analysis results (in part)

Keywords	Degree	Nrm degree
Report	122	38.245
Environmental protection	119	37.304
Relevant units	110	34.483
Environmental protection laws and regulations	96	30.094
Environmental pollution	94	29.467
The state council	93	29.154
The region	90	28.213
Radioactivity	73	22.884
Relevant departments	70	21.944
...	...	...
Standardization	15	4.702
Safety production	15	4.702
Evaluation report	14	4.389

Table 3 The social risk policy point degree of center degree analysis results (in part)

Keywords	Degree	Nrm degree
The state council	120	36.364
The region	120	36.364
Responsible individual	114	34.545
Relevant departments	92	27.879
Database	86	26.061
Groupment	85	25.758
Relevant units	81	24.545
Environmental protection	72	21.818
Flammable and combustible	71	21.515
...	...	...
Comprehensiveness	32	9.697
Facticity	28	8.485
Evaluation report	28	8.485

6 Conclusion and Suggestion

1. Research Conclusion

Based on content analysis, the research builds coding analysis unit of the policy system. With the help of co-word analysis, the research gives social network analysis to the policy system and further researches the policy system structure in two aspects of the social risk of environmental protection. The research extracts three modules (the policy goals, the applicable objects and role means) based on keyword classification and draws the outline of the control policy system of social risk of large engineering's environment pollution, as shown in Fig. 4.

2. Suggestion

The research provides a quantitative research method for the government and enterprises to analyze relevant control policy. The quantitative research method can help relevant departments have more scientific analysis of the content of the relevant policy, accurately analyze the defects of policy and put forward targeted policy suggestions, so as to more effectively improve relevant control policies.

From the perspectives of government, the government should intensify its efforts to provide the safeguard for the relevant aspects of the control policy in the next work. It mainly control large engineering from two aspects of environmental protection and social risk. The relevant pollution control policy files can reach controlling comprehensively, better guaranteeing to minimize the environmental pollution of the large engineering project and minimize the outbreak of the social risk caused by environmental pollution. But the research finds that the control supervision of the two aspects of environmental protection and social risk is weaker in end stage, leading to the control supervision of policy control system is inadequate in the project

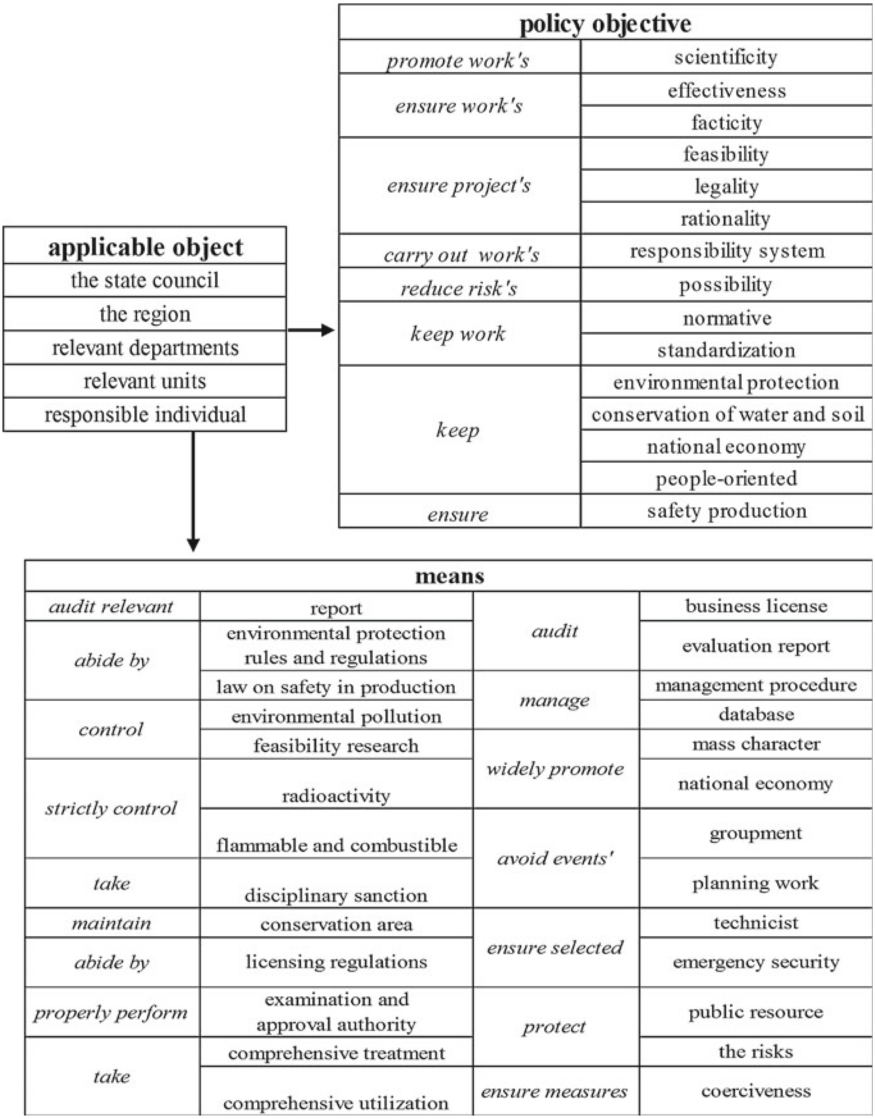

Fig. 4 Control policy system structure of social risk of large engineering's environment pollution

operation, thus inducing irregularity phenomenon; from key phrase extraction, media participation is not high, however, media interaction has a significant positive function in society. Above of all, it should be highly valued by the government.

From the perspective of enterprise, the enterprise should be active in corporate social responsibility, normative production management and production safety, achieving transparency for consumers. From the social network analysis of control policy system, “environmental protection”, “safe production” and “normative” are the key points of enterprise brand management, improving enterprise image and reducing the perceived risk of the consumers.

7 Research Prospects

This research mainly analyzes the control policy system of social risk of large engineering’s environment pollution by quantitative methods of content analysis and co-word analysis. In order to prove the effectiveness of this quantitative method, further research can be carried out in other control policy system in the future.

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Credit Risk Assessment of SEMs Based on Multi-Attribute Decision Making Method

Yi Zhang

Abstract In this paper, the multiple attribute decision making method is applied to credit risk asessment of SMEs. According to the theory of enterprise credit risk assessment, the index system of enterprise credit risk assessment is proposed based on the analysis of relation between SMEs credit evaluation and historical financial indicators and non-financial indicators. And a enterprise credit risk assessment model is built based on multiple attribute decision making. Multiple attribute decision making method can directly compare the size of SMEs' risks, it is significant for the credit risk monitoring of SMEs. Finally, multiple attribute decision making method of SMEs applied to four enterprises in risk assessment, the results show that the multiple attribute decision making method is effective and feasible.

Keywords SMEs · Credit risk asessment · Multiple attribute decision making

1 Introduction

Credit risk is one of the most important forms of risk in financial markets, which affects the various activities directly in the modern economic life, and affects the macro decision-making and economic development of a country, even affects the stable development of the global economy. Credit risk is a kind of intrinsic attributes of financial markets, and it play a certain role in adjusting the credit activities. Although participants of market can reap the benefits in the credit activities, the the credit risk may leads serious consequence. It not only affects decision-making and benefits of the microscopic economic subject, but affects formulation and implementation of the macro decision-making, even disturbs the market order, causes social unrest. Small and medium-sized enterprises (SMEs) have more innovation Ability, which

Y. Zhang (✉)
Department of Mathematics, Yibin University, Yibin 644007, People's Republic of China
e-mail: zhangyi_110_110@163.com

Y. Zhang
Business School, Sichuan University, Chengdu 610064, People's Republic of China

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will push the development of enconomic in a country. SMEs play a important role in our national economy and social development. Promoting the development of SMEs is an important basis to maintain steady and rapid development of national economy, is a major strategic task of relationship between the people's livelihood and social stability. Therefore, it is necessary to promote SMEs credit system construction, strengthen the credit consciousness of SMEs, and improve the SMEs' credit rating.

In the past few years, many researches have give enough attention to credit risk management of the enterprise, especially enterprise credit risk analysis and forecasting, which are the emphasis and difficulty in the present study. In terms of analysis and forecasting, research mainly focus on the establishment of the evaluation model and build up the forecast model and the application. The earliest risk prediction model which was proposed by the Beaver [8], Altman [11] was univariate analysis according to the financial and accounting data. After extending its variables, it is the famous Z score model, these analyses are used least squares estimate. In addition, Multivariate logistic regression model is a common used statistical method of credit risk analysis [2]. In the 1990s, the neural network was introduced into the banking sector, which is used for credit risk identification and prediction [1]. Small and medium-sized enterprise credit risk was assessed by the KMV model [7].

Multiple attribute decision making is applied widely in economic management and engineering design, and other fields. In existing research, there are a lot of scholars have carried on the detailed discussion for multiple attribute decision making, such as Han [3] used multiple attribute decision making problems to study the case in scientific research equipment tendering projects, Xia [4] proposesd a precise count blended with interval number multiple attribute decision making method based on TOPSIS method. Zhang [6] proposed a method considering incomplete information on attribute weights of interval muti-attributes problems, it is also a revised TOPSIS method. On the basis of existing research, there are no literature introducing multiple attribute decision making method to analyze the credit risk. This paper tries to apply multiple attribute decision making method to credit risk analysis and forecasting. And this model is used to solve a illustrate example to verified the validity and accuracy of the model.

2 Basic Concepts

In this section, some basic concepts and definitions of multi-criteria problem are presented.

For simplicity, let $M = 1, 2, \ldots, m$, $N = 1, 2, \ldots, n$ and $T = 1, 2, \ldots, t$. Let $X = x_1, x_2, \ldots, x_n (n \geq 2)$ be a finite set of n potential alternatives, $F = (f_1, f_2, \ldots, f_m)$ be a finite set of m attributes, and $w = (w_1, w_2, \ldots, w_m)^T$ is the weight vector of attributes, where $\sum_{j=1}^{m} w_j = 1$, $w_j \in [0, 1]$, $j \in M$ and w_j denotes the weight of attribute f_j. Suppose $A_k = (a_{ij})_{n \times m}$ is the numeric decision matrix, where i, j represents the preference of the alternative x_i with respect to the attribute f_j.

In multiple attribute decision making problems, as different attributes are often incommensurable, the attribute values must be normalized. Generally, there are benefit attributes and cost attributes. Suppose $R_k = (r_{ij})_{n\times m}$ is the corresponding normalized decision matrix, where for benefit attributes and cost attributes f_j.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n}(a_{ij})^2}}, \quad i \in N, j \in M. \tag{1}$$

Additive weighting method are used to get the alternative x_i, based on the relationship between the comprehensive attribute value and weight: $z_i(W) = \sum_{j=1}^{m} r_{ij}w_j$, $i \in N$.

When the weight vector w value is determined, we can get a order by the scheme of the comprehensive attribute values, but when the attribute weights are unknown values, it is unable to prioritize, this paper will give a new method to determine the weight of attributes.

3 Index Selection

3.1 The Principle of Index System Building

Index system construction should follow the following principles:

1. The independence principle
There is big correlation between some indexes, so they should be merged. Different indexes of enterprise explain different credit conditions degree, so they prone to similar or overlapping. Therefore, we should choose independent indexes.

2. Less reliance on financial statements
Due to the small and medium-sized enterprise financial information is not sound, the financial system is not standard, in view of this characteristic, we should increased the indexes about the small business non-financial factors, external macro conditions. Under these rules, it is important that increasing indexes about the industry experience, product competition.

3. Considering the quality of SMEs owner
Small and medium-sized enterprise management level is decided by enterprise experience and ability of management. Therefore, when deciding the indexes of small and medium-sized enterprise credit risk evaluation, the study of the basic quality of enterprise repayment willingness and the quality of owner, perfect assessment system the SMEs.

4. Combining quantitative and qualitative indexes
In the design of index system, when combined with the quantitative and qualitative index, as far as possible comprehensively reflect the status of small and medium-sized enterprise credit.

3.2 Index Systems of Mall and Medium-Sized Enterprise Credit Risk Assessment

Different from large enterprises, Small and medium-sized enterprises has disadvantages that information is not transparency, stability of management is poor. And it has the operation flexibility, strong innovation ability, strong development growing power and national policy support. So it should be considered innovation ability, growth ability, development ability, etc. When setting up the index system.

According to the characteristic of SMEs, when building a credit rating index system that is suitable for the SEMs, we should be based on the analysis of the financial factors, such as enterprise's operation ability, profit ability, at the same time, analyze debt paying ability combining enterprise's external macro environment and industry development situation. In addition, the analysis of the debt paying ability should also examine the repayment willingness of the enterprise. Only on the analysis of the enterprise debt paying ability and review the repayment willingness of enterprises, can objectively grasp the credit status of enterprises. Here, based on the existing research results and actual situation, we construct small and medium-sized enterprise credit risk index system and divide into financial indexes and non-financial indexes.

1. The financial indexes
Quantitative indexes are determined mainly according to the enterprise's financial data, different financial indexes reflect the different aspects of enterprise, including financial situation, business situation and profitability. Due to the financial index number, so you have to draw lessons from the existing index system and research results [12]. When choosing quantitative indexes, we need to consider what indexes can best illustrate the solvency of the enterprise, at the same time, we need to eliminate the indexes that the correlation coefficient are large, because the correlation between the indexes can lead to repeated calculation, reduce the effectiveness of the assessment. In conclusion, based on the domestic and foreign research results, and rational analysis, the paper build the financial index system from the following several aspects, debt paying ability, profit ability, operation ability and growth ability.

2. The non-financial indexes
Assessing the credit risk of SMEs, not only need to analyze the financial index and investigate the solvency of the enterprise, but also analyze macro environment, enterprise's basic quality, enterprise credit and other non-financial factors to affect the enterprise credit assessment. Bergeretal [9] pointed out that the comprehensive consideration of financial indexes and non-financial indexes, is more accurately than just considering financial indexes. Fridson [10] argued non-financial indexes made the assessment model more effective. Liang [5] pointed out that non-financial indexes were introduced to enhance the assessment model prediction ability, because it can better predict the future development trend, the overall evaluation of enterprise performance. Due to the importance of non-financial indexes for evaluation of enterprise credit risk assessment, on the basis of predecessors' research, we bulid the

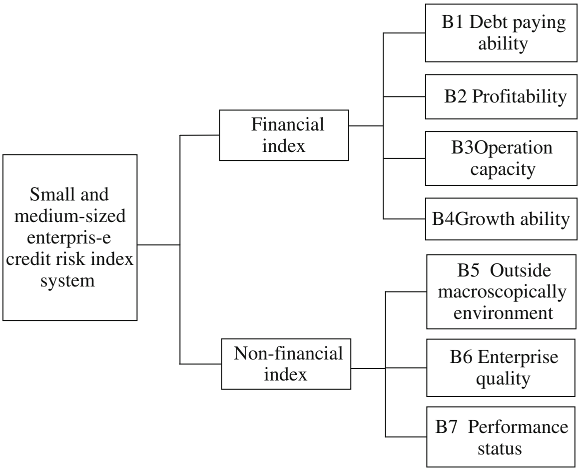

Fig. 1 Small and medium-sized enterprise credit risk index system

non-financial index system, outside macroscopically environment, enterprise quality, the performance status.

From discussed above, credit risk index system can be bulit as shown in Fig. 1. Based on the index system, we introduce multiple attribute decision making method to solve the problem of SMEs risk assessment.

4 Model

4.1 Problem Description

According to the theory of multi-attributes decision making model, the given a set of SME is seen as a set of possible solutions, each SME is regarded as a feasible solution, and denoted them by A_1, A_2, …, A_m; and credit risk indexes evaluating SMEs denoted by $c_1, c_2, \ldots, c_m$; weights of each index denoted by $\omega_1, \omega_2, \ldots, \omega_n$, $\omega_1 + \omega_2 + \cdots + \omega_n = 1$. The purpose of this paper is find out the SME facing smallest credit risk using multiple attribute decision making in $A_1, A_2, \ldots, A_m$.

Due to contradiction and equilibrium relation between different credit risk index system, there is no general optimal solution in the multiple attribute decision-making model of SMEs credit risk assessment. In the following, some concept of multiple attribute decision making solution will be explain.

According to the basic idea of TOPSIS method, If a solution is provided by the best results of all the attributes of small and medium-sized enterprise credit evaluation, then the solution is known as the positive ideal solution. Its expression is $A^+ = (c_1^+, c_2^+, \ldots, c_j^+, \ldots, c_n^+)$, there $c_j^+ = \max U_j(c_{ij}), i = 1, 2, \ldots, m$. $U_j(\cdot)$ is the jth attribute index value or utility function.

On the other hand, the negative ideal solution is made up of the worst attribute index, its expression is: $A^- = (c_1^-, c_2^-, \ldots, c_j^-, \ldots, c_n^-)$, there $c_j^- = \min U_j(c_{ij})$, $i = 1, 2, \ldots, m$. $U_j(\cdot)$ is the jth attribute index value or utility function.

4.2 Assessment Process

According to the basic idea of TOPSIS method, we applied the multiple attribute decision making model to small and medium-sized enterprises credit risk assessment. In following paragraph, we give the evaluation process.

Step 1. Index standardization. Different attribute index numerical units are usually different, if not attribute index value as a standard of indexes, there is no comparability. In this paper, using the vector normalization method for index standardization, making all attributes have the same vector element, calculation formula is (1).
Step 2. Weight distribution. This paper use the weight allocation method is the entropy method. The calculation formula is:

$$S(P_1, P_2, \ldots, P_N) = -k \sum_{j=1}^{n} p_j \ln(p_j),$$

there k is a positive constant, p_i is a discrete probability distribution.

Because SMEs credit risk index contains information at risk, so the SME itself is a kind of information carrier, so the entropy can be used as evaluation attributes relative important degree of a parameter. For different decisions, if they are no big difference on a property, you can think this property right decision, the choice of a smaller weights are given this attribute. As an extreme case, if all the decision of a certain attributes are exactly the same, you can think this did not attribute decision to choose, can be carved in addition, the weight given is 0. On the contrary, if a different decision on a particular attribute of difference is very big, is considered the attribute provides a large amount of information, a great influence on the choice of decision making, so give this attribute larger weights.

In containing m and n attributes of decision matrix, the properties of projective geometry p_{ij} can be defined as: $p_{ij} = c_{ij} / \sum_i^m c_{ij}, \forall i, \forall j$, the entropy of attributes E_j is

$$E_j = -k \sum_{i=1}^{m} p_{ij} \ln(p_{ij}, \forall j.$$

In order to ensure the $0 \leq E_j \leq 1$, for $k = 1/\ln(m)$. Due to the weight ω_j and entropy E_j is opposite, so we can use $1 - E_j$ instead of E_j, and to ensure that the weight of the normalized condition, namely $\omega_1 + \omega_2 + \cdots + \omega_n = 1, 0 \leq \omega_j \leq 1$, so

$$\omega_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)}, \forall j.$$

Step 3. TOPSIS sorting method. A good decision should be more close to the ideal solution, away from the negative ideal solution. But, in some cases, the decision-making plan may not be closest to the ideal solution is furthest from the negative ideal solution, and so the ideal solution and negative reason want to solution as reference in the different situations of various schemes of resolving power is different, so the choice of reference should be set by the decision makers, according to the specific circumstances. This paper, by using TOPSIS method to sort for decision making, this method at the same time considering the ideal solution and negative reason want to solution, and adopts Euclidean distance to measure any decision A_i and positive ideal solution A_+ and negative ideal solution is A_- the distance between notes for d_+ and d_- respectively, its expression is:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}, i = 1, 2, \ldots, m, \tag{2}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, i = 1, 2, \ldots, m,$$

there $v_{ij} = \omega_j c_{ij}$, $v_j^+ = \max c_{ij}$, $v_j^- = \min c_{ij}$.

Blend two distance calculated decision utility $U(A_i)$, formula is:

$$U(A_i) = d_i^- / (d_i^+ + d_i^-), i = 1, 2, \ldots, m.$$

Obviously, the bigger the $U(A_i)$, the decision A_i is better, that is to say, the credit risk of enterprise A_i is smaller.

5 An Illustrate Example

We apply the multiple attribute decision making method of credit risk assessment to the four small and medium-sized enterprise. Denoted enterprise A_1 and A_2, A_3 and A_4 respectively. According to the index selection, this article selects the seven indexes of risk, that is B_1, B_2, B_3, B_4, B_5, B_6, B_7.

Below we apply the multi-attribute decision making method to select the best option.

Step 1. Standardized indexes using the Eq. (1)

For SMEs credit risk indexes do normalized processing, this paper get a set of new indexes after normalization (Table 1).

Table 1 Indexes after normalization

Rnterprises	B_1	B_2	B_3	B_4	B_5	B_6	B_7
A_1	0.19	0.48	0.41	0.37	0.5	0.43	0
A_2	0.3	0.52	0.27	0.26	0.52	0.48	0
A_3	0.24	0.63	0.25	0.27	0.56	0.32	0
A_4	0.42	0.55	0.4	0.46	0.31	0.23	0

Table 2 The weight of each attribute

	B_1	B_2	B_3	B_4	B_5	B_6	B_7
Weight	0.36	0.21	0.25	0.18	0.24	0.29	0.47

Table 3 The distance from the positive and negative ideal point

Enterprises	d^+	d^-
A_1	0.092	0.071
A_2	0.071	0.08
A_3	0.096	0.07
A_4	0.096	0.102

Step 2. Weight distribution

According to the entropy method, this article will be treated as the normalized data generation into the calculated formula of entropy, it is concluded that the weights are the seven attributes such as shown in Table 2.

Step 3. Decision ordering

According to the formula $U(A_i) = d_i^- / (d_i^+ + d_i^-)$, we calculate the four enterprises' decision-making utility value, 0.4358, 0.5296, 0.4234, 0.5167 respectively. The value close to 1, which means that the credit risk of enterprise is small. On the contrary, the distance is as close to zero, it means that the credit risk is big. In conclusion, it can be seen that the order of credit risk of the four enterprise from small to large is A_2, A_4, A_1, A_3. Among them, the credit risk of enterprise A_2 is smallest, the credit risk of A_3 is the largest (Table 3).

6 Conclusion

In this paper, we propose a multi-attribute decision model to assess credit risk of small and medium-sized enterprise. This model based on credit risk indexes SMEs, which fully consider the feature of the SMEs. We apply this model to credit risk assessment of four SMEs, and the results show that the multiple attribute decision making method is scientific and feasible. Multiple attribute decision making method can compare the size of the credit risk of enterprises directly, which is significant for credit risk monitoring of the SMEs in our country. In addition, Multiple attribute decision making method has strong applicability. it can be apply to sort credit risk analysis of more SMEs as long as data is availability. With the deepening of research, the index system of credit risk may change, but the multiple attribute decision making model can be incorporated all relevant indexes into the model. Therefore, this method can get more application in the risk assessment of SMEs in the future.

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Game Analysis on Urban Tap Water Price under the Condition of Incomplete Information

Jianjun Yuan, Bin Wang, Lequn Zhang and Yubang Liu

Abstract Affected by various uncertain factors, it is difficult for interest-related parties to obtain the complete information in the process of urban tap water price setting, which makes urban tap water price deviates from its actual value. To solve this problem, the paper firstly analyses different factors influencing price setting, then takes advantage of bargaining theory to discuss the game process between interest-related parties in urban tap water price setting. Finally, it establishes the calculation formula at the lowest transaction costs on the basis of price theory, which is the most acceptable way to both supplying and purchasing parties. With the example of Chengdu water pricing in 2010, the paper also validates the accuracy of calculation formula. It is concluded that the price calculated by the formula is in line with the actual situation and is conducive to shorten the process of water pricing, reduce the cost and improve the efficiency of management.

Keywords Urban tap water · Price · Game · Incomplete information

1 Introduction

As a public product, urban tap water plays a rudimentary role in influencing citizens' living standard [3]. So it is necessary to build a sound and scientific price adjustment mechanism in order to reasonably adjust the water price, along with the

J. Yuan (✉)
College of Water Resources & Hydropower, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 784214641@qq.com

B. Wang · L. Zhang
State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, Chengdu 610064, People's Republic of China

Y. Liu
Editorial Center of Academic Journals, Chengdu University of Technology, Chengdu 610064, People's Republic of China

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dramatic change of economy, market conditions and the financial afford ability of citizens. In several developed countries such as America, Britain, France and Australia, regular price adjustment mechanisms have been enacted according to their actual conditions. For instance, Affairs Bureau of Public regularly held the public price hearing to determine the reasonable return on water supply companies' investment in America; Britain has established the price-cap adjustment mechanism on the basis of negotiation and France has applied the water cost compensation price mechanism by self-sustainable water projects [4–9].

In recent years, the urban tap water price adjustment mechanism has been developed in our country, although it is in the primary stage due to the particularity of water products and historical reasons. But the price increase in many areas neither spotlights the demand and supply of tap water nor meets with the development of economy, which is detrimental to social harmonious. Therefore, under the circumstance of lacking data and information, it is crucial and urgent for us to find effective solutions to improve the situation, which is also a key stage in establishing our urban tap water price adjustment mechanism.

Based on the current situation of our city urban tap water price, the paper mainly analyses factors influencing urban tap water price and relationships between them. It not only studies the game process under the condition of incomplete information, during which a reasonable price for both water companies and citizens can be set, but also establishes the quotation formula with high efficiency and low cost. Finally, the paper validates the accuracy of the formula with the example of Chengdu water pricing in 2010 and thus provides a reliable scientific support for establishing city urban tap water price adjustment mechanism.

2 Influencing Factors and Game Analysis of Urban Tap Water Price

2.1 Factors Influencing Urban Tap Water Price

In urban tap water market, the information obtained by water companies and citizens are so incomplete that the price setting is only carried out without enough data and materials. On the one hand, the accurate cost estimation of urban tap water and its complete clarity has certain difficulty; on the other hand, it is hardly possible to gain the exact information of average citizens' financial afford ability. Price hearing, as the most popular way in price setting, is a favorable dynamic game process between water companies and citizens, during which a relatively reasonable water price will be determined by accepting or rejecting the quotation of water companies. Not only the costs and profits of water supply but also expenses in game process are supposed to be considered by water companies. And citizens should take their financial afford ability, agreement for quotation and game expenses into account.

2.2 Game Analysis on Urban Tap Water Price

In the quotation process, water companies may offer a fair price accepted by both parties as soon as possible for minimizing the expenses of game.

Assuming that game times are i (i refers to 2 because the price hearings are generally finished within three times), P_c is the water price before adjustment, P_i is the quotation of water companies in the i round of price hearings; $\bar{P}$ is the actual price afforded by citizens and $\tilde{P}$ is citizens' affordable price estimated by water companies, in general, $\bar{P} \geq \tilde{P}$ and $\mid \tilde{P} - \bar{P} \mid \ll \mid \tilde{P} - P_c \mid$; $P_{i\alpha}$ and P_{ir} are probabilities of the success or failure of negotiation in the i round of price hearings; δ_{gi} and δ_{yi}, which called reduction factors, are expressed by the percentage of benefits, including labors, money, materials and time expensed by water companies and citizens in the second game; $E(P)$ refers to the maximum expected benefit of per unit water, which is the expected benefit what we discussed in the paper.

To find the most reasonable water price, the paper firstly analyzes both parties' sequential rational strategies in the second round of negotiations by using backward induction method. If the second negotiation not progress smoothly, the price hearings will end up with a failure of price increase because there are generally only two rounds of game. Only when $P_2 > P_c$, can water companies accept the adjustment. Supposing that citizens reject the adjustment in the first negotiation because of two reasons, one is their pursuits for more benefits in the second round, and the other is that P_1 is higher than their financial afford ability $\bar{P}$.

According to rational principle, citizens usually choose the quotation which will bring higher benefits for them. Since P_2 should be uniformly distributed between P_c and $\tilde{P}$ (see Fig. 1), citizens' expected benefits can be calculated by the following equation:

$$E(P_2)_i = (\bar{P} - P_2)P_{2a} + 0 \cdot P_{2r}. \tag{1}$$

The expected benefits of water companies can be obtained by Eq. (2).

$$E(P_2)_g = (P_2 - P_c)P_{2a} + 0 \cdot P_{2r}. \tag{2}$$

The probabilities of the success or failure of the second negotiation can be determined by P_2, which is a certain figure given by water companies, but $\bar{P}$ (the actual price afforded by citizens) is less known to them.

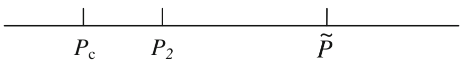

Fig. 1 The quotation of water companies in the second negotiation

$$P_{2a} = p(\overline{P} > P_2) = \frac{\tilde{P} - P_2}{\tilde{P} - P_c}, \quad (3)$$

$$P_{2r} = p(\overline{P} < P_2) = \frac{P_2 - P_c}{\tilde{P} - P_c}. \quad (4)$$

Based on profit maximum principle, Eq. (3) and Eq. (4) are substituted in Eq. (2), and then the perfect quotation price can be given by water companies by derivation.

$$P_2 = \frac{\tilde{P} + P_c}{2}. \quad (5)$$

And the water company's expected benefits in second negotiation is:

$$E(P_2)_g = \frac{\tilde{P} - P_c}{4}. \quad (6)$$

Citizens' expected benefits in the second game is:

$$E(P_2)_y = \frac{2\bar{P} - \tilde{P} - P_C}{4}. \quad (7)$$

Generally, it is can be known that $E(P_2)_y > 0$ for $\tilde{P}$ (the citizens' affordable price estimated by water company) is very close to that the actual price afforded by citizens.

If citizens know that the result of Eq. (7) is their final expected benefits once the second round of price hearings begins, they will accept P_1 under the following conditions:

$$\begin{cases} \overline{P} - P_1 \geq E(P_2)_y \delta_{y2} \\ \overline{P} - P_1 \geq 0. \end{cases} \quad (8)$$

Then Eq. (9) can be given by solving above two equations.

$$\overline{P} \geq \frac{4P_1 - \delta_{y2} P_c - \delta_{y2} \tilde{P}}{2(2 - \delta_{y2})}. \quad (9)$$

If:

$$P_0 = \frac{4P_1 - \delta_{y2} P_c - \delta_{y2} \tilde{P}}{2(2 - \delta_{y2})}. \quad (10)$$

Then under the maximum expected benefits principle, water companies will still choose P_1 although they have got a well-round understanding of citizens' decision methods in first negotiation and the outcome of the second round of negotiations.

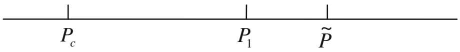

Fig. 2 The quotation of water companies in first negotiation

$$E(P_1)_g = \frac{\max[(P_1 - P_c) \cdot P_{1a} + (P_2 - P_c)\delta_{g2} \cdot P_{ra}]}{P_1}. \tag{11}$$

In Eq. (11), P_{ra} is the probability that citizens reject the quotation in first negotiation but accept in the second one, P_{1a} means the probability of their acceptability to P_1 in first negotiation. Both of them can be worked out by following equations due to the fact that P_1 is uniformly distributed in $[p_c, \tilde{p}]$ (see Fig. 2).

$$P_{1a} = \frac{\tilde{P} - P_0}{\tilde{P} - P_C} = \frac{2(2 - \delta_{y2})\tilde{P} - 4P_1 + \delta_{y2}(P_c + \tilde{P})}{2(2 - \delta_{y2})(\tilde{P} - P_C)}, \tag{12}$$

$$P_{ra} = P_{1r} \cdot P_{2a} = \frac{P_0 - P_C}{\tilde{P} - P_c} \times \frac{\tilde{P} - P_2}{\tilde{P} - P_c} = \frac{4P_1 - \delta_{y2}(\tilde{P} + P_C) - 2(2 - \delta_{y2})P_C}{4(2 - \delta_{y2})(\tilde{P} - P_c)}. \tag{13}$$

Eq. (12) and Eq. (13) are substituted in Eq. (11), and then it can be expressed as follows after the derivation of P_1.

$$P_1 = \frac{4(\tilde{P} + P_c) + (\delta_{g2} - \delta_{y2})(\tilde{P} - P_c)}{8}. \tag{14}$$

From Eq. (14), we can know that citizens cannot accept the price offered by water companies unless it satisfies above equations and correlates with the initial water price P_c, their financial afford ability and the reduction factors δ_{g2} and δ_{y2}.

If there are more price hearings, the results can also be achieved like by backward induction method.

3 Research on Chengdu Urban Tap Water Price Adjustment

3.1 Game Theory in Chengdu Urban Tap Water Price Setting

In order to ease water supply problems and cover the huge expenses on pipe work modification, the urban tap water price in Chengdu is necessary and urgent to be adjusted [1].

According to the survey, urban tap water price of Chengdu is 2.15 yuan per cubic meters in 2009, but the price finally approved by the water company is 2.31 yuan per cubic meters by the end of 2009, which means that the water company was operated in the red so that price adjustment has been a pressing problem of the day. The maximum water price affordable to citizens is 5.5 yuan per cubic meters, and the reduction factors of the water company and citizens, δ_{g2} and δ_{y2} (In reality, δ_{g2} is higher than δ_{y2}), including labors, money, materials and time spent in price setting, are 0.02 and 0.06 . Then based on above data, a rational analysis will be carried out by the water company before quotation.

To avoid the ultimate failure of price adjustment, the quotation given by the water company in the second negotiation should satisfy the condition that $P_2 \geq 2.31$. And citizens would seek for the perfect price which brings them the maximum benefits after judging that it is the figure between 2.31 and P_1. After the rational judgment of both parties' benefits, the water company can obtain the result that $P_2 = \frac{\tilde{P}+2.31}{2}$ calculated by equation (5), then the final benefits achieved by the water company and citizens are $\frac{\tilde{P}-2.31}{2}$ and $\frac{2\bar{P}-\tilde{P}-2.31}{4}$ calculated by Eq. (6) and Eq. (7).

Then the first round of negotiation will be considered, $P_1 = 3.89$ can be obtained by substituting $\delta_I = 0.01$, $\delta_1 = 0.01$, $P_c = 2.31$ and $\tilde{P} = 5.5$ into Eq. (14).

3.2 Analysis on the Research of Chengdu Urban Tap Water Price Setting

Under the above studies, it can be known that the most reasonable water price accepted by both parties is 3.89 yuan per cubic meters and the most acceptable quotation of the water company is 2.89 yuan per cubic meters (excluding the profits) by deducting 1 yuan per cubic meters subsidized by government. Actually, on May 6th, 2010, according to price hearings and various opinions, Chengdu Bureau of Commodity Price has enacted the price adjustment strategy that the adjustment of urban living water price will be finished within two years. The price of urban tap water has increased from 2.15 yuan to 2.50 yuan per ton since June 1st, 2011, and then has increased from 2.50 yuan to 2.85 yuan per ton since January 1st, 2011, including the water price in water conservancy project and sewage treatment fee [2]. The final water price is very close to 2.89 yuan per cubic meters which is the price without considering profits and subsidies.

4 Conclusion

On the basis of above researches, two significant conclusions are drawn from the paper. Firstly, the urban tap water price is mainly determined by water costs, citizens' financial afford ability and the game expenses and capability of both supplying and purchasing parties. In the process of price adjustment, game costs and capability is the comprehensive expression of all costs, skills, patience and the information they mastered in rounds of negotiations, which ultimately exert a significant influence on price validity. Secondly, it is necessary for water companies to conduct an intensive and comprehensive investigation on citizens' financial afford ability before applying for price adjustment. Then after the reasonable expenses estimation of negotiations, the most available water price to citizens would be easily worked out, which contributes to save the labors, money, materials and time spent in price hearings, enhances the efficiency of price setting and establishes a harmonious society with crucial theoretic and practice implications.

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The Impact of Mutual Fund Investment Trading on Stock Prices: Evidence from the Chinese Stock Market

Kun Li, Bo Zhou and Die Hu

Abstract This paper examines the impact of mutual fund trading on stock prices in the Chinese equity market from 2004 to 2013. We have found that there is a strong positive contemporaneous correlation between stock returns and mutual fund holdings and trading. In addition, the price impact is more significant in mutual funds buying than in mutual funds selling. Finally, our findings support the hypothesis that the price impact of mutual fund holdings and trading on stock returns arise from momentum trading or price pressure.

Keywords Price impact · Mutual funds · Momentum trading · Price pressure

1 Introduction

China opened its stock market in 1991. The first closed-end fund was set up in 1998, and the first open-end fund was set up in 2001. Since then, the mutual fund industry has been expanding rapidly. By the end of 2013, mutual funds managed total assets of more than 3 trillion RMB, and their investment accounted for about 15 % of the total value of the floating stocks in the Chinese equity market (see Table 1).

As major institutional investors, mutual funds are playing an increasingly important role in the Chinese equity market. Both practitioners and academia have shown deep interest in the performance of mutual funds. Are mutual funds "smart investors"? Do stocks held by mutual funds perform better than other stocks and why? While much evidence from overseas markets shows that mutual fund holdings have a positive correlation with stock returns, does the Chinese market follow the same pattern? This paper tries to answer the above questions by examining the price impact of mutual funds in the Chinese market and exploring the nature of the price impact.

K. Li · B. Zhou · D. Hu (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: hudiescu@163.com

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Table 1 The development of investment companies in China (NAV in million RMB)

Year	Number of open-end funds	Number of closed-end funds	NAV of open-end funds	NAV of closed-end funds
1998	0	5	0	100
1999	0	23	0	510
2000	0	39	0	610
2001	3	49	85	680
2002	17	54	395	717
2003	56	54	711	862
2004	100	54	2391	854
2005	169	54	3874	817
2006	268	53	6942	1623
2007	330	36	30490	2468
2008	420	34	19080	789
2009	565	33	29848	1454
2010	700	47	23034	1621
2011	946	70	20916	1552
2012	1314	82	27139	1527
2013	1865	76	29496	1179

Sources SEC, Shanghai Securities Exchange and Shenzhen Securities Exchange

This paper is organized as follows: Sect. 2 reviews the literature; Sect. 3 discusses the data; Sect. 4 provides the empirical test results; and Sect. 5 states the authors' conclusions.

2 Literature Review

Much evidence from overseas research shows that mutual funds have a significant price impact on stock returns (i.e., mutual fund holdings show a positive correlation with stock returns). The existing literature presents three major explanations for the positive correlation: momentum trading, information advantages, and price pressure.

Momentum traders buy stocks of historically superior performance and sell stocks of historically inferior performance. They anticipate that the price trend will continue moving in the same manner, and in this way they can obtain the desired profit in the future. Numerous research findings indicate that stock returns tend to have momentum in the short-term but reverse in the long-term. Jegadeesh and Titman [13] showed thatmomentum-trading strategy can be profitable over a 3–12-month time frame. Acharya [1] looked at equity markets inseveral different countries and confirmed the existence of momentum of stock returns in these markets.

If momentum trading is profitable and mutual fund investors follow momentum trading strategy, then the return on stocks traded by mutual fund investors will show a positive correlation with their trading. Thus, the stocks bought by mutual fund investors tend to have higher future returns, and the stocks sold by mutual fund investors tend to have lower future returns. Many empirical studies have provided evidence of momentum trading by mutual funds [4, 6]. Grinblatt et al. [11] examined the portfolios of 274 mutual funds during 1974–1984 and found 77 % of mutual funds were engaged in momentum trading. But some studies arrived at different conclusions. Campbell [5] and Yan [17] found no evidence of "herdin" and momentum trading. If the price impact of mutual fund trading is due to momentum strategy, the price impact would not last long and price reversal would likely occur in the mid-term future.

Another explanation for the positive correlation between mutual fund holdings and stock returns is information advantage. Institutional investors have tremendous advantages both in information acquisition and information analysis. They may learn the true value of stocks well in advance and trade based on their private information. Thus, the trading done by mutual fund investors is based on predicted changes in the value of the stocks and is positively correlated with stock returns.

Douglas [10] found that the stocks bought by mutual funds had higher future returns than stocks sold by mutual funds, and he argued that the "herding" behavior of mutual funds might be rational and speed the absorption of information, thus stabilizing the market. Dasgupta [9] also concluded that mutual funds improved the informational efficiency of the equity market. Compared to stocks with low mutual fund holdings, prices of stocks with high mutual fund holdings tend to be closer to their intrinsic values. Daniel et al. [8] found that the demand of mutual funds positively correlates with future stock returns. They believe that this indicates that mutual fund investors have some ability or means to predict future stock returns.

Price pressure is the third explanation for the price impact of mutual funds. Equity markets are seldom perfectly liquid. If mutual fund investors as a group are adding to their holdings of a certain stock, it is intuitive to expect that the large amount they demand will push up the price of the stock because mutual fund investors have to offer a premium price to persuade other investors to sell. In the case of mutual fund selling, mutual fund investors have to offer a price concession if they want to sell a large quantity of a stock [2, 3, 16]. If the positive correlation between institutional trading and stock returns is due to price pressure, then the price movement tends to reverse in the future when the pressure on the demand or supply disappears. However, Hu [12] argued that the price deviation due to pressure from supply or demand might also persist for a considerable period due to the limitation of arbitrage. Rebello [15] found that the price impact after mutual fund buying would persist instead of reversing, thus supporting the informational-advantage hypothesis of institutional buying. However, they both found price reversals after mutual fund selling which indicates that pressure from supply or demand is in fact the major cause of price impact in the case of mutual fund selling.

Most of the studies focused on developed markets. Our paper adds value to the existing literature on the price impact of mutual funds by providing evidence from China, an emerging but very important equity market. The findings of this paper also have practical implications for investors and regulators.

3 Data

Although strictly defined, mutual funds only include open-end funds; however, we also include closed-end data in our study. This is relevant because our focus is the price impact of both closed-end and open-end funds as institutional investors. The major source of information on mutual fund stock holdings is the portfolio from the semi-annual and annual report of mutual funds. In China, mutual funds are required to reveal their complete holdings for only the second and fourth quarter in the semi-annual and annual reports. Thus, only data from the semi-annual and annual reports are used in this study. Taking into consideration the reliability of the data, we chose stocks established before December 31, 2003 for our sampling group. The stock-holding data included in this study are from the beginning of 2004 to the end of 2013.

When studying the impact of mutual fund holdings on returns, the stocks with less than 1 % mutual fund holdings are excluded from the sampling, and when studying the impact of mutual fund trading on stock returns, the stocks with less than 1 % change in mutual fund holdings are excluded from the sampling. Stocks with missing data are also excluded from the sampling. Stock-holding data are collected from the semi-annual and annual reports of mutual funds, and other data are from the CSMAR (China Stock Market & Accounting Research Database).

4 Empirical Results

1. Mutual fund holdings and stock returns

We first tested the relationship between mutual fund holdings and stock returns by comparing the returns of stocks with high level and low level mutual fund holdings. We then sorted the stocks with mutual fund holdings into 10 groups and examined the stock returns of the groups with highest and lowest levels of mutual fund holdings. The stocks included in the high-level group were stocks with the highest deciles of mutual fund holdings, and the stocks in the low-level group were stocks with the lowest deciles of mutual fund holdings.

Table 2 provides the results of the sorting. The average return of the high-level group is much higher than the low-level group. During the sampling period, the average semi-annual return of the high-level group was 0.2349, while the average semi-annual return of the low-level group was only 0.0532. This implies a difference of 0.18 for a six-month holding period or 0.36 for a one-year holding period, which is

Table 2 Contemporaneous return of stocks with high-level and low-level mutual fund holdings

Year	Low			High			Average		
	Hold%	C-return	A-return	Hold%	C-return	A-return	Hold%	C-return	A-return
2004 mid	1.19	−0.1239	0.0727	16.73	0.0143	0.2109	5.69	−0.0659	0.1307
2004 end	1.16	−0.0796	0.0136	21.68	0.1628	0.256	7.1	0.0082	0.1014
2005 mid	1.24	−0.1324	−0.0475	23.3	0.0811	0.166	7.74	−0.0421	0.0428
2005 end	1.24	0.0521	0.0474	23.81	0.141	0.1363	7.7	0.1039	0.0992
2006 mid	1.19	0.4597	0.1717	22.27	0.9966	0.7086	7.23	0.6298	0.3418
2006 end	1.24	0.1768	−0.3499	27.4	0.5392	0.0125	9.35	0.3612	−0.1655
2007 mid	1.35	0.7432	0.5432	33.54	0.7215	0.5215	11.3	0.7719	0.5719
2007 end	1.35	0.2868	0.3392	35.8	0.4137	0.4661	12.37	0.4657	0.5181
2008 mid	1.39	−0.4393	−0.2272	36.8	−0.2784	−0.0663	12.13	−0.3893	−0.1772
2008 end	1.33	−0.1429	0.0633	37.48	−0.2647	−0.0585	11.99	−0.2573	−0.0511
2009 mid	1.34	0.6561	0.4091	31.6	0.6908	0.4438	10.33	0.6304	0.3834
2009 end	1.35	0.2579	0.0788	32.87	0.4746	0.2955	10.71	0.3183	0.1392
2010 mid	1.37	−0.2283	0.0003	32.59	−0.0006	0.228	10.1	−0.1465	0.0821
2010 end	1.39	0.2576	0.2002	30.99	0.4895	0.4321	9.73	0.4115	0.3541
2011 mid	1.35	0.0156	0.0723	27.91	0.0109	0.0676	8.93	0.0195	0.0762
2011 end	1.26	−0.3119	−0.2442	30.52	−0.1165	−0.0488	8.61	−0.2599	−0.1922
2012 mid	1.22	0.0275	0.044	29.43	0.2059	0.2224	8.23	0.0725	0.089
2012 end	1.15	−0.0625	−0.1502	29.06	0.0542	−0.0335	7.96	−0.02	−0.1077
2013 mid	1.21	−0.1655	−0.0504	27.73	0.1345	0.2496	7.59	−0.0855	0.0296
2013 end	1.23	−0.1631	−0.1361	26.46	0.2269	0.2539	7.32	0.2093	0.2363
Total	1.28	0.0542	0.0425	28.9	0.2349	0.2232	9.11	0.1368	0.1251

C-return: contemporaneous return, A-return: contemporaneous abnormal return economically highly significant. At the same time, the average return of the high-level group was 0.10 higher than the average return of the whole mutual fund holdings sampling.

We calculated the abnormal return by subtracting the market return from the average return of each group. The average abnormal return of stocks with mutual fund holdings was 0.1251 (i.e., the return of the stocks with mutual fund holdings was 0.1251 higher than the average market return during our sample period). The abnormal return of the high-level group was 0.2232.

We extended the above comparison to examining the relationship between stock returns and lagged mutual-fund holdings. Table 3 presents these empirical results. The return difference between the high-level and low-level groups was very small in this comparison. The average semi-annual return of the high-level group (0.1020) was 0.001 lower than the low-level group (0.1030) and 0.0054 lower than the whole mutual-fund holding sampling. If we look at the abnormal returns, then the average returns of the mutual fund holdings for the high-level group and the low-level group are all slightly lower than the average market return.

The empirical results of sorting indicate that there is a positive contemporaneous correlation between stock returns and mutual-fund holding levels. Stocks with high levels of mutual fund holdings tend to have much higher contemporaneous returns than stocks with low mutual fund holdings, and they also demonstrate higher than average contemporaneous market returns. But the level of mutual fund holdings does not show a significant correlation with lagged stock returns.

Sorting may reveal the price impact of mutual fund holdings in a simple way, but the criteria of sorting are highly arbitrary, and many other important factors which may affect stock returns are neglected. Thus, we used regression to further test the correlation between stock returns and mutual fund holdings. We first tested the correlation between stock returns and contemporaneous mutual fund holdings (i.e., the stock returns during each six-month period and the mutual-fund holding levels at the end of each of the six-month periods). The regression model is:

$$R_t = \alpha + \beta_1 R_{t-1} + \beta_2 LnC_t + \beta_3 H_t + \sum_{22}^{4} \beta_i \text{Year} + \varepsilon_t. \quad (1)$$

The dependant variable R_t is the return on stocks in period t, and H_t is the level of mutual-fund stock holdings at the end of period t (i.e., the percentage of floating shares held by all mutual funds). R_{t-1} and C_t are control variables in which R_{t-1} is the lag return of stocks in the previous period. If mutual funds follow positive-feedback strategy and stock returns have momentum in the short-term future, then stock returns can be partly explained by historical returns. C_t is the company size at the end of period t. Company size is included as a control variable in its logarithmic form. The other variables represented by “Year” are time dummies, and the first half of year 2004 serves as the omitted class.

Table 3 Stock returns with lagged high-level and low-level mutual fund holdings

Year	Low			High			Average		
	Hold%	L-return	A-return	Hold%	L-return	A-return	Hold%	L-return	A-return
2004 mid	1.21	−0.1180	−0.0248	21.17	−0.024	0.0692	5.93	−0.0195	0.0737
2004 end	1.22	−0.0846	0.0003	21.68	−0.0373	0.0476	7.47	−0.0718	0.0131
2005 mid	1.25	0.103	0.0983	23.71	0.0596	0.0549	7.97	0.0519	0.0472
2005 end	1.25	0.3968	0.1088	23.86	0.5134	0.2254	7.92	0.5115	0.2235
2006 mid	1.21	0.2806	−0.2461	22.82	0.3072	−0.2195	7.66	0.3108	−0.2159
2006 end	1.26	0.7091	0.5091	27.7	0.6006	0.4006	9.63	0.6675	0.4675
2007 mid	1.45	0.4711	0.5235	34.01	0.2458	0.2982	12.04	0.4114	0.4638
2007 end	1.5	−0.4272	−0.2151	36.12	−0.3485	−0.1364	13.01	−0.4011	−0.189
2008 mid	1.45	−0.2755	−0.0693	37.11	−0.3093	−0.1031	12.56	−0.2806	−0.0744
2008 end	1.35	0.6351	0.3881	38.08	0.36	0.113	12.35	0.5389	0.2919
2009 mid	1.34	0.2765	0.0974	31.88	0.2826	0.1035	10.47	0.2898	0.1107
2009 end	1.38	−0.1891	0.0395	33.07	−0.1141	0.1145	10.91	−0.164	0.0646
2010 mid	1.4	0.3304	0.273	31.9	0.3624	0.305	10.2	0.3607	0.3033
2010 end	1.41	0.0206	0.0773	31.16	−0.0596	−0.0029	9.92	0.0098	0.0665
2011 mid	1.35	−0.3033	−0.2356	28.26	−0.1731	−0.1054	9.06	−0.2785	−0.2108
2011 end	1.26	0.0537	0.0702	30.81	0.1302	0.1467	8.68	0.0703	0.0868
2012 mid	1.23	−0.0801	−0.1678	29.71	−0.0102	−0.0979	8.28	−0.0329	−0.1206
2012 end	1.15	−0.0664	0.0487	29.29	0.0061	0.1212	8	−0.0991	0.016
2013 mid	1.2	0.2252	0.2522	28.08	0.1463	0.1733	7.59	0.1659	0.1929
Totle	1.31	0.103	0.0804	29.5	0.102	0.0794	9.46	0.1074	0.0848

L-return: lagged return, A-return: lagged abnormal return

Table 4 Stock returns and contemporaneous mutual fund holdings

Variables	R_t
R_{t-1}	−0.0755***
	(0.00876)
Size	0.594***
	(0.0151)
Fund holding	0.00830***
	(0.000795)
Year	control
AR(1)	0.052
AR(2)	0.208
Sargan	0.944
Observations	7528
Number of stocks	852

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. AR(1), AR(2): Arellano-Bond AR(1), AR(2) test

As the lagged return is included in the explanatory variables, this may lead to the problem of endogeneity, which results in biased and inconsistent estimates in the regression of the panel data with fixed effect or random effect. Thus, we use the Arellano-Bond Dynamic Panel GMM Estimators in Stata to make the analysis.

Table 4 presents the results of the regression model. The results show that the coefficient of historical returns is significantly negative (coefficient, −0.0755) which indicates that there is a mean reverting phenomenon for the stock returns within the framework of the six-month period. If mutual funds follow a contrarian strategy based on the returns of the previous six months, then they could gain abnormal returns. The coefficient of the company size is positive and significant. It indicates that the returns of larger-sized companies tend to be higher.

The coefficient of mutual fund holdings is 0.0083 and significant at a 1 % level. This indicates that during the sampling period, generally stocks with higher mutual fund holdings tended to have higher contemporaneous returns, and this was consistent with the conclusion from the sorting in the previous test.

The positive correlation between stock returns and contemporaneous mutual fund holdings can arise from momentum trading, price pressure or informational advantage. Our test showed that overall the mutual funds did not follow momentum trading strategy; unfortunately, there was no way to directly test the hypothesis for the influence of price pressure and informational advantage because we did not have the data to observe the mutual fund trading within the test period. However, we can test the predictive power of mutual funds by looking at the returns in the sequential period for stocks held by mutual funds. If mutual fund holdings can predict future stock returns, then it is likely that mutual funds have an informational advantage. We follow the regression model in Eq. (1) by replacing the dependent variable R_t with R_{t+1}, that is, we regress the lagged stock returns on the contemporaneous mutual fund holdings.

Table 5 Mutual fund holding and lagged stock returns

Variables	R_{t+1}
R_t	−0.0545***
	(0.0178)
Size	0.141***
	(0.0195)
Fund holding	−0.0181***
	(0.000868)
Year	control
AR(1)	0.031
AR(2)	0.269
Sargan	0.998
Observations	7755
Number of stocks	863

$$R_{t+1} = \alpha + \beta_1 R_t + \beta_2 LnC_t + \beta_3 H_t + \sum_{22}^{4} \beta_i \text{Year} + \varepsilon_t. \tag{2}$$

Table 5 presents results of Eq. (2). As in Eq. (1), the coefficient of stock return at t is significantly negative, and the coefficient of company size is significantly positive. The coefficient of stock holdings is negative and significant, which indicates there is reversal of stock returns. Combined with the results of Table 4, we may say that stocks with higher mutual fund holdings tend to have higher contemporaneous return but reversal occurs in the successive period. This supports the hypothesis of momentum trading or price pressure because in the case of these two, the stock returns tend to reverse in the sequential period. However, this does not support the hypothesis that mutual funds trade on superior private information.

2. Mutual funds trading and stock returns

In this section, we examine the relationship between mutual fund holdings and stock returns by looking at the change of mutual fund holdings. In accordance with the availability of data, the change of mutual fund holdings is calculated on a six-month basis as follows, the change of stock holdings at the end of year 2013 is obtained by subtracting the 2013 mid-year stock holdings from the 2013 year-end holdings.

Table 6 provides the correlation coefficients of change of mutual fund holdings and stock returns. It shows that during the whole sampling period, the mutual fund trading positively correlated with contemporaneous stock returns. In other words, stocks which are being purchased by more mutual funds have higher contemporaneous returns, and stocks which are being sold by more mutual funds have lower contemporaneous returns. The average correlation coefficient is 0.356 and highly significant.

We asked the question again: What is behind the positive correlation between mutual fund trading and contemporaneous stock return? As we did not know the

Table 6 Correlation coefficients between the change of mutual fund holdings and stock returns

	R_t	R_{t-1}	R_{t+1}
δH_t	0.356***	0.035***	0.074***

details of trading during each period, we looked at the correlation between mutual fund trading and stock returns during the previous and successive periods in order to obtain any clues to the answer.

Table 6 shows that the average correlation coefficient between mutual fund trading and stock returns for the previous period is significant (0.035) but much smaller than 0.334. This indicates that momentum trading is unlikely a cause for the positive correlation between stock returns and mutual fund trading. Table 6 also presents the correlation between mutual fund trading and lagged stock returns. The average correlation coefficient is 0.074 and significant at the 1 % level. This indicates that mutual fund trading might be able to predict future price change, and the price change associated with contemporaneous mutual fund trading is persistent and does not reverse in the successive period. Thus, the empirical results of the correlation coefficient tend to support the information-advantage hypothesis, not the momentum-trading or price-pressure hypotheses.

The correlation coefficient provides some information about the mutual fund trading and stock returns, but it might neglect the impact of other factors on the stock returns. Thus, we use the following regression models to further examine the relationship between mutual fund trading and stock returns:

$$R_t = \alpha + \beta_1 R_{t-1} + \beta_2 LnC_t + \beta_3 \delta H_t + \sum_{22}^{4} \beta_i \,\text{Year} + \varepsilon_t, \tag{3}$$

$$R_{t+1} = \alpha + \beta_1 R_t + \beta_2 LnC_t + \beta_3 \delta H_t + \sum_{22}^{4} \beta_i \,\text{Year} + \varepsilon_t. \tag{4}$$

The definition of variables in the above model follows that in Eq. (1). Equation (3) tests the relationship between mutual fund trading, contemporaneous stock returns, and $\delta H_t = H_t - H_{t-1}$ (i.e., the change of mutual fund holdings from the end of the previous period to the end of the current period). Equation (4) tests the relationship between mutual fund trading and the lagged stock returns.

Table 7 presents the results of regression in Eq. (3). The coefficient of mutual fund trading is positive and highly significant. This indicates that during the sampling period, stock returns are positively correlated with contemporaneous mutual fund buying or selling. The stocks bought by mutual funds tend to have higher contemporaneous returns than stocks sold by mutual funds. In addition, the more the mutual funds buy, the higher the return. While the more the mutual funds sell, the lower the returns. The coefficient here is 0.0151, while the average coefficient in Table 4 for the case of mutual fund holdings is 0.0083. This means the mutual fund trading has a stronger impact on contemporaneous stock returns than mutual fund

Table 7 Mutual fund holding and lagged stock returns

Variables	R_t
R_{t-1}	−0.0284***
	(0.00686)
Size	0.586***
	(0.0107)
Fund trading	0.0151***
	(0.000509)
Year	control
AR(1)	0.004
AR(2)	0.243
Sargan	0.840
Observations	11618
Number of stocks	1050

Table 8 Mutual fund trading and lagged stock returns

Varables	R_{t+1}
R	−0.0413***
	(0.0140)
Size	0.0902***
	(0.0159)
Fund trading	−0.0064***
	(0.000585)
Year	control
AR(1)	0.004
AR(2)	0.345
Sargan	0.740
Observations	10367
Number of stocks	1001

holdings. In Table 7, the coefficient of company size is positive. This indicates that the price impact of mutual fund trading also depends on the size of the mutual fund company. The larger the company is, the larger the price impact. Table 8 presents the results of Eq. (4). The coefficient of mutual fund trading is negative and statistically significant. This indicates that mutual fund trading has no predictive power and the contemporaneous price impact reverses in the successive period. This is opposite to the sign of the correlation coefficient in Table 6. The coefficient of contemporaneous return is negative and significant, indicating there is a return mean reverting phenomenon for the stocks traded by mutual funds.

3. Differences in the Price Impact Between Mutual Fund Buying and Selling
Some studies demonstrate that institutional buying and selling have different price impacts, and institutional buying has a larger price impact than institutional selling. One possible explanation is that institutional buying is more information-based than institutional selling. Due to investment constraints, most mutual fund managers are not allowed to sell short, thus the only way for them to make a profit is to purchase stocks at a relatively low price and hold them until they can sell them at a higher price. When mutual fund managers buy stocks, they may look at almost any stock available on the market, use their informational advantage and pick up those stocks they believe are most valuable. When mutual fund managers sell stocks in their portfolio, the selling might be information-based (i.e., they have learned those stocks are overvalued). But, there are also many other reasons for selling their portfolio stock, such as these stocks have risen to target prices and should be sold for rebalancing the portfolio, or the desire to redeem investments on the part of the investors forces the mutual funds to liquidate part of their stock assets. So, the purchasing behavior of the mutual fund managers might be more autonomous than the selling behavior,and they will base their decisions more heavily on information. If the above hypothesis is correct, we should be able to observe a difference in the price impact between mutual fund buying and selling, and from this we should observe that mutual fund buying has a stronger impact on prices than mutual fund selling.

Keim and Madhavan [14] provided evidence showing that mutual fund buying is more information-supported than selling. But there are also other studies with different observations. Chiyachantana [7] examined the equity markets of 36 countries and found that mutual funds have a different price impact during different market situations. In a bull market, the investors are more willing to buy than to sell, thus when institutional investors want to purchase a large block, they have to offer larger price premiums than what they would sell them for. In other words, in a bull market, purchasing has a larger price impact than selling. In a bear market, the investors are more willing to sell than to buy, thus when mutual funds want to sell a large block, they have to offer a larger price concession than what they had bought them for. Therefore, in this situation, selling has a larger price impact than buying.

In order to test if mutual fund buying and selling have different price impacts in the Chinese market, we regress the mutual fund trading on the contemporaneous stock returns accordingly for mutual fund buying and selling separately. The model follows Eq. (3).

Table 9 provides the empirical results of the price impact of mutual fund selling, and Table 10 provides the empirical results of the price impact of mutual fund buying. The regression results show that when mutual funds are sold (i.e., the holding level decreases), the coefficient of mutual funds selling is 0.0142, and when mutual funds are purchased (i.e., the holding level increases), the coefficient of mutual funds buying is 0.017. This indicates that the price impact is larger when mutual funds increase holdings than when they decrease holdings. This provides some evidence supporting the hypothesis that mutual fund buying is more information-based than selling. Our results do not support the hypothesis that the difference in the price impact is due

Table 9 Mutual funds selling and contemporaneous stock returns

Variables	R_t
R_{t-1}	−0.0976***
	(0.0142)
Size	0.638***
	(0.0202)
Fund trading	0.0142***
	(0.000717)
Year	control
AR(1)	0.004
AR(2)	0.243
Sargan	0.840
Observations	3622
Number of id	866

Table 10 Mutual funds buying and contemporaneous stock returns

Variables	R_t
R_{t-1}	−0.0204
	(0.0178)
Size	0.764***
	(0.0234)
Fund trading	0.0170***
	(0.00105)
Year	control
AR(1)	0.065
AR(2)	0.682
Sargan	0.998
Observations	3236
Number of id	806

to different market situations because our sampling period covers both bear and bull markets, but we can conclude that buying has a larger price impact than selling during most market periods.

5 Conclusion

Our empirical evidence shows that the percentage of mutual fund holdings is positively correlated with stock returns. The positive correlation is very strong in a contemporaneous relationship between mutual fund holdings and stock returns. The stocks with higher level of mutual fund holdings tend to have higher contemporaneous returns. In addition, the average return of stocks within mutual fund holdings is higher than the market returns.

The empirical evidence also shows that mutual fund holdings have some weak predicative power for future stock returns. In other words, stocks with high mutual fund holdings tend to have higher returns in the next period,while reversal occurs in the successive period. This supports the hypothesis of momentum trading or price pressure because in the case of momentum trading or price pressure, the stock returns tend to reverse in the successive period. The empirical evidence shows that the trading of mutual funds (the change of mutual fund holdings) is positively correlated with contemporaneous stock returns, i.e. stocks with higher increase (decrease) in mutual fund holdings tend to have higher (lower) contemporaneous return. Another finding of the empirical test is the asymmetric impact of buying and selling of mutual funds on stock return. We find that mutual fund buying has stronger impact on stock return than mutual fund selling.

In general, the test shows that mutual fund holdings and trading are positively correlated with stock returns, and our evidence supports the hypothesis that the price impact arises from momentum trading or price pressure.

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Does Hedge Fund Support Pakistan Economy

Asif Kamran and Syed Faheem Hasan Bukhari

Abstract This study analyzes and explores the Scope of Hedge Fund in Pakistan. Due to time constraint the research is limited to certain core point. Main focus is to find out the reason why Hedge fund is not started in Pakistan till yet, what are the major problems hedge fund has to encounter. What style and strategies will be successful in Pakistan and what are the main challenges that the hedge fund has to face in Pakistan. Due to shortage of primary data availability in references of Pakistan, the study is design in an exploratory form to get the maximum insight over the topic with in limited time period. Data is gathered through questionnaire and interviews both are structured. The respondents of the study are the top head of Investment banks as the investment bank play a big role in bringing Hedge funds in Pakistan economy and financial market. One interview is conducted with Dr. Ishrat Husain to find out the view of regulatory bodies over the issue. Through this research it is found that there are very few investment strategies/option available for hedge fund which can limit the huge investment style menu to very few options. And if we start hedge fund on this stage it would not as successful idea as it globally.

Keywords Commodity trading advisor (CAT) · Collateralized mortgage obligations (COMs) · Real estate mortgage investment conduits (REMICs) · Stripped mortgage-backed securities (SMBSs) · Fund of funds (FOF) · Hedge fund returns (HRF)

A. Kamran (✉)
School of Management and Economics, University of Electronic Science and Technology of China, Chengdu 610054, People's Republic of China
e-mail: asifkamrankhan@gmail.com

S.F.H. Bukhari
Management Science Department, Shaheed Zulfikar Ali Bhutto Institute of Science and Technology (SZABIST), Karachi 75600, Pakistan

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1 Introduction

Over the last 10 years, the hedge fund market has grown dramatically. Although hedge funds have existed since Alfred Winslow Jones created the first one in 1949, the market began experiencing its most rapid growth in recent years. Since the start of the bear market in stocks 4 year ago, hedge funds have been growing at the rate of 20 % per year. A total of 8,500 such funds control 1.0 trillion dollars, up from 400 billion dollars 5 year ago and 100 billion dollars 10 year ago; the hedge fund market is expected to increase to 1.5 trillion in the next 2–5 years. There are several factors driving the growth and interest in this area. Robert [1] found that hedge fund provides the investor new source of return as well as opportunities for diversification. In addition to the allure of higher absolute returns, hedge funds, with generally low correlations to traditional investments, are being considered as complements to traditional investment strategies in order to improve total portfolio performance. A hedge fund is an investment structure for managing a private, loosely regulated investment pool that can invest in both cash (physical securities) and derivative markets on a leveraged basis. Legally, it may take the form of a limited partnership, corporation, trust or mutual fund depending on where the fund is domiciled and the type of investors it seeks to attract. The domicile or legal location of the hedge fund determines the structure i.e. domestic or offshore fund. As with more traditional styles of management, investor funds are allocated either in a separate account or, more typically, in a commingled fund. The hedge fund structure gives investors access to hedge fund managers with specialized investment skills. Return opportunities come from two sources: an expanded universe of securities from which to trade; and a wider array of trading strategies implemented without the constraints of regulation common to most traditional products. For example, hedge fund strategies may access financial and commodity markets and may take Long, short, spread, option and levered positions in any of these markets. Therefore, Hedge funds provide unique risk and return characteristics that are not accessible by traditional asset management strategies. The hedge fund structure encompasses a diverse set of strategies that attempt to create value by exploiting specific arbitrage opportunities. Investment objectives vary widely among hedge fund managers. Liaw [2] proposed some hedge fund strategies, such as market neutral, attempt to avoid systematic exposure to the capital markets and are true diversifiers. Other hedge fund strategies, such as equity long/short, are more sensitive to the same market factors as traditional stock strategies. The institutional investment universe consists of traditional investments and a growing list of alternative investments. Figure 1 illustrates where hedge funds fall within the universe of investment opportunities with respect to their composition versus more traditional investments.

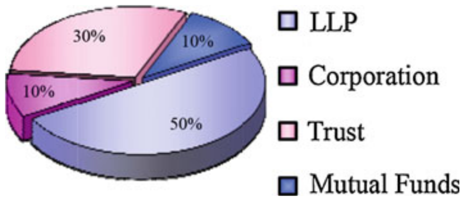


Fig. 1 Analysis of successful hedge fund

2 Statement of Problem

The Research Objective is to analyze "The Scope of Hedge Fund in Pakistan Economy". The idea is to explore the difficulties faced by the investors without Hedge funds. The Research objective is to explore the following.

(1) Hedge fund will or will not Successful in Pakistan?
(2) What will be the sources of Capitals for Hedge fund?
(3) What Improvements are required in infrastructure and Legal Regulation?
(4) Who are the potential users of Hedge fund?
(5) How hedge fund operation Support the Pakistan Economy?

1. Significance of Study
This research is helpful for those who are interested in starting Hedge Fund in Pakistan i.e. Brokerage Houses, trading Firms, Private Individual and Institutional investors. The research is also helpful for those who want to learn about the hedge fund importance within Pakistan. It is useful for all Bahria students who want to do their research in same direction and all faculty members.

2. Scope
Due to the limited time and resource availability, Research will be conduct in Karachi. The time period is for 3 month. The hedge fund is started its operation since 1949 but this research will only analyzed the data from 2000 to 2005.

3. Delimitation
There are number of delimitation that affects the validity and effectiveness of research. Some of them are government policies, performance of financial sector of Pakistan on the broadest level.

3 Literature Review

Convertible Arbitrage involves purchasing a portfolio of convertible securities, generally convertible bonds, and hedging a portion of the equity risk by selling short the underlying common stock. Distressed Securities strategies invest in, and may sell short, the securities of companies where the security's price has been, or is expected to be, affected by a distressed situation. This may involve reorganizations, bankruptcies, distressed sales and other corporate restructurings. Emerging Markets funds invest in securities of companies or the sovereign debt of developing or "emerging" countries. Investments are primarily long. "Emerging Markets" include countries in Latin America, Eastern Europe, the former Soviet Union, Africa and parts of Asia. Equity Hedge investing consists of a core holding of long equities hedged at all times with short sales of stocks and/or stock index options Ackermann [3]. Some managers maintain a substantial portion of assets within a hedged structure and commonly employ leverage. Equity Market Neutral investing seeks to profit by exploiting pricing inefficiencies between related equity securities, neutralizing exposure to market risk by combining long and short positions. Equity Non-Hedge funds are predominately-long equities although they have the ability to hedge with short sales of stocks and/or stock index options. These funds are commonly known as "stock-pickers". Event-Driven is also known as "corporate life cycle" investing. This involves investing in opportunities created by significant transactional events, such as spin-offs, mergers and acquisitions, bankruptcy reorganizations, recapitalizations and share buy backs. Fixed Income: Arbitrage is a market neutral hedging strategy that seeks to profit by exploiting pricing inefficiencies between related fixed income securities while neutralizing exposure to interest rate risk.

Fixed Income: Convertible Bonds fund are primarily long only convertible bonds. Convertible bonds have both fixed income and equity characteristics [4]. Fixed Income: Diversified funds may invest in a variety of fixed income strategies. While many invest in multiple strategies, others may focus on a single strategy less followed by most fixed income hedge funds. Fixed Income: High-Yield managers invest in noninvestment grade debt. Objectives may range from high current income to acquisition of undervalued instruments. Fixed Income: Mortgage-Backed funds invest in mortgage-backed securities. Many funds focus solely on AAA-rated bonds. Instruments include: government agency, government-sponsored enterprise, private-label fixed- or adjustable-rate mortgage pass-through securities, fixed-or adjustable-rate collateralized mortgage obligations (CMOs), real estate mortgage investment conduits (REMICs) and stripped mortgage-backed securities (SMBSs). Macro involves investing by making leveraged bets on anticipated price movements of stock markets, interest rates, foreign exchange and physical commodities. Macro managers employ a "top-down" global approach, and may invest in any markets using any instruments to participate in expected market movements.

Chan et al. [5] proposed Market Timing involves allocating assets among investments by switching into investments that appear to be beginning an uptrend, and switching out of investments that appear to be starting a downtrend. Merger Arbitrage, sometimes called Risk Arbitrage, involves investment in event-driven situations such as leveraged buy-outs, mergers and hostile takeovers. Regulation D Managers invest in Regulation D securities, sometimes referred to as structured discount convertibles. The securities are privately offered to the investment manager by companies in need of timely financing and the terms are negotiated. Statistical Arbitrage utilizes quantitative analysis of technical factors to exploit pricing inefficiencies between related equity securities, neutralizing exposure to market risk by combining long and short positions. Short Selling involves the sale of a security not owned by the seller; a technique used to take advantage of an anticipated price decline. To affect a short sale, the seller borrows securities from a third party in order to make delivery to the purchaser. The seller returns the borrowed securities to the lender by purchasing the securities in the open market. Fund of Funds invest with multiple managers through funds or managed accounts. The strategy designs a diversified portfolio of managers with the objective of significantly lowering the risk (volatility) of investing with an individual manager. The Fund of Funds manager has discretion in choosing which strategies to invest in for the portfolio [6].

4 Research Methodology and Procedures

1. Research Design

Research is design in a way to get as much as information possible within limited time. As there is no hedge fund in Pakistan, so the primary data is conducted through interviews and questionnaire so the research is exploratory in nature. The purpose is to get the enough information that supports the research objectives. The causal study is also done to find out weather or not the hedge funds provide any good opportunities for the big investors. For this purpose investment styles of hedge fund are analyzed and also define their pros and cons. Graphical representation is used to present the data for analyzing past, present and projection trends. Interviews are conducted with sophisticated investors like PIPIC, Arif Habib, Jhangir Siddique. In the end final interview is done with the Governor, State bank of Pakistan that defines the Scope and Hedge fund in Pakistan.

2. Respondent of the Study

Respondents for the research are the financial institutions specially the top heads of investments bank.

3. Instruments

The data for research is conducted through primary and secondary Sources.

For primary Data Collection;

(a) Questionnaires (structured and open-end). (b) Interviews (structured).

4. Treatment of Data/Information/Analysis

The data gathered through the sources are analyzed by quantitative and qualitative methods and verbal analyses also done.

5. Presentation Analysis

The final presentation of the data is in the form of tables, graph and charts and in qualitative fame work to present the clear picture of the Scope of hedge fund in Pakistan economy. Table 1 shows the major Characteristics of Selected Hedge Fund Styles.

Table 1 Hedge fund style

No.	Name of style	Expected	Leverage	Derivatives	Risk	Return	Correlation to markets	Holding period
1	Aggressive growth	High	Possible	No	Enhancer	Enhancer	Low	Medium/long
2	Distressed securities	Low-moderate	Possible	Yes	Enhancer	High	Very low or no	Short
3	Emerging markets	Very high	Few	Depends	High	Limited	High	Short/medium
4	Funds of hedge funds	Low-moderate-high	Highly possible	Yes	Diversified	High	Low	Medium
5	Income	Low	Possible	Yes	High	Limited	High	Medium
6	Macro	Very high	Zero	Yes	Low	Enhancer	High	Medium
7	Market neutral-arbitrage	Low	Possible	Yes	Enhancer	Limited	Low or no	Short
8	Market neutral-securities hedging	Low	Possible	Yes	Reducer	High	Low	Medium
9	Market timing	High	Possible	Yes	Enhancer	Limited	High	Short
10	Opportunistic	Variable	Low	No known	Reducer	Enhancer	No	Short
11	Multi strategy	Variable	High	Possible	Diversified	High	High	Can be any
12	Short selling	Very high	Low	Itself	High	High	No	Medium
13	Special situations	Moderate	Possible	Yes	Low	High	High	Medium
14	Value	Low moderate	High	Yes	Reducer	Enhancer	Low	Long

Question No. 1: In reference to hedge fund business in Pakistan, which from will be more successful?

(a) Limited Liability Partnership, (b) Corporation, (c) Trust, (d) Mutual Fund.

Purpose of Question: To determine which form of Hedge fund business the investors wants to adopt in Pakistan.

Analysis: Figure 1 shows the analysis of successful hedge fund business in Pakistan. Majority of respondents are in favor of structuring hedge fund as LLP, well Trust will be next favorable option.

Question No. 2: Should the Hedge fund industry be re gulated through SECP?

(a) Yes, (b) No.

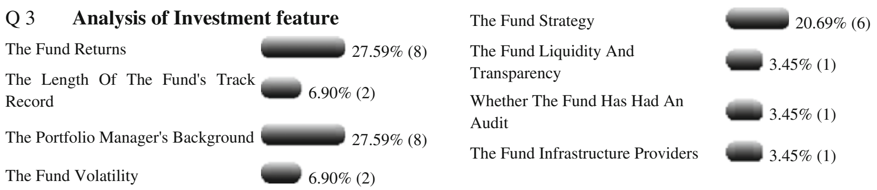
Purpose of Question: To find out, what are the opinions of Pakistan's Institutional Investors about the regulation of hedge fund, which is now a days hot issue in hedge fund industry.

Analysis: Figure 2 show the analysis of result, it is prove that most of the investors are in favor of hedge fund regulation, only 30 % (3) asking for its non-regulation.

Question No. 3: What is the most important ingredient you look for before making an investment in a hedge fund? (Rank them)

(a) The Fund Returns, (b) The Length Of The Fund's Track Record,
(c) The Portfolio Manager's Background, (d) The Fund Volatility,
(e) The Fund Strategy, (f) The Fund Liquidity And Transparency,
(g) Whether The Fund Has Had An Audit, (h) The Fund Infrastructure Providers.

Purpose of Question: To find out what will be the most important thing that has to be analyzed before making an investment in hedge fund.

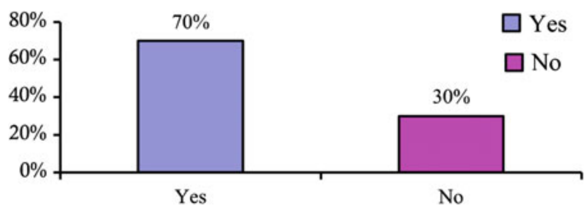


Analysis: Q3 shows that Majority of respondents are interested in Fund Returns and Manager's background while the strategy fund employed is also important to analyze.

Question No. 4: What should be the "LOCK UP" period? (Normally, 6 month)

(a) 6 months. (b) 1 year. (c) 1.5 year. (d) 2 year. (e) Above 2 year.

Fig. 2 Opinion of regulation



Purpose of Question: The idea behind the question is to find out what will be minimum duration for investment in hedge fund. It shows investor's desire for liquidity.

Analysis: Figure 3 show that The result is quite ambiguous. Still we can say minimum duration can be 2 years or any time period above 2 years. No respondents are in favors of 6 month lock up period. While the other options also get some marks.

Question No. 5: The Return of hedge fund mostly depends upon.

(a) Performance of the market in which hedge fund manager invest.

(b) The style and strategies that hedge fund managers employ.

(c) Level of manager skill and expertise.

Purpose of Question: To find out the factor that is most important in generating the returns from hedge funds.

Analysis: Figure 4 show that the amongst the three, the most important one is the performance of the market in which the hedge fund manager makes investment. The other two are also very important in driving the return.

Question No. 6: What should be the minimum amount of investment? (In US minimum amount for investment is 250,000$)

(a) Rs. 5 million. (b) Rs. 10 million. (c) Other.

Purpose of Question: To find out the investor's desirability to invests in Hedge fund as a new investment opportunity. It shows the tolerance level against the risk bring by any new financial product.

Analysis: Figure 5 result show that 50 % of the respondents think that the minimum investment should be 10 million and 30 % are in favor of option 3 i.e. above 10 million. So the favorable option according to respondents is option 1.

Fig. 3 Lockup period

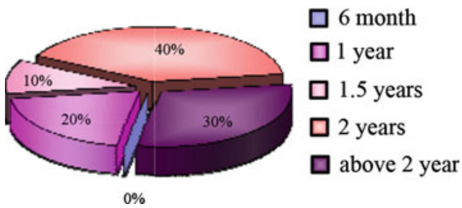


Fig. 4 Return of hedge fund

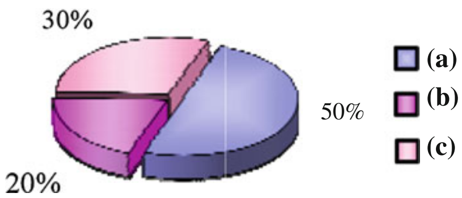
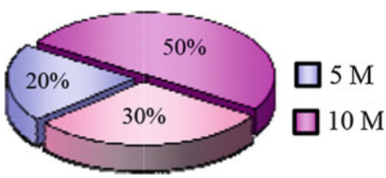


Fig. 5 Minimum amounts of investment



Question No. 7: From the following, which strategy will be more successful in Pakistan?

(a) Selling Short, (b) Using Arbitrage, (c) Trading Options Or Derivatives, (d) Investing In Anticipation of A Specific Event, (e) Investing In Deeply Discounted Securities, (f) Using leverage, (g) Investing in "Out-Of-Favor" Or "Unrecognized Undervalued Securities"(Debt and bond).

Purpose of Question: To determine which strategies hedge fund can easily adopt in Pakistan by keeping in mind the present status of financial market environment.

Analysis: Figure 6 show that the most of the respondents are in favor of option (g) while the other choice can option (b), (e), (f) and (g). These ranking are given by the respondents.

Question No. 8: What type of Hedge Fund you are most interested to invest?

(a) Convertible arbitrage. (b) Distressed Securities. (c) Equity hedge. (d) Event Driven. (e) Fixed Income-High Yield. (f) High Growth. (g) Macro. (h) Risk arbitrage. (i) Relative Value.

Purpose of Question: To find out what style hedge fund can easily adopt in Pakistan from the huge menu.

Analysis: Figure 7 show the Relative Value and macro can be the best option. The other can also be employed in Pakistan. But the most favorable are choices are c, e, f, g, h, and i.

Question No. 9: What will be the Source Of capital for Hedge fund in Pakistan? (If possible, define in term of Percentage)

(a) Financial Institutions, (b) Endowments, (c) Foundations, (b) Pension Fund Of Funds HNW, (e) Families/individual investors, (f) Offices.

Purpose of Question: To find out the sources of capital for hedge fund industry and the contribution ratios. Analysis: Fig. 8 show that The largest source of capital is the Families/Individual investors they can bring most of the capital for hedge fund while the second biggest source can be financial institutions. Endowments, foundation and Pension fund can also contribute but the ratio will be very low.

Fig. 6 Strategy

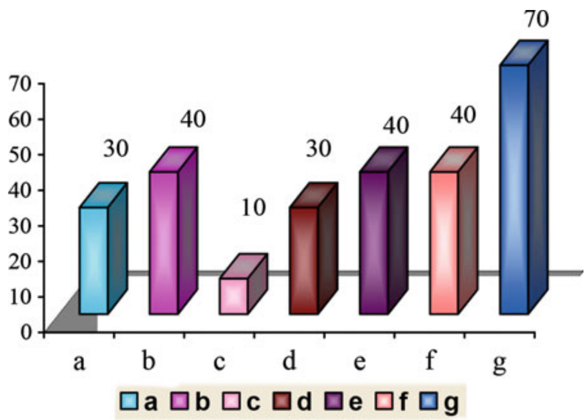


Fig. 7 Type of hedge fund

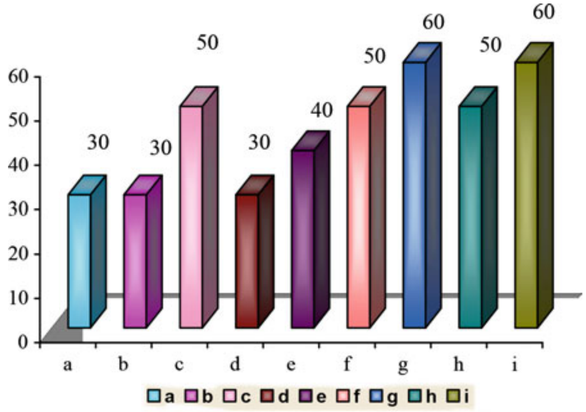


Fig. 8 Source of capital

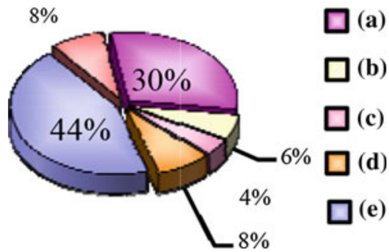
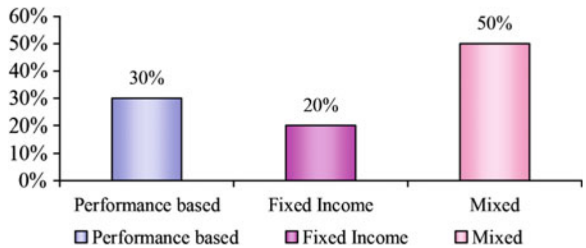


Fig. 9 Fees structure



Question No. 10: What should be the Fees Structure for hedge fund? (Normally 1 % of assets plus 20 % of profits).

(a) Performance based, (b) Fixed income, (c) Mixed (1 % of assets plus 20 % of profits).

Purpose of Question: To find out the acceptable fee structure in Pakistan from the point out view of investors. Analysis: Fig. 9 Majority of respondents are in favor of mixed i.e. 1 % of the asset plus 20 % of Profit, which is one of the common fees structure globally. Some respondents assume that it should be performance based while some give there vote to fixed income.

Question No. 11: In Pakistan, Hedge fund mostly face.

(A) Political Risk, (B) Transfer Risk, (C) Settlement Risk, (D) Credit Risk, (E) Legal Risk, (F) Market Risk, (G) Liquidity Risk, (H) Operational Risk.

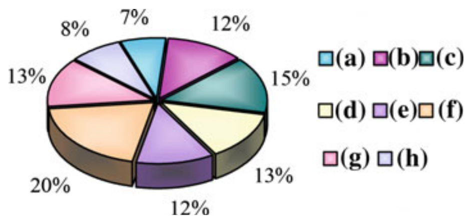


Fig. 10 Risk of hedge fund

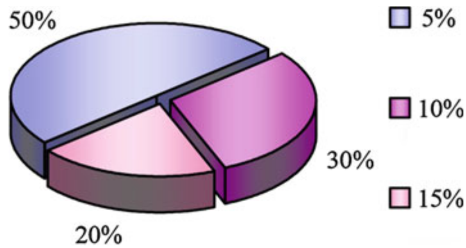


Fig. 11 Investor portfolio

Purpose of Question: To find out the types of risk hedge fund will has to face in Pakistan. And what safeguard. Analysis: According to Fig. 10 respondents, on an initial hedge fund has to face almost every type of risk. But the major one will be the operation, marketing and credit risk.

Question No. 12: What place do you believe that hedge fund investing should have in an investor's portfolio, amongst the other asset classes?

(a) 5 % of Assets value, (b) 10 % of Asset Value, (c) 15 % of Asset Value, (d) Other.

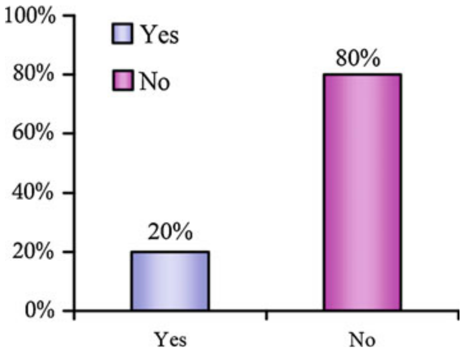
Purpose of Question: To find out what should be the favorable percentage of allocation with respect to total assets. Analysis: According to Fig. 11 the majority investor i.e. 50 % are saying that , almost 5 % of the total assets should be allocated to hedge fund. 30 % saying that 10 % is the better option and 2 % are in favor of the 15 %.

Question No. 13: Does Local Index will provide good bench mark for performance measurement of hedge fund?

(a) Yes, (b) No.

Purpose of Question: To find out bench mark problem faced by the hedge fund in Pakistan what will be possible remedies to reduce problem that occur because of this. Analysis of Result: Well 80 % of the respondents are in favor of that local index will not provide an adequate measure for performance evaluation while 20 % are saying that its better to evaluate the performance by using Local indexes and bench marks (Fig. 12).

Fig. 12 Performance measurement



5 Findings from Interview

With Dr. Ishrat Husain (Governor State Bank of Pakistan) Coordinated, By Mr. Suleman Chhagla (Head of Risk Management) and Mr. Sibt-ul-husnain (Assistant Director).

Hedge funds are private, usually unregulated investment pool, in which fund manager and investors invest together. The distinctive feature of such fund is that they yield an absolute return i.e. the return that does not depends on the financial market movement. In Pakistan, hedge fund can adopt the form as a limited Company or as a limited liability partnership. According to Dr. Ishrat Husain as a regulatory body and as an investor suggested that hedge fund industry should be regulated through federal bodies both globally and also in Pakistan.

"Lock up period can be any timing on which the parties agree. As an investment base the minimum amount of investment for institutional investors can not be more then 5 lacs (3000$) for an initial period. Because there are few firms who have high risk appetite they generally make their investment in traditional investment opportunities (bond and stock Market). 5 % of the total asset can be the suitable figure for investment". Said by Dr. Suleman Chhagla. So in order to expand its user the minimum amount of investment should be low as much as possible. In Pakistan, the investment strategies available for hedge funds are very limited. Short selling is very rare and only done by professional and educated investor. Short selling is totally illegal in Stock exchanges. We don't have mature derivative market. Derivative might take 3–4 year to become mature. The option can be to invest in "out-of-favor" and "unrecognized undervalued securities", "arbitrage" and "Leverage". Even there are some other hedging techniques available for hedge fund but there are not sufficient to support the hedge fund industry at this stage. Hedge fund can select very few styles from huge menu. The reason can be again the same the limited investment opportunities. Yes! Hedge fund has scope in Pakistan but not at this stage. If we start hedge fund in such situation that I mentioned above its impossible for hedge fund to become successful in Pakistan as it globally.

Findings from Questionnaire:
Hedge funds, including fund of funds ("Hedge Funds"), are unregistered private investment partnerships, funds or pools that may invest and trade in many different markets, strategies and instruments (including securities, non-securities and derivatives) and are NOT subject to the same regulatory requirements as mutual funds, including mutual fund requirements to provide certain periodic and standardized pricing and valuation information to investors. Through the research following facts are analyzed. As long as regulation of hedge fund is concern it should be regulated but it directly affects its performance. As freedom is necessary because hedge fund managers require to do anything they want to do i.e. they can use leverage short selling and derivative instruments without any limitation. This is a basis difference between Hedge fund and other financial product and by using such hedging techniques, hedge fund yields "absolute return", and because of non regulation it is very risky investment and the money of investors is on sake. Hence to provide security to the money of investor it should be regulated. Well this is up to the fund manager to use its freedom to creates high risk portfolio or risk averse portfolio. The return that hedge fund generate depends on three factors. One is the performance of the market in which hedge fund manager invest, second is the style and strategies that hedge fund managers adopt and third is level of manager skill and expertise. And according to the respondents the most important is the performance of the market in which manager invest. Hedge fund is not for every body. Most investors are ineligible to invest in hedge fund. Even not for all those who have high investment horizon and high tolerance for the volatility of the Standard Equity Investing. An investor must keep this in mind that hedge fund represent speculative investment and involve high degree of risk and he/she can lose all or substantial portion of his/her investment. So every investor before making investment in hedge fund or any other financial products must know its positive and negative aspects. The minimum amount of investing can be above 10 million or may be 10 % to 15 % of total asset value (for institutional investor) which can be increase up to 25 %. But important thing is that investor must have the financial ability, experience and willingness to take risk of investment in hedge fund.

6 Conclusion

Globally Hedge fund is one of a very successful product. Hedge fund also possesses an ability to do well in under developing countries as it already do in Srilanka, Malaysia, India. Well in Pakistan economy after analyzing the facts it is concluded that the scope is not good at this stage. The Essential thing is to educate the peoples about the advantages for this alternative/non traditional investment. Generally, peoples are looking for the high profit by taking certain type of risk. Over here we have enough institutions and families who can be the potential user of hedge fund. But the need is to create awareness. Investment banks are required to recognize their role. There is also need to develop professional expertise, increase derivative instrument and improved our stock and debt market. These all may take time for about 3–4 years. And after making all such improvement we will be in better position to get advantage from this different type of financial product.

Recommendations:
Hedge fund provides us new way for money management. It's also called alternative to traditional investment styles. It requires different things to work with. After this 3 month research process I would like to recommend following suggestion related to scope of hedge fund in Pakistan economy.

(1) There is a strong need to improve our derivative market.
(2) To get more depth in stock and bond market.
(3) It is also necessary to develop professional expertise in people because the investment decisions require high skills.
(4) Investment bank must recognize their role and play their part in the game and they should make things easier to understand even for uneducated investors.
(5) And in last, investors must get know-how about the positive and negative aspects of particular financial product to economy before making an investment decision.

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Empirical Research on Influence of China Listed Companies Using the Derivative Financial Instruments on Its Own Value

Chaojin Xiang and Chong Bi

Abstract The exchange rates and interest rates fluctuations are being aggravated by the floating exchange rates system and the interest rates liberalization, increasing corresponding risk that enterprise facing up to, which accelerates the enterprise's need of using derivative financial instruments for risk management. According to the general study of western scholars, enterprises which use derivative financial tools can effectively improve the value of the company. Especially under the background of economic globalization, more and more Chinese enterprises began to use derivatives, in the process of trade, to evade the risk of exchange rates and interest rates fluctuations. Based on 46 China Shanghai a-share listed companies, empirical research finds that using derivatives have observably positive impact on the value of listed companies, but the effect was extremely limited, which is different with the analysis of the western scholars that companies using derivatives can significantly enhance the value of the company. The reason of cross light is that Chinese listed companies will be influenced by some disadvantages on the subjective and objective when they use derivative financial tools, affecting the effects of the value of company by using of derivative financial instruments, because of this, this paper puts forward the corresponding policy recommendations.

Keywords Derivative financial tools · Value of company · Risk management

1 Introduction

The gold standard collapsed along with the opening of the Bretton Woods Conference in 1970s, some of the developed countries represented by the United States and Western Europe have adopted floating exchange rates system. After entering the 80s, America began to relax restrictions on interest rates, thus interest rates entered a stage of liberalization. Floating exchange rates system and the interest rates

C. Xiang (✉) · C. Bi
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 332776179@qq.com

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liberalization make the corresponding risks increasingly apparent in the whole financial system. Especially under the background of the deepening global economic integration process, these significant risks further threaten enterprise operation stability. Therefore, demand of strengthening the enterprise' ability of risk control has become more and more urgent.

Fluctuations of exchange rates and interest rates sped up the development of derivatives hedging the risk of exchange rates and interest rate, which provides more options for the companies when dealing with such risks. Derivative financial instruments began to play an important role in the process of risk configuration, and especially entering the 21st century, companies are popular in the use of derivative financial tools. The 24th annual meeting of international swaps and derivatives association (ISDA) held in Beijing On April 23, 2009, in the annual meeting ISDA released a report about the usage of derivatives in the world top 500 enterprises, which shows that more than 90 % of the world top 500 companies manage their risk by using derivative financial instruments, this data have grew compared with the results of a survey in 2003. According to the newest survey published in the latest annual meeting in Singapore in 2013, the scale of the world top 500 enterprise using derivative financial instruments for risk management is still at a high level.

The development of economic globalization also speed up the pace of the Chinese enterprise internationalization management, enterprises are inevitably affected by the international economic environment in the process of actively participating in international competition, facing various aspects of the potential threats such as the commodity and raw materials price risk, exchange rates risk and interest rates risk and so on. Especially some enterprises producing products related with futures such as companies of non-ferrous metal processing, energy products production and processing, agricultural production and other enterprises engaged in the foreign trade are more and more using derivative financial instruments to hedge risks, guaranteeing the stable operation.

As a kind of financial contracts, derivatives have the characteristic of "double-edged sword". The rational use of derivative financial tools can make the enterprise effectively evade the risks of raw materials and finished goods cost fluctuations, which is beneficial to maintain the stability of production and business operation. However, derivative financial instruments will also bring great losses to the enterprise and even cause the enterprise bankruptcy if companies improperly use of it. For instance, in 1995 the salesman who illegally traded derivatives trading caused huge losses, and eventually the British Barings Bank had to file for bankruptcy; in China, more than a few enterprises suffer great losses due to improper derivative financial tools operation. For example, Eastern Airlines loses more than 60 billion by operating fuel option hedging.

Today, increasingly enterprises begin to use derivative financial instruments for risk aversion, by empirical study, we can find that the enterprise using derivatives whether increase enterprise value and further reveal that the impact of derivative financial tools on the enterprise value, and we can offer some proposals about how to use derivative financial tools for the enterprise and how to develop the derivatives market for regulator.

2 Relevant Theories and Literature Review

2.1 Relevant Theories on Influences of Using Derivative Financial Tools on the Value of Company

For the motivation of enterprises using derivative financial tools and its influence on corporate value, academic community put forward three theories.

1. MM Theory
Modigliani and Miller proposed the famous MM theory in 1958. This theory assumes the market is so perfect that there is no tax and transaction costs, and all kinds of parties on the market grasp the same trading information. On this market, whether companies use derivative financial instruments or not will not influence their value, as investors can make leverage to earn the same investment returns.

Li [12] selected the 44 American's metallurgical companies financial data between 1991 and 2000 for research, it is concluded that these companies using derivative financial instruments have not affect the value of the companies.

2. The Company Value Maximization Theory
There is no perfect market in the real world. For main body on the market, there exists various limiting conditions, such as tax constraint, transaction cost, financing cost and so on. Therefore, the later scholars started to relax the assumptions of MM theory and put forward the theory of company value maximization, who studied influence of using derivative financial instruments on the value of the company. This theory is that the use of derivative financial tools can improve the company's cash flow situation, affecting the company's investment decision-making and ultimately reflected in the change of the value of the company.

(1) Save Tax
Company's ability to loan can be enhanced by using derivative financial tools, so the effect of tax shield producing by debt financing can increase the value of the company. For example, using options futures for company risk management can reduce the company's cash flow volatility and promote corporate finance credit, so the company can easier to get bank loans and release the ability of tax shield.

The research of Dionne and Triki [6] shows that using derivatives can effectively reduce the tax burden. They use numerical simulation methods to quantify the benefits of reducing taxable income volatility after companies used the derivative financial instruments.

(2) Reduce Financial Distress Cost
Company's financial leverage rate, to a certain extent, reflects its financial condition. The usual thinking is that the higher the company's leverage rate, the greater the chance in financial trouble. Companies using derivatives can maintain the stability of cash flow; reduce the probability of financial crisis and increase the value of the company.

Graham and Rogers's [8] research results indicate that, the higher the financial leverage of the company, the more the tendency to use derivative financial instruments for risk management, which is same as the viewpoints of company which use derivatives for reducing the cost of financial distress.

(3) Avoid the Lack of Investment
If the enterprise's cash flow situation is not stable, meanwhile company seeking external financing cost is too high, the company is likely to give up favorable investment opportunities due to shortage of current. However, through the use of derivative financial instruments can stabilize cash flow volatility, making the company has plenty of own capital to invest project. After the project produce income, the value of the company will also get corresponding improvement.

Géczy et al. [7] get the conclusion that there is a positive correlation between use of derivative financial tools and R&D spending. R&D spending itself as a kind of investment spending, which is identical with the view of company with the use of derivative financial instruments can alleviate inadequate investment.

3. Manager Utility Maximization Theory
The separation of operation right and ownership make the company produce the principal-agent relationship between managers and shareholders. The conflict between them is different target between interests of the shareholders and the operator. When managers are facing with investment opportunities, they think more from personal point, rather than from the interests of shareholders. In order to secure their position and wealth; to make their own management level recognized by the talent market and to increase their market value, managers often want to maintain the company's stability of operating and cash flow and avoid risk as far as possible. In this case, managers will be more willing to use derivatives to manage company's risk, so they will choose to give up some potential investment opportunities, which will damage the shareholders' interests.

The study of Breeden and Viswanathan [3] found that the more the manager hold stocks, the more inclined to use derivative financial tools, providing strong evidence for manager utility maximization theory.

2.2 Literature Review

Allayannis et al. [1] made the pioneer empirical study about the impact of derivative financial tools use on the value of the company. They found that use of derivative financial instruments company can achieve 3–8 % of the value appreciation, choosing data from 720 non-financial companies in the United States between the year of 1990 and 1995 as the sample. Bartram et al. [2] selected 7319 non-financial companies from 50 countries as the research sample, finding that the use of derivative financial tools can increase the value of the company, but the effect is not significant. Carter et al. [4] selected 28 American airlines between the year of 1992 and 2003 as the research sample, finding that companies buying fuel options can win 10 % of the value increase.

In China, compared with abroad, empirical study of impact of using derivative financial instruments on the value of the company started relatively late. Chen and Wang [5] selected 39 non-ferrous metal processing or manufacturing industry listed in Shanghai or Shenzhen Stock Exchange in China as the research sample, finding that the use of derivative financial tools did not significantly enhance the value of the company. Zhao [14] chosen 28 listed companies of nonferrous metals industry from China as the research object and set the observation period from 2004 to 2008, through the empirical study he found that the use of derivative financial tools have significant positive influence on the value of the company. Guo [10] made a research about the Chinese listed non-financial transnational companies, choosing 968 groups from 2007 to 2009 as the observations, and get the conclusion that using foreign exchange derivatives to manage exchange rates risk can bring an average of 10 % of the value premium. Si [13] selected Chinese manufacturing listed companies during 2007–2011 as the observation, the empirical results showed that Chinese manufacturing industry listed companies using derivative financial instruments has a positive effect on corporate value, the effect size as high as 15 %.

There are some scholars hold the opposite view, they consider the industry risk and external economic environment changes are the primary risk on enterprise, which will exert a significant impact on the company value. The exchange rates risk and interest rates risk are the secondary risks, so hedging these risks will not have a significant impact on the company value and the premium is not obvious. Guay and Kothari [9] selected the 234 large non-financial companies from United States as research samples, finding that companies'impact of using derivatives on its value is limited.

Although academic community has controversial views on whether company can use derivative financial instruments to raise their value or not, the existing research results give more support to the viewpoint that use of derivatives can improve the value of the company. Companies use derivatives can reduce the friction cost, save tax expenditures, avoid the company in financial trouble, reduce the yield loss caused by inadequate investment and promote company's value.

3 Status Quo of Use of Derivative Financial Instruments with in Listed Companies in China

Only a few enterprises use derivative financial instruments in China at present stage, and it reflects a certain industry characteristics. According to the Jia's [11] study, the 116 listed companies in China have used derivative financial tools in 2008. These enterprises are mainly distributed in the mechanical equipment, instrumentation industry, metal, nonmetal industries, transportation and warehousing, otherwise a small number of enterprises in agriculture, commercial brokers and agents and other industries.

Companies choose more derivative financial tools related to the exchange rates and interest rate. Using this kind of derivative financial instruments mainly are enterprises which are engaged in import and export trade, large amount of foreign exchange settlement and exporting products to overseas. In addition, agriculture, equipment manufacturing and air transport enterprises often choose goods class derivative financial tools to deal with the risk of price fluctuations caused by price of raw materials.

Due to domestic derivatives market development is not perfect and the operation of foreign derivative financial instruments is limited by trading qualification and rules, the number of Chinese listed companies which use derivative financial instruments for risk management are few, and the amount involving derivatives exchange frequency is not huge. In the scale of world, there is a big gap between Chinese and foreign listed companies about the use of derivatives for the risk management, which brings greater risks to Chinese enterprises in business activities. In general, only a handful of Chinese listed companies use derivative financial instruments for risk management, in addition, the type and amount of using derivative financial tools still need to be improved.

4 Model and Analysis

4.1 Sample Selection

This paper takes 2009–2013 in annual as the period of observation, and screens to China Shanghai a-share listed companies to determine the sample selection according to the following conditions: (1) companies used derivative financial instruments at least 3 years from 2009 to 2013 as the research sample; (2) because ST and *ST shares are more likely to be manipulated, which will cause the relevant financial data unreal, so we reject such companies including in any year becoming ST and *ST companies; (3) financial companies are usually derivative financial tools maker, it is difficult to distinguish their usage of derivative financial instruments, thus excluding financial companies; (4) remove companies, related to research variables, of the lack of financial data. According to the method of screening above, we ultimately selected 46 China Shanghai a-share listed companies as research samples.

4.2 Variable Selection

1. Dependent Variable
This paper research on influence of using the derivative financial instruments on corporate value, we define the value of the company as the dependent variables. Tobin Q value is most widely used in the measure of the value of the company, the higher Tobin Q value indicates that the higher value of company. For the reason of

easy to access data, this article uses the simple Tobin Q value calculation method. Tobin Q = (value of equity + market value of net debt)/total assets book value. These indexes take from the Taian database.

2. Independent Variables
The China ministry of finance issued the new accounting standard for business enterprises in February 2006. The new rules require listed companies disclose information about the type of derivative financial instruments, book value, fair value and earnings of fair value in the notes section of the financial report since January 1, 2007. So we can get more accurate specific situation of the listed companies about usage of derivative financial instruments. This paper selects the final fair value of derivative financial instruments disclosed in the listed company annual report as independent variables.

3. Control Variables
(1) Company Assets
Company's risk management requires the corresponding cost. Only large companies can afford this part of the cost, so they incline to use derivative financial tools as a choice of risk management. This paper chooses the logarithmic of final book value of total assets as variable measuring the company's assets scale.

(2) Profitability
For the listed companies, the stronger the profitability, the more likely they get investors to chase after, leading to its positive shares reaction on the stock market's, which makes the higher company's market value. This paper selects the roe as the variables reflecting the company profitability level.

(3) Growth Ability
The company's growth reflects its operating condition, which have directivity effect to investors. Growth ability is the important factor that affects the enterprise value. This article selects operating income growth rate as a measure of company growth.

(4) Financial Soundness
The company's huge short-term debt may arouse the great possibility of financial distress. Corporate financial liquidity reflects the company's short-term solvency. This article selects the quick ratio as the variables measuring enterprise financial robustness.

(5) Equity Structure
Shareholders will affect the company's business decision; different decision may bring to the different development, and ultimately reflect on the changes of the value of the company. Large shareholder's stake determines its influence on the management decision; the higher major shareholders holdings make the greater influence. This article chooses major shareholders holdings of listed companies to measure the company ownership structure.

4.3 Data Source

This paper empirical data about the final derivatives values excerpts from the 2009–2013 annual report of listed companies, other data from WIND database and the Taian database. In this paper, we use Eviews7.1 statistical analysis software and EXCEL software for data processing.

4.4 Research Hypothesis and Model Design

1. Research Hypothesis

From the preceding theoretical analysis, we know enterprises using derivative financial tools can reduce the friction cost, save tax expenditures, avoid the company sink into financial trouble and reduce the yield losses caused by inadequate investment. However, the relatively mature in the study of foreign scholars still do not form a consistent conclusion that the company using derivatives can improve the value of the company. This paper selects the Tobin Q value as the representative of the company's value. Validating how company using derivative financial tools will impact on its own value, thus put forward the corresponding assumption:

Hypothesis 1. Using derivatives have significant positive effects on Tobin Q value, which means using derivative financial instruments can promote the value of the company.

2. Model Design

We build multivariate regression model according to the dependent variable, independent variables and control variables mentioned above: $\text{tobinq} = \alpha + \beta_1 der + \beta_2 \text{lnasset} + \beta_3 roe + \beta_4 \text{growth} + \beta_5 \text{quick} + \beta_6 \text{fshare} + \varepsilon$.

All variables are detailed in Table 1.

Table 1 Variable declaration

Variable types	Variable name	Variable meaning
Dependent variable	Tobinq	Tobin Q value
Independent variables	Der	Derivative financial instruments final fair value
Control variables	lnasset	The final total assets of the exponential
	Roe	Return on equity
	Growth	Sales revenue growth
	Quick	Quick ratio
	Fshare	The first shareholder shareholding

5 Empirical Analysis Results

5.1 Descriptive Statistics

From Table 2, we can see sample average of Tobin Q value is greater than 1, indicating that companies using derivatives, at least 3 years of 2009–2013, have favorable growth. The maximum value of final fair value of derivative financial instruments is 484 million and the minimum value is 0, the reason of volatility is that some companies did not use derivative financial instruments in some year from 2009 to 2013.

5.2 Correlation Analysis of Variables

We can see the correlation coefficient between variables all under 0.6 from Table 3, representing the variable selected in this paper does not exist obvious problem of multi collinearity. From the results of correlation analysis, derivative financial instruments are positively correlated with Tobin Q value, but the correlation is very limited; roe, quick ratio and rate of operating income growth all have great positively correlated with Tobin Q value.

Table 2 Results of variable descriptive statistical

Variable	Tobinq	Der	Lnasset	Roe	Growth	Quick	Fshare
Average	1.685	27,227,181	23.503	0.120	0.135	1.029	0.398
Median	1.361	3,529,354	23.210	0.114	0.113	0.832	0.387
Maximum	7.138	484,000,000	27.166	0.595	0.943	5.453	0.797
Minimum	0.416	0	18.847	−0.31	−1.000	0.166	0.152
Standard deviation	0.984	71,211,832	1.647	0.117	0.251	0.829	0.151
Partial degrees	2.847	4.639	0.134	0.805	0.058	3.097	0.373
Kurtosis	13.091	26.270	2.223	7.349	5.756	14.512	2.503

Table 3 Results of variable correlation analysis

	Tobinq	Der	Lnasset	Roe	Growth	Quick	Fshare
Tobinq	1.000						
Der	0.004	1.000					
Lnasset	−0.404	0.349	1.000				
Roe	0.302	0.134	0.13	1.000			
Growth	0.171	0.072	0.15	0.397	1.000		
Quick	0.372	−0.036	−0.373	0.166	−0.062	1.000	
Fshare	−0.091	0.227	0.462	0.117	0.022	−0.159	1.000

Table 4 Results of variable correlation analysis

Variable	Coefficient	Standard deviation	T statistic	Prob
Constant term	7.503	0.9329	8.043	0.000
Der	1.51×10^{-9}	8.04×10^{-10}	1.8836	0.0609
Lnasset	−0.2837	0.0411	−6.9101	0.000
Roe	2.0901	0.5148	4.0597	0.0001
Growth	0.5686	0.2343	2.4273	0.016
Quick	0.2161	0.0716	3.0181	0.0028
Fshare	0.6535	0.3989	1.6384	0.1028
Adjusted R^2 0.3336 F-statistic 20.1058 Prob (F-statistic) 0.0000				

1. Empirical Results and Analysis
Table 4 shows the adjusted R^2 is 0.3336, there are a great many of factors can impact the change of dependent variable's, but we only chosen 6 independent variables explaining 30 % change difference of dependent variable, combined with reality situation, we think the fit of the equation is good.The F-statistic is 20.1058 and Prob(F-statistic) less than 0.05, which means the equation is significant.Derivative financial instrument is significant at 10 % level, coefficient of derivative financial instrument is greater than 0 and the coefficient value is 1.51×10^{-9}, which indicates using derivatives will be a positive impact on the value of the company. However, due to the coefficient value is close to 0, showing that the use of derivative financial tools will has little influence on the company.The main reasons of leading to the phenomenon above are two points: (1) the derivatives market in China started relatively late, trading rules and regulation is not perfect enough. Operating overseas derivatives trading is limited by the qualification, causing the problems of higher transaction cost and less financial derivative products company can use, which result in the less amount of business transaction of the derivative financial instruments. Thus, the enterprise using derivatives for risk management only hedge a few risks and the effect is very limited, which fails to significantly increase the value of the company. (2) part of the listed companies does not realize derivatives enough.Because of managers lack risk consciousness, they cannot see the derivatives'characteristic of "double-edged sword", so they use derivatives for speculative trading blindly, which brings enterprise greater risks and makes them suffer huge losses.

6 Conclusion and Suggestions

Through the empirical analysis above, we can get the following conclusion: China listed companies using the derivative financial instruments have significantly positive impact on their value, but the effect is very limited. According to the results of empirical research, combined with condition of using derivatives of China listed companies and the present development of the derivatives market in China, we proposal the following suggestions.

1. Steady Progressing in Developing Derivatives Market in China
The empirical results of this paper indicate that the company using derivative financial instruments can have significantly positive effect on its value enhancement; this conclusion provides the theoretical support for related policy management institutions to speed up the development of derivatives market.Under the current background, China should enrich derivatives transaction type and provide more tool of enterprise risk management. Regulators should formulate corresponding trading rules and ensure that the interests of the trading main body. Meanwhile, regulators should relax for trading main body qualification and encourage more enterprises to participate in derivatives trading according to their own demands, making the derivative financial instruments truly become an effective means of risk management.

2. Fully Understanding the Characteristics of Derivative Financial Instruments
Enterprises should be fully aware of the dual characteristics of derivative financial instruments, knowing clearly the original cause of production of the derivative financial tools is risk aversion rather than speculative profits. In addition, enterprise should give full play to function of risk aversion and the price stability of the derivative financial instrument, according to the risk factors companies are confronted with.

3. Strengthening Enterprise Risk Consciousness and Management and Control Level
Enterprises should have a clear purpose in the operation of the derivative financial instruments and establish the reasonable risk management system: (1) strengthening internal control and regulating the derivatives trading operation process; (2) establishing a risk assessment system according to own condition and confirming enterprise risk appetite and risk points, choosing derivative financial tools meeting the needs of their own risk management; (3) operating derivative financial instruments should comply with relevant trading rules and national laws and regulations, avoiding losses caused by illegal operation.

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Safety Evaluation of Gantry Crane Based on Entropy-Fuzzy Comprehensive Evaluation Model

Fuming Deng, Daopeng Ren, Chunqing Wang, Xuedong Liang and Zhaoxia Guo

Abstract Aiming at giving the accurate value of risk assessment and the level of gantry crane in risk management. Firstly, this paper use relationship diagraph to generalize and analyze four different aspects-People, Machine, Management, Environment. Secondly, a new model named "Entropy-Fuzzy Comprehensive Evaluation Model" can be constructed which combines a safety assessment method (multivariate risk evaluation) with a coefficient resulting from Entropy Method (EM) to avoid the uncertainty in Gantry Crane. By following, when it comes to the reaction between different factors, there are distinguished levels of safety problems. Therefore, from the four aspects mentioned above to estimate the possibilities of accident, the new constructed model (EFCEM) is one of the methods to make managing and controlling the problems of Gantry Crane's safety in different levels comes true. At last, a specific verification of Gantry Crane taken advantage of demonstrates that the new model is viable from the perspective of safety assessments and solutions.

Keywords Gantry crane · Safety assessment · Entropy-fuzzy comprehensive evaluation model · Relationship diagraph

1 Introduction

Gantry Crane, one of the special equipment, becomes the significant equipment which is responsible for loading and unloading assignment duo to well-done work and universally applied. Owing to its outdoor and corrosive working environment, high frequency of usage and intensity of work, gantry crane is one of the special equipment with high operating risks and accident rate. Therefore, it is necessary to do safety assessment for gantry crane obviously. At the same time, giving the exact value at risk is the basis of safety management.

F. Deng (✉) · D. Ren · C. Wang · X. Liang · Z. Guo
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: dengfum@sina.com

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Crane risk management in our country is to supervise the inspection by national and local special equipment safety supervision mechanism, and the risk assessment of equipment focus on the equipment safety performance evaluation technical report. When it comes to establish the evaluation system, the integrity of the special equipment system must be affected if researchers only considering the factors of the equipment, and it will also affect the accuracy of evaluation result [2].

With the development and penetration of safety science, the crane safety evaluation index system has been put forward from the view of man-machine system by some domestic scholars currently. Xu and Fan [6] used the fuzzy hierarchy analysis method, through bridge, safety lifting mechanism, operating agencies, personnel and the safety factors to evaluate the safety of general overhead traveling crane; Qian and Li et al. [4] evaluated the safety of crane equipment body by using LM method, Zhou et al. [9] came up with a comprehensive evaluation method which combines with the principle of the risk based inspection (RBI) and fuzzy analytical hierarchy process (FAHP) to evaluate the safety of gantry crane.

In this paper, an evaluation model combining the entropy method and fuzzy comprehensive evaluation through literature survey and communication with the expert was applied to the safety assessment of gantry crane, it has achieved unity with economy based on the insurance of gantry crane's safety and realized the organic integration of subjectivity and objectivity; it is more in line with the actual situation. Finally, maintenance plan could be formulated efficiently according to the results of the risk assessment to ensure the operation of gantry crane and the economic benefits.

2 Entropy-Fuzzy Comprehensive Evaluation Model

Fuzzy comprehensive evaluation method can show the inner link of things in grading. Optimized entropy weight-fuzzy comprehensive evaluation method is presented in this paper, on the basis of integrating the concept of safety system engineering, using the risk comprehensive evaluation method which combines a variety of evaluation method, from the point of "People, Machine, Management, Environment system" to evaluate accident probability, so as to realize the gantry crane classification grading control, the specific process is shown in Fig. 1 [1].

Note:

X : represents the evaluation value of each factors;
W : represents the weight vector of each layer factors;
R : represents the membership matrix of each layer factors;
B : represents the final weighting results;
EM : represents the entropy method.

The calculation process of this figure is shown in the following Sects. 2.1 and 2.2.

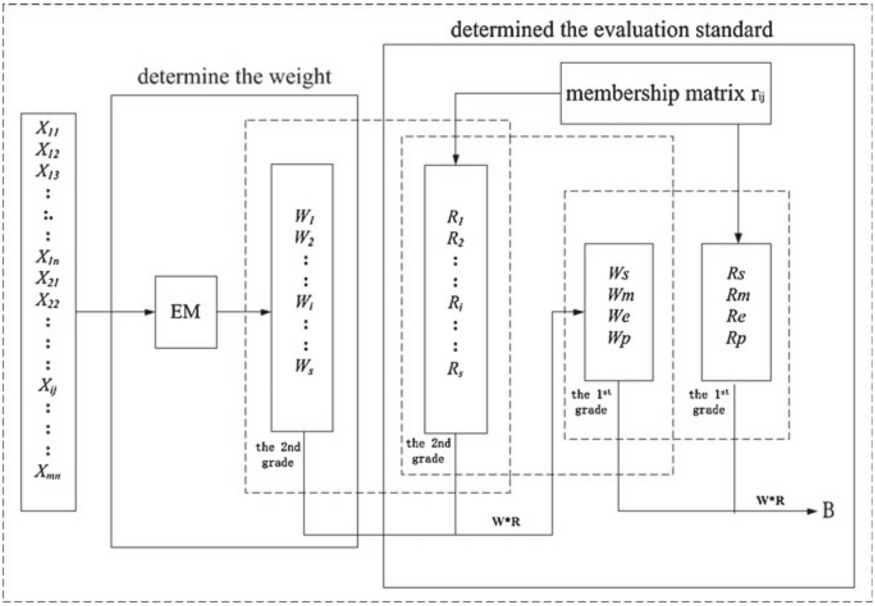

Fig. 1 Process of gantry crane safety evaluation

2.1 Determine the Weights of Evaluation Factors by Using the Entropy Weight Method

Determine the weight coefficient is a very important part in the comprehensive evaluation problem. In order to reflect the affect influence correctly and properly, this study determines the weight coefficient by introducing entropy method [3].

Assuming that the number of evaluation object is m, the number of evaluation index is n, calculation steps of entropy method are as follows:

(1) Construction characteristic matrix of comprehensive evaluation
Determine the candidate plan system: $Q = (q_1, q_2, \ldots, q_m)$, the comprehensive evaluation index system: $P = (p_1, p_2, \ldots, p_n)$, and the evaluation of n sub index for m candidate scheme is described by index characteristic matrix $X = (x_{ij})_{mn}$.

$$X = \begin{pmatrix} x_{11} & x_{12} & x_{13} & \ldots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \ldots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \ldots & x_{mn} \end{pmatrix}, \tag{1}$$

where x_{ij} denotes the degree that factor i belongs to level j $(i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, m)$.

(2) The data standardization of indicators

$$b_{ij} = \frac{\left(x_{ij} - \min\limits_{1 \leqslant i \leqslant m}\{x_{ij}\}\right)}{\max\limits_{1 \leqslant i \leqslant m}\{x_{ij}\} - \min\limits_{1 \leqslant i \leqslant m}\{x_{ij}\}}, \tag{2}$$

where $\max_{1 \leqslant i \leqslant m}\{x_{ij}\}$ and $\min_{1 \leqslant i \leqslant m}\{x_{ij}\}$ represent the maximum value and the minimum value of different objects of the same indicator.

(3) Determine the entropy of evaluation index, according to the definition of entropy

$$H_i = -\frac{\sum\limits_{i=o}^{m} f_{ij} \ln f_{ij}}{\ln m}, \quad f_{ij} = \frac{b_{ij}}{\sum\limits_{j=1}^{m} b_{ij}}, \tag{3}$$

where $0 < H_i < 1, i = 1, 2, 3 \ldots n, j = 1, 2, 3 \ldots m$. If $f_{ij} = 0$, get $f_{ij} \ln f_{ij} = 0$.

(4) Calculation the entropy weight of evaluation index by using the entropy, and define entropy weight of evaluation index i

$$w_i = \frac{1 - H_i}{n - \sum\limits_{j=1}^{m} H_i}, \tag{4}$$

where $W_i \in [0, 1], \sum\limits_{i=1}^{n} W_i = 1$.

2.2 Establishing Evaluation Criteria Based on Fuzzy Comprehensive Evaluation Method

(1) Establish the factor sets of gantry crane safety evaluation
U marked as: $U = \{u_1, u_2, \ldots, u_n\}$ is defined as the factors set that composes safety factors whose number is n. Through on-the-spot investigation to collect relevant data, classifying the master data, sorting and induction, and combined with the interview of experts, sort out factor set, finally draw connection diagram, as shown in Figs. 2 and 3.

(2) Select the evaluation set
Determine comments set: $V = \{v_1, v_2, \ldots, v_m\}$, m represents the grade number of comments. In this study, $V =$ {Good, Preferably, General, Poorer, Extremely poor} is used.

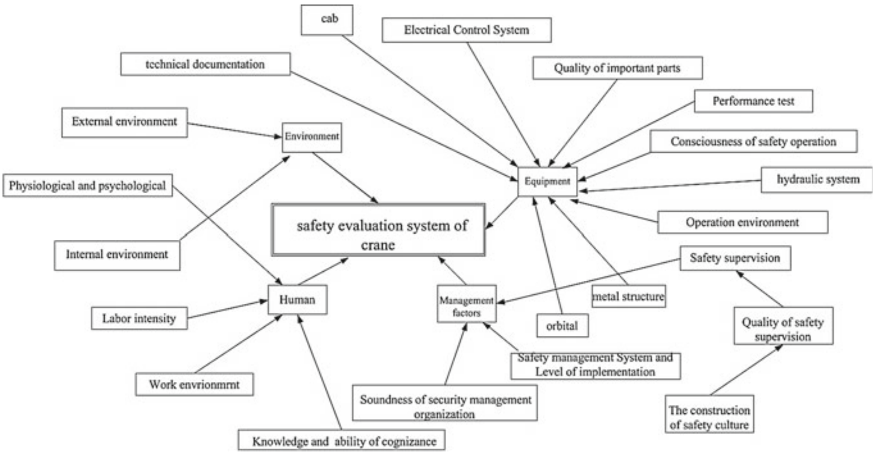

Fig. 2 Influencing factors' relationship graph of gantry crane safety management

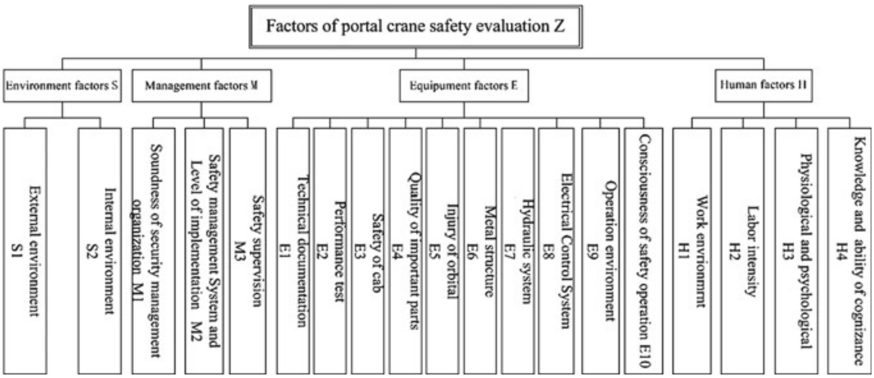

Fig. 3 Factors of gantry crane safety evaluation

(3) Determine the membership function

In this study, the formulas of membership function are presented below combining with the characteristics of the unit and the results of interviews with experts [8].

$$\text{Good:}\, u(x) = \begin{cases} 0, & 0 \leqslant x < 80 \\ (x-80)/10, & 80 \leqslant x < 90 \\ 1, & 90 \leqslant x \leqslant 100, \end{cases} \tag{5}$$

$$\text{Preferably:}\, u(x) = \begin{cases} 0, & 0 \leqslant x < 70 \\ (x-70)/10, & 70 \leqslant x < 80 \\ 1, & x = 80 \\ (90-x)/10, & 80 < x \leq 90 \\ 0, & 90 < x \leqslant 80, \end{cases} \tag{6}$$

$$\text{General: } u(x) = \begin{cases} 0, & 0 \leqslant x < 60 \\ (x-60)/10, & 60 \leqslant x < 70 \\ 1, & x = 70 \\ (80-x)/10, & 70 < x \leq 80 \\ 0, & 80 < x \leqslant 100, \end{cases} \tag{7}$$

$$\text{Poore: } u(x) = \begin{cases} 0, & 0 \leqslant x < 60 \\ (x-50)/10, & 50 \leqslant x < 60 \\ 1, & x = 60 \\ (70-x)/10, & 60 < x \leq 70 \\ 0, & 70 < x \leqslant 100, \end{cases} \tag{8}$$

$$\text{Extremely poor: } u(x) = \begin{cases} 0, & 0 \leqslant x < 50 \\ (60-x)/10, & 50 \leq x < 60 \\ 0, & 60 \leq x \leq 100. \end{cases} \tag{9}$$

Determine the membership matrix R_i, by judging each factors u_i which are belonged to gantry crane factors set U.

$$R = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{pmatrix}, \tag{10}$$

where r_{ij} is the membership degree that factor u_i belongs to fuzzy subset v_j $(i = 1, 2, \dots, n)$.

(4) Calculation of fuzzy comprehensive evaluation
Use an appropriate algorithm "$\circ$" whose calculation steps are same with the multiplication of double matrixes to calculate the results between the membership matrix R and the weight matrix W, and it's detailed steps are as follows, fuzzy comprehensive evaluation results are obtained.

$$B = W \circ R = (w_1, w_2, w_3, \dots, w_n) \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{pmatrix} = (b_1, b_2, \dots, b_m), \tag{11}$$

$$b_j = \sum w_i \times r_{ij}, (i = 1, 2, \dots, n; j = 1, 2, \dots, m), \tag{12}$$

where B is a fuzzy subset of the evaluation set V [7].

3 Application of Case Gantry Crane

The M10-30 type gantry crane was made in May 1989 Port Machinery Plant of Shanghai and was installed in 1990 in Quanzhou harbor. After putting use for 10 years, increasing workload and fatigue crack of metal structure would probably increase the risk of accidents. So, it needs to be evaluated for safety [5].

4 Determine the Initial Weight

Determine the weight coefficient of index based on the gantry crane safety evaluation factors set, through combined interview of experts and standard-data method to obtain the concrete data of each index. For example, the original data of equipment factors were quantified as shown in the following Table 1.

Determine the evaluation of each index entropy H_i by using the Eq. (3), as shown in the following Table 2. Get the weight vector that is E_{1-10} to E, by using the Eq. (4): W_2 = (0.2053, 0.0157, 0.1017, 0.0942, 0.1487, 0.1249, 0.0498, 0.1191, 0.0823, 0.0582). Similarly, the weight of all factors can be calculated as shown in the following Table 3.

1. Establish the Degree of Membership Function
According to the calculation of membership function, operational results can be obtained as shown in the following Table 3.

2. Fuzzy Comprehensive Evaluation
Weights that the 2nd grade factors: S1-S2, M1-M3, E1-E10, H1-H4 belong to the 1st grade factor: S, M, E, H are given in Table 3. As shown in the following Table 4, the fuzzy judgment analysis set is obtained by the Eq. (10): S = (0, 0.2701, 0.3650,

Table 1 Numerical value of b_{ij}

	$i = 1$	$i = 2$	$i = 3$
$j = 1$	0	0	0
$j = 2$	0.1035	0.0067	0.007
$j = 3$	0.1068	0.358	0.762
$j = 4$	0.1474	0.1838	0.1744
$j = 5$	0.0575	0.0358	0.0484
$j = 6$	0.0925	0.0884	0.0949
$j = 7$	0.0308	0.2264	0.1587
$j = 8$	0.0226	0.0864	0.0557
$j = 9$	0.289	0.1796	0.2518
$j = 10$	0.0999	0.1549	0.133

Table 2 Numerical value of H_i

Sequence number	Index	Entropy H_i
E1	Technical documentation E1	0
E2	Performance test E2	0.0716
E3	Safety of cab E3	0.5054
E4	Quality of important parts E4	0.5991
E5	Injury of orbital E5	0.3914
E6	Metal structure E6	0.5409
E7	Hydraulic system E7	0.4196
E8	Electrical control System E8	0.7571
E9	Operation environment E9	0.2755
E10	Consciousness of safety operation E10	0.9233

0.3650, 0), M = (0.4277, 0, 0.5278, 0, 0), E = (0.2053, 0.1174, 0.1831, 0.3620, 0.1312), H = (0, 0.7291, 0.2701, 0, 0).

Get membership matrix of grade factor Z obviously:

$$R = \begin{pmatrix} 0 & 0.2701 & 0.3650 & 0.3650 & 0 \\ 0.4277 & 0 & 0.5278 & 0 & 0 \\ 0.2053 & 0.1174 & 0.1831 & 0.3620 & 0.1312 \\ 0 & 0.7291 & 0.2701 & 0 & 0 \end{pmatrix}.$$

Get weights of the 1st grade factors: S, M, E, H to Z from the table, and obtain the final results of the safety of gantry crane by the Eq. (10).

$$B = (0.4374, 0.2367, 0.1933, 0.0966) \circ R = (0.1409, 0.2258, 0.3626, 0.2358, 0.0255).$$

It is concluded that the final level of security of gantry crane is general, combining the evaluation set: V = {Good, Preferably, General, Poorer, Extremely poor} and according to the maximum membership degree principle.

Get the results by calculating the score of experts of membership functions, according to different factors: internal environment gets 65 points; injury of orbital and metal structured hydraulic system get 60 points, they belong to the Poorer; consciousness of safety operation gets 50 points, electrical Control System gets 40 points, they belong to the Extremely poor. These factors are the important causes of safety accidents in the units. It is necessary to pay more attention and propose measures.

Table 3 Weight value of all levels evaluation index: *w*

Factors	Weights *w*	Index	Weights *w*
Environment factors: *S*	0.4734	External environment *S*1	0.2701
		Internal environment *S*2	0.7299
		Soundness of security management organization *M*1	0.4277
Management factors: *M*	0.2367	Safety management system and level of implementation *M*2	0.3273
		Safety supervision M3	0.2005
		Technical documentation E1	0.2053
		Performance test E2	0.0582
		Safety of cab E3	0.1017
		Quality of important parts E4	0.1249
Equipument factors: *E*	0.1933	Injury of orbital E5	0.1487
		Metal structure E6	0.0942
		Hydraulic system E7	0.1191
		Electrical control system E8	0.0498
		Operation environment E9	0.0157
		Consciousness of safety operation E10	0.0823
		Work environmrnt H1	0.0093
Human factors: *H*	0.0966	Labor intensity H2	0.3130
		Physiological and psychological H3	0.2538
		Knowledge and ability of cognizance H4	0.4239

Table 4 Degree of membership r_{ij}

Index	Score	Degree of Membership: r_{ij}				
		Good	Preferably	General	Poorer	Extremely poor
External environment S1	80	0	1	0	0	0
Internal environment S2	65	0	0	0.5	0.5	0
Soundness of security management organization M1	90	1	0	0	0	0
Safety management System and level of implementation M2	70	0	0	1	0	0
Safety supervision M3	70	0	0	1	0	0
Technical documentation E1	95	1	0	0	0	0
Performance test E2	70	0	0	1	0	0
Safety of cab E3	80	0	1	0	0	0
Quality of important parts E4	70	0	0	1	0	0
Injury of orbital E5	60	0	0	0	1	0
Metal structure E6	60	0	0	0	1	0
Hydraulic system E7	60	0	0	0	1	0
Electrical Control System E8	40	0	0	0	0	1
Operation environment E9	80	0	1	0	0	0
Consciousness of safety operation E10	50	0	0	0	0	1
Work environmrnt H1	70	0	0	1	0	0
Labor intensity H2	80	0	1	0	0	0
Physiological and psychological H3	80	0	1	0	0	0
Knowledge and ability of cognizance H4	75	0	0.5	0.5	0	0

5 Conclusion

Using the relationship diagraph from four aspects of people, machine, management and environment carries on the inductive analysis in the gantry crane safety evaluation activities. In order to guarantee the objectivity and accuracy of the influence that various factors on the evaluation results fully, this paper introduces the entropy method (EM) to determine the weight coefficient by building the entropy weight-fuzzy comprehensive evaluation model, and making depth analysis and research. Realize classification management of the gantry crane, by using comprehensive risk evaluation which is combined with various evaluation methods, from the view of "People, Machine, Management, Environment" system. At the same time, verify feasibility and effectiveness of the entropy weight-fuzzy comprehensive evaluation model's, by building the safety evaluation system of a M10-30 type's gantry crane. The key features of entropy weight-fuzzy comprehensive evaluation model are discussed in this paper as follows:

(1) Using the relationship diagraph to summarize the influence factors of gantry crane from personnel, machine, environment and management four aspects, it not only can reflect the factors set of gantry crane safety evaluation system completeness, but also can reflect the relationship between various factors in the process of the security evaluation.
(2) The introduction of entropy method determining the weight coefficient compensates for the lack of traditional method using expert experience and historical data on weight assignment. It makes the determination of the weight coefficient more objective and accurate, and reflects the effect of various evaluation factors among the evaluation results scientifically.
(3) Construct entropy weight-fuzzy comprehensive evaluation model from the view of system engineering, based on the multi risk factors comprehensive evaluation method. Evaluating the possibility of accident from the view of "People, Machine, Management, Environment" system and making subjective evaluation and objective evaluation of organic integration not only can reduce the traditional problem which is that gantry crane evaluation system is unitary and subjective, but also can achieve classification management of gantry crane from multi-angle and multi-level view, compensate the lack of safety analysis in gantry crane fields. The work in further will be focused on the safety performance of a gantry crane depth research, and provide more optimization scheme to gantry crane safety work, at the same time, use entropy weight-fuzzy comprehensive evaluation model to develop the gantry crane safety evaluation system platform.

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Research on the Intrinsic Mechanism of Major Disaster and Crisis Management from the Perspective of Social Governance—Based on the Practice of 4.20 Lushan Earthquake Post-disaster Reconstruction

Jingdong Zhao, Xiaoqing Wang, Yuxin Zhu, Long Zhao and Tianwei Yu

Abstract 4.20 Lushan earthquake in 2013 is another major natural disaster happened in Sichuan, China after 5.12 Wenchuan earthquake in 2008. The practical experience gained during the earthquake relief and post-earthquake reconstruction would have profound influence on China's model of earthquake management, post-earthquake reconstruction and even social governance in 21st century. The present paper is based on personal experience during 4.20 Lushan earthquake reconstruction from an overall perspective. With a detailed systemization of all practical experience gained through government-leading post-disaster rescue and reconstruction work, the Lushan post-earthquake social reconstruction with a connotation of "resource coordination platform as the carrier, social organization cultivation the foundation, social service provision the method" has been brought up. The new post-earthquake social reconstruction operation model of "government leading, government and society coordinating, rescue in order, mutual support" has also been put forward. Effort has also been done in the analysis of the intrinsic operation mechanism of the previous model to reconstruct China's disaster and crisis management model, hoping to provide practical evidence for China's regular social governance operation mechanism.

J. Zhao (✉)
Ya'an Earthquake Relief Social Organization and Volunteer Service Center, Sichuan University Business School, Ya'an 625000, People's Republic of China
e-mail: 290914682@qq.com

X. Wang
Staff of Social Management Service Group in Sichuan Disaster Reconstruction Committee, Chengdu 610015, People's Republic of China

Y. Zhu
Social Work Department, Sichuan Agricultural University, Ya'an 625000, People's Republic of China

L. Zhao · T. Yu
Ya'an Earthquake Relief Social Organization and Volunteer Service Center, Ya'an 625000, People's Republic of China

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Keywords 4.20 Lushan earthquake · Social governance · Post-disaster social reconstruction

1 Inspirations and Challenges of Wenchuan Earthquake

In April 20, 2013, an earthquake at a scale of 7.8 on the Richter calculations happened in Lushan county, Ya'an city, Sichuan province, impacting 32 counties (cities or districts) radiating from Ya'an, causing 196 deaths, over 14 thousand injuries and affected 2.18 million people. Houses were severely damaged. 186.3 thousand rural houses were collapsed; 43 thousand rural houses were severely damaged; over 6,700 urban houses were collapsed; and more than 80 thousand urban houses were severely damaged. Roads, bridges, electric power, telecommunication, hydropower stations, water reservoirs and other infrastructures have all been damaged to different degrees. Earthquake has caused great economic losses and severely damaged the ecosystem.

Lushan earthquake is another strong earthquake happened in Sichuan province after 5.12 Wenchuan earthquake in 2008. There are similarities in disaster type, disaster-affect area, history, culture and even reconstruction mechanism between these two earthquakes in 2008 and 2013. In order to understand Lushan earthquake's profound influence on China's major disaster and crisis tackling as well as regular management mechanism, it is a must to briefly review the relevant situations of Wenchuan earthquake.

Wenchuan earthquake in 2008 was a turning point for China's history of major disaster and crisis tackling. From then on, disaster and crisis tackling is not solely down by government and it has become normality for social forces to participant. However along with the achievements made by social forces, social forces' extensive participation have also brought up new challenges for China's major disaster and crisis tackling as well as regular management mechanism in the following three aspects:

The first challenge is how to guarantee the effectiveness of disaster and crisis tackling mechanism. This challenge mainly was reflected on the issue of "subjectivity", "identity positioning" and "job responsibility". Specifically speaking, disaster and crisis tackling was solely led or done by government before Wenchuan earthquake, so how to effectively involve social forces into China's traditional disaster emergency mechanism and differentiate it from as well as make it a positive and effective amendment to the government-leading disaster tackling system has become a question to be answered.

The second challenge is how to guarantee the orderly operation of disaster tackling mechanism. This challenge mainly was reflected on the issue of "management norm", "coordination measure" and "sense of order" in institution design. Specifically speaking, the inrush of social organizations and volunteers after social pep talk may not bring high efficiency to post-disaster rescue and reconstruction work in the hit area, and it may even cause disagreement between social forces and government mechanism. So a reasonable institution design that can not only protect and stimulate the enthusiasm of social forces' participation, but also guarantee the orderliness and effectiveness of post-disaster relief work is of vital importance.

The third challenge is how to guarantee the orderly operation of disaster tackling mechanism. This challenge was mainly reflected in the issue of "information communication", "sharing mechanism" and "proficiency" of content. Specifically speaking, in face of large scale natural disasters affecting large area and population, and changes in people's demand, how social forces can get the first-hand demand information in a timely manner, effectively satisfy people's demand with their professional services, play an important role in the government-leading post-disaster rescue and reconstruction mechanism and safeguard the orderliness and effectiveness of disaster relief mechanism's operation have become an issue.

In conclusion, the post-disaster relief practice of Wenchuan earthquake can be called the Chinese social forces' debut in major disaster and crisis tackling. Breakthroughs in practice and innovation have been made in the process of earthquake relief and post-earthquake rescue. However, how to transfer from "extensive voluntary participation" to "orderly, powerful, effective" management or even mechanism deepening, further clarify social forces' subjectivity and legitimacy, and promote a effective seamless linking up between government and social forces need more practical exploration and theoretical research.

2 Theoretical Requirements of Social Governance

On the third plenary session of 18th central committee of CPC in 2013, the core concept of "social governance" was put forward, symbolizing China's transition from sole government management model to a diversified management model. Due to China's uniqueness in politics, administration, culture and society, social governance in China is different from that in the west. Social governance in China is in line with the present social and economic development and a positive attempt to improve the government-leading "strong government, weak society" social management model. The basic positioning of social governance should be "social rights" other than "social power" and the aim is to realize an optimum transfer of government function from controlling to serving, in a wish to establish the "self-management, self-supervision, self-education, self-service" standard for society's self-governance.

Social governance can provide theoretical support for the research of social participation and practice in Wenchuan and Lushan earthquake rescue works. It also echoes the three issues of reflection on Wenchuan earthquake practice as "subjectivity", "sense of order" and "proficiency". At present, theoretical studies of social governance in China mainly concentrate on structure positioning, institution design and content framework.

First, the major issues for structure positioning concentrate on the subjectivity of social governance or the subject and object of governance. Zhang [1] stated that the aim of social governance is to alter the sole government-controlled social management model and to transfer from government control to equal cooperation between government and society. Zhang and Lu [2] and Yang [3] proposed that more scholars further emphasize that the innovation of social governance mechanism is the transition of the subject of governance from unitary to multiple. Meanwhile, based on the reality and practical operation in China, some scholars think it is too early to transfer from "government control" to "multiple shared governance". It is more reasonable to adopt the "government-governing, public participating" model at present and then gradually transfer to the "cooperating governance" model [4].

Second, studies on institution design are not yet into the operation phase of institution design content, but many from the perspective of institution type analysis. Shi and Liang [5] explored the issue from the perspective of social governance's occurrence mechanism and conclude the institutional transformation process is from "power-govern mechanism" to "law-govern" and then "virtue-govern". Fang [6] contends that social governance should fulfill the role of safeguarding mechanism in the following five aspects: behavior and environment standardization mechanism, participation route implementation mechanism, opinion and emotion expressing and interacting mechanism, fiscal budget support mechanism and competence improvement mechanism. And Yang and Shi [7] held that public extensive participation mechanism, social influence evaluation mechanism, scientific decision-making mechanism and social safety network establishment are of extreme importance.

Finally, judging from the content framework, a widely spreading opinion is that at present the content of China's social governance is complicated, covering many fields but rarely touching upon the implementation of concrete contents. Through the analysis of government policies, Bao [8] listed ten major fields, including public service, social organization, grass-root society, and emergency tackling. Ye and Xu [9] emphasized that social governance should focus on stimulating the endogenous power of the society, on the public participation in social service and management, and promote the construction from the aspects of government service purchasing, public service production and entity project operation.

In conclusion, although at present different scholars have taken different research angles, they all emphasizes social governance should be a shared governance of "multiple subjects and multiple objects". Government, market and society should be both subject and object of each other. The core concept of related studies can be summarized as "social participation", "multiple cooperation", "institution innovation" and "project operation".

3 Practice and Innovation of Lushan Earthquake

The summary on above practical experience of Wenchuan earthquake and theoretical requirements of social governance will lead to issues of three aspects, namely the subject's identity, institution framework and content function. Lushan earthquake's rescue and relief work was the first time for China to have positive approaches and practices on the above issues through major disaster and crisis tackling.

On April 25th, a three-tire social management service team consisting of province, city, and county level was launched. It clearly pointed out the team's duty, operation and working mechanism. On April 28th, Earthquake Relief Social Organization and Volunteer Service Center that participated in relief work through cooperation with other social groups was established in Lushan, the epicenter. On May 12th, Sichuan social governance Service Team officially announced the joint establishment of Ya'an Earthquake Relief Social Organization and Volunteer Service Center. Information publishing, registration and report and orderly guiding were provided to social groups and volunteers that engaged in quake relief work. Meanwhile, county-level centers and township and village service stations were formed in the worst-hit areas as well as a three-tire system consisting of the city, county (or district) and township.

The center's job was positioned as actively cooperating with the local quake relief headquarters in its work, providing service to social groups and volunteers, continuously strengthening its communication and coordination with social groups and volunteers and guiding social force to participate in relief work orderly and effectively. The government and social organizations were closely linked up through social organizations' engagement, working regulation making, support of related departments and service from the center.

As for the function of the center, "Four Platforms", i.e., Information Publishing Platform, Project Matching Platform, Public Service Platform and Incubation and Training Platform effectively engaging and providing service in quake relief and post-disaster reconstruction through cooperation with social organizations and volunteers. Information Publishing Platform: publishing and categorizing information of demands and needs of party committee, government, victims and social organizations; Project Matching Platform: transforming the demands of party committee, government, victims and social organizations into specific projects and providing assistance platform to match needs on resources and fulfill the projects; Public Service Platform: offering stable and convenient working environment to engaging social organizations; Incubation Training Platform: giving training on staff of specific service project and incubating new projects while conducting the existing projects.

By November 2014, 350 social organizations have registered in the center and 62 of them, which are professional and trustworthy social organizations, have entered and worked in the center. The center supported 101 social organizations and helped to build up over 90 grass-root service stations and mobilized more than 5,400 volunteers to provide regular service to the grass-root people. Over 2,000 social service programs of ten categories, including social aid, employment and starting one's own business, new villages construction, disaster prevention and mitigation, and psychological counseling were outlined. An initial charity project database adapting to the real needs of disaster-hit areas was launched. 1,386 charity projects with value of 3.131 billion RMB were matched up, bringing great progress to post-disaster reconstruction.

Moreover, due to the outstanding achievement and persistent improvement of social governance service team and service center, China for the first time attached great importance to social reconstruction after Lushan earthquake. It was the first time to include social reconstruction programs like volunteer service system construction, social organization cultivation, social worker nourishing and disaster area humanistic care into the overall plan of post-disaster reconstruction. It is also the beginning of the virtuous transition from crisis handling to regular management. Gradually form a working system that cooperates with other social forces in the engagement of social and economic development; widely incubate social groups of charity work and community development that satisfies different and individualized needs of public; and build up a highly professional local social work team; buy service from social organizations; and continuously galvanize the vitality of social organizations and social development so as to forge ahead social governance.

4 Institution Innovation and Restructuring

The great breakthrough made in social governance innovation after Lushan earthquake was reflected on the establishment of "social governance service team" in government system for the first time, including social governance and reconstruction to overall crisis coping system; moreover, through the platform of "social organization and volunteer service center", which was also the carrier in practice for social governance service team, new measures that take the resources coordination platform as carrier, incubation of social organizations foundation and providing social service means were brought up, tried and improved all the time; in response to the restructuring of crisis managing model at present, a new model of post-disaster reconstruction under the guidance of government which highlights the coordination between government and society, orderly relief work and mutual support was put forward, offering experience and evidence to operation of regular social governance. All of these are specifically shown in the following three aspects:

First, the function and working content of indirect service center under the guidance of government was clarified for the first time from micro perspective. Social forces clearly found their "legitimate identity" in crisis responsive system through the center; through the plural coordination mechanism, regular operation mechanism, opening service mechanism, projectized operation mechanism and scientific evaluation mechanism, effective matching between party/government system and the needs of social organizations and disaster area were promoted, which fully allowed social forces to be the important constituent of disaster responsive system.

Second, coordination and unity of multiple subjects were achieved on madhyamika level and issues of "coordination measures" and "management regulations" in institution designing were effectively coped with. Through the practical and regular operation of the center, coordination between party and government, public and league, among social forces and volunteers were creatively and basically achieved and a cooperation mechanism featured multiple subjects and perspectives was established.

Finally, the dual structure design of the center's "coordination among party, government and society" as well as the clear positioning of subject and rule making was adjusted to the requirements of the present times on macro level. Active participation of social organizations and volunteers in disaster aid and post-disaster reconstruction was fully guaranteed and effectively encouraged the involvement of social forces in China's existing crisis handling system. With the gradual transition from earthquake relief work to post-disaster reconstruction, the center has shifted its focus from combating crisis to regular management, which provided valuable experience and evidence for operation of regular social governance.

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Development Environment and Strategic Choice for Rural Endowment Insurance Fee-to-Tax: An Analysis Based on PEST-SWOT Model

Jie Tong, Hongwei Li and Qifeng Wei

Abstract The core of social insurance fee-to-tax research is the endowment insurance tax, which is always one of the hot academic questions. Existing researches mainly focus on the endowment insurance fee-to-tax, but the fee-to-tax study is still an outstanding issue. This paper tries to figure out the problem of rural endowment insurance fee-to-tax by using the PEST-SWOT analysis model, from the aspects of political, economic, social and technical, and discusses the advantages and disadvantages, opportunities and challenges of rural endowment insurance fee-to-tax, and finally assesses the development environment, in order to make an exploratory research on the strategic choice of rural endowment insurance fee-to-tax.

Keywords Rural endowment insurance · Fee-to-tax · Development environment · Strategic choice · PEST-SWOT model

1 Introduction

The social insurance fee-to-tax is a reformation assignment and a policy opinion, which is a hot topic in the academic world. However, not all people agree with the new plan. On the one hand, some scholars support the reform of social insurance fee-to-tax. Deng said that the social insurance fee-to-tax is the most ideal financing mechanism for social security fund [1]. Wang believed that with the improvement of

J. Tong (✉)
School of Public Administration, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: tj436@163.com

H. Li
College of Literature and Law, Chengdu University of Technology, Chengdu 610059, People's Republic of China

Q. F. Wei
Faculty of Business and Economics, The University of Melbourne, Melbourne, VIC, Australia

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the social security system and Chinese legalization, the social insurance fee-to-tax should become the main mode of financing [11]. Xu pointed out that we need to implement social security fee-to-tax as a strategy for levying social security fund to solve the problem of social security system. The social security fund from the law shall be collected by the tax authorities, which can not only make full use of their own advantages, such as the tax department, network and information superiority, but also can improve work efficiency and save cost [13]. Hu pointed out that as early as 1999 in China, the average wage for urban workers as a standard, which has reached the economic conditions for the collection of social insurance tax [2]. Ma and Tu stated that social security fund management is inefficiency and mismanagement in our country at present, but social security fee-to-tax reform will conducive to establish of a unified management and supervision mechanism [6]. As Li considered, the social insurance tax can make the collection of social insurance fund legalization, standardization and open [3]. From the perspective of the mandatory features of social insurance, Long stated that the social insurance tax is the natural financing tool of social insurance system [4].

On the other hand, as a representative of the scholars, Zheng strongly opposed the social insurance reform of fee-to-tax. To summarize the experience of the social insurance tax all over the world, he believes that the endowment insurance tax is not the international trend, but the tax-to-fee [15]. If implemented, the endowment insurance tax not only can not conform to the principle of the payment age limit and the pension treatment link up, but also cannot meet the requirement of social security system on elastic [14]. The endowment insurance fee-to-tax, from the perspective of the tax itself, not only it will be very difficult to distinguish between the central tax and local tax, but also not easy to divide the respective responsibilities and obligations. In addition, it will face the problem of how to design the tax incentive mechanism [16]. Zheng considered that both tax mode and payment mode is relying on perfect legal system. Once the tax reform is implemented, the existing pattern of social security must be changed, and the main responsibility of the government will be from the background to the front desk. And what's more, some technical problems remains there because of the imbalance between regions in China, and the government may get unlimited liability for doing so [17].

From what has been discussed above, the scholars who support the reform of endowment insurance fee-to-tax mainly pay attention to the shortcomings of social insurance payment mode at present. The supporters expect the advantage of tax system, such as the rule of law, mandatory, high efficiency, low cost and so on, which could break the current social security dilemma. The scholars who oppose the tax reform from the existing social security system mode, and they are focused on the regional differences of economic and social development. The opponents insist that the risk of policy and technical barriers to the social insurance fee-to-tax may exist, and couldn't be blind to the implementation of social insurance fee-to-tax. By analyzing and summarizing the tax reform, whether supporters or opponents, their research was just the urban pension insurance fee-to-tax. Due to the differences between the urban and rural areas, the rural endowment insurance system which can cover all farmers was completed until 2012. Compared with urban endowment insurance, the government provides financial support for endowment insurance not enough in rural areas, and the rural endowment insurance only can provide a low level of benefit for members. The new rural endowment insurance system has just set up, and it is still in a weak position. With all the concerns about urban pension insurance fee-to-tax, there is almost no relevant study about rural endowment insurance fee-to-tax at present. With the development of the strategy of coordinating between urban and rural, it is a rare opportunity to push forward the development of rural in China. Whether or not will implement the reform of the urban endowment insurance fee-to-tax, the rural endowment insurance need fee-to-tax in the future is very worthy to study.

This paper provides a comprehensive analysis of the development environment of rural endowment insurance fee-to-tax. This paper will gain the important conclusion that the current social and economic environment is good for the rural endowment insurance system, and the implementation of rural endowment insurance fee-to-tax is beneficial to the development of rural endowment insurance system. Moreover, the integration of urban and rural tax system is very important for the country's endowment insurance system. Finally, whether or not will implement the reform of the rural endowment insurance fee-to-tax, to strengthen the publicity of rural endowment insurance is very important.

2 The PEST-SWOT Model

2.1 The SWOT Model

In the early 1980s, Heinz.Verick, who is a professor of management at the university of San Francisco, created the SWOTStrengths, Weakness, Opportunity, Threatstheory which is also known as situation analysis method. The SWOT theory is a kind of objective and accurate analysis tool, and which is used to study on the current situation of the development of an organization or unit. It could easily see the micro environment of an organization by introducing SWOT model, such as advantages, disadvantages, opportunities, threats, etc. In Fig. 1, the SWOT model is usually used to carry out a comprehensive evaluation, and realize the goal of the organization, and so that the strategic decision-making based on careful sifting of the evidence.

2.2 The PEST Model

The PEST analysis model is another analysis tool, which is generally used to analyze and identify the macro environment of a trade or business, such as political environment, economic environment, social environment, technical environment, etc. The

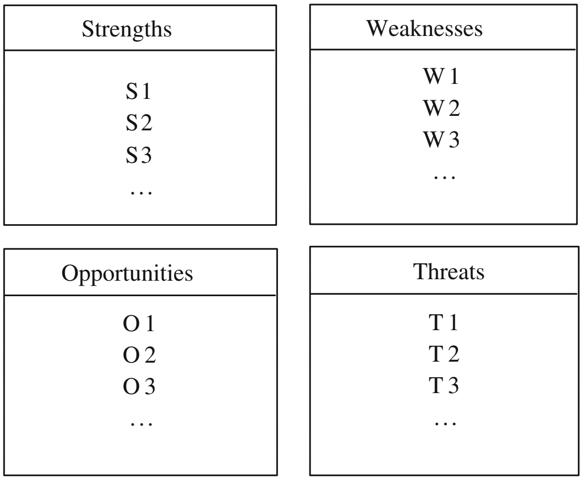

Fig. 1 The SWOT model

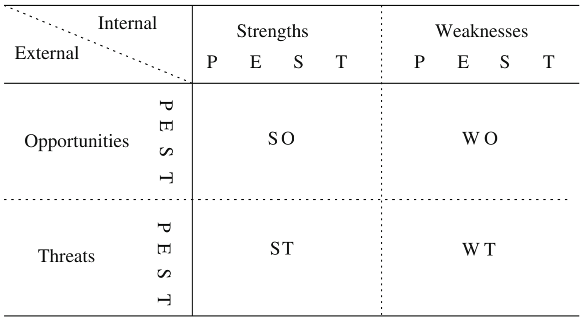

Fig. 2 The PESE-SWOT model

entire macro environment factor had become the main factor that can influence the strategy and operational activities of the firms, as well to change the decision making in business (Fig. 2).

2.3 *The PEST-SWOT Model*

The PEST-SWOT model is the integration of PEST model and SWOT model, which has obtained the advantages of the two models and made the analysis more comprehensive and in-depth. As one of the main analysis tools, PEST-SWOT model has been widely used in many industries and fields [5].

3 Model Analysis

3.1 Model Description

According to the analysis of the preceding context, this paper analyzes the impact of the rural endowment insurance fee-to-tax from four aspects, that is political, economic, social and technology. Based on the model of PEST-SWOT, this paper puts forward to the environment of rural endowment insurance fee-to-tax, and in-depth analyses of the internal strengths and weakness, and the external opportunities and threats of rural endowment insurance.

These relationships are summarized in the following Table 1.

3.2 Analysis of the PEST-SWOT Model of Rural Endowment Insurance Tax

1. The political environment of rural endowment insurance fee-to-tax
(1) The internal political advantages and disadvantages
There are two internal political advantages which can promote the rural endowment insurance fee-to-tax. First of all, "Social insurance law of China" began to implement since July 1, 2011, marking China's social insurance work entered the orbit of the legal system. The "social insurance act" not only stipulates the rights and obligations of the insured object, but also clears the responsibility of the government, and stipulates the urban endowment insurance and rural endowment insurance in the direction of development. Second, at the end of 2012, the vice minister Xiaoyi-Hu pointed out: "The implementation of new rural endowment insurance, marking the main social security system covering urban and rural residents in China have set up, and that to achieve full coverage of old-age security system". Full coverage of the system, not only good for the rural old-age insurance plays a fundamental role, but also one of the necessary conditions for the implementation of the rural old-age insurance fee-to-tax.

There are two internal political disadvantages against rural endowment insurance fee-to-tax. First, the difference between urban and rural endowment insurance system will become a barrier which against reform of endowment insurance fee-to-tax. Rural endowment insurance fee-to-tax can not only promote the development of rural endowment insurance, but more important to promote synchronous development of urban and rural endowment insurance. If the rural endowment insurance system is more superior to the urban endowment insurance system, it will seriously weaken the support ability of the whole security system. Second, there are many differences among different regions in our endowment insurance system. These distinctions increased a lot of difficulties for rural endowment insurance fee-to-tax. Furthermore, it is not conducive to the establishment of a unified social security system.

Table 1 The environment of rural endowment insurance fee-to-tax

			PEST			
			Politics	Economic	Society	Technology
SOWT	The internal environment	Strength	Social insurance law issued and came into effect The rural endowment insurance system to achieve full coverage	The government responsibility will more clear, collection rate is expected to	Farmers have a good awareness of rural endowment insurance	Taxation has the characteristic of compelling
		Weakness	Big regional difference in economic development and endowment insurance system	The tax is free of charge, while the social insurance is paid	The actual pension is too small, but farmers' expectation is very high	Tax regulation in rural is difficult, but also high cost
	The external environment	Opportunity	The strategy of balancing urban and rural development and industry finances agriculture	Great changes have taken place in the rural economy development	Establishing harmonious society and new socialist village	The experience from abroad for us to study andreference
		Threat	Household registration system	Imbalances of social and economic development	The aging of the rural population has been very serious	Social insurance tax will be contrary to the current rural policy of "tax cuts"

(2) The external political opportunity and threat

Our country is now at a crucial stage of development. Balancing urban and rural development and Industry finances agriculture had become two major strategies in order to solve the “three rural” issue. The crucial stage of development is external political opportunity for rural endowment insurance tax. The modernization drive of developing countries, depend on a great extent between city and country to dual economic structure, but the dual structure in urban and rural economy in China has not yet been changed, and the gap between regions is still widening and there are still quite a large number of impoverished people. The endowment insurance system is an important system in modern society, and it has important influence on urban and rural development as a whole. Our country in promoting urban and rural development issued a series of fiscal policy and tax policy, and that is the precondition and the necessary basis for rural endowment insurance fee-to-tax. Rural endowment insurance can take advantage of these policies, and actively promote the rural endowment insurance fee-to-tax. The implementation of industry nurturing agriculture policy is a strategic decision after China entered the medium-term industrialization [12]. Industry nurturing agriculture not only can realize the collaborative development of the city and countryside, but also the industry and agriculture. Fiscal transfer is regarded as one of the main ways of industry nurturing agriculture, and rural endowment insurance could have become one of the objects of fiscal transfer. The primary problem of rural endowment insurance in China is the raising of pension funds. If the rural endowment insurance will have a stable source of income, it will greatly promote the rural endowment insurance fee-to-tax.

Not only demarcation in jurisdiction between the Central and local authorities in tax revenue and administration, but also China’s household registration system which has long separated people into either rural or urban citizens, all is the external political threat for rural endowment insurance fee-to-tax. The allocation of tax revenue between the central and local institutions was reformed and fixed in 1994 in China. Meanwhile, the preliminary local tax system was defined accordingly. In fact, the reform of tax distribution system has evolved the substance of the central and local governments between the disguise of the game. The endowment insurance, it is an important part of the national operation. Both the central and local, have the responsibility and obligation to the development of the insurance system. Therefore, the existing tax system, not only have a negative effect on the construction of the national social security system, will also hinder the rural endowment insurance tax. Household registration system is another external political threat to rural endowment insurance fee-to-tax. The long-term goal of rural endowment insurance tax reform is to synchronize with the endowment insurance in urban areas. The household registration system is one of the most important factors affecting the rural endowment insurance [7]. Not only the financial resources allocation of social security will affected by the household registration system, but also the farmers’ willing of participants of the rural social endowment insurance also affected by the household registration system.

2. The economic environment of rural endowment insurance fee-to-tax

(1) The internal economic advantages and disadvantages

The advantage of tax system is the internal economic advantages of rural endowment insurance fee-to-tax. The implementation of rural endowment insurance fee-to-tax, most directly, it can not only strengthen the social insurance tax collection efforts, and improve the collection rate, but also can reduce the system operation cost. In addition, the rural old-age insurance tax can make clear the local government's responsibility. Although there is resistance for China to raise overall plan level of endowment insurance in system and finance, the rural endowment insurance fee-to-tax will created some conditions what is important to put the old age pension into overall planning.

The tax is free of charge, while the social insurance is paid, so the tax and social insurance is inconsistent, and this is the right internal economic disadvantage of rural endowment insurance fee-to-tax. Taxes are owned by the state the individual has no right to dominate. Taxes are used by state to provide public services for citizens, and citizens can enjoy the perfect public service, so as to obtain the indirect return. For the tax, there is no positive relationship between rights and obligations. On the contrary, the nature of the social insurance premium is completely different. And the social security system shall comply with the principles of adjusting rights and obligations. Anyone who pay more in the young, and he could get more after retirement. As a result, once the implementation of social insurance fee-to-tax, then the society insurance system may lose the incentive mechanism.

(2) The external economic opportunities and threats

Because of the development of the social economy and the rural reform from the introduction of the household contract responsibility systemthe rural economic has made tremendous achievements. The development of the rural economy provides a good external economic opportunity for rural endowment insurance fee-to-tax. The economic base not only determines the existence and development of endowment insurance system, but also determines the level of social security. The government can't provide all the funds for the social security system, and the public is still the main source of capital. Now, peasants have become richer, and they have enough money attend rural endowment insurance except meet the basic living security, and they will require for the pension insurance become higher in the future.

According to the National Bureau of Statistics, the following Table 2 summarizes the net income of rural and urban residents from 2000 to 2013.

In order to have an effective description on the development of the rural economic, we summarize the growth rate of the rural and urban residents in the following Fig. 3.

Although the rural economy has achieve great development, but there are also some problems. The prominent problem in rural economic today is the serious development imbalance between regions, and this is the right threat for rural endowment insurance fee-to-tax. The discrepancy, diversity and imbalance of rural district economies in China are the key factors that have important impact on rural endowment insurance system. Quite a number of low-income people peasants could not meet their basic needs of subsistence, especially in the western poverty-stricken areas. From this point on, the imbalance of economic development is the threat for rural endowment insurance fee-to-tax.

Table 2 The net income of the rural and urban residents (2000–2013)

Time (Y)	The average net income of rural households (Yuan)	Avg. per capital disposable income in urban areas (Yuan)
2000	2253.4	6,280.00
2001	2366.4	6,859.60
2002	2475.6	7,702.80
2003	2622.2	8,472.20
2004	2936.4	9,421.60
2005	3254.9	10,493.00
2006	3587	11,759.50
2007	4140.4	13,785.80
2008	4760.6	15,780.80
2009	5153.2	17,174.70
2010	5919	19,109.40
2011	6977.3	21,809.80
2012	7916.6	24,564.70
2013	8895.9	26,955.10

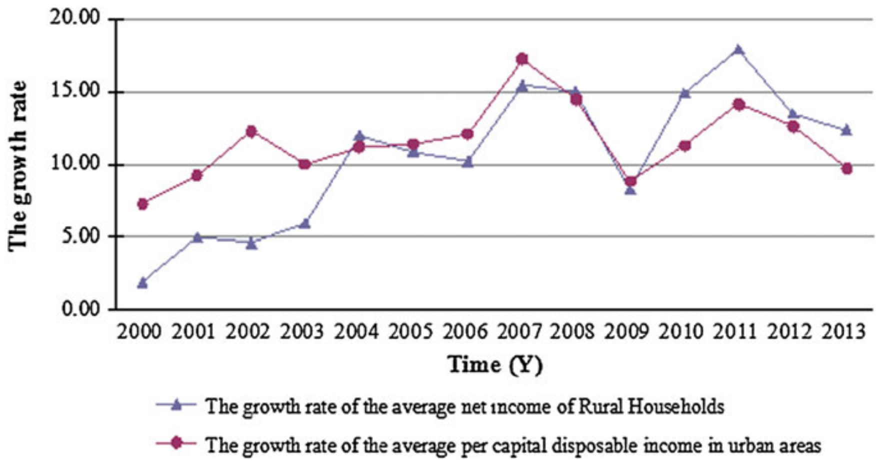

Fig. 3 The growth rate of the average net income of the rural and urban residents (2000–2013)

According to the National Bureau of Statistics, the following table summarizes the per capita net income of Chinese rural households from 2000 to 2012. The big imbalance between regions is also clear. The development of economic in rural areas is unbalance can be seen in the Table 3.

In order to have an effective description on the unbalance of the rural economic, we take case of the per capita net income of Chinese rural households in 2013. The difference in rural economic is much more obvious in the following Fig. 4.

Table 3 The per capita net income of Chinese rural households (2000–2013)

Each area in China	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
National total	2253.4	3254.9	3587	4140.4	4760.6	5153.2	5919	6977.3	7916.6	8895.9
Beijing	4604.6	7346.3	8275.5	9439.6	10661.9	11668.6	13262.3	14735.7	16475.7	18337.5
Tianjin	3622.4	5579.9	6227.9	7010.1	7910.8	8687.6	10074.9	12321.2	14025.5	15,841
Hebei	2478.9	3481.6	3801.8	4293.4	4795.5	5149.7	5958	7119.7	8081.4	9101.9
Shanxi	1905.6	2890.7	3180.9	3665.7	4097.2	4244.1	4736.3	5601.4	6356.6	7153.5
Inner mongolia	2038.2	2988.9	3341.9	3953.1	4656.2	4937.8	5529.6	6641.6	7611.3	8595.7
Liaoning	2355.6	3690.2	4090.4	4773.4	5576.5	5958	6907.9	8296.5	9383.7	10522.7
Jilin	2022.5	3264	3641.1	4191.3	4932.7	5265.9	6237.4	7510	8598.2	9621.2
Heilongjiang	2148.2	3221.3	3552.4	4132.3	4855.6	5206.8	6210.7	7590.7	8603.8	9634.1
Shanghai	5569.4	8247.7	9138.7	10144.6	11440.3	12482.9	13,978	16053.8	17803.7	19,595
Jiangsu	3595.1	5276.3	5813.2	6561	7356.5	8003.5	9118.2	10,805	12,202	13597.8
Zhejiang	4253.7	6660	7334.8	8265.2	9257.9	10007.3	11302.6	13070.7	14551.9	16,106
Anhui	1934.6	2641	2969.1	3556.3	4202.5	4504.3	5285.2	6232.2	7160.5	8097.9
Fujian	3230.5	4450.4	4834.8	5467.1	6196.1	6680.2	7426.9	8778.6	9967.2	11184.2
Jiangxi	2135.3	3128.9	3459.5	4044.7	4697.2	5075	5788.6	6891.6	7829.4	8781.5
Shandong	2659.2	3930.6	4368.3	4985.3	5641.4	6118.8	6990.3	8342.1	9446.5	10619.9
Henan	1985.8	2870.6	3261	3851.6	4454.2	4807	5523.7	6604	7524.9	8475.3
Hubei	2268.6	3099.2	3419.4	3997.5	4656.4	5035.3	5832.3	6897.9	7851.7	8867
Hunan	2197.2	3117.7	3389.6	3904.2	4512.5	4909	5622	6567.1	7440.2	8372.1

(continued)

Table 3 (continued)

Each area in China	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
Guangdong	3654.5	4690.5	5079.8	5624	6399.8	6906.9	7890.3	9371.7	10542.8	11669.3
Guangxi	1864.5	2494.7	2770.5	3224.1	3690.3	3980.4	4543.4	5231.3	6007.5	6790.9
Hainan	2182.3	3004	3255.5	3791.4	4390	4744.4	5275.4	6446	7408	8342.6
Chongqing	1892.4	2809.3	2873.8	3509.3	4126.2	4478.4	5276.7	6480.4	7383.3	8332
Sichuan	1903.6	2802.8	3002.4	3546.7	4121.2	4462.1	5086.9	6128.6	7001.4	7895.3
Guizhou	1374.2	1877	1984.6	2374	2796.9	3005.4	3471.9	4145.4	4753	5434
Yunnan	1478.6	2041.8	2250.5	2634.1	3102.6	3369.3	3952	4722	5416.5	6141.3
Xizang	1330.8	2077.9	2435	2788.2	3175.8	3531.7	4138.7	4904.3	5719.4	6578.2
Shanxi	1443.9	2052.7	2260.2	2644.7	3136.5	3437.6	4105	5027.9	5762.5	6502.6
Gansu	1428.7	1979.9	2134.1	2328.9	2723.8	2980.1	3424.7	3909.4	4506.7	5107.8
Qinghai	1490.5	2151.5	2358.4	2683.8	3061.2	3346.2	3862.7	4608.5	5364.4	6196.4
Ningxia	1724.3	2508.9	2760.1	3180.8	3681.4	4048.3	4674.9	5410	6180.3	6931
Xinjiang	1618.1	2482.2	2737.3	3183	3502.9	3883.1	4642.7	5442.2	6393.7	7296.5

Note: Data in this table are calculated at current price

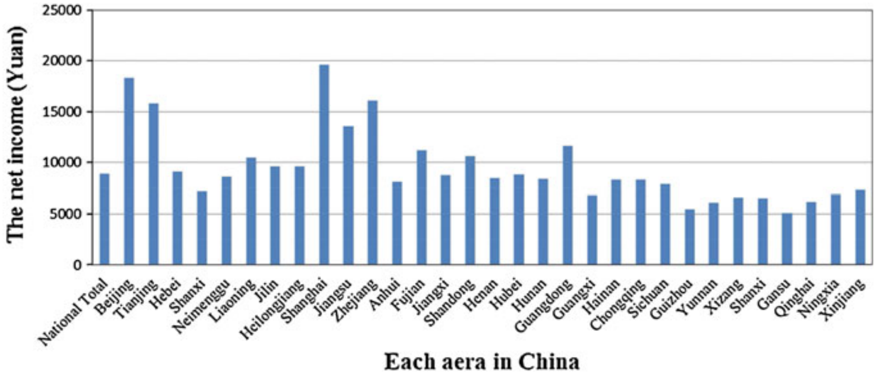

Fig. 4 The per capita net income of Chinese rural households (2013)

3. The social environment of rural endowment insurance fee-to-tax

(1) The internal social advantages and disadvantages

Since the Basic scheme of county-level rural social endowment insurance (for trial implementation) issued in January, 3, 1992, and it has a good mass base in the vast rural areas. For two decades of reform and development, the rural endowment insurance system has given enough benefit to thousands of peasants. The new type of pension insurance system began a pilot implementation in 2009, and this pilot program has already received a wide degree of public support. Thus, public support and good awareness of rural endowment insurance is the advantage to rural endowment insurance fee-to-tax.

By the end of 2012, the entire population was cover by endowment insurance system. Because of dualistic urban-rural social and economic structure brings about too large gap between city and country, as well as underdevelopment rural economy. Rural social security system lagged behind the needs of economic development. In the past, because of the rural endowment insurance system was not perfect in a long time, thousands of peasants unable to attend endowment insurance. Now, the new rural endowment insurance actual pension is too low, but the farmers' expectations are very high in the meantime. If enact the reform of rural endowment insurance fee-to-tax, but couldn't improve the pension benefit immediately, and there is no complete tax bureau and simple operating instruction, it will most likely lead to unfavorable consequences.

(2) The external social opportunities and threats

The construction of a harmonious society of our socialism and a new socialist village provides an opportunity for rural endowment insurance fee-to-tax. Dualistic urban-rural social and economic structure brings about too large gap between city and country, as well as underdeveloped rural economy. To some extent, it hinders our footsteps of building up a harmonious society. Since a long time, the rural endowment insurance lags behind the city endowment insurance. To lessen the gaps between urban and rural endowment insurance has become a more and more important strate-

Table 4 The old-age dependency rate (2000–2013)

Time (Y)	The annual total population (ten thousand people)	The population of age 65 and above (ten thousand people)	Old-age dependency rate (%)
2000	126,743	8821	9.9
2001	127,627	9062	10.1
2002	128,453	9377	10.4
2003	129,227	9692	10.7
2004	129,988	9857	10.7
2005	130,756	10,055	10.7
2006	131,448	10,419	11
2007	132,129	10,636	11.1
2008	132,802	10,956	11.3
2009	133,450	11,307	11.6
2010	134,091	11,894	11.9
2011	134,735	12,288	12.3
2012	135,404	12,714	12.7
2013	136,072	13,199	13.1

gically problem of our country, which has real meaning for constructing a harmonious society. The gap of endowment insurance system between urban and rural is the most typical gap. The development strategy of the socialist harmonious society provides a good opportunity for the rural endowment insurance fee-to-tax. Moreover, a good rural endowment insurance system is the important guarantee of the construction of socialism new countryside. The implementation of rural endowment insurance fee-to-tax can help the government to clear the responsibility. The rural endowment insurance will get more funds and attention.

With the aging trend of the population in the world, the social security system has become the world-wide focus, and China isn't an exception. With the one-child policy and promoting the rural population transfer output in recent years, the speed of population aging in rural area is faster than urban area [18]. No matter what kind of payment model can avoid the negative influence presented by aging population. So, the aging population has become the external social threat for rural endowment insurance fee-to-tax.

For the better description of the aging population in China, we summarize the old-age dependency rate from 2000 to 2013 according to the National Bureau of Statistics in the following Table 4.

The following Fig. 5 summarizes the rate of people over 65 years old of the total population from 2000 to 2013.

4. The technical environment of rural endowment insurance fee-to-tax
(1) The internal technical advantage and disadvantage
The characteristic of tax system itself is the internal technical advantage for rural endowment insurance fee-to-tax, and this is the most direct advantage of all the

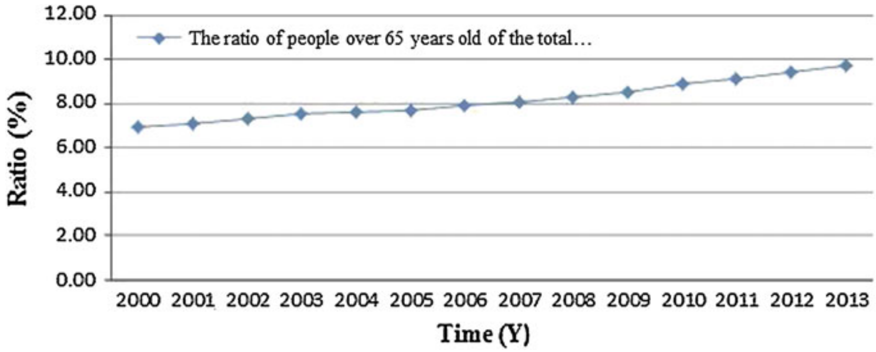

Fig. 5 The ratio of people over 65 years old of the total population (2000–2013)

advantages of rural endowment insurance fee-to-tax. As is known to all, the principle of voluntariness shall be practiced in commercial insurance, but social security is just the opposite. As a mandatory government savings, the old-age insurance system makes it possible for us to remedy individual's short-sighted behavior, and the state and society through the law for the redistribution of national income, the members of the community to guarantee the basic livelihood of the social security measures. The basic attribute of the new rural endowment insurance is voluntary [9]. For this exact reason, it is easy to increase the short-sighted behavior [10]. The biggest advantage is the mandatory of tax revenue. The implementation of rural endowment insurance fee-to-tax, it can enhance the mandatory of the new rural endowment insurance, and it can expand coverage and improve collection rate. In addition, rely on the maturity and perfection of the tax system, it can improve the efficiency of management and reduce the running cost.

The uneven development phenomenon in rural area is very outstanding. Quite a number of low-income people could only meet their basic needs for subsistence. Because of the rural education is far behind the urban in a long time, the peasants' overall quality of cultural in a lower level. The taxpayers' awareness of paying tax is relatively weak, and it is difficult to ensure that all the peasants can take initiative to pay taxes. In addition, not only a vast territory with a sparse population, but also due to the mountains and hills mainly, the traffic is not convenient, which increase the difficulty of tax collection and management. From what has been discussed above is the internal technical disadvantage for endowment insurance fee-to-tax.

(2) The external technology opportunities and threats

The experience of reference at home and abroad is the external technological opportunity for rural endowment insurance fee-to-tax. On the one hand, there have been 18 provinces' tax department is responsible for the collection of social insurance premiums at present in our country, such as Chongqing, Jiangsu, Fujian etc. Experience of these areas is important for rural endowment insurance fee-to-tax. On the other hand, there has been more than 170 countries establish the social security system at present all over the world, and 132 countries levy social security tax [8]. The foreign tax experience is equally important for rural endowment insurance fee-to-tax.

During the National People's Congress in 2005, premier Jiabao-Wen announced to cancel the agriculture tax, officially ending the centuries-old practice farmers paying taxes. In order to solve the issue of agriculture, countryside and farmers, our country proposed to reduce farmers' burden of rural taxes as early as in 2000. Social insurance tax will be contrary to the current rural policy of "tax cuts". The peasants' understanding of insurance tax is very shallow, and they may not understand and accepted the new tax policy, which may bring some negative effect for rural endowment insurance fee-to-tax.

4 Conclusions

According to the analysis of the preceding context, the implementation of rural endowment insurance fee-to-tax can be beneficial to development of rural endowment insurance. It is the most important task for solving the problem of rural endowment insurance to strengthen the construction of rural endowment insurance. In this case, we urgently need a new pension model to get adapt to the rural economic development and expectation of the peasants. Therefore, it is of great significance to study this topic.

(1) The current social and economic environment is good for the rural endowment insurance system, and the implementation of rural endowment insurance fee-to-tax is beneficial to the development of rural endowment insurance system. For the existence of the urban-rural dualistic structure, the development of rural insurance lags behind that of the city. The rural endowment insurance has missed a good development opportunity. Yet there's still an important opportunity for rural endowment insurance at present. We all could continue studying urban endowment insurance fee-to-tax, and spend more time on collecting experiences. For the rural endowment insurance has missed an opportunity for development before, we mustn't miss the next chance.

(2) The integration of urban and rural tax system is very important to the endowment insurance system. In order to promote the development of rural endowment insurance and keeping up with urban pension insurance, the implement of rural endowment insurance tax won't be the ultimate objective. Since the abolishment of agricultural tax on January 1, 2006, the taxation system is not perfect. If the implementation of rural endowment insurance fee-to-tax comes true, the local tax agencies will need to reconstruct the tax system, and especially in rural areas. Moreover, the urban tax system's also needed to be improved, and make sure that the rural endowment insurance tax and urban endowment insurance could realize fee docking.

(3) To strengthen the publicity of rural endowment insurance is very important. The new rural endowment insurance system began a pilot implementation in 2009, and it is a signal of the establishment of a basic and full-covered social endowment insurance system in China. However, not everyone is participated in the new rural endowment insurance, and in the vast rural areas, there are majority of peasants

even don't know the endowment insurance system. A good job of propaganda of endowment insurance policy is urgent to expand the coverage of rural endowment insurance. The publicity of rural endowment insurance tax is more important, since if most of the peasants don't understand the benefits of the endowment insurance tax, their resistance and the new policy can't be successfully implemented in the end.

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The Risks of Knowledge Chain and Measures to Prevent–from the Evolutionary Game Theory

Weixin Yu, Xin Gu and Tao Wang

Abstract In the cooperative innovation process of knowledge chain, benefts conflicts between different partners will produce opportunism behavior and lead to the risks. According to related theories and hypotheses, this paper constructs an evolutionary game model to simulate the process of benefits conflicts. After, the evolutionary stable strategies (ESS) of the model are discussed. Further, based on the ESS analysis, it illustrates the generation mechanism of these risks and puts forward corresponding measures to prevent these risks based on the benefits synergism perspective.

Keywords Knowledge chain · Knowledge chain risks · Evolutionary game theory · ESS analysis · Benefits synergism

1 Introduction

In the knowledge economy times, knowledge becomes the core elements of economic growth from exogenous variables, just as the well-known American management scientist Peter. F. Drucker said "the knowledge will become the real capital and the first wealth". For company, there are two ways to obtain knowledge: internal R&D and external access. But with the knowledge updating accelerates and competition intensifies, the single enterprise can't create all the necessary knowledge in the process of production and management relying on the strength of its own. Therefore, more and

W. Yu
Business School, Sichuan University, Chengdu 610064, People's Republic of China

X. Gu (✉)
Institute for Soft Science, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: guxin@scu.edu.cn

T. Wang
Institute for Innovation and Entrepreneurial Management, Sichuan University,
Chengdu 610064, People's Republic of China

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more enterprises cooperate with their suppliers, their clients, universities, research institutes and even their competitors to set up knowledge strategy alliances. In the alliances, they can share and create knowledge through knowledge flowing. Then, the knowledge chain is formed in the process of knowledge flow between different organizations [7]. Since the 1990s, more and more enterprises constitute knowledge strategy alliances in the form of knowledge chain. In the future, the company complete with the others not only by the strength of its self, but also in the form of knowledge chain.

Because of its main characteristic "informal control", however, there exist information asymmetry, goal inconsistent, ability mismatch and cultural conflict phenomenon etc. in he process of innovation. By the function of circumstance uncertainty and knowledge tacitness, all these phenomena will lead to the risks of knowledge chain. The so-called knowledge risk refers to the loss the chain's members when knowledge can't be transferred, shared and created, because of the uncertainty of the circumstance, the characteristic of both organization and knowledge. Cooperation risk is everywhere in knowledge chain. Das & Teng [10] found that the failure rate of enterprise alliance in the form of knowledge chain ranged from 30 to 50 %.

Some scholars have summarized the risks which exist in knowledge chain and classified these risks. Such as, Yang [2] researched the risks in the knowledge chain and divided these into controllable and uncontrollable. Li [1] analyzed and evaluated the risk of knowledge sharing in knowledge chain. Grabber [4] pointed out that the risk of lock-in include three aspects: function, cognition and politics lock-in. The present research mainly concentrates in the risk type, assessment and measures to prevent. However, the formation mechanism of in-depth analysis of knowledge chain risk and corresponding treatments based on the analysis are less studied. According to related theories and hypotheses, this paper constructs an evolutionary game model to simulate the benefits game process in the cooperative innovation of knowledge chain. After, the evolutionary stable strategies (ESS) of the model are discussed. Further, based on the ESS analysis, it illustrates the generation mechanism of the knowledge chain risks and puts forward corresponding measures based on benefits synergism to prevent these risks. This research may give some inspirations to the enterprises about risk management in cooperative innovation.

2 Evolutionary Game Model of Knowledge Chain

2.1 Hypothesis to the Knowledge Chain Evolutionary Game Model

The cooperative innovation of knowledge chain requires its members to share their information and knowledge [3]. Nevertheless, the members are independent and they cooperate-compete to each other. In order to maximize their own interests, they adjust their strategies constantly. If there is improper distribution of interests, it will lead to the deviation between individual interests and the overall interests. Then, the members may take opportunistic behavior in pursuit of maximum interest, which will result in the failure of cooperative innovation and produce the knowledge chain risks. In order to facilitate the research, the following hypothesizes are putted forward:

1. Hypothesize to partners
The knowledge chain members include core enterprise, university, scientific research institutions, suppliers and dealers etc. [11]. Here two organizations will be considered, partner 1 and partner 2. The two partners are limited rationally, which means that they can't find their optimal strategy in the beginning but they can find the better strategy through trial and error. That's to say, the equilibrium of the game is adjusted and improved constantly in the process, rather than a result of selection only once.

2. Hypothesize to strategy space
Both partner 1's and partner 2's strategy spaces are cooperation, non-cooperation. Under the "cooperation strategy", the partners fulfill the contract and cooperate with each other to innovate. They share their knowledge and collaborate with each other in order to maximize the value of knowledge chain. While under the "non-cooperation", they research independently or take opportunistic behavior in the process of cooperative innovation. For example, they don't share their knowledge completely. At the same time, they learn the knowledge shared by others or steel others' core technology even, on basis of which they research by their selves. Hypothesize that the probability for partner 1 to take "cooperation strategy" is "x" and "non-cooperation" is "$1 - x$", while "y", "$1 - y$" for partner 2. $0 \leq x, y \leq 1$.

3. Hypothesize to benefits function
Amuse that amount of knowledge invested by partner 1 and partner 2 is "a" and "b". (1) When both partners choose "non-cooperation", each gets income λA^a and λB^b, and knowledge chain gets total income $\lambda B^b + \lambda B^b$. "A" and "B" are numbers greater than 1, which stand for the contribution degree to the knowledge respectively. "A", "B" is bigger, the contribution to the knowledge is larger. λ is a number greater than 0, which stands for benefit factor. (2) When both partners choose "cooperation strategy", partner 1 and partner 2 get excess benefits $\lambda A^a B^b - \lambda A^a \lambda B^b$ because of the synergistic effect. They distribute the excess return according to their respective contribution to knowledge and bargaining power. Assuming that the distribution proportion is θ and $1-\theta$ $(0 < \theta < 1)$, partner 1 and partner 2 get $\lambda A^a + \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b)$ and $\lambda B^b + (1-\theta)(\lambda A^a B^b - \lambda A^a - \lambda B^b)$ respectively under the strategy "cooperation". (3) When partner 1 chooses "cooperation" strategy, while partner 2 chooses "non-cooperation", partner 1 can get its own independent innovation return and penalty C, $\lambda A^a + C$ totally. Partner 2 breaks his promise to innovate independently after he has learned partner 1's core technology and gets benefits π. The total benefits of him is $\lambda B^b + \pi - C$. By the same token, when partner 1 chooses "non-cooperation" strategy, while partner 2 chooses "cooperation", they get $\lambda A^a + \pi - C$ and $\lambda B^b + C$ respectively. 2×2 game payment matrix is shown in Table 1.

Table 1 Game payment matrix of cooperative innovation

		Partner 2 cooperation (y)	Non-cooperation ($1-y$)
Partner 1	Cooperation (x)	$\lambda A^a+\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b)$, $\lambda B^b+(1-\theta)(\lambda A^a B^b-\lambda A^a-\lambda B^b)$	λA^a+C, $\lambda B^b+\pi-C$
	Non-cooperation ($1-x$)	$\lambda A^a+\pi-C, \lambda B^b+C$	$\lambda A^a, \lambda B^b$

2.2 Construction of Evolutionary Game Model for Knowledge Chain

According to "2 × 2 game payment matrix" (Table 1), Partner 1's expected return under "cooperation" strategy is,

$$U_{11}=y[\lambda A^a+\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b)]+(1-y)(\lambda A^a+C). \tag{1}$$

Partner 1's expected return under "non-cooperation" strategy is,

$$U_{12}=y(\lambda A^a+\pi-C)+(1-y)\lambda A^a. \tag{2}$$

Partner 1's average expected return is,

$$\begin{aligned}U_1=&x\{y[\lambda A^a+\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b)]+(1-y)(\lambda A^a+C)\}\\&+(1-x)[y(\lambda A^a+\pi-C)+(1-y)\lambda A^a].\end{aligned} \tag{3}$$

So, partner 1's replicated dynamic equation is,

$$\frac{dx}{dt}=x(U_{11}-U_1)=x(1-x)\{[\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b)-\pi]y+C\}. \tag{4}$$

By the same token, partner 2's replicated dynamic equation is,

$$\frac{dx}{dt}=x(U_{21}-U_2)=y(1-y)\{[(1-\theta)(\lambda A^a B^b-\lambda A^a-\lambda B^b)-\pi]y+C\}. \tag{5}$$

Let $\frac{dx}{dt}=0$, $\frac{dy}{dt}=0$. Five equilibrium points of cooperative innovation dynamic game strategy system can be getted. That's (0, 0), (0, 1), (1, 1), (1, 0) and $\left(\frac{C}{(\pi-(1-\theta)(\lambda A^a B^b-\lambda A^a-\lambda B^b))}, \frac{C}{(\pi-\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b))}\right)$.

3 Analysis of the Formation Mechanism of Knowledge Chain Risk

3.1 ESS Analysis of Partner 1

Let $F_1(x) = \frac{dx}{dt}$. When $F_1^{'}(x^*) < 0$, x^* is the ESS (Evolutionary Stable Strategy), according to the properties of differential equation stability theorem and the evolutionary stable strategy.

(1) When $0 < \frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} < 1$, if $y > \frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$, then $F_1^{'}(0) < 0$ and $x^* = 0$ is the ESS. The result of the game is that partner 1 with bounded rationality will choose "non-cooperation" eventually when the probability of partner 2 to choose "cooperation" strategy is greater than a certain value.

If $y < \frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$, then $F_1^{'}(1) < 0$ and $x^* = 1$ is the ESS. The result of the game is that partner 1 with bounded rationality will choose "cooperation" eventually when the probability of partner 2 to choose "cooperation" strategy is smaller than a certain value.

If $y = \frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$, then $F_1(x) = 0$ and all the "x" is the ESS.

(2) When $\frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} > 1$, then $F_1^{'}(1) < 0$ and $x^* = 1$ is the ESS under any conditions. The result of the game is that partner 1 with bounded rationality will choose "cooperation" eventually no matter what strategy partner 2 chooses, when penalty increased to the degree that partner 1's extra net return under "non-cooperation" strategy is less than the excess return under "cooperation" strategy.

(3) When $\frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} < 0$, then $F_1^{'}(1) < 0$ and $x^* = 1$ is the ESS under any conditions. The result of the game is that partner 1 with bounded rationality will choose "cooperation" eventually no matter what strategy partner 2 chooses, when partner 1's extra net return under "non-cooperation" strategy is less than the excess return under "cooperation" strategy because of the reasonable benefits allocation.

3.2 ESS Analysis of Partner 2

Let $F_2(y) = \frac{dy}{dt}$. When $F_2^{'}(y^*) < 0$, y^* is the ESS.

(1) When $0 < \frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} < 1$,

If $x > \frac{C}{(\pi-\theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$, then $F_2^{'}(0) < 0$ and $y^* = 0$ is the ESS. The result of the game is that partner 2 with bounded rationality will choose "non-cooperation" eventually when the probability of partner 1 to choose "cooperation" strategy is greater than a certain value.

If $x < \frac{C}{(\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$, then $F_2^{'}(1) < 0$ and $y^* = 1$ is the ESS. The result of the game is that partner 2 with bounded rationality will choose "cooperation" eventually when the probability of partner 1 to choose "cooperation" strategy is smaller than a certain value.

If $x = \frac{C}{(\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$, then $F_2(y) = 0$ and all the "y" is the ESS.

(2) When $\frac{C}{(\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} > 1$, then $F_2^{'}(1) < 0$ and $y^* = 1$ is the ESS under any conditions. The result of the game is that partner 2 with bounded rationality will choose "cooperation" eventually no matter what strategy partner 1 chooses, when penalty increased to the degree that partner 2's extra net return under "non-cooperation" strategy is less than the excess return under "cooperation" strategy.

(3) When $\frac{C}{(\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} < 0$, then $F_2^{'}(1) < 0$ and $y^* = 1$ is the ESS under any conditions. The result of the game is that partner 2 with bounded rationality will choose "cooperation" eventually no matter what strategy partner 1 chooses, when partner 2's extra net return under "non-cooperation" strategy is less than the excess return under "cooperation" strategy because of the reasonable benefits allocation.

3.3 Analysis of Knowledge Chain Risk

Draw the phase diagram of partner 1 and partner 2 in the same coordinate representation on the plane, as shown in Fig. 1.

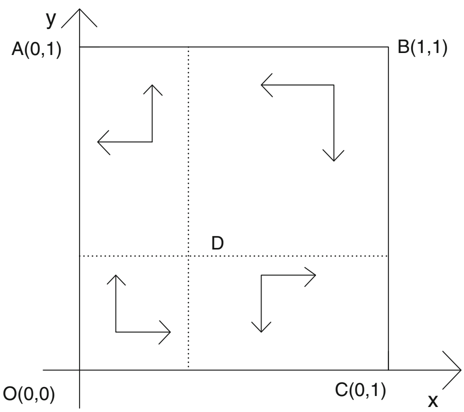

Fig. 1 The phase diagram of partner 1 and partner 2

As is seen in the Fig. 1, point O and B are not stable starting points, point D is saddle point, and point A as well as point C are the evolutionary stable points. That's to say, when partners' extra net return under "non-cooperation" strategy is greater than the excess return under "cooperation", and the extra return under "non-cooperation" is greater than excess return, there exit many risks in the process of cooperative innovation. These risks are as follows:

1. The leakage of core knowledge
The knowledge of organization, especially the technical knowledge is the source of organization's competitive advantage [9]. Because the extra benefits getted from breaking contract then to innovate independently after learning the others' core knowledge is greater than allocated benefits excess from continuing to cooperation innovation. That's to say $\pi > \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b)$ and $\pi > (1-\theta)(\lambda A^a B^b - \lambda A^a - \lambda B^b)$. On this condition, there exist opportunism behavior tendency. Because the relationship between the partners is implicit contract relationship, the punishment to the opportunism behavior is insufficient, which means $\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b) > C$ and $\pi - (1-\theta)(\lambda A^a B^b - \lambda A^a - \lambda B^b) > C$. Under these conditions, with the increase of partners' interaction frequency in the cooperative innovation process, it may happen that some partners steal the others' core knowledge. If the knowledge and technology is copied, its ability to create a unique value will lose, which lead to the loss of competitiveness, but also cultivate its competitors. If there are no strong punitive measures, the behavior that harms others to benefit oneself will become more and more frequent until when the knowledge chain collapse [6].

2. The lack of knowledge sharing
In order to realize knowledge transferring and sharing successfully, mutual trust is an important element [8]. If the knowledge chain is lack for sufficient trust, its partners will tend to conservative or try for knowledge sharing, which will form a strong resistance to the flow of knowledge and knowledge creation. On the one hand, if $0 < \frac{C}{(\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))} < 1$ and $0 < \frac{C}{(\pi - (1-\theta)(\lambda A^a B^b - \lambda A^a - \lambda B^b))} < 1$, there exist opportunism behavior tendency. Under these conditions, it's easy to produce a suspicion and opposite atmosphere, which causes the partners unwilling to share their knowledge. On the other hand, a necessary condition for cooperation and knowledge sharing among knowledge chain is fair and reasonable distribution of cooperation benefits. If the allocation is unreasonable which means $\frac{a}{b} \neq \frac{\theta}{1-\theta}$, the trust will be destroyed and the knowledge sharing willingness will be reduced. Lack of knowledge sharing will reduce $\lambda A^a B^b - \lambda A^a - \lambda B^b$, $\frac{C}{(\pi - (1-\theta)(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$ and $\frac{C}{(\pi - \theta(\lambda A^a B^b - \lambda A^a - \lambda B^b))}$. It will strengthen the opportunism behavior further, as a result forming a vicious circle of mutual distrust, which leads to the disintegration of knowledge chain.

3. Path lock-in
Path lock-in refers to one system once in a path, will reinforce and expand itself along the path in the role of inertia, so that the system tends to lock [12]. With the further expansion of cooperative innovation in the knowledge chain, "a", "b" increase, and the special assets increase as a result. Firstly, as the increase of group

interaction, partners deepen understanding the others' advantage and disadvantages. Because of the imperfection of the contract, there will exists a "rip off" behavior, for instance some partners may use other partners' weakness to blackmail. Secondly, with the increase of "a" and "b", the scale effect and learning effect of knowledge chain highlight, which means $\lambda A^a B^b - \lambda A^a - \lambda B^b$ gets greater. Then the initial technology route will continue to enhance. If there is a major technological change, too much dependence on initial path will lead to the decline of the knowledge chain along the "North path II". At this time, technology choices of the partners are bound to the collective choice. It's very difficult to get rid of the strong ties. As a result, technology path and cooperative relationship will be locked in the existing path of low efficiency for a long time.

4. The weakness of innovation dynamic
Because the achievements of knowledge innovation are non-competitive and low exclusive public goods, such as CDs, software, pharmaceuticals, all partners can benefit from it, including those who didn't share the cost of innovation. That the partners can obtain these achievements without paying any cost will lead to $\pi - (1 - \theta)(\lambda A^a B^b - \lambda A^a - \lambda B^b)$ increase. Then some partners may obtain the achievements by the way of "free rider". Knowledge creation is a high input and high risk activity. However, all the costs and risks are undertaken by those who take "cooperation" strategy only. This unreasonable cost-income structure will lead to "free rider" behavior. As a result, rational, self interested partners are unwilling to contribute to the overall interests of knowledge chain. Moreover, with the increasing of partners, hitchhike motivation is more intense and free riding behavior is also more difficult to find out, which will continue to weaken the dynamic of cooperative innovation [13].

4 Measures to Prevent Knowledge Chain

Draw the phase diagram of $\frac{C}{(\pi-\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b))} < 0$, or > 1 and $\frac{C}{(\pi-(1-\theta)(\lambda A^a B^b-\lambda A^a-\lambda B^b))} < 0$, or > 1 in the same coordinate representation on the plane, as shown in Fig. 2.

As is seen in the Fig. 2, point O is not stable starting point, point D and C are saddle points, and point B is the evolutionary stable point. That's to say, when partners' extra net return under "non-cooperation" strategy is greater than the excess return under "cooperation", but the increasing of penalty or allocated excess cooperative innovation returns reasonably leads to the benefits under "cooperation" strategy of both partners is more than the benefits under "non-cooperation" strategy. The evolutionary result of cooperation ship is that both partners take "cooperation" strategy in the long run. Then they continue to perform the contract and the knowledge chain runs healthily. So, we can take measures to reduce the returns under "non-cooperation" strategy and increase the returns under "cooperation" strategy in order to prevent knowledge chain risks. The measures are as following:

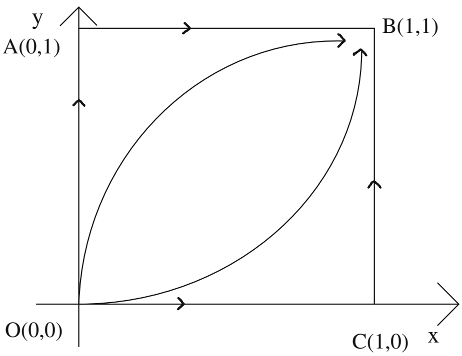

Fig. 2 The phase diagram under the reasonable cost-income structure

(1) The cooperative innovation returns should be allocated fairly and reasonably. The process of knowledge creation in the knowledge is a business process of value creation, benefits sharing and risks sharing [5]. The smooth operation of this process requires a fair and reasonable profit distribution scheme of benefits. The reason is that a fair and reasonable profit distribution can help to strengthen the sense of fairness, form a rational expectation to future income and enhance cooperation confidence, so as to reduce opportunistic behavior. Fairness is come from the comparison their investment and their future earnings. If the contribution degree and the proportion of income distribution doesn't equal $\frac{a}{b} \neq \frac{\theta}{1-\theta}$, some partners' knowledge transfer enthusiasm will be greatly reduced and may even take opportunistic behaviors.

(2) To develop different interest allocation scheme according to the different stage of knowledge innovation. In the process of innovation, the influence factors of cooperative benefits distribution will continue to change, which will affect the distribution pattern. For example, the motivation of partners to stop cooperation and innovate independently after learning others' knowledge is small, because the knowledge sharing is little and the future is uncertain at the beginning of cooperation. But with the expansion of knowledge sharing and creation in a wider range, will gradually increase and the motivation of stopping cooperation will be strengthen. Therefore, it's very necessary to develop different benefits allocation scheme according to different stage of knowledge innovation.

(3) To establish benefit compensation mechanism for knowledge sharing. To get some shared knowledge is one purpose for partners in the knowledge chain. However, "public goods" as the knowledge is, there exist retention behavior in the process of cooperative innovation because of "free rider" behavior, which results in the lack of knowledge sharing. In order to improve the willing of the partners to share their knowledge, we should establish a set of interest compensation mechanism. Reasonable compensation to the partners, who share and dissemination of technology in order to enhance the whole interests of knowledge and make their own interests temporarily affected, so that the marginal

spillover can be compensated at the margin, makes cooperative cooperation of them to be their own needs.

(4) To increase the penalty for contract breaking. The partner take "cooperation" or "non-cooperation" is depending on the consideration about the returns and costs of contract breaking. Therefore improving the penalty "C" can reduces the opportunism behavior effectively. Through property rights and relevant contract law gives the contract breakers sufficient punishment, which can encourage partners to give up opportunism behavior and increase the cooperative innovation benefits "$\lambda A^a B^b$" as a result. The increase of "C" and "$\lambda A^a B^b$", can make $\frac{C}{(\pi-\theta(\lambda A^a B^b-\lambda A^a-\lambda B^b))}$ and $\frac{C}{(\pi-(1-\theta)(\lambda A^a B^b-\lambda A^a-\lambda B^b))}$ become bigger, and prevent knowledge chain risks as well.

(5) To establish a long-term relations of cooperation. From the perspective of game theory, in the process of single game, partners are easy to take opportunistic behaviors. On the one hand, to establish a long-term relationships of cooperation can increase the potential benefits of cooperative innovation "$\lambda A^a B^b$". On the other hand, in the long-term cooperation the opportunism behavior can only obtain short-term benefits and long-term benefits can't be obtained, but also left a bad reputation, making the contract breakers' reputation depreciation. In addition, a long-term relationship can make proprietary assets become larger and larger just like a rolling snowball, which forms a virtuous circle of trust, thereby reducing the knowledge chain risks.

5 Conclusions

In this paper, according to related theories and hypotheses, we construct an evolutionary game model and use this model to analysis the formation mechanism of knowledge chain risks, for example, leakage of core knowledge, lack of knowledge sharing, path lock-in and weakness of dynamic. After, 5 measures are put forward to prevent these risks. These discussions can provide some enlightens for the organization in cooperative innovation risk management: benefits synergism can reduce opportunistic behavior, which can prevent knowledge chain risk to take place. However, there is no mandatory power to ensure interest coordination mechanism, because cooperative innovation is the spontaneous behavior of equal partner. This can be discussed in-depth in the future.

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Impact of Organizational Justice on Job Satisfaction of Employees in Banking Sector of Pakistan

Muhammad Umair Akram, Muhammad Hashim and Zubair Akram

Abstract The aim of this study was to determine the relationship between organizational justice and employee job satisfaction. Privatize banks (ABL, UBL, SCB, Kasahf, Alfalah) were selected for the study and a questionnaire were distributed among the 100 bank employees. A total of 53 questionnaires were received back with a response rate of 53 %. The results showed that distributive justice has positive and significant impact on job satisfaction. The analysis also revealed that procedural justice has significant negative relationship with job satisfaction. Practical level of organizational justice can be enhanced the level of job satisfaction.

Keywords Organizational justice · Procedural justice · Distributive justice · Banking employees

1 Introduction

A group of peoples that work together for achieving common goals under a structured system is called organization. For the achievement of these goals there is also a need of effective managers or employees. Now organizations are considering human resource as the most precious asset for them because human resource is an important factor for effectiveness and success of organization.

Organizational justice concerns employees' perceptions of fairness in workplaces and has become a popular concept in understanding workplace attitudes and behavior

M.U. Akram
School of Economics and Management, Beijing University of Posts and Telecommunication, Beijing 100876, People's Republic of China

M. Hashim (✉)
Faculty of Management Sciences, National Textile University, Faisalabad 38000, Pakistan
e-mail: Phashimscu@gmail.com

Z. Akram
Institute of Business and Management Science University of Agriculture, Faisalabad 38040, Pakistan

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[3, 9]. Greenberg [13] suggested the four factor model (including distributive and procedural justice and breaking down interactional justice into informational and interpersonal justice and researcher [7] have provided a strong empirical support for this model.

In a society, people perceived justice from the legitimacy of their country same like that people in an organization have perception of organizational justice, which comprises of four dimensions namely distributive justice, procedural justice, informational justice and interactional justice.

First dimension distributive justice is concerned with fairness of allocation of resources [2]. Refers to perceives fairness of outcomes such as pay, recognition, promotion, performance appraisal and rewards. Second dimension is procedural justice concerned with the procedure use to allocating resources [17] refers to perceived fairness of decision making process. Third dimension interactional justices concerned with the quality of treatment perceived form decision maker [4], refer to respect of the relationship between employee and manager. The last dimension is informational justice which refers to the truth fullness justification of important information provided to employee [4, 7, 14].

The term organizational justice is used in this study to express the degree to which employees perceive the overall fairness in organizational rules, procedures and policies that are related to their work. In this study, two components of organizational justice are included which are distributive justice and procedural justice. Human wants justice in the working environment, in terms of procedures used to determine reward, distribution of reward which make them satisfied or committed towards their work or organization. Organization justice is based on equity theory [1], which demostrated that worker bring his input in the organization like input of education, effort experience etc. and in return of these input he expected the fair outcome of distribution of reward and procedure [11, 13], therefore distributed justices is perceive fairness in distribution and allocates of outcomes which base on input provided by employees in organization [6, 12, 26].

Procedural justice refers to procedure how pay or promotion is decided within the organization [5, 10, 18, 21]. Mcfarlin and Weeney [19] explained that distributive justice is good predictor of both pays and job satisfaction. Procedural justice is good predictor of personal outcomes and organizational commitment.

Job satisfaction is defined as a person's evaluation of his or her job and work context [20]. Common job satisfaction facets include coworkers, appreciation, benefits, job conditions, pay, promotion, supervision, and organization's policies or procedures [25]. Job satisfaction can be defined as a positive feeling about one's job resulting from evaluating of its characteristics and employees high degree of trust for their employer can cause job satisfaction [23]. Job satisfaction also have impact on other variables like turnover intentions, such as if employee are unsatisfied then they like to leave that organization [8, 22] reported that job satisfaction mean that an employee have effective and emotional responses towards his particular job. Spectur [24] referred job satisfaction as extent a person like his job. Organizational justice has impact on the employee satisfaction regarding his job, environment which motivates him toward organizational commitment. When employee feel that he or she has been not treated fair process in an organization then it's difficult for an employee that he must be satisfied from his job [16]. As job satisfaction will result in committed employees who help in the achievement of organizational goals it is important to identify the factors that affect employee's behavior or job satisfaction. When employees feel that they are treated fairly by organization in every aspect they are motivated to show positive attitude and behavior like job satisfaction. Griffin et al. [15] reported that correctional staff's level of job satisfaction had a significant negative relationship with their emotional exhaustion and feeling of reduced accomplishment.

Banks in Pakistan are more focused industry for economic development. As a result, several banks are performing a significant role in the economic development of the country. This research is an attempt to explore the relationship between organizational justice dimensions and job satisfaction in Pakistani banks.

1. Significance

This study would be helpful to find out that whether or not organizational justice exists in the private banks in Pakistan. This research is important in the sense that it will provide results that can help HR managers to develop and implement an effective strategy considering the justice perception of employees by making suitable decisions about the outcomes and procedures for the employees that can increase their job satisfaction, motivation and commitment of employees that will ultimately increase performance of employees in organization to achieve organizational goals. Distributive and procedural justice have a vital role in determining job satisfaction of employees and if management makes proper communication with employee regarding justice dimensions it will bring positive behaviors in employees. It would show the level of these two justice dimensions exists in Pakistan private banks in this current situation of crises. This research will help bank authorities to notice what dimensions of organizational justice are most important in current era to increase job satisfaction in employees.

2. Research Question

On the basis of pervious researches the following research questions are formulated.

- How Organizational Justice impact on Job satisfaction?
- What is the relationship between distributive justice and job satisfaction?
- What is the relationship between procedural justice and job satisfaction?

3. Research Objectives

- To examine the relationship between organizational justice and Job satisfaction.
- To find out the relationship between distributive justice and Job satisfaction.
- To investigate the relationship between procedural justice and Job satisfaction.

4. Contribution

The contribution of our research is to give guidance to banking sector of Pakistan to improve their existing policies related to rewards and fairness in procedures and develop new policies where it required. Independent Variables: Distributive Justice and Procedural Justice;

Dependent Variable: Job Satisfaction.

5. Hypotheses

Hypothesis 1. There is a positive relationship between distributive justice and job satisfaction.

Hypothesis 2. There is a positive relationship between Procedural justice and job satisfaction.

2 Methodology

All banking employees are population of this study. The data was collected from banking employees. The reason behind using the banking sector was that in banking sector there are proper rules and regulations that are followed in many aspects or as with the advent of time banking industry starts focus on the enhancement of HR practices to show the level of improvement about their workforce or that is the reason for its easiness to determine the level of organization justice exists in banks because it's easy to determine the justice in that environment where proper regulations are defined rather than to its opposite environment industry. The data was collected through self administered questionnaires from one hundred individuals and convenience sampling technique was used in this study.

A total of five commercial banks were taken Standard Chartered Bank, Bank Alfalah, Allied Bank, UBL bank, and Kashf Bank. A sample of 100 employees was consider for analysis and we received back 53 questionnaires with response rate of 82 % male and 12 % female.

Instrument & Measurement

Distributive and Procedural Justice Measure on the scale of Parker et al. [21]. Job satisfaction was assessed by Overall Job Satisfaction measure which is part of the Michigan organizational questionnaire developed by Cammann et al. [5]. This measure has three items that indicate employees' satisfaction with his/her job. A sample item from this scale is "All in all I am satisfied with my job". Responses were taken on a five point scale ranging from 1 = strongly disagree to 5 = strongly agree (Fig. 1).

The purpose behind using already developed scale was that they provide more reliable information related to this kind of project. Respondents who did not complete the questionnaire were not included in our research.

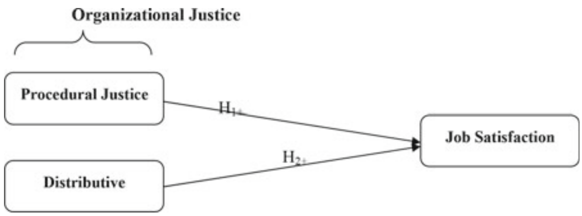

Fig. 1 Theoretical framework

3 Data Analysis

The research was directed in order to measure the job satisfaction concerning organizational justice in banking sector of Pakistan. SPSS 20 version was used to analyze and to test the hypotheses. Descriptive statistics, Mean, S.D, Correlation and Regression Analysis tools was used to analyze the data.

3.1 Results

The reliability of procedural justice and distributive justice are (0.830) and (0.817) respectively. The reliability of job satisfaction is (0.877).

Table 1 shows the mean and standard deviation for overall organizational justice and job satisfaction. The mean score of procedural justice, distributive justice and job satisfaction was in the range of 3.1500–3.7267. It showed that most of respondent were neutral or agree that organizational justice have impact on job satisfaction. Employee will more satisfy if more degree of organizational justice will exists.

The basic purpose of correlation was to find the relationship between variables. The result showed that there is a positive and significant relationship between distributive justice and job satisfaction ($r = 0.278$, $p < 0.05$) so it mean that distributive justice have significant relationship with job satisfaction. The result confirmed (Hypothesis 2) that there was a positive relationship between distributive justice and job satisfaction where the procedural justice have highly significant but negative relationship with job satisfaction ($r = -0.305$, $p < 0.05$). This result rejected the Hypothesis 1 that is there is positive relationship between procedural justice and job satisfaction (Table 2).

Table 3 shows the model summary of regression analysis of independent and dependent variable R the value of table showed correlation coefficient (r) for analysis ($r = 0.4129$). The value of R square (R^2) showed the amount of change in dependent variable due to independent variable. Value R square ($R^2 = 0.169$) in this table showed 16.9 % of change in job satisfaction due to procedural and distributive justice, and rest could be attribute to other factors causes change (Tables 4 and 5).

In this table ANOVA showed the fitness of the model, F value showed that model is fit (between independent and dependent variables) ($p < 0.05$) which is 0.013 it mean this model is highly fit or this result also showed that model is statistically fit.

Table 1 Mean and standard deviation of organizational justices dimension and job satisfaction

	Mean standard	S. deviation
Procedural justice	3.1500	0.67951
Distributive justice	3.7267	0.71484
Job satisfaction	3.5467	0.49377

Table 2 Correlation between organizational justice dimension and job satisfaction

		DJ	PJ
Procedural justice	Pearson correlation	−0.005	
	Sig(2-tailed)	0.973	
Distributive justice	Pearson correlation		−0.005
	Sig(2-tailed)		0.975
Job satisfaction	Pearson correlation	0.278	−0.305[a]
	Sig(2-tailed)	0.051	0.031

[a]Correlation is significant at the 0.05 level (2-tailed)

Table 3 Regression analysis

Regression	0.4129
R^2	0.169
Adjusted R^2	0.134
Standard error	0.45947

Table 4 Regression analysis

	Sum of sqr	Df	Mean srq	F	Sig.
Regression	2.024	2	1.012	4.794	0.013[a]
Residual	9.922	47	0.211		
Total	11.947	44			

[a]Significant at the 0.05 level

Table 5 Coefficients

	Beta	S.E for beta	T	Sig.
DJ	0.191	0.092	2.078	0.043
PJ	−0.221	0.097	−2.285	0.027

DJ distributive justice, *PJ* procedural justice

This table shows the significant relationship between organizational justices. PJ and DJ are independent variables and job satisfaction dependent variable. The result shows that if there is one unit change in distributive justice then it would change 19.1 % increase in employee job satisfaction. The results also showed the significant relationship between distributive justice and job satisfaction ($p = 0.043 < 0.05$), but the relationship with procedural justice is negative and highly significant ($p = 0.027 < 0.05$). It depicted that if there is a one unit change then it could decrease −22.1 % in the job satisfaction of employees.

3.2 Discussion

The research model revealed important findings regarding impact of organizational justice on job satisfaction. This present revealed that distributive justice has positive impact on the banking employee's job satisfaction. It mean if employees find the level of existence of distributive justice in the organization then employee feels more satisfied in term of pay, rewards etc. Result proved that employee were more satisfied when they perceived their outcomes and rewards to be fair as compared to those employees who consider their reward and outcomes as unfair. If employee feels discontent regarding their reward they may decide to leave the organization. There is positive significant relationship found in this study between distributive justice and job satisfaction.

Results also showed that there is significant negative relationship between procedural justice and job satisfaction of banking employees. The reason for this is that employee does not have voice empower in decision making, decisions are made at upper level and move downward as an orders but procedural justice play a major role in perception of employee for job satisfaction. If the high degree of level procedural justice existed in the organization then employee were more motivated and satisfied from their job. Use of procedural justice in organization created positive influence on employee performance, behavior and perception which creates job satisfaction otherwise in the situation of un satisfaction, chances of negative response would increase like leaving the organization. So in order to increase positive attitudes and behavior management of banking sector have to improve organizational justice system in their organizations. It will show more positive behavior in employees rather than negative.

4 Conclusion and Recommendations

This study explored employee perception towards organizational justice in the form of (Distributive justice, procedural justice) and examines its impact on employee job satisfaction in private banks. This study showed that there was positive significant relationship between distributive justice and job satisfaction of employees but there was negative significant relationship between procedural justice and job satisfaction exists in banking sector employees. As correlation analysis showed positive relationship with distributive justice so it accept Hypothesis 2 which prove in results, while Hypothesis 1 is rejected because procedural justice showed negative relationship with job satisfaction of banking employees.

This study recommend that management of banking sector or any other organization should focus on the improvement of organizational justice and make more emphasis on procedural justice present in their organizations because human relations are one of the most important factor lie behind in the success of any organization.

As with any research, this study has several limitations that should be focused. The study is limited only to private banking sector for data collection. The sample size was short to generalized result or only two facets of justice (procedural and distributive) are used in this study. For the future study other two facets can be explore which are interactional or informational justice or other sectors of originations can be use to know that what level and type of justice exist there.

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Study on the Incentive Contracts of Knowledge Chain Organizations' Cooperative Innovation Under Mixed Asymmetric Information

Jian Li, Xianyu Wang and Quan Zhou

Abstract According to incentive problem of cooperative innovation in knowledge chain which is composed of production enterprises and scientific research institutions, this paper puts forward the game model of the simultaneous presence of adverse selection and moral hazard problems based on the principal-agent theory and game theory. Further more, the effective contract incentive mechanism is established. Under this mechanism, scientific research institutions weigh the pros and cons, choose the contracts in consistent with it's knowledge stock quality and pay the appropriate level of efforts, standardize and restrict the research institutes of the behavior, reduce agency problems in the cooperative innovation among organizations in knowledge chain.

Keywords Knowledge chain · Cooperative innovation · Adverse selection · Mixed asymmetric · Information · Incentive contract

1 Introduction

Knowledge chain refers to the chain structure [4], which is formed by knowledge flow between different organizations involved in innovation activities. And its objective is to realize knowledge sharing and creation with enterprise as the core body of innovation. Knowledge chain is composed of organizations with different knowledge resources, including core enterprise (leader), universities, research institutes, suppliers, distributors, customers, and even competitors. In practical social production, any production activity should combine various fields and multidisciplinary professional knowledge together to work smoothly. Any incomplete fragments of knowledge may

J. Li (✉) · X. Wang
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: healthleee@163.com

Q. Zhou
Strategic Planning School, Chongqing Technology and Business University,
Chongqing 400067, People's Republic of China

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lead to counterproductive results. And only combination of individual master pieces of knowledge can maximize the role of knowledge [1]. Therefore, the enterprises, which master different segments of knowledge, need to cooperate, form a knowledge chain, and participate in production process. The formed knowledge-chain should share the resources, costs and benefits.

Since the concept of knowledge chain was first proposed by [7], its research mainly focused on the following aspects: (1) Some studies considered the knowledge chain management as a part of the organization (enterprises) knowledge management. For example, Chen et al. [3] expounded the meanings of the knowledge chain and its role in knowledge management. (2) Some studies constructed the concept model of knowledge chain. From the relationship between an organization's knowledge and its core competitiveness, Holspple and Singh [5] put forward the systematic knowledge chain model on the basis of "value chain" model (Michael porter). (3) Some studies made Proposal of optimization method of Knowledge. The optimization method of enterprise internal knowledge chain was proposed by TKCI [8] (The Knowledge Company Incorporated, 2001), which enhanced an organization's value chain through optimizing participants' individual knowledge and the information flow. (4) Some studies discussed cooperating coordination and conflicting coordination between knowledge chain organizations. For instance, Wu and Gu [9] analyzed the relationship between strength of knowledge chain organizations with innovation efficiency, and believed too high or too low efficiency of relationship intensity are not conducive to innovation. Wu and Zhou [10] studied the cooperative innovation' optimal incentive contract of the knowledge chain under different information condition. Although existing literatures on knowledge chain have done so much research work, most of them put focus on qualitative analysis or single moral hazard study of cooperative innovation between knowledge chain organizations.

Consequently, Based on the condition that the cooperative organization's (agent) quality of knowledge stock and level of knowledge commitment are unobservable, i.e., adverse selection and moral hazard are considered simultaneously, we utilize principal-agent theory to build the game model of both sides, study the incentive contract of the knowledge chain 'cooperative innovation, and find out some useful results, which have certain theoretical value and practical significance.

2 Issues Raised

When a production enterprise (core enterprise) and a research institutes (cooperative organization) cooperate on the function of a product, a cooperative innovation of knowledge chain is formed. As effort level and knowledge stock quality of the scientific research institute are unobservable, the production enterprise faces the problem of how to design an incentive contract to improve the performance of the knowledge chain.

In a knowledge chain, it induces a principal-agent relationship between the enterprise and the scientific research institute, in which the former is the principal, and the latter is the agent.

Function as an agent, the scientific research institute has more information about its own stock of knowledge quality than the production company, which acts as a client. So the production enterprise is the information inferior cooperator.

At the same time, because the production enterprise cannot observe the cooperator' effort degree of (or too high to observe), the adverse selection and moral hazard problems co-exist in the knowledge chain. This problem is caused by asymmetric information of the production enterprise and research institute. So, How to solve the agency problem between the production enterprise and scientific research institute effectively becomes a critical factor in enhancing efficiency of the knowledge chain. In this paper, based on principal-agent theory and game theory, we set up a model to elaborate the relationship between production enterprise and scientific research institute, research the problem of agency for the production enterprise due to the asymmetric information, and try to find out how the production enterprises overcome the problem of agency through incentive contract design.

3 Model Hypothesis and Building

3.1 Model Hypothesis

To facilitate expression, we make the following assumptions:

A knowledge chain formed by a production enterprise (core enterprise) and a cooperative organizations (universities, research institutes and other) (agents). We suppose that the production enterprise (client) in a knowledge chain is risk neutral, and risk aversion coefficient of the cooperative organization (agent) is ρ. The production enterprise authorizes the research institute to innovate on the functions of a product cooperatively in the form of a contract.

The cooperative innovation output $R(e, \theta, \gamma)$ is influenced by the effort level, the quality of knowledge stock of the cooperative organization and external random factors. And level of the output, which is expressed as $R = e + \theta + \gamma$, is positive correlated to the cooperative knowledge organization's effort level e and quality of the knowledge stock, in which R is the innovation output of the knowledge and it can be observed by both sides.

e is the cooperative knowledge organization's effort level, and it cannot be observed by the core enterprise or observation-cost is too high. Let $\theta \in \Theta = [0, 1]$ denotes quality indicator of knowledge stock of the cooperative organization, which is known unilaterally by the cooperative organization. The core enterprise only knows its cumulative distribution function $F(\theta)$ and the distribution density function $f(\theta)$. γ is the external random factor, which follows the averages 0, variance of δ^2 normal

Gaussian distribution. The negative utility of knowledge cooperation organization's inputted effort is denoted as: $\psi(e) = \frac{1}{2}e^2$.

We consider the contract structure as a fixed payment and sharing model $\{w(\theta), k(\theta)\}$, $s(\{R, \theta\}) = w(\theta) + k(\theta) R$, where $s(R, \theta)$ is the total revenue of cooperative organizations (agents), and $w(\theta)$ is a fixed payment paid by the core enterprise. The share proportion of $k(\theta)$ is the payment which the core enterprise gives cooperate organization per unit of product after output increasing. ($k(\theta) \in [0, 1]$) R is the core enterprise's output which results from cooperative innovation after Knowledge chain composed.

Game time sequence is:

(1) The core enterprise (principal) designs a contract including level of output and mode of payment.
(2) The cooperation organization (agent) chooses to accept the contract or not according to its own knowledge stock quality status, showing (Displaying) their own level of knowledge stock quality high and low through contract selection. If it is not accepted, the contract is terminated.
(3) If the cooperation organization (agent) accepts the contract, it determines its level of effort in the knowledge chain according to the terms of the contract.
(4) The core of the enterprise (principal) gives payment according to the level of output and contract.

3.2 Model

The core enterprise's (principal) issue is to design incentive contract menu $\{w(\theta), k(\theta)\}$, and suggest a level of effort to maximize the expected utility; Cooperation organization (agent) chooses corresponding stock of contract according to its Knowledge stock quality θ. The expected utility of core enterprise is as follows:

$$\underset{\theta,\gamma}{E}\,[R - s(\hat{\theta})] = \int_0^1 [e + \theta - w(\theta) - k(\theta)(e + \theta)] f(\theta)\, d\theta. \tag{1}$$

We set up cooperation organization's utility function as $\mu(x) = -\exp-(\rho s)$, $(\rho \geqslant 0)$ as the risk aversion coefficient, $\rho = 0$ shows that the participants are risk neutral, then the expected utility of cooperation organization is as follows:

$$\underset{\gamma}{E}[\mu(s(R, \theta) - \psi(e))], \tag{2}$$

where $s(R, \theta)$ is the actual contract chosen by the cooperative organization, whose quality of knowledge stock is θ-type.

The cooperation organization's deterministic value is as follows:

$$U(\theta, e) = w(\theta) + k(\theta)(e + \theta) - \psi(e) - \frac{1}{2}\rho k^2(\theta)\sigma^2. \tag{3}$$

Core enterprise is the dominant party of the game. When pursuit its own expected utility maximization, it will be affected by the cooperative organization participation constraint and incentive compatibility constraint (moral hazard and adverse selection incentive constraint incentive constraint) control.

The participation constraint of the cooperation organization is that the deterministic value greater than its reservation utility, while giving optimal effort and choosing the contract consistent with its true stock quality of knowledge. That is:

$$U\left(\theta, e^*\right) \geqslant U_0. \tag{4}$$

Moral hazard incentive constraint:

$$e^* \in \arg\max U\ (\theta, e). \tag{5}$$

Adverse selection incentive constraint meets the condition that certainty equivalent income of the cooperation organization is not less than the certainty income of choosing other contracts, That is:

$$U\left(\theta, e^*\right) \geqslant U\left(\tilde{\theta}, e^*\right). \tag{6}$$

So the core enterprise planning issue is:

$$\begin{aligned}(P1)\ \max_{\{w(\theta),k(\theta),e\}} \int_0^1 [e + \theta - w\,(\theta) - k\,(\theta)\,(e + \theta)]f\,(\theta)\,d\theta \\ s.t.\ (I)U\left(\theta, e^*\right) \geqslant U_0 \\ (II)e^* \in \arg\max U\ (\theta, e) \\ (III)U\left(\theta, e^*\right) \geqslant U(\tilde{\theta}, e^*).\end{aligned}$$

4 Model Analysis

By Eqs. (2) and (4) have optimal effort e^*:

$$\begin{aligned}\psi'(e^*) &= k(\hat{\theta}), \\ e^* &= k(\hat{\theta}).\end{aligned} \tag{7}$$

The Eq. (6) into the planning P1, have

$$(P2)\max_{\{w(\theta),k(\theta),e\}}\int_0^1[k(\theta)+\theta-w(\theta)-k(\theta)(k(\theta)+\theta)]f(\theta)d\theta$$

$$\text{s.t. } U(\theta,\theta,k(\theta))\geq 0 \tag{8}$$

$$U(\theta,\theta,k(\theta))\geq U(\theta,\tilde{\theta},k(\tilde{\theta})),\forall\theta,\tilde{\theta}\in[0,1]^2. \tag{9}$$

To ensure that agents do not lie, namely to prevent agent inducing adverse selection problems on θ, it is necessary to make the contract terms $[w(\theta), k(\theta)]$ to meet the following incentive compatibility constraint: derivation of $\forall(\theta,\tilde{\theta})\in[0,1]^2$ there is:

$$\begin{aligned}&(\theta)+k(\theta)(k(\theta)+\theta)-\psi(k(\theta))-1/2\rho k^2(\theta)\sigma^2\geqslant\\&w(\tilde{\theta})+k(\tilde{\theta})(k(\tilde{\theta})+\theta)-\psi(k(\tilde{\theta}))-1/2\rho k^2(\tilde{\theta})\sigma^2.\end{aligned} \tag{10}$$

Equation (1) indicates that when the real technical indicator is θ, the agent lied that $\tilde{\theta}$ is unprofitable.

From Eq. (9), we can get the following first order conditions of $\tilde{\theta}$.

$$\dot{w}(\tilde{\theta})+\left(1-\rho\sigma^2\right)\dot{k}(\tilde{\theta})k(\tilde{\theta})+\dot{k}(\tilde{\theta})\theta=0. \tag{11}$$

To make it the best choice for Cooperation Organization that telling the truth shows its real type, there must be:

$$\dot{w}(\theta)+\left(1-\rho\sigma^2\right)\dot{k}(\theta)k(\theta)+\dot{k}(\theta)\theta=0. \tag{12}$$

And the local second-order conditions must be met, which means the second derivative is less than zero. That is,

$$\left\{\ddot{w}(\tilde{\theta})+\left(1-\rho\sigma^2\right)[\ddot{k}(\tilde{\theta})k(\tilde{\theta})+\dot{k}(\tilde{\theta})\,\dot{k}(\tilde{\theta})]+\ddot{k}(\tilde{\theta})\theta\right\}|_{\tilde{\theta}=\theta}\leqslant 0, \tag{13}$$

$$or\ \ddot{w}(\theta)+\left(1-\rho\sigma^2\right)[\ddot{k}(\theta)k(\theta)+\dot{k}(\theta)\,\dot{k}(\theta)]+\ddot{k}(\theta)\theta\leqslant 0. \tag{14}$$

θ is the optimal value point, and differentiate the Eq. (11) for θ on both sides, we have:

$$\ddot{w}(\theta)+\left(1-\rho\sigma^2\right)[\ddot{k}(\theta)\,\dot{k}(\theta)+\dot{k}(\theta)\,\dot{k}(\theta)]+\ddot{k}(\theta)+\dot{k}(\theta)=0. \tag{15}$$

By Eqs. (12) and (13), it can be derived:

$$\dot{k}(\theta)\geqslant 0. \tag{16}$$

Equations (10) and (13) constitute a local incentive constraint and the local incentive constraints can replace the global incentive [2].

Denote $U(\theta)$ be $U(\theta, e) = w(\theta) + k(\theta)(k(\theta) + \theta) - \frac{1}{2}k^2(\theta) - \frac{1}{2}\rho k^2(\theta)\sigma^2$. Mark $U(\theta, e) = w(\theta) + k(\theta)(k(\theta) + \theta) - \frac{1}{2}k^2(\theta) - \frac{1}{2}\rho k^2(\theta)\sigma^2$, and $\dot{U}(\theta) = \dot{w}(\theta) + (1 - \rho\sigma^2)\dot{k}(\theta)k(\theta) + \dot{k}(\theta)\theta + k(\theta)$.

Furthermore, Eq. (11) gives the following:

$$\dot{U}(\theta) = k(\theta). \tag{17}$$

Programming problem (P2) can be converted into programming problem as follows:

$$(P3) \max_{\{U(\theta), k(\theta), e\}} \int_0^1 \left[k(\theta) + \theta - \frac{1 + \rho\sigma^2}{2}k^2(\theta) - U(\theta)\right] f(\theta)\, d\theta$$

$$\text{s.t. } \dot{U}(\theta) = k(\theta) \tag{18}$$

$$\dot{k}(\theta) \geqslant 0 \tag{19}$$

$$U(\theta) \geqslant U_0. \tag{20}$$

By Eq. (16) and objective function, the participation constraint Eq. (20) can be simplified as $U(\theta) = U_0$. Ignored the Eq. (17) temporarily to work out Eq. (16) as follows:

$$U(\theta) = U(0) + \int_0^\theta k(\tau)\, d\tau, \tag{21}$$

let $U(0) = U_0$ and the result is:

$$U(\theta) = U_0 + \int_0^\theta k(\tau)\, d\tau. \tag{22}$$

Substitute Eq. (21) into principal objective function, there is:

$$\int_0^1 \left[k(\theta) + \theta - \frac{1 + \rho\sigma^2}{2}k^2(\theta) - U_0 - \int_0^1 k(\tau)\, d\tau\right] f(\theta)\, d\theta.$$

By subsection integration, we have the following expression:

$$\int_0^1 \left[k(\theta) + \theta - \frac{1 + \rho\sigma^2}{2}k^2(\theta) - U_0 - k(\theta)\frac{1 - F(\theta)}{f(\theta)}\right] f(\theta)\, d\theta.$$

Derivate the above formula for $k(\theta)$, we can get the first-order condition of $k(\theta)$:

$$k(\theta) = \frac{1}{1+\rho\sigma^2}\left(1 + \frac{F(\theta)-1}{f(\theta)}\right). \tag{23}$$

So:

$$e^* = \frac{1}{1+\rho\sigma^2}\left(1 + \frac{F(\theta)-1}{f(\theta)}\right). \tag{24}$$

Finally, inspect whether meets the monotonic constraint of Eq. (19), which is defined by Eq. (23). In general, condition Eq. (19) meets the condition of dependence on the form of $f(\theta)$. The definition of risk rate [6] is as follows:

$$h(\theta) = \frac{f(\theta)}{1-F(\theta)}.$$

For common distribution, $h(\theta)$ is non-decreasing to θ; Therefore $k(\theta)$ given by the Eq. (23) meets the constraints conditions of Eq. (19), and cooperation organization's sharing ratio $k(\theta)$ is the monotone increasing function of its knowledge stock quality k. That is to say, cooperation organizations that have different knowledge stock quality will choose different contracts, so there is no confusion phenomenon in the optimal contract.

By $U(\theta)$ expression and Eq. (23), have

$$\begin{aligned} w(\theta) &= U(\theta) - k(\theta)(k(\theta)+\theta) + \frac{1+\rho\sigma^2}{2}k^2(\theta) \\ &= U(\theta) + \int_0^1 k(\tau)\,d\tau + k(\theta)\theta - \frac{1-\rho\sigma^2}{2}k^2(\theta). \end{aligned} \tag{25}$$

5 Conclusion

(1) The optimal effort level is equal to the sharing ratio.

By Eq. (7) in the linear payment contract, the optimal effort level e^* of the cooperation organization is equal to the sharing ratio $k(\theta)$. That is, the more output share the Cooperation Organization get, the more effort it will pay.

(2) The optimal level of effort and sharing ratio of knowledge chain Cooperation Organization (agent) is the increasing function of its ability.

By Eq. (19), the sharing ratio of Cooperation Organization increases with the enhancement of its knowledge stock quality θ, and the maximum sharing ratio of cooperation organization is. Therefore, the higher stock quality of the knowledge Cooperation Organization is $k(\theta) = 1/(1+\rho\sigma^2)$, the higher level of their efforts is. Because the cooperation organizations get more shares. For the cooperation Organizations with low quality of knowledge stock, they maintain smaller sharing ratio and less incentive efforts, so their effort level will drop accordingly.

(3) The optimal level of effort and sharing ratio of knowledge chain Cooperation Organization (agent) is a decreasing function of the risk aversion degree.

By Eq. (23), $k(\theta) > 0$ namely cooperation organizations must assume some risks, and the sharing ratio decreases with enhancement of the aversion degree. When $k(\theta) \to 0$, $e^* \to 0$, $w \to U_\theta$, cooperation organization have fixed income, pays no effort, and does not assume any risk; When $\rho \to 0$, for risk-neutral cooperation organization, $k(\theta) \to 1 + (F(\theta) - 1)/f(\theta)$, the sharing ratio $k(\theta)$ of knowledge chain Cooperation Organization reaches the maximum, and they can get a larger proportion of the residual claim right. So the effort level e^* is also maximized.

(4) The optimal effort level e^* and sharing ratio $k(\theta)$ of Cooperation Organization are the decreasing function of the variance of external random factors.

The greater variance of external random factors is, the higher risk cost is. So the optimal risk-sharing requires smaller sharing ratio. When $\sigma^2 \to \infty$, $k(\theta) \to 0$. cooperation organization does not take any risk, so it will not make any effort either.

(5) Deterministic utility of the Cooperation organization is the increasing function of its knowledge stock quality and the growth rate increases with the enhancement of its knowledge stock quality.

By Eq. (21), $\dot{U}(\theta) > 0, \ddot{U} \geqslant 0$, the knowledge stock of high quality can get higher utility.

This paper analyzes the game relation of the knowledge chain organizations in the process of cooperation innovation and sets up effective contract incentive mechanisms based on the principal-agent theory. Under this mechanism, if knowledge chain cooperation organization (agent) chooses the contract which is higher than the quality of its knowledge stock, it will get more negative utility by paying more efforts. Because it must make more efforts to conceal its true quality of knowledge stock in order to get the same output, although it is possible to get a bigger share coefficient. If knowledge chain cooperation organization (agent) chooses a contract in which knowledge stock quality lower than its actual level, it may pay less effort to achieve the same output, but the share coefficient is smaller. Knowledge chain cooperation organization (agents) will weigh the gains and losses, choose its actual knowledge stock quality consistent with the contract and pay the corresponding effort level. Incentive contract mechanism can regulate and restrain the behavior of cooperative organizations, reduce the conflictions among organizations in knowledge chain, and promote the healthy development of the knowledge chain.

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Part V
Computing Methodology

Shrinkage Ridge Regression Estimators in High-Dimensional Linear Models

Bahadır Yüzbaşı and S. Ejaz Ahmed

Abstract In this paper, we suggest shrinkage ridge regression estimators for a multiple linear regression model, and compared their performance with some penalty estimators which are lasso, adaptive lasso and SCAD. Monte Carlo studies were conducted to compare the estimators and a real data example is presented to illustrate the usefulness of the suggested methods.

Keywords Shrinkage estimation · Ridge regression · High-dimensional data · Asymptotic and simulation · Big data

1 Introduction

Consider a linear regression model:

$$y_i = \boldsymbol{x}_i^\top \boldsymbol{\beta} + \varepsilon_i, \quad i = 1, 2, \ldots, n, \tag{1}$$

where $y_i^\top s$ are responses, $\boldsymbol{x}_i = \left(x_{i1}, x_{i2}, \ldots, x_{ip}\right)^\top$ is design points, $\boldsymbol{\beta} = \left(\beta_1, \beta_2, \ldots, \beta_p\right)^\top$ is vector denoting unknown coefficients, ε_i's are unobservable random errors and the superscript $\left(^\top\right)$ denotes the transpose of a vector or matrix. Further, $\boldsymbol{\varepsilon} = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n)^\top$ has a cumulative distribution function $F(\boldsymbol{\varepsilon})$; $E(\boldsymbol{\varepsilon}) = \mathbf{0}$ and $Var(\boldsymbol{\varepsilon}) = \sigma^2 \boldsymbol{I}_n$, where σ^2 is finite and $\boldsymbol{I}_n$ is an identity matrix of dimension $n \times n$.

Along with the rapid development and widespread application of computer technology, the collection and storage of high dimensional data with $p > n$ has become possible in genomics, financial markets, mobile phone communication,

B. Yüzbaşı
Department of Econometrics, Inonu University, 44280 Malatya, Turkey
e-mail: b.yzb@hotmail.com

S.E. Ahmed (✉)
Department of Mathematics and Statistics, Brock University,
St.Catharines L2S 3A1, Canada
e-mail: sahmed5@brocku.ca

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bioinformatics and risk management. From the last two decades, there are many research papers on various penalized approaches for exploring the selection of variables and explaining the statistical properties of high dimensional data.

The properties of shrinkage estimators for fixed dimension have been extensively investigated and well document in reviewed literature, for example we refer to [1–6, 9]. However, there is little available for high dimensional shrinkage estimators. For this reason we propose high dimensional shrinkage estimators using ridge regression estimator, which is introduced by [11, 12], as a full model estimator.

In a high-dimensional setting, that is when $p > n$ model is assumed to be sparse. Under the sparsity assumption, the vector of coefficients $\boldsymbol{\beta}$ can be partitioned as $(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2)$ where $\boldsymbol{\beta}_1$ is the coefficient vector for main effects, and $\boldsymbol{\beta}_2$ is the vector for nuisance effects or insignificant coefficients. We are essentially interested in the estimation of $\boldsymbol{\beta}_1$ when it is reasonable that $\boldsymbol{\beta}_2$ is close to zero.

The paper is organized as following. The full and submodel estimators based on ridge regression and their asymptotic properties are given in Sects. 2 and 3, respectively. The proposed shrinkage and positive shrinkage estimators are introduced in Sect. 4. Penalized estimations are presented briefly in Sect. 5. Results of a simulation study that includes a comparison with penalty estimators in Sect. 6. A real data example is given in Sect. 7. Finally, in Sect. 8, the conclusion is given.

2 Estimation Strategies

First, we consider the case when $p > n$ and p is fixed and the remaining discussions holds.

To begin the work, let us consider the model:

$$\boldsymbol{y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad \text{subject to } \boldsymbol{\beta}^\top \boldsymbol{\beta} \leq \phi,$$

where $\boldsymbol{X} = (\boldsymbol{x}_1, \boldsymbol{x}_2, \ldots, \boldsymbol{x}_n)^\top$, $\boldsymbol{y} = (y_1, y_2, \ldots, y_n)^\top$ and ϕ is inversely proportional to λ^R, which is equal to:

$$\underset{\boldsymbol{\beta}}{\arg\min} \left\{ \sum_{i=1}^{n} \left(y_i - \boldsymbol{x}_i^\top \boldsymbol{\beta} \right)^2 + \lambda^R \sum_{j=1}^{p} \beta_j^2 \right\}.$$

It yields:

$$\widehat{\boldsymbol{\beta}}^{RFM} = \left(\boldsymbol{X}^\top \boldsymbol{X} + \lambda^R \boldsymbol{I}_p \right)^{-1} \boldsymbol{X}^\top \boldsymbol{y},$$

where $\widehat{\boldsymbol{\beta}}^{RFM}$ is called ridge estimator and λ^R is ridge parameter. If $\lambda^R = 0$, then $\widehat{\boldsymbol{\beta}}^{RFM}$ is ordinary least square estimator, and $\lambda^R = \infty$, then $\widehat{\boldsymbol{\beta}}^{RFM} = \boldsymbol{0}$.

A submodel or restricted model with a general restriction is defined as:

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{\varepsilon} \quad \text{subject to } \boldsymbol{\beta}^\top \boldsymbol{\beta} \le \phi \text{ and } \boldsymbol{R\beta} = \boldsymbol{r},$$

where $\boldsymbol{R}$ is an $s \times p$ restriction matrix, and $\boldsymbol{r}$ is an $s \times 1$ vector of constants.

In this paper, we let $\boldsymbol{X} = (\boldsymbol{X_1}, \boldsymbol{X_2})$, where $\boldsymbol{X_1}$ is an $n \times p_1$ sub-matrix containing the regressors of interest and $\boldsymbol{X_2}$ is an $n \times p_2$ sub-matrix that may or may not be relevant in the analysis of the main regressors. Similarly, $\boldsymbol{\beta} = (\boldsymbol{\beta}_1^\top, \boldsymbol{\beta}_2^\top)^\top$ be the vector of parameters, where $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ have dimensions p_1 and p_2, respectively, with $p_1 + p_2 = p, p_i \ge 0$ for $i = 1, 2$.

If model is sparse $\boldsymbol{\beta}_2 = \boldsymbol{0},$ then we have the following submodel:

$$\boldsymbol{y} = \boldsymbol{X}_1\boldsymbol{\beta}_1 + \boldsymbol{\varepsilon} \text{ subject to } \boldsymbol{\beta}_1^\top \boldsymbol{\beta}_1 \le \phi. \tag{2}$$

For the full model estimation, we denote $\widehat{\boldsymbol{\beta}}_1^{RFM}$ as the full model or unrestricted ridge estimator of $\boldsymbol{\beta}_1$ is given by:

$$\widehat{\boldsymbol{\beta}}_1^{RFM} = \left(\boldsymbol{X}_1^\top \boldsymbol{M}_2^R \boldsymbol{X}_1 + \lambda^R \boldsymbol{I}_{p_1}\right)^{-1} \boldsymbol{X}_1^\top \boldsymbol{M}_2^R \boldsymbol{y},$$

where $\boldsymbol{M}_2^R = \boldsymbol{I}_n - \boldsymbol{X}_2 \left(\boldsymbol{X}_2^\top \boldsymbol{X}_2 + \lambda^R \boldsymbol{I}_{p_2}\right)^{-1} \boldsymbol{X}_2^\top$.

For model (2), the submodel or restricted estimator $\widehat{\boldsymbol{\beta}}_1^{RSM}$ of $\boldsymbol{\beta}_1$ has the form:

$$\widehat{\boldsymbol{\beta}}_1^{RSM} = \left(\boldsymbol{X}_1^\top \boldsymbol{X}_1 + \lambda_1^R \boldsymbol{I}_{p_1}\right)^{-1} \boldsymbol{X}_1^\top \boldsymbol{y}.$$

Generally speaking, $\widehat{\boldsymbol{\beta}}_1^{RSM}$ performs better than $\widehat{\boldsymbol{\beta}}_1^{RFM}$ when model is sparse, that is, $\boldsymbol{\beta}_2$ close to a null vector. However, for $\boldsymbol{\beta}_2$ away from the null vector, $\widehat{\boldsymbol{\beta}}_1^{RSM}$ can be inefficient.

3 Asymptotic Analysis

In this section, we present the expressions for asymptotic distributional bias (ADB) and asymptotic distributional risks (ADR) of the full and submodel estimators.

We consider a sequence of local alternatives $\{K_n\}$ given by:

$$K_n : \boldsymbol{\beta}_2 = \boldsymbol{\beta}_{2(n)} = \frac{\boldsymbol{w}}{\sqrt{n}},$$

where $\boldsymbol{w} = \left(w_1, w_2, \ldots, w_{p_2}\right)^\top \in \mathbb{R}^{p_2}$.

The ADB of an estimator $\boldsymbol{\beta}_1^*$ is defined as:

$$ADB\left(\boldsymbol{\beta}_1^*\right) = E\left\{\lim_{n\to\infty}\sqrt{n}\left(\boldsymbol{\beta}_1^* - \boldsymbol{\beta}_1\right)\right\}.$$

The definition of ADR of an estimator $\boldsymbol{\beta}_1^*$ is given by:

$$\begin{aligned} R\left(\boldsymbol{\beta}_1^*\right) &= nE\left[\left(\boldsymbol{\beta}_1^* - \boldsymbol{\beta}_1\right)^\top \boldsymbol{W}\left(\boldsymbol{\beta}_1^* - \boldsymbol{\beta}_1\right)\right] \\ &= n\text{tr}\left[\boldsymbol{W}E\left(\boldsymbol{\beta}_1^* - \boldsymbol{\beta}_1\right)\left(\boldsymbol{\beta}_1^* - \boldsymbol{\beta}_1\right)^\top\right] \\ &= \text{tr}\left(\boldsymbol{W}\boldsymbol{\Gamma}^*\right), \end{aligned} \tag{3}$$

where $\boldsymbol{W}$ is a positive definite matrix (p.d.m) and $\boldsymbol{\Gamma}^*$ is the covariance matrix of $\boldsymbol{\beta}_1^*$.

Assumption 1. We make the following two regularity conditions:

(1) $\frac{1}{n}\max_{1\leq i\leq n}\boldsymbol{x}_i^\top(\boldsymbol{X}^\top\boldsymbol{X})^{-1}\boldsymbol{x}_i \to 0$ as $n \to \infty$, where $\boldsymbol{x}_i^\top$ is the ith row of $\boldsymbol{X}$,

(2) $\boldsymbol{Q}_n = \frac{1}{n}\sum_{i=1}^n \boldsymbol{X}^\top\boldsymbol{X} \to \boldsymbol{Q}$.

We assume that the sub-matrices of $\boldsymbol{Q}$ satisfy the following equations

$$\begin{aligned} \lim_{n\to\infty}\frac{1}{n}\left(\boldsymbol{X}_1^\top\boldsymbol{X}_1 + \lambda^R\boldsymbol{I}_{p_1}\right) = \lim_{n\to\infty}\frac{1}{n}\boldsymbol{X}_1^\top\boldsymbol{X}_1 &= \boldsymbol{Q}_{11}, \\ \lim_{n\to\infty}\frac{1}{n}\boldsymbol{X}_1^\top\boldsymbol{X}_2 &= \boldsymbol{Q}_{12}, \\ \lim_{n\to\infty}\frac{1}{n}\boldsymbol{X}_2^\top\boldsymbol{X}_1 &= \boldsymbol{Q}_{21}, \\ \lim_{n\to\infty}\frac{1}{n}\left(\boldsymbol{X}_2^\top\boldsymbol{X}_2 + \lambda^R\boldsymbol{I}_{p_2}\right) = \lim_{n\to\infty}\frac{1}{n}\boldsymbol{X}_2^\top\boldsymbol{X}_2 &= \boldsymbol{Q}_{22}, \end{aligned}$$

where $\boldsymbol{Q} = \begin{pmatrix} \boldsymbol{Q}_{11} & \boldsymbol{Q}_{12} \\ \boldsymbol{Q}_{21} & \boldsymbol{Q}_{22} \end{pmatrix}$.

Theorem 1 *If* $\lambda^R/\sqrt{n} \to \lambda_0 \geq 0$ *and* $\boldsymbol{Q}$ *is non-singular, then*

$$\sqrt{n}\left(\widehat{\boldsymbol{\beta}}^{RFM} - \boldsymbol{\beta}\right) \xrightarrow{d} N_{p_1+p_2}\left(-\lambda_0\boldsymbol{Q}^{-1}\boldsymbol{\beta}, \sigma^2\boldsymbol{Q}^{-1}\right).$$

Proof For proof we refer to Knight and Fu [13].

The *ADBs* of the estimators are given as follows:

Theorem 2

$$ADB\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right) = -\boldsymbol{\mu}_{11.2}, \quad ADB\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right) = -\boldsymbol{\gamma},$$

where $\boldsymbol{\mu} = -\lambda_0 \boldsymbol{Q}^{-1}\boldsymbol{\beta} = \begin{pmatrix} \boldsymbol{\mu}_1 \\ \boldsymbol{\mu}_2 \end{pmatrix}$, $\boldsymbol{\mu}_{11.2} = \boldsymbol{\mu}_1 - \boldsymbol{Q}_{12}\boldsymbol{Q}_{22}^{-1}\left((\boldsymbol{\beta}_2 - \boldsymbol{w}) - \boldsymbol{\mu}_2\right)$, $\gamma = \boldsymbol{\mu}_{11.2} + \boldsymbol{\delta}$ *and* $\boldsymbol{\delta} = \boldsymbol{Q}_{11}^{-1}\boldsymbol{Q}_{12}\boldsymbol{\omega}$.

Proof See Appendix.

We would like to remark here that the submodel estimator bias function has additional positive term.

Finally, we obtain the *ADR*s of the estimators under $\{K_n\}$ as follows:

Theorem 3

$$R\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right) = \sigma^2 tr\left(\boldsymbol{W}\boldsymbol{Q}_{11.2}^{-1}\right) + \boldsymbol{\mu}_{11.2}^{\top}\boldsymbol{W}\boldsymbol{\mu}_{11.2},$$
$$R\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right) = \sigma^2\, tr\left(\boldsymbol{W}\boldsymbol{Q}_{11}^{-1}\right) + \gamma^{\top}\boldsymbol{W}\gamma.$$

Proof See Appendix.

The above Theorem reveals that if $\boldsymbol{Q}_{12} = \boldsymbol{0}$, then $\boldsymbol{\delta} = \boldsymbol{0}$, $\gamma = \boldsymbol{\mu}_{11.2}$ and $\boldsymbol{Q}_{11.2} = \boldsymbol{Q}_{11}$, all the *ADRs* reduce to common value $\sigma^2 \mathrm{tr}\left(\boldsymbol{W}\boldsymbol{Q}_{11}^{-1}\right) + \boldsymbol{\mu}_{11.2}^{\top}\boldsymbol{W}\boldsymbol{\mu}_{11.2}$ for all $\boldsymbol{\omega}$. On the other hand, if we suppose that $\boldsymbol{Q}_{12} \neq \boldsymbol{0}$, then it is given by following results:

(1) When $\Delta = \left(\boldsymbol{w}^{\top}\boldsymbol{Q}_{22.1}^{-1}\boldsymbol{w}\right)\sigma^{-2}$ (where $\boldsymbol{Q}_{22.1} = \boldsymbol{Q}_{22} - \boldsymbol{Q}_{21}\boldsymbol{Q}_{11}^{-1}\boldsymbol{Q}_{12}$) moves away from 0, the risk of $R\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right)$ becomes unbounded.
(2) If $\boldsymbol{\omega} = 0$, $R\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right) \leq R\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right)$ holds.

In the following section we define high-dimensional shrinkage estimation strategy which combines both full and submodel estimators in an optimal way.

4 High-Dimensional Shrinkage Estimation

The shrinkage ridge regression estimator of $\boldsymbol{\beta}_1$ is defined by:

$$\widehat{\boldsymbol{\beta}}_1^{RS} = \widehat{\boldsymbol{\beta}}_1^{RSM} + \left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \widehat{\boldsymbol{\beta}}_1^{RSM}\right)\left(1 - \kappa\mathscr{L}_n^{-1}\right),$$

where κ is the shrinkage constant and this value is numerically computed.

$$\mathscr{L}_n = \frac{1}{\widehat{\sigma}_{RE}^2}\left(\widehat{\boldsymbol{\beta}}_2^{RFM}\right)^{\top}\left(\boldsymbol{X}_2^{\top}\boldsymbol{M}_1^{R}\boldsymbol{X}_2\right)\widehat{\boldsymbol{\beta}}_2^{RFM},$$

where $\widehat{\sigma}^2_{RE}$ is estimated as follows:

$$\widehat{\sigma}^2_{RE} = \frac{1}{(n-p_1)}(\boldsymbol{y} - \boldsymbol{X}_1\widehat{\boldsymbol{\beta}}_1^{RSM})^\top(\boldsymbol{y} - \boldsymbol{X}_1\widehat{\boldsymbol{\beta}}_1^{RSM}).$$

To overcome the over-shrinking problem inherited by shrinkage ridge estimator, we suggest using the positive shrinkage ridge estimator (RPS). The positive shrinkage ridge estimator $\widehat{\boldsymbol{\beta}}_1^{RPS}$ of $\boldsymbol{\beta}_1$ is defined by:

$$\widehat{\boldsymbol{\beta}}_1^{RPS} = \widehat{\boldsymbol{\beta}}_1^{RSM} + \left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \widehat{\boldsymbol{\beta}}_1^{RSM}\right)\left(1 - \kappa\mathscr{L}_n^{-1}\right)^+,$$

where $z^+ = \max(0, z)$.

5 Penalized Estimation

For a given penalty function $\pi(\cdot)$ and tuning parameter that controls the amount of shrinkage λ, penalized or penalty estimators are estimated by minimizing the following penalized least squares criterion:

$$\sum_{i=1}^{n}\left(y_i - \boldsymbol{x}_i^\top\boldsymbol{\beta}\right)^2 + \lambda\pi(\beta).$$

The general form of penalty function can be defined as follows:

$$\pi(\beta) = \sum_{j=1}^{p}|\beta_j|^\gamma,\ \gamma > 0.$$

5.1 Lasso Strategy

For $\gamma = 1$, we obtain the L_1 penalized least squares estimator or commonly known as Lasso which is introduced by [15],

$$\widehat{\boldsymbol{\beta}}^{\text{Lasso}} = \underset{\beta}{\arg\min}\left\{\sum\nolimits_{i=1}^{n}\left(y_i - \boldsymbol{x}_i^\top\boldsymbol{\beta}\right)^2 + \lambda\sum_{j=1}^{p}|\beta_j|\right\}.$$

The parameter $\lambda \geq 0$ controls the amount of shrinkage. However, this procedure is not oracle.

To resolve this issue, [16] introduced adaptive lasso (aLasso) and [10] suggested the smoothly clipped absolute deviation (SCAD).

5.2 Adaptive Lasso Strategy

The adaptive lasso estimator β^{aLasso} is defined as:

$$\widehat{\boldsymbol{\beta}}^{\text{aLasso}} = \underset{\boldsymbol{\beta}}{\arg\min} \left\{ \sum\nolimits_{i=1}^{n} \left(y_i - \boldsymbol{x}_i{}^{\top} \boldsymbol{\beta} \right)^2 + \lambda \sum_{j=1}^{p} \widehat{\xi}_j \left| \beta_j \right| \right\}, \tag{4}$$

where the wight function is:

$$\widehat{\boldsymbol{\xi}} = \frac{1}{\left| \boldsymbol{\beta}^{*} \right|^{\gamma}}; \ \gamma > 0,$$

$\boldsymbol{\beta}^{*}$ is a consistent estimator of $\boldsymbol{\beta}$. For example, least square estimator can be used as a starting point. The adaptive lasso is essentially an L_1 penalization method and the estimates in (4) can be solved by LARS algorithm developed by [8].

5.3 SCAD Strategy

The L_γ and hard thresholding penalty functions do not simultaneously satisfy the mathematical conditions for unbiasedness, sparsity, and continuity. The continuous differentiable penalty function is defined by:

$$J_{\alpha,\lambda}(x) = \lambda \left\{ I\left(|x| \le \lambda\right) + \frac{(\alpha\lambda - |x|)_{+}}{(\alpha - 1)\lambda} I\left(|x| > \lambda\right) \right\}, \quad x \ge 0, \tag{5}$$

for some $\alpha > 2$ and $\lambda > 0$. SCAD penalty is a symmetric and a quadratic spline on $(0, \infty]$ with knots λ and $\alpha\lambda$. if $\alpha = \infty$, the expression (5) is equivalent to the L_1 penalty in Lasso. The SCAD estimation is given by:

$$\widehat{\boldsymbol{\beta}}^{\text{SCAD}} = \underset{\boldsymbol{\beta}}{\arg\min} \left\{ \sum\nolimits_{i=1}^{n} \left(y_i - \boldsymbol{x}_i^{\top} \boldsymbol{\beta} \right)^2 + \lambda \sum_{j=1}^{p} J_{\alpha,\lambda} \left\| \beta_j \right\|_1 \right\}.$$

6 High Dimensional Simulation Studies

We perform Monte Carlo simulation experiments to examine the quadratic risk performance of the proposed estimators. We simulate the response from the following model:

$$y_i = x_{1i}\beta_1 + x_{2i}\beta_2 + \cdots + x_{pi}\beta_p + \varepsilon_i, \quad i = 1, 2, \ldots, n,$$

where $\boldsymbol{x}_i \sim N_p(\mathbf{0}, \boldsymbol{\Sigma}_x)$ and ε_i are i.i.d. $N(0, 1)$. We also define $\boldsymbol{\Sigma}_x$ that is positive definite matrix with correlated. To generate $\boldsymbol{\Sigma}_x$, we define ρ which is coefficient of correlation $\boldsymbol{X}$. In simulation results are obtained for three kinds of correlation which are low ($\rho = 0.25$), medium ($\rho = 0.5$) and high ($\rho = 0.75$) levels. We assume that the simulated model is sparse, that is $\beta_j = 0$, for $j = p_1 + 1, p_1 + 2, \ldots, p$, with $p = p_1 + p_2$. Hence, we partition the regression coefficients as $\boldsymbol{\beta} = (\boldsymbol{\beta}_1, \boldsymbol{\beta}_2) = (\boldsymbol{\beta}_1, \mathbf{0})$ with $\boldsymbol{\beta}_1 = (1, 1, 1, 1, 1)$.

Each realization was repeated 1000 times to obtain sensible results, and for each realization, we calculated bias of the estimators. We define $\Delta^* = \left\| \boldsymbol{\beta} - \boldsymbol{\beta}_0 \right\|$, where $\boldsymbol{\beta}_0 = (\boldsymbol{\beta}_1, \mathbf{0})$, and $\|\cdot\|$ is the Euclidean norm. In order to investigate the behaviour of the estimators for $\Delta^* > 0$, further samples were generated from those distributions under local alternative hypotheses.

The performance of an estimator $\boldsymbol{\beta}_1$ was evaluated by calculating its mean squared error (MSE) criterion. We numerically calculated the RMSE of $\widehat{\boldsymbol{\beta}}_1^{RSM}$ and $\widehat{\boldsymbol{\beta}}_1^{RPS}$ with respect to $\widehat{\boldsymbol{\beta}}_1^{RFM}$. The relative mean square efficiency(RMSE) of the $\boldsymbol{\beta}_1^{\blacktriangle}$ to the full model estimator $\widehat{\boldsymbol{\beta}}_1^{RFM}$ is indicated by:

$$RMSE\left(\widehat{\boldsymbol{\beta}}_1^{RFM} : \boldsymbol{\beta}_1^{\blacktriangle}\right) = \frac{MSE\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right)}{MSE\left(\boldsymbol{\beta}_1^{\blacktriangle}\right)},$$

where $\boldsymbol{\beta}_1^{\blacktriangle}$ is one of the proposed estimators. The amount by which a RMSE is larger than one indicates the degree of superiority of the estimator $\boldsymbol{\beta}_1^{\blacktriangle}$ over $\widehat{\boldsymbol{\beta}}_1^{RFM}$. All computations were conducted using [14].

We summarized the simulation results in Tables 1 and 2.

It is evident from both tables that the $\widehat{\boldsymbol{\beta}}_1^{RPS}$ estimator outperforms the $\widehat{\boldsymbol{\beta}}_1^{RFM}$ for all Δ^* values. As $\Delta^* = 0$, not surprisingly, $\widehat{\boldsymbol{\beta}}_1^{RSM}$ has the biggest RMSE. However, $\widehat{\boldsymbol{\beta}}_1^{PRS}$ performs better than $\widehat{\boldsymbol{\beta}}_1^{RSM}$ when Δ^* larger than zero.

6.1 Comparison with Penalty Estimators

In this subsection, we compare positive shrinkage ridge regression estimator with penalty estimators. The results are summarized in the following Table 3. We also plot

Table 1 Simulated relative efficiency with respect to $\widehat{\beta}_1^{RFM}$ for $n = 30$ and $p_1 = 5$

ρ	p_2	Δ^*	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$	p_2	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$	p_2	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$
		0.0	7.947	2.636		8.948	3.348		9.541	3.196
		0.5	5.739	2.414		7.488	3.140		7.577	3.174
		1.0	3.074	2.154		4.116	2.659		5.490	2.855
0.25	100	1.5	1.901	1.901	250	2.991	2.524	500	3.165	2.567
		2.0	1.396	1.832		1.880	2.317		2.008	2.414
		4.0	0.497	1.512		0.667	1.893		0.677	1.996
		8.0	0.161	1.277		0.193	1.415		0.216	1.574
		16.0	0.065	1.064		0.076	1.051		0.078	0.990
		0.0	5.059	1.643		6.210	2.140		7.498	2.259
		0.5	4.464	1.528		5.151	2.011		6.509	2.073
		1.0	3.120	1.461		3.440	1.898		3.920	2.159
0.5	100	1.5	1.872	1.444	250	2.332	1.818	500	2.137	1.890
		2.0	1.349	1.444		1.802	1.778		1.781	1.942
		4.0	0.453	1.382		0.512	1.745		0.576	1.862
		8.0	0.139	1.344		0.173	1.639		0.194	1.814
		16.0	0.044	1.278		0.053	1.445		0.069	1.817
		0.0	4.354	1.246		3.392	1.579		4.899	1.813
		0.5	3.328	1.233		3.579	1.476		3.799	1.686
		1.0	2.422	1.218		3.056	1.459		3.013	1.637
0.75	100	1.5	1.892	1.219	250	1.713	1.413	500	2.440	1.608
		2.0	1.281	1.216		1.288	1.397		1.499	1.611
		4.0	0.478	1.229		0.578	1.398		0.608	1.586
		8.0	0.137	1.259		0.186	1.437		0.196	1.607
		16.0	0.042	1.326		0.055	1.475		0.063	1.697

the simulation results in the Fig. 1. In summary, the performance of RPS outperforms penalty estimators in situation both the larger sizes of the coefficient of multicollinearity and the larger values of p_2. We can also conclude that RFM dominates adaptive lasso and SCAD estimators when $n = 30$ and some p_2 values, indicated by the RMSE of aLasso and SCAD being smaller than one.

7 Real Data Application

In this section, we present a real data example to illustrate the usefulness of the suggested strategies for high-dimensional data.

Table 2 Simulated relative efficiency with respect to $\widehat{\beta}_1^{RFM}$ for $n = 80$ and $p_1 = 5$

ρ	p_2	Δ^*	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$	p_2	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$	p_2	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$
		0.0	9.192	3.846		17.351	11.482		23.027	16.243
		0.5	7.054	2.857		12.337	9.339		17.020	11.279
		1.0	4.040	2.295		7.077	5.919		9.852	7.605
0.25	100	1.5	2.312	1.885	250	4.390	4.115	500	6.311	5.565
		2.0	1.690	1.647		2.708	3.043		4.317	4.042
		4.0	0.580	1.365		0.943	2.135		1.054	2.695
		8.0	0.192	1.255		0.240	1.703		0.307	2.263
		16.0	0.068	1.145		0.079	1.324		0.090	1.469
		0.0	8.459	2.051		12.663	5.337		15.923	8.041
		0.5	6.474	1.804		9.487	4.288		12.648	6.168
		1.0	3.884	1.612		6.116	3.293		7.445	4.707
0.5	100	1.5	2.435	1.525	250	3.506	2.767	500	4.337	4.055
		2.0	1.665	1.446		2.323	2.372		3.102	3.595
		4.0	0.511	1.325		0.736	2.019		0.895	2.918
		8.0	0.159	1.277		0.200	1.794		0.251	2.706
		16.0	0.052	1.242		0.063	1.589		0.070	2.094
		0.0	7.535	1.425		8.480	2.729		9.407	4.756
		0.5	4.944	1.321		6.849	2.240		8.171	3.978
		1.0	3.967	1.274		4.523	1.975		5.014	3.058
0.75	100	1.5	2.741	1.245	250	3.156	1.840	500	3.670	2.810
		2.0	1.793	1.233		2.301	1.707		2.329	2.571
		4.0	0.594	1.202		0.709	1.540		0.807	2.348
		8.0	0.165	1.191		0.207	1.468		0.231	2.231
		16.0	0.044	1.204		0.057	1.414		0.059	1.881

7.1 Riboflavin Data

Dataset of riboflavin production by bacillus subtilis containing 71 observations of 4088 predictors (gene expressions) and a one-dimensional response (riboflavin production). In this data set, the response variable is Log-transformed riboflavin production rate (original name: qRIBFLV) and the predictor variables are measuring the logarithm of the expression level of 4088 genes, Bühlmann et al. [7].

In Table 4, it has been shown that the average prediction errors and their standard deviations for proposed estimators based on 10-fold cross validation repeated 1000 times for the Riboflavin Data. As it can be seen from Table 4 that Lasso shrinks 4047 parameters to zero. For this data, RPS outperforms penalty estimators.

Table 3 Simulated relative efficiency with respect to $\widehat{\beta}_1^{RFM}$ for $p_1 = 5$ and some (n, p_2) values when $\Delta^* = 0$ and $\rho = 0.25, 0.5, 0.75$

n	ρ	p_2	$\widehat{\beta}_1^{RSM}$	$\widehat{\beta}_1^{RPS}$	$\widehat{\beta}^{Lasso}$	$\widehat{\beta}^{aLasso}$	$\widehat{\beta}^{SCAD}$
30	0.25	100	6.635	2.517	1.613	1.298	0.685
		200	9.215	2.859	1.530	1.313	0.800
		400	9.699	3.197	1.284	1.011	0.761
		600	9.703	3.088	1.251	1.021	0.767
		1000	10.935	2.889	1.193	1.029	0.835
	0.5	100	4.755	1.622	1.331	1.007	0.649
		200	6.285	1.961	1.335	1.060	0.561
		400	6.295	2.080	1.244	0.995	0.569
		600	6.896	2.126	1.198	0.948	0.588
		1000	7.313	1.993	1.160	1.006	0.589
	0.75	100	3.531	1.241	1.190	0.799	0.486
		200	3.718	1.484	1.165	0.821	0.493
		400	3.799	1.611	1.090	0.837	0.545
		600	4.525	1.801	1.135	0.899	0.535
		1000	4.972	1.746	1.086	0.885	0.534
75	0.25	100	8.208	3.596	3.750	6.013	4.489
		200	14.504	7.407	4.978	9.970	6.607
		400	21.165	11.092	5.230	12.038	7.731
		600	24.800	12.248	5.458	12.270	8.499
		1000	25.067	8.526	4.591	11.103	7.888
	0.5	100	9.045	2.004	3.345	4.919	3.823
		200	10.880	3.740	3.564	5.185	3.684
		400	15.651	5.677	3.526	5.663	3.934
		600	17.820	5.762	3.555	5.181	3.368
		1000	20.151	4.260	3.362	5.356	3.995
	0.75	100	6.779	1.395	2.267	1.786	1.095
		200	7.343	2.085	2.298	1.767	1.017
		400	8.160	3.293	2.114	1.733	1.133
		600	9.156	3.699	1.934	1.490	1.081
		1000	10.562	3.509	1.834	1.458	1.064

8 Conclusion

We suggested shrinkage ridge regression estimators for high-dimensional data in the context of a multiple linear regression model. We provided some asymptotic results and conducted a Monte Carlo simulation. Not surprisingly, when the assumption of sparsity is correct then $\widehat{\beta}_1^{RSM}$ is relatively more efficient than other estimators.

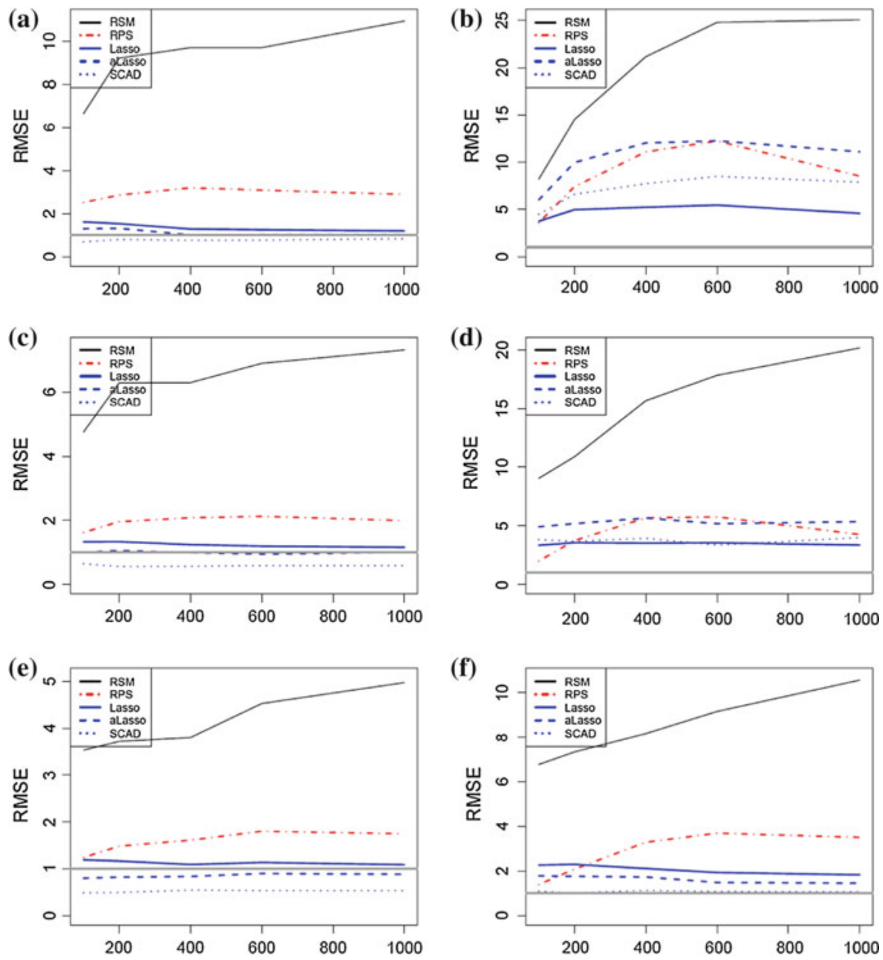

Fig. 1 Relative efficiency of the estimators for $n = 30, 75, p_1 = 5, p_2 = 100, 200, 400, 600, 1000$ and $\rho = 0.25, 0.5, 0.75$ **a** $n = 30, p_1 = 5, \rho = 0.25$ **b** $n = 75, p_1 = 5, \rho = 0.25$ **c** $n = 30, p_1 = 5, \rho = 0.5$ **d** $n = 75, p_1 = 5, \rho = 0.5$ **e** $n = 30, p_1 = 5, \rho = 0.75$ **f** $n = 75, p_1 = 5, \rho = 0.75$

Table 4 Average prediction errors repeated 1000 times for Riboflavin Data

Dataset	(n, p_1, p_2)	RFM	RSM	RPS	Lasso	aLasso	SCAD
Riboflavin	(71, 41, 4047)	0.4224	0.0089	0.0166	0.0169	0.0609	0.0469
		(0.0071)	(0.0010)	(0.0010)	(0.0014)	(0.0027)	(0.0024)

Numbers in the brackets are the corresponding standard errors of the prediction errors

Also, shrinkage estimator performs well when the number of inactive predictors are extremely large relative to the sample size. Further, multicollinearity among the predictors increases, shrinkage estimator performs better penalty estimators.

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Appendix

The distributions of $\widehat{\boldsymbol{\beta}}_1^{RFM}$ and $\widehat{\boldsymbol{\beta}}_1^{RSM}$ are given by:

$$\vartheta_1 = \sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \boldsymbol{\beta}_1\right) \xrightarrow{d} N_{p_1}\left(-\boldsymbol{\mu}_{11.2}, \sigma^2 \boldsymbol{Q}_{11.2}^{-1}\right),$$
$$\text{and } \vartheta_2 = \sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RSM} - \boldsymbol{\beta}_1\right) \xrightarrow{d} N_{p_1}\left(-\boldsymbol{\gamma}, \sigma^2 \boldsymbol{Q}_{11}^{-1}\right),$$

where "$\xrightarrow{d}$" denotes convergence in distribution, $\boldsymbol{\gamma} = \boldsymbol{\mu}_{11.2} + \boldsymbol{\delta}$ and $\boldsymbol{\delta} = \boldsymbol{Q}_{11}^{-1}\boldsymbol{Q}_{12}\boldsymbol{\omega}$.

To obtain the relationship between sub-model and full model estimators of $\boldsymbol{\beta}_1$, we use following equation by using $\widetilde{\boldsymbol{y}} = \boldsymbol{y} - \boldsymbol{X}_2\widehat{\boldsymbol{\beta}}_2^{RFM}$.

$$\begin{aligned}
\widehat{\boldsymbol{\beta}}_1^{RFM} &= \underset{\boldsymbol{\beta}_1}{\arg\min}\left\{\left\|\widetilde{\boldsymbol{y}} - \boldsymbol{X}_1\boldsymbol{\beta}_1\right\| + \lambda^R \left\|\boldsymbol{\beta}_1\right\|^2\right\} \\
&= \left(\boldsymbol{X}_1^\top \boldsymbol{X}_1 + \lambda^R \boldsymbol{I}_{p_1}\right)^{-1} \boldsymbol{X}_1^\top \widetilde{\boldsymbol{y}} \\
&= \left(\boldsymbol{X}_1^\top \boldsymbol{X}_1 + \lambda^R \boldsymbol{I}_{p_1}\right)^{-1} \boldsymbol{X}_1^\top \boldsymbol{y} - \left(\boldsymbol{X}_1^\top \boldsymbol{X}_1 + \lambda^R \boldsymbol{I}_{p_1}\right)^{-1} \boldsymbol{X}_1^\top \boldsymbol{X}_2 \widehat{\boldsymbol{\beta}}_2^{RFM} \\
&= \widehat{\boldsymbol{\beta}}_1^{RSM} - \left(\boldsymbol{X}_1^\top \boldsymbol{X}_1 + \lambda^R \boldsymbol{I}_{p_1}\right)^{-1} \boldsymbol{X}_1^\top \boldsymbol{X}_2 \widehat{\boldsymbol{\beta}}_2^{RFM}.
\end{aligned} \tag{6}$$

Proof (Proof of Theorem 2) From the definition of ADB,

$$\begin{aligned}
ADB\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right) &= E\left\{\lim_{n\to\infty}\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \boldsymbol{\beta}_1\right)\right\} \\
&= -\boldsymbol{\mu}_{11.2}.
\end{aligned}$$

To verify the asymptotic bias of $\widehat{\boldsymbol{\beta}}_1^{RSM}$, we use the Eq. (6). Hence, it can be written as follows:

$$ADB\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right) = E\left\{\lim_{n\to\infty}\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RSM} - \boldsymbol{\beta}_1\right)\right\}$$

$$
\begin{aligned}
&= E\left\{\lim_{n\to\infty}\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \boldsymbol{Q}_{11}^{-1}\boldsymbol{Q}_{12}\widehat{\boldsymbol{\beta}}_2^{RFM} - \boldsymbol{\beta}_1\right)\right\} \\
&= E\left\{\lim_{n\to\infty}\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \boldsymbol{\beta}_1\right)\right\} - E\left\{\lim_{n\to\infty}\sqrt{n}\left(\boldsymbol{Q}_{11}^{-1}\boldsymbol{Q}_{12}\widehat{\boldsymbol{\beta}}_2^{RFM}\right)\right\} \\
&= -\boldsymbol{\mu}_{11.2} - \boldsymbol{Q}_{11}^{-1}\boldsymbol{Q}_{12}\boldsymbol{\omega} \\
&= -\left(\boldsymbol{\mu}_{11.2} + \boldsymbol{\delta}\right) \\
&= -\boldsymbol{\gamma}.
\end{aligned}
$$

Proof (Proof of Theorem 3) Firstly, the asymptotic covariance of $\widehat{\boldsymbol{\beta}}_1^{RFM}$ is given by:

$$
\begin{aligned}
\Gamma\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right) &= E\left\{\lim_{n\to\infty}\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \boldsymbol{\beta}_1\right)\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RFM} - \boldsymbol{\beta}_1\right)^\top\right\} \\
&= E\left(\vartheta_1\vartheta_1^\top\right) \\
&= Cov\left(\vartheta_1\vartheta_1^\top\right) + E\left(\vartheta_1\right)E\left(\vartheta_1^\top\right) \\
&= \sigma^2\boldsymbol{Q}_{11.2}^{-1} + \boldsymbol{\mu}_{11.2}\boldsymbol{\mu}_{11.2}^\top.
\end{aligned}
$$

The asymptotic covariance of $\widehat{\boldsymbol{\beta}}_1^{RSM}$ is given by:

$$
\begin{aligned}
\Gamma\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right) &= E\left\{\lim_{n\to\infty}\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RSM} - \boldsymbol{\beta}_1\right)\sqrt{n}\left(\widehat{\boldsymbol{\beta}}_1^{RSM} - \boldsymbol{\beta}_1\right)^\top\right\} \\
&= E\left(\vartheta_2\vartheta_2^\top\right) \\
&= Cov\left(\vartheta_2\vartheta_2^\top\right) + E\left(\vartheta_2\right)E\left(\vartheta_2^\top\right) \\
&= \sigma^2\boldsymbol{Q}_{11}^{-1} + \boldsymbol{\gamma}\boldsymbol{\gamma}^\top,
\end{aligned}
$$

By using the Eq. (3),

$$
\begin{aligned}
R\left(\widehat{\boldsymbol{\beta}}_1^{RFM}\right) &= \sigma^2 tr\left(\boldsymbol{W}\boldsymbol{Q}_{11.2}^{-1}\right) + \boldsymbol{\mu}_{11.2}^\top\boldsymbol{W}\boldsymbol{\mu}_{11.2}, \\
R\left(\widehat{\boldsymbol{\beta}}_1^{RSM}\right) &= \sigma^2 \mathrm{tr}\left(\boldsymbol{W}\boldsymbol{Q}_{11}^{-1}\right) + \boldsymbol{\gamma}^\top\boldsymbol{W}\boldsymbol{\gamma}.
\end{aligned}
$$

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Applying K-Means Clustering Algorithm Using Oracle Data Mining to Banking Data

Jafarova Hilala and Aliyev Rovshan

Abstract Data clustering refers to the method of grouping data into different groups depending on their characteristics. This grouping brings an order in the data and hence further processing on this data is made easier. In this paper k-means clustering algorithm using Oracle Data Mining is investigated. Applying clustering method to 18 parameters of 40 banks and 10 centralized clusters are obtained.

Keywords Data mining · Cluster analysis · K-means algorithm · Banking data

1 Introduction and Formulation of the Problem

Generally, Data mining is the analysis of data for relationships that have not previously been discovered. Clustering is a popular data analysis and data mining technique. A popular technique for clustering is based on k-means such that the data is partitioned into k clusters. In this method, the number of clusters is predefined and the technique is highly dependent on the initial identification of elements that represent the clusters well.

There are some interesting studies on this topic in literature. For example, Tudor [10] is build an useful model for banking field, based on data mining techniques, by dividing the groups of borrowers into clusters, in order to obtain a profile of the customers (debtors and good payers). As result of clustering, data mining techniques

J. Hilala (✉) · A. Rovshan
Department of Stochastic Control and Applied Statistics,
Institute of Control a Systems of ANAS, Baku, Azerbaijan

J. Hilala
Department of Information Technology in Public Administration,
State Management Academy Under the President Republic of Azerbaijan,
Baku, Azerbaijan
e-mail: hilalajafarova@gmail.com

A. Rovshan
Department of Probability Theory and Mathematical Statistics, Baku State University,
Baku, Azerbaijan

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are implemented on the cluster with bad debtors, reaching a very high accuracy after implementation. Amita and Ashwani [1] the most delegate algorithms k-means and enhanced k-means were examined and analyzed based on their basic approach. The best algorithm in each category was found out based on their performance using Distance measure. These proposed algorithm is implemented and analyzed using a clustering tool WEKA. Koupaie et al. [4] proposed cluster based outlier detection in data stream. Fichtenberger et al. [3] proposed a data stream algorithm for the k-means problem called BICO (BIRCH Meets Core sets for k-means Clustering), that combines the data structure of the SIGMOD test of time award winning algorithm birch with the theoretical concept of corsets for clustering problems. Vijayarani and Jothi [11] two clustering algorithms namely BIRCH with k-means and Birch with CLARANS are used for clustering the data items and finding the outliers in data streams. Different types, sizes of data sets and two performance factors such as clustering accuracy and outlier detection accuracy are used for analysis. Ruth [8] k-means and Fuzzy Logic algorithms also showed an acceptable level of accuracy. Jayakameswaraiah and Ramakrishna [7] ten existing decision tree algorithms have been applied on some data datasets for predicting the performance and all the algorithms are applied for the efficiency of various decision tree algorithms can be analyzed based on their accuracy and time taken to draw from the tree. Indira and Ghosh [5] had revealed a survey of data mining techniques that have been applied to some datasets from UCI machine learning repository by various research groups. Deepika and Bhatia [2] presented a new approach to k-means clustering by providing a solution to initial selection of cluster centroids and a dynamic approach based on silhouette validity index and using algorithm is implemented in the MATLAB R2009b and results are compared with the original k-means algorithm.

Unlike of above mentions studies in present paper k-means clustering algorithm using Oracle Data Mining is investigated. Jafarova and Aliyev [6] applying clustering method to 18 parameters (which are listed in Table 1) of 40 banks (for privacy bank name not given) and 10 centralized clusters are obtained.

Table 1 List of parameters of banks

No.	Name (designation) parameters	No	Name (designation) parameters
1	Liquidity (LIKVID)	10	Interest and similar types of income (FGN)
2	Share capital (NK)	11	Interest and related expenses (FX)
3	Cash (NV)	12	Net interest income (FXM)
4	Requirements to the National Bank (AM)	13	Noninterest income (QFG)
5	Nostro accounts (Nostro)	14	Noninterest expenses (QFX)
6	Loans to banks (BK)	15	Net operating income (XEM)
7	Loans to customers (MK)	16	Special provision for the payment (AXEY)
8	Other assets (DA)	17	Deposit (DEPOZIT)
9	Other liabilities (DP)	18	Taxes and banking activities (VBF)

2 Main Results

It's known that Oracle Data Mining system has two clustering algorithms: k-means and O-cluster. In this study we used a clustering algorithm k-means. Using methodology allows grouping of banks in clusters, that is to combine a number of banks in a single group for the purpose of further comparison between them. Finding the parameters influencing the formation of the cluster allows to identify the main factors clustering.

Note that the cluster analysis is needed for classify of information, it can be used in a certain way to structure variables and see what variables are combined in the first place, and which should be considered separately. This makes it possible to partition objects not on one parameter, and on a set of attributes. In addition, clustering analysis does not impose any restrictions on the form of the objects unlike most mathematical and statistical methods, and allows us to consider the set of initial data almost arbitrary nature.

When comparing objects, it is necessary to have a criterion, on the basis of which will be compared. Typically, such a criterion is the distance between objects. k-means algorithm as the distance using Euclidean distance (Fig. 1).

The node which is called BCUSTER contains data of all parameters are used in the clustering model. Clust Build is designed to build the cluster model. Apply

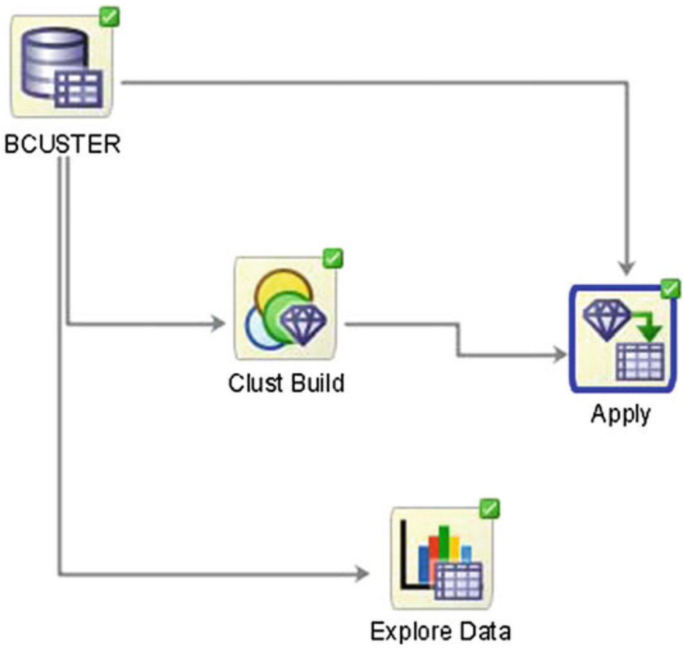

Fig. 1 Interface clustering model

Table 2 Clustering results obtained using the apply function

Designation banks	Number of cluster	Degree of member-ship	Designation banks	Number of cluster	Degree of member-ship
B1	15	0.9999	B21	19	0.9702
B2	14	1	B22	19	0.9651
B3	19	0.9457	B23	19	0.9705
B4	9	1	B24	19	0.9688
B5	19	0.9692	B25	19	0.9703
B6	19	0.9461	B26	19	0.968
B7	2	1	B27	19	0.8102
B8	19	0.9678	B28	19	0.9678
B9	18	0.6903	B29	19	0.9705
B10	13	0.9674	B30	13	0.7846
B11	8	1	B31	19	0.9705
B12	19	0.9661	B32	17	0.9908
B13	18	0.7929	B33	17	0.9941
B14	17	0.9992	B34	19	0.9669
B15	13	0.995	B35	18	0.7229
B16	13	0.9877	B36	19	0.5239
B17	19	0.9426	B37	18	0.9796
B18	19	0.9699	B38	19	0.8414
B19	13	0.8939	B39	16	0.9993
B20	19	0.9703	B40	19	0.5015

represents the result of clustering (Table 2). Using the Explore Data can easily obtain important numerical characteristics (for example, arithmetic mean, standard deviation, skewness and kurtosis) and a histogram.

Oracle Data Mining implements the extended version of the k-means algorithm with the following characteristics: a function of distance, evolution trees, cluster properties (Fig. 2).

The next step is to create a hierarchical clustering algorithm model. Model built from the top down in a hierarchical manner, using binary nodes that are specified in the end. Centroid of internal nodes in the hierarchy are updated to reflect the changes. The algorithm uses the specified criterion branching from one node of the tree until a maximum is achieved when the number of clusters. The criterion branching of a node may be cluster size or dispersion. Default branching criteria is the variance.

Note that for each cluster, k-means algorithm returns the center of gravity, the histogram for each attribute, and generally describing the hyperbox, which covers most of the data related to the cluster. The centroid represents the most typical case in a cluster and provides information about the degree of importance of each attribute and numerical characteristics. This information allows you to determine the degree of membership of an object to a particular cluster. Figures 3 and 4 are examples.

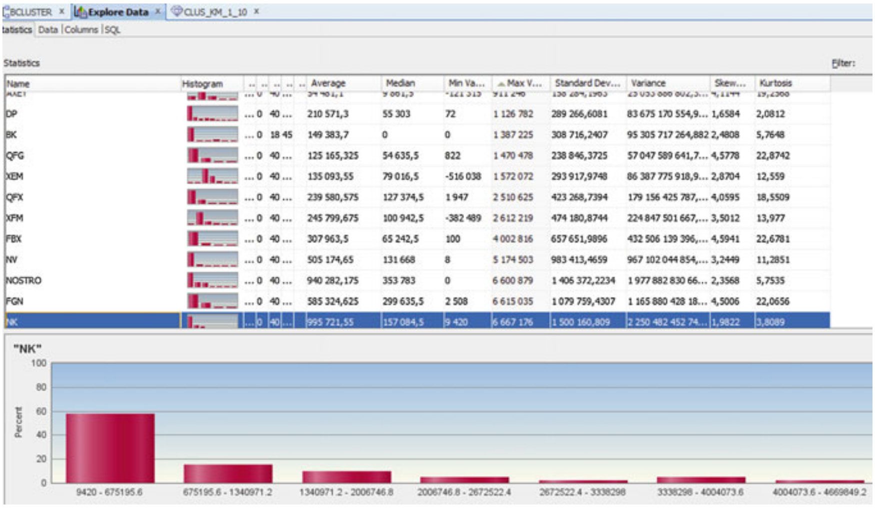

Fig. 2 The result function of explore data

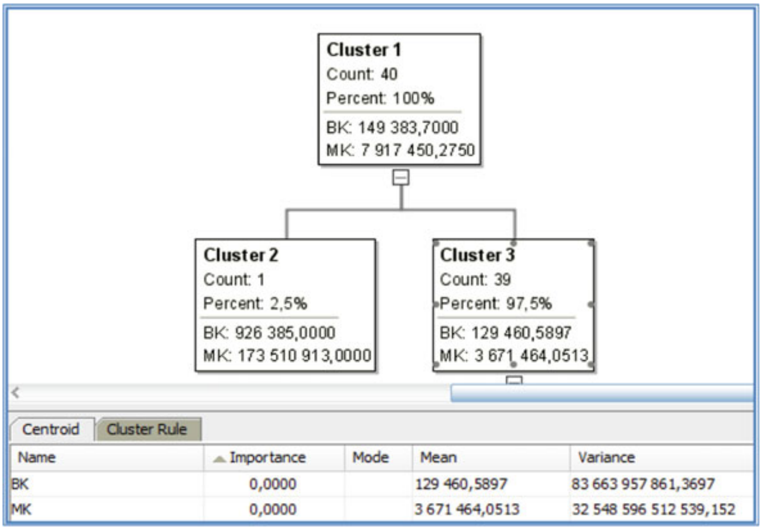

Fig. 3 Clustering centroid panel for cluster 3

Since it was built ten clusters, we got ten rating groups; maximum and minimum power supplies groups are presented in the following Table 2.

The clusters discovered by enhanced k-means are used to generate a Bayesian probability model that is then used during scoring (model apply) for assigning data points to clusters. The traditional k-means algorithm can be interpreted as a mixture model where the mixture components are spherical multivariate normal distributions

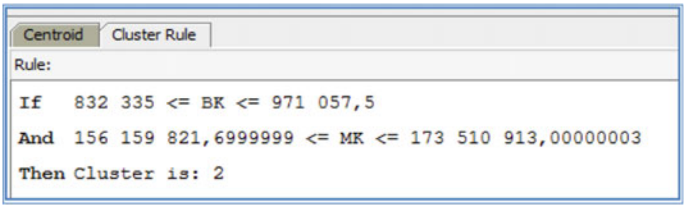

Fig. 4 Clustering rule panel for cluster 2

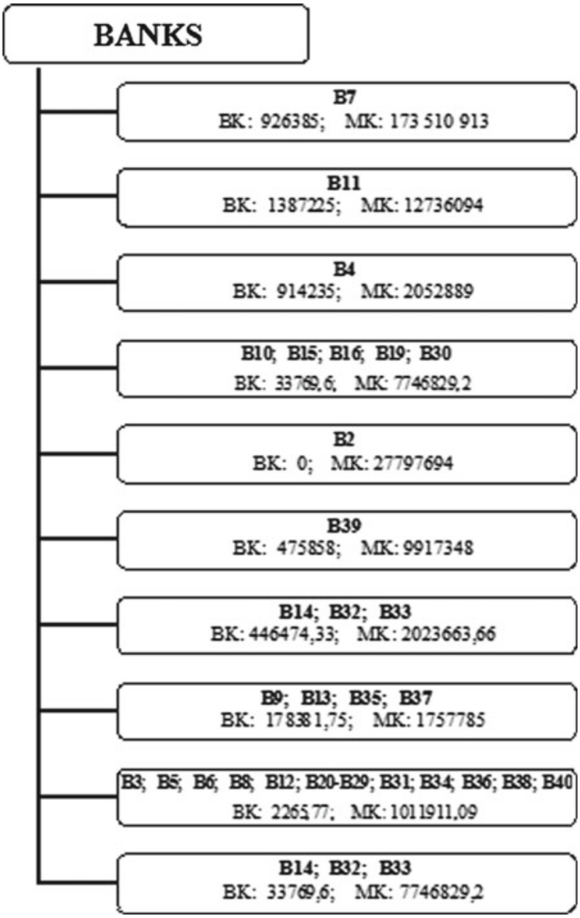

Fig. 5 Dendogram clustering banks on the according centroids

with the same variance for all components. A mixture model is a type of density model that includes several component functions (usually Gaussian) that are combined to provide a multimodal density [9].

Taft et al. [9] mixtured model created from the clusters discovered by enhanced k-means, on the other hand, the mixture components are a product of independent normal distribution with potentially different variances. Because of this greater flexibility, the probability model created by enhanced k-means provides a better description of the underlying data than the underlying model of traditional k-means (Fig. 5).

According to the results of clustering can be grouped according to the same banks centroids. For a complete picture of the group of banks in ten clusters defined below chart. In the diagram marked by appropriate notation banks and centroid by two parameters: loans to banks (BK); Loans to customers (MK).

3 Conclusions

Clustering analysis is very important in the business decision process and management. In the present paper k-means clustering algorithm using Oracle Data Mining is investigated. As result of investigation allows to group of 40 banks with 18 parameters in 10 centralized clusters, and at the same time shows the attributes and rules of the clustering. This, in turn, allows for comparison of parameters of banks and the association of banks in their specialization.

Other clustering algorithm O-cluster of the Oracle Data Mining systems and Classification, Anomaly Detection, Association Rules improve in effective banking management can be investigated in future studies.

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Financial Characteristic and Disclosure Delay of Annual Report: Evidence from Listed Companies in China

Rui Xiang, Yun Chen and Xiaojuan He

Abstract This paper empirically examines the relationship between financial characteristic and disclosure delay of annual report based on the data consisting of Chinese A-share listed companies from 2007 to 2009. We find that the financial Leverage has a significant negatively correlation with disclosure delay of annual report, performance loss, accounting complexity and non-standard audit opinion have significant positively correlation with disclosure delay of annual report. Moreover, this paper also empirically examines the relationship between disclosure delay of annual report and economic consequences. The results show that disclosure delay of annual report has significantly negative impact on the Resource allocation efficiency.

Keywords Financial characteristic · Disclosure delay · Resource allocation efficiency

1 Introduction

A very important goal that companies prepare financial reports is to provide useful information to external users to help them make economic decisions. These information are required to be disclosed timely at the end of the reporting period, or they will lose some economic value. So, timeliness is recognized to be one of the important features of accounting information quality [12, 13, 27]. In 2006, Chinese Ministry of Finance promulgated the new Accounting standards for enterprises-basic standards which stipulates that the accounting information quality includes "reliability" "relevance" and "timeliness", timeliness has a significant connection with relevance, the loss of timeliness will reduce relevance at the same time. So national regulators in every country stipulate the statutory period of annual report disclosure. In 2002, SEC (Securities and Exchange Commission) issued the No. 33-8128 regulation, and emphasized that the annual report of the listed company should be disclosed within

R. Xiang (✉) · Y. Chen · X. He
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: xiangrui@scu.edu.cn

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the required time. IASC ruled the reasonable time of financial statements disclosure in the 1997 revision of International accounting standards 1 presentation of financial statements. CSRC (China Securities Regulatory Commission) stipulates that listed company should compile the annual report within 4 months at the end of each accounting year and disclose the annual report information through newspapers and websites which appointed by CSRC.

Academia has pay high attention to the research of the annual report disclosure problem. In abroad, many literatures suggests that the more timely of annual report disclosure, the more useful for investors' decision [3, 5, 15, 18], the more untimely of annual report disclosure, poorer relevance for investors'decision [7, 26, 34]. At the same time, there are also some foreign literatures discussing the influencing factors of the annual report disclosure delay [2, 3, 19, 23, 28, 42, 43, 54]. But most of these studies are based on the empirical evidence of the mature markets, the conclusion may not be applied to the emerging market countries. There are some literatures discussing the annual report disclosure problem of listed companies in our country [19, 37, 50], but the analysis to influence factors of the annual report disclosure delay is not profounding, and neglecting the study of economic consequences caused by the annual report disclosure delay. So, basing on this emerging market in China, the paper investigates the relationship between the financial characters and disclosure of annual report systemly, and discusses the economic consequences resulting from the annual report disclosure delay, aiming to promote the exploring to the influence factors of the annual report disclosure delay of listed companies and economic consequences in China's regulators, academics and practice.

The remainder of the paper proceeds as follows. Section 2 develops the theoretical analysis and the research hypotheses. Section 3 describes the research design. Section 4 presents the results of regression analysis. Finally, Sect. 5 concludes the study.

2 The Theoretical Analysis and the Research Hypothesis

2.1 Financial Characteristics and Disclosure Delay of Annual Report

1. Financial Characteristics and Disclosure Delay of Annual Report
Generally speaking, financial leverage raises the cost of the agency conflict. According to agency theory [30], the higher the financial leverage of the company, the greater interest conflict among the shareholders, creditors and managers, and the agency cost is higher. So to protect the safety of wealth, the long-term creditors require the company with high financial leverage to improve the quality of information disclosure in order to remove their doubts [6].

Ahmed and Courtis [4] showed that managers in high debt company reduced agency costs through disclosing more information of the annual report. Berlin and

Loeys [10] showed that when it came to reducing agency conflicts and asymmetric information problems, bank financing was more effective than the public debt. This is mainly because banks have a comparative advantage in terms of supervising company, collecting and processing information. Johnson [31] showed as a professional financial intermediary, banks can inhibit the company morally repugnant, and other problems related to information through the more detailed supervision in debt. Conover et al. [20] found that financial leverage was negatively associated with disclosure delay of annual report. Wang and Sun [47] showed that the accounting information robustness was rising according to the rising of bank loan proportion. Xiang et al. [52] found that the bank debt had a significant negative influence on the accounting information risk. Based on the discussion above, the debt in the listed companies of China is mainly long-term bank loans, the bank gives more supervision on company's operating activities, which can promote company to disclose annual report information as early as possible. Therefore, we form the following Hypothesis 1.

Hypothesis 1 Financial leverage is negatively associated with disclosure delay of annual report.

2. Performance Loss and Disclosure Delay of Annual Report
Because of the existence of information asymmetry, blue-chip companies will try to distinguish themselves with low quality companies in order to avoid being mistaken as "lemon" by the market, so voluntary information disclosure is a common practice for blue-chip company. Lang and Lundholm [33] showed that companies with higher information disclosure rating usually had a high earnings level. Laurie [35] found that if managers' own performance evaluation and salary incentive system was directly related to corporate earnings level, then managers have more motivation to delay the disclosure of earnings "bad news", in this way, managers can strive for more time to deal with criticism from all sides, or to take measures to improve the poor performance. Whittred [49] showed that listed companies in financial distress need longer time to disclose financial information. Begley and Fischer [9] found that, annual report disclosed delay usually conveyed bad news comparing with the annual report disclosed in advance, Sengupta [44] found that quarterly earnings announcement time was relatively late in loss-making firms. Ertimur et al. [22] found bad-news firms were more likely to delay disclosure if VCs sell significant quantities of shares but only when managers do not also sell. Sletten [45] showed that disclosing good news early and delaying bad news would maximize trading gains for pre-IPO shareholders by altering investors' assessments of firm value. Lu [38] showed that in our country there existing artificially lowered earnings management behavior in loss-making firms in the loss annual.

Based on the discussion above, we think that, compared with blue-chip companies, performance loss is bad news that managers are reluctant to reveal, which promotes managers to delay the disclosure of annual report. So, we form the following Hypothesis 2.

Hypothesis 2 Performance loss is positively associated with disclosure delay of annual report.

3. Accounting Complexity and Disclosure Delay of Annual Report

The complexity of accounting events is one of the important factors that affect the disclosure time of annual report. Sengupta [44] used the number of reportable segment, the number of mergers & acquisitions subsidiary, and special accounting events as three different variable indicators to study the influence the complexity of accounting has on disclosure of time, suggesting that company accounting complexity leaded to disclosure delay of the annual report. Carslaw and Kaplan [14] found that the existence of the special accounting events leaded to the disclosure delay of audit report of listed companies in New Zealand. Ng and Tai [41], Jaggi and Tsui [29], and Habib et al. [25] used the number of subsidiaries as the accounting complexity variables, showed that the complexity of accounting had significant positive effects on audit report delay. Based on the discussion above, the complexity of the accounting events affects the input, processing, conversion and the timeliness output of the company's accounting information, so, we can expect that the higher the complexity of the accounting events, the later was annual report information disclosure time. Thus, we predict the following Hypothesis 3.

Hypothesis 3 Accounting complexity is positively associated with disclosure delay of annual report.

4. Non-standard Audit Opinion and Disclosure Delay of Annual Report

Generally speaking, companies signed with the standard unqualified audit opinion have a very good tube control mechanisms, which results in time reduction for audit process and procedure [11]. Whittred [49] found that company signed with reservation audit opinion, the disclosure of annual report needed a longer time. Elliott [21] mainly studied the effects that qualified audit opinion had on the timeliness of annual surplus. Bamber et al. [8] deemed that qualified opinion audit report will be signed only after auditors spent a lot of time and energy to complete some additional audit procedures. Chen et al. [17] examined that audit hysteresis was positively associated with the frequency of the non-standard audit opinions, which suggested that the protracted negotiations consultation between the two sides were more likely the signal of non-standard audit opinions. Abbott et al. [1] found that auditors need taking some additional audit work if they signed non-standard audit opinion. Che-Ahmad and Abidin [16] found that the confliction about qualified audit opinion between auditors and managers leaded to audit report delay. Based on the discussion above, we believe that non-standard audit opinions requires auditors to complete some additional audit work, and to communicate, coordinate with managers constantly, which makes signing time of auditing report delay, accordingly lead to disclosure delay of annual report. So, we form the following Hypothesis 4.

Hypothesis 4 Non-standard audit opinions is positively associated with disclosure delay of annual report.

2.2 Economic Consequence of Disclosure Delay of Annual Report-Resource Allocation Efficiency

Timeliness of information disclosure is one of the most important features in the annual report disclosure. High quality information disclosure can reduce information asymmetry and alleviate agency conflicts, so as to promote the configuration optimization of enterprise resource. A good financial report system is one of the prerequisite conditions for the existence of the securities market. wurgler finds that a country's capital allocation efficiency is positively associated with the country's stock market information and the degree of legal protection for the rights of minority shareholders. Leuz and Verrecchia [35] found that a good accounting system can strengthen the liquidity of the stock market and the international capital. Leuz and Verrecchia [36] found that the quality of accounting information can promote managers to improve allocation efficiency of enterprise assets. Zhou and Chen [55] used listed companies in stock markets of Shanghai and Shenzhen as research samples, showed that the industry with higher transparency of accounting information, the better the allocation efficiency of the securities market resource. Xiang et al. [53] used the family listed companies in our country as the research samples, suggesting that the quality of company information disclosure had a significant negative impact on debt capital cost and has a significant positive effect on the corporate value. Based on the discussion above, we believe that the disclosure delay of annual report will reduce the quality of company's information disclosure, and exacerbate the agency conflicts between managers and shareholders, which is not conductive to the optimal allocation of corporate resources. Therefore, we form the following Hypothesis 5.

Hypothesis 5 Disclosure delay of annual report is negatively associated with resource allocation efficiency.

3 Research Design

3.1 Sample Selection

This article selects all the A-share listed companies in Shenzhen and Shanghai stock markets from 2007 to 2009 as research samples. We have sifted samples according to the following program:

(1) Exclude the financial listed companies because of their own characteristics;
(2) Eliminate the companies that disclosure time is later than April 30 each year;
(3) Eliminate the samples whose list is less than 2 years;
(4) Exclude the companies whose data is missed. After the above screening, there are 2966 samples, including 657 samples in 2007, 1111 in 2008 and 1198 in 2009.

3.2 The Regression Model

Firstly, the paper checks the influence of company ownership structure and financial characteristic on disclosure delay of annual report. According to the above theoretical analysis, we build the following Eq. (1) to carry out the empirical test:

$$\begin{aligned}\text{RLday} &= \alpha_0 + \alpha_1\text{Lev} + \alpha_2\text{Loss} + \alpha_3\text{Accomplex} + \alpha_4 Ao + \alpha_5\text{Indu} + \alpha_6\text{Outdir} \\ &\quad + \alpha_7\text{Size} + \varepsilon. \end{aligned} \tag{1}$$

In Eq. (1), the dependent variable is the disclosure delay of annual report (Rlday), which is measured by number of days from the end of the fiscal year day (December 31) to the actual disclosure time, the more the number of days is, the bigger is the Rlday.

Independent variables: Lev (financial leverage)—total long-term debt divided by total equity (excluding current liabilities); Loss (performance loss)—dummy variable, 1 if the company net profit is negative, 0 otherwise; Accomplex (complexity of accounting)— abnormal loss divided by net income, according to Sengupta [44]; Ao—dummy variable, 1 if the company is issued by non-standard unqualified opinions, 0 otherwise.

Control variables: Indu—dummy variable, the industry type, 1 if the company belongs to the manufacturing industry, 0 otherwise; Oudir (the proportion of the independent directors)—the number of independent directors divided by the total number of board; Size (scale of company)—the natural logarithm of the final total assets of the company.

Then the article further investigates the economic consequences of disclosure delay of annual report, that is the influences on the efficiency of resource allocation. In detail, using Wurgler [44] for reference, we build the following Eq. (2) to carry out the empirical test:

$$\begin{aligned}\ln(I_t/I_{t-1}) &= \alpha + \lambda_1 \ln(Tq_t/Tq_{t-1}) + \lambda_2 \ln(Tq_t/Tq_{t-1}) \times \text{Rlday} \\ &\quad + \lambda_3\text{Lev}_{t-1} + \lambda_4\text{Cash}_{t-1} + \lambda_5\text{Size}_t + \lambda_6\text{Indu}_t + \delta. \end{aligned} \tag{2}$$

In Eq. (2), $\ln(I_t/I_{t-1})$ the growth rate of investment, I_t and I_{t-1} are separately measured by final fixed assets inventory in year t and $t-1$; $\ln(Tq_t/Tq_{t-1})$ investment opportunities, Tq_t and Tq_{t-1} are the Tobin's Q value in year t and $t-1$, regression coefficient λ_1 is the reaction coefficient of the growth rate of investment to investment opportunities, if the λ_1 is significantly positive that means investment increasing with the "expanding" investment opportunities and decreasing with the "reducing" investment opportunities, the bigger the λ_1 is, the higher the enterprise resource allocation efficiency. Rlday—the disclosure delay of annual report, the bigger the Rlday is, the worse the timeliness of listed companies' information disclosure is. To examine the Hypothesis 5, we multiply Rlday and $\ln(Tq_t/Tq_{t-1})$ together, if the coefficient (λ_2) is significantly negative, that means the disclosure delay of annual report will significantly reduce the efficiency of resource allocation. Control variables: Lev_{t-1}-year-end asset-liability ratio in year $t-1$; Cash_{t-1} (cash flow)-final cash divided by total assets in year $t-1$; Size_t-the natural logarithm of the final total assets of company in year t; Indu_t-dummy variable, 1 if the company belongs to the manufacturing industry, 0 otherwise.

4 The Empirical Test and Analysis

4.1 Descriptive Statistical Analysis

Table 1 lists the annual changes in disclosure delay of annual report (Rlday). Generally speaking, the shortest time of annual report disclosure is 12 days after year-end, and the longest is 120 days, and the average is 97.19 days, showing that Chinese listed companies have performed related regulations about the time of companies' disclosure.

Tables 2 and 3 are simple descriptive analysis of variables involved in Eqs. (1) and (2). According to Table 2, the long-term debt (Lev) is at a low level, the average and median are 16.7 and 10.4 %; the mean value of Loss is 12.3 %; the average value of Accomplex is 51.3 %, the median is 6.5 %, indicating that the complexity difference is bigger among Chinese listed companies; the mean value of *Ao* is 4.4 %.

Table 1 The annual changes in disclosure delay of annual report (Unit: day)

Year	Number of samples	Mean	Median	Min	Max	SD[a]
2007	657	77.2	80	22	120	23.012
2008	1111	91.82	91	15	120	21.095
2009	1198	88.35	89	12	120	23.538
Sum	2966	87.19	88	12	120	23.195

[a] Standard deviation

Table 2 Descriptive analysis of variables involved in model (1)

Variable	Number of samples	Mean	Median	Min	Max	SD[a]
Lev	2966	0.167	0.104	0	0.989	0.18
Loss	2966	0.123	0	0	1	0.329
Accomplex	2966	0.513	0.065	−128.281	204.324	5.525
Ao	2966	0.044	0	0	1	0.205
Indu	2966	0.536	1	0	1	0.499
Oudir	2966	0.36	0.333	0.091	0.667	0.05
Size	2966	21.729	21.642	15.77	28.003	1.227

[a] Standard deviation

Table 3 Descriptive analysis of variables involved in model (2)

Variable	Number of samples	Mean	Median	Min	Max	SD[a]
Lev	2966	0.167	0.104	0	0.989	0.18
Loss	2966	0.123	0	0	1	0.329
Accomplex	2966	0.513	0.065	−128.281	204.324	5.525
Ao	2966	0.044	0	0	1	0.205
Indu	2966	0.536	1	0	1	0.499
Oudir	2966	0.36	0.333	0.091	0.667	0.05
Size	2966	21.729	21.642	15.77	28.003	1.227

[a] Standard deviation

According to Table 3, the mean value of $\ln(I_t/I_{t-1})$ is 4.7 %, the average value of $\ln(Tq_t/Tq_{t-1})$ is 12.6 %, preliminary showing that the resource allocation of Chinese listed companies is effective.

4.2 The Regression Analysis of Financial Characteristic and Disclosure Delay of Annual Report

Table 4 shows the regression result of model (1). According to the regression result, there is a significant negative relationship between Lev and Rlday, indicating that the higher the level of long-term debt is, the more timely is the disclosure of annual

Table 4 The regression result of financial characteristic and disclosure delay of annual report (dependent variable: Rlday)

Variable	Coefficient	*P* Value
Intercept	61.832[c]	0
Lev	−12.531[c]	0
Loss	15.275[c]	0
Accomplex	0.160[b]	0.033
Ao	9.601[c]	0
Indu	−2.957[c]	0
Oudir	10.343	0.212
Size	1.055[c]	0.006
Number of samples	2966	
R2	0.065	
F-test	29.559[c]	
Significance	0	

[a,b,c] are respectively significance level in 0.1, 0.05 and 0.01 (two-tailed test)

report, supporting hypothesis $H1$. There is a significant positive relationship between Loss and Rlday, suggesting that the companies with poor performance tend to have a longer corporate report disclosure lag, supporting Hypothesis 2. The relationship between Accomplex and Rlday is significant positive, consistent with Hypothesis 3, showing that the more the extraordinary profit, loss and the more complex of accounting, the longer is the time lag. Also a significant positive relationship exists between Ao and Rlday, consistent with 4, indicating that non-standard audit opinions require large extra auditing, which delayed the disclosure time. For the other control variables, Indu and Size are both significantly negative with Rlday, suggesting that the company belongs to the manufacturing industry, the company with larger scale, the disclosure tends to be more timely.

4.3 Regression Analysis About Economic Consequences of Disclosure Delay of Annual Report

Table 5 shows the regression result of model (2). According to Table 5, there is a significant positive relationship between $\ln(Tq_t/Tq_{t-1})$ and $\ln(I_t/I_{t-1})$ in the regression, indicating that the efficiency of resource allocation is better in general, stock market has fully played the resource allocation function during the China's economic development.

In the regression, we multiply Rlday and $\ln(I_t/I_{t-1})$ together, and the coefficient of $\ln(I_t/I_{t-1})\times$Rlday is significant negative, the empirical evidence supports the Hypothesis 5. That indicates the disclosure delay of annual report will influence the efficiency of resource allocation significantly, the longer the delay is, the lower is

Table 5 The regression result of economic consequences of disclosure delay (dependent variable: $\ln(I_t/I_{t-1})$)

Variable	Coefficient	P Value	Coefficient	P Value
Intercept	0.048^{c}	0	-1.784^{c}	0
$\ln(Tq_t/Tq_{t-1})$	0.102^{a}	0.083	0.142^{b}	0.014
$\ln(Tq_t/Tq_{t-1})\times$ Rlday	-0.002^{b}	0.012	-0.002^{c}	0.002
Lev_{t-1}			-0.018^{c}	0.004
Cash_{t-1}			0.256^{c}	0.003
Size_t			0.082^{c}	0
Indu_t			0.045^{b}	0.017
Number of samples	2966		2966	
$R2$	0.004		0.045	
F-test	6.242^{c}		24.260^{c}	
Significance	0.002		0	

^{a,b,c}are respectively significance level in 0.1, 0.05 and 0.01 (two-tailed test) the efficiency. In the regression, the coefficient of ($\ln(Tq_t/Tq_{t-1}) \times$Rlday) is still significantly negative after adding control variables, and the significance level even increases. According to the regression result of control variables, the coefficient of Lev_{t-1} is significantly negative, the coefficients of Cash_{t-1}, Size_t and Indu_t are all significantly positive, showing that the debt level, cash level, scale and manufacture industry have significant influence to the efficiency of resource allocation.

5 Research Conclusions

This paper empirically examines the relationship between financial characteristic and disclosure delay of annual report based on the data consisting of Chinese A-share listed companies from 2007 to 2009. We find that the financial Leverage has a significantly negative correlation with disclosure delay of annual report, performance loss, accounting complexity and non-standard audit opinion have significantly positive correlation with disclosure delay of annual report. Moreover, this paper also empirically examines the relationship between disclosure delay of annual report and economic consequences. The results show that disclosure delay of annual report has significantly negative impact on the Resource allocation efficiency, that is to say the longer the disclosure time, the lower the allocation efficiency of enterprise resources.

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A New Evaluation Model of Customer Satisfaction Index

Xiangqing Chen , Lixia Yu, Mingjun Tan and Qiuyan Guan

Abstract Customer satisfaction index, a new kind of economic index, is studied and adopted by more and more countries or regions. This paper builds a new CSI model on the basis of the present research achievements and the characteristics of consumer behavior in China. Basing on expectancy disconfirmation mode, this model simultaneously considers equity mode and need disconfirmation mode, introduces perceived equity and perceived price variables, designs the corresponding observable variables and path relations for these structural variables, builds three paths from customer satisfaction, corporate image, perceived price to the customer loyalty, changes the situation of sole path from the customer satisfaction to the customer loyalty in the traditional models.

Keywords Customer satisfaction index · Model · Perceived price · Perceived equity · Customer loyalty

1 Introduction

CSI (Customer Satisfaction Index) is a new economic index studied and adopted by many countries or regions, mainly used to determine the customer satisfaction on products or services, and evaluate the quality of economic output [3]. It is not only beneficial to the improvement of product quality and the competitiveness of enterprise, but also provides pre-warming and monitoring of the economic growth of a nation and guidance to the macro-regulation of government [11]. Since the conception of SCSB (Swedish Customer Satisfaction Barometer) in 1989, evaluation on the customer satisfaction of the nation or region has been carried out in USA,

X. Chen (✉) · M. Tan · Q. Guan
Department of Business Administration, Foshan Polytechnic, Foshan 528137, People's Republic of China
e-mail: chenxiangq@163.com

L. Yu
Commercial School, Sichuan Normal University, Chengdu 610101, People's Republic of China

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European Union, Norway, New Zealand, Australia, Canada, Korea, Taiwan and so on. China has studied CSI since the late 1990s and made some achievements. Regional and industrial evaluations have been carried out in Shanghai and Beijing. However, a national evaluation system has not been set up completely due to some key problems pending to be solved. Further study and investigation are required.

"Expectancy Disconfirmation" is the most popular customer satisfaction evaluation mode at present, which is used by almost all popular evaluation models including SCSB, ACSI (American Customer Satisfaction Index) and ECSI (European Customer Satisfaction Index) to evaluate the customer satisfaction [4, 5, 13]. In addition, other comparison criteria used during the formation of customer satisfaction include perceived performance mode, need disconfirmation mode, equity mode, individual difference mode, etc. [1, 6]. A lot of empirical studies have been done by some scholars based on it. According to the empirical study of Tse and Wilton [18], need disconfirmation could better evaluate the general satisfaction compared to expectancy disconfirmation in some cases. The positive effect between equity and satisfaction is supported by many research and studies [10, 17] that perceived equity and expectancy were closely related to the customer satisfaction [14].

As for the result of customer satisfaction, it is agreed that customer satisfaction means the increase of customer loyalty. However, whether customer complaint is caused by customer dissatisfaction or not, there are two different opinions. According to ACSI, the dissatisfaction of customer will be expressed through complaints, and the positive settlement of customer compliant will turn the complaining customer into loyal customer. Customer complaint variable was introduced to the evaluation modes of SCSB, ACSI, etc. [4, 5]. However, according to another viewpoint of presented by ECSI [7], with more and more attention given to the settlement of customer complaint, it is improper to consider customer compliant as the result of customer satisfaction. This viewpoint seems to receive supports from empirical studies [9].

2 Specification of Model

2.1 Construction of Model

According to the expectancy disconfirmation mode, customer satisfaction depends on the degree of the disconfirmation between expectancy before purchase and perception after purchase: if the perception after purchase meets the expectation of customer, the customer will neither feel satisfied nor unsatisfied; if perception after purchase exceeds the expectation of customer, the customer will feel satisfied; if perception after purchase is below the expectation of customer, the customer will feel unsatisfied. A lot of theories and empirical studies show that customer expectation and perceived quality have direct effects on customer satisfaction [4, 5, 13]. Further more, it is proved in some researches that multiple comparison criteria shall be included in the forming process of customer satisfaction [19]. Therefore, the author adopts the said research achievements on customer satisfaction studies in recent years during the construction of a new evaluation model, takes into consideration the equity mode and expectancy disconfirmation mode, introduces the variables of perceived equity, customer expectation, perceived quality, customer satisfaction, customer loyalty, etc., and build the following hypothesis.

Hypothesis 1 *(H1)* Customer expectation has direct effects on customer satisfaction.
Hypothesis 2 *(H2)* Customer expectation has direct effects on perceived quality.
Hypothesis 3 *(H3)* Perceived quality has direct effects on customer satisfaction.
Hypothesis 4 *(H4)* Perceived quality has direct effects on perceived equity.
Hypothesis 5 *(H5)* Perceived equity has direct effects on customer satisfaction.
Hypothesis 6 *(H6)* Customer satisfaction has direct effects on customer loyalty.

To determine whether the satisfaction and loyalty of customer are quality-driven or price-driven, perceived value variable is introduced into most existing evaluation models. However, as value contains many quality factors, or quality itself is part of the value, it is hard to strictly differentiate quality from value based on definition [15]. Therefore, it is necessary to build the independent perceived price and perceived equity variable. Perceived price variable is used to explain the price-driven part, and the perceived equity variable is used to analyze the cost performance ratio part in this model. Based on it, the following hypotheses are built.

Hypothesis 7 *(H7)* Perceived price has direct effects on customer satisfaction.
Hypothesis 8 *(H8)* Perceived price has direct effects on perceived equity.
Hypothesis 9 *(H9)* Perceived price has direct effects on customer loyalty.

According to marketing theory, the purchase decision process of customer is classified into five stages: Recognition of needs, information collection, information evaluation, purchase decision and post purchase behavior. Information is very important to the purchase decision of customer. The impression of a corporate or a brand is built based on the information cognized by consumer. The more correct information consumers know about, the higher the expectation and the bigger opportunity of choosing this brand will be. Structural variable is also introduced in some satisfaction index evaluation models in China [16]. For that, the author put forward the following hypothesis.

Hypothesis 10 *(H10)* Information has direct effects on customer expectation.
Hypothesis 11 *(H11)* Information has direct effects on corporate image.

One of the differences between ECSI and ACSI/SCSB is adding a latent variable—corporate image into the model, believing that corporate image will affect the expectation, satisfaction and loyalty of customer. It is shown by empirical study that corporate image is one of the most important factors affecting customer satisfaction to the service providers of telephone, bank, supermarket and restaurant [8, 12]. Based on it, the author builds the following hypotheses.

Hypothesis 12 *(H12)* Corporate image has direct effects on customer expectation.
Hypothesis 13 *(H13)* Corporate image has direct effects on customer satisfaction.

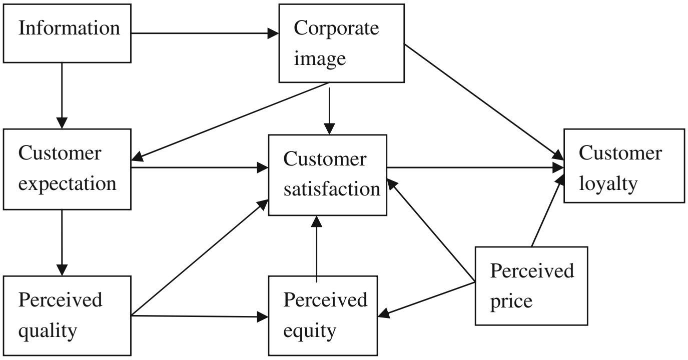

Fig. 1 A new evaluation model of CSI

Hypothesis 14 *(H14)* Corporate image has direct effects on customer loyalty.

Based on the above hypotheses, a new evaluation model of CSI is constructed, as shown in Fig. 1.

2.2 Evaluation Method and Indicators of Model

The new evaluation model of CSI consists of the following eight structural variables: information, customer expectation, perceived quality, corporate image, perceived equity, perceived price, customer satisfaction and customer loyalty. Among which, information and perceived price are two exogenous variables, the others are endogenous variables. All these structural variables are difficult to measure directly, which are considered the latent variables. Each latent variable corresponds to several directly the measurable manifest variables, as shown in Table 1.

The evaluation system is made up of four levels of indicators, and the above-mentioned eight structural variables will be used as the second level indicator in the customer satisfaction evaluation system, the corresponding observable variables (manifest variables) will be the third level indicator, and questions on the questionnaire are the forth level indicator, which are quantifiable multivariate calibration in the evaluation system. The first, second and third level indicator will be calculated through recursive method. The ten scoring method is adopted in this model (relative to the five scoring method or seven scoring method) to reduce deviation of statistics caused by the extreme skewness. It also allows consumers to have a better classification and minimize the negative effect caused by skewness distribution. ACSI, ECSI and other traditional mature scales are adopted to increase the accuracy and efficiency of questionnaire [2]. For example, based on the research achievement of Tsinghua model, the observable variable of "compared with other brands" is added to the structural variables of "customer satisfaction", but bold innovation is made at

Table 1 Customer satisfaction evaluation indicator system

First level indicator	Second level indicator	Third level indicator
	Information ($\xi 1$)	sufficiency of information $x1$, authenticity of information $x2$
	Perceived price ($\xi 2$)	General perceived price $x3$, perceived price compared to expected price $x4$, perceived price compared to competed price $x5$
	Customer expectation ($\eta 1$)	General quality expectation $y1$, reliability expectation $y2$, customization expectation $y3$, price expectation $y4$
	Perceived quality ($\eta 2$)	General perception of product quality $y5$, perception of product quality reliability $y6$, perception of product quality customization $y7$, perception of service quality $y8$
Customer satisfaction index (CSI)	Corporate image ($\eta 3$)	General corporate/brand image $y9$, corporate/ brand popularity $y10$, corporate/brand reputation $y11$
	Perceived equity ($\eta 4$)	Equity of payment compared to product purchased $y12$, Equity of payment compared to service received $y13$, Equity compared to similar competitor $y14$
	Customer satisfaction ($\eta 5$)	General satisfaction $y15$, customer satisfaction compared to expectation $y16$, customer satisfaction compared to desire $y17$, customer satisfaction compared to other competitor $y18$
	Customer loyalty ($\eta 6$)	Possibility of repeated purchase $y19$, Possibility of recommending to others $y20$, endurance capacity to the change of price $y21$

the same time. It is considered that customers usually have significant price expectation before purchase, and it is improper to measure customer expectation only by the quality under traditional models. Thus, price expectation as observable variable is added to the latent variables of customer expectation for the first time in new model, to improve the completeness and reasonability of customer expectation.

2.3 Mathematical Expression of the Model

As shown in Fig. 1, corresponding structural equation is set up based on the customer satisfaction evaluation model, which is divided into two parts, i.e. structural model and measuring model. The structural model describes the relations of latent variables, and the measuring model describes the relations between latent variables and observable variables.

1. Structural model

ξ is used to represent the vector of exogenous latent variable (2×1), and η is used to represent the vector of endogenous latent variable (6×1). The structural model is as follows:

$$\eta = B\eta + \Gamma\xi + \zeta.$$

Among which, B is the coefficient matrix of the effect of endogenous variable versus endogenous variable (6×6), its diagonal entries are 0 and I-B is non degenerate; Γ is the coefficient matrix of the effect of exogenous variable versus endogenous variable (6×2), and ζ is the vector of potential error (6×1). Its matrix form is as follows:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \\ \eta_6 \end{bmatrix} = \begin{bmatrix} 0 & 0 & \beta_{13} & 0 & 0 & 0 \\ \beta_{21} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \beta_{42} & 0 & 0 & 0 & 0 \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & 0 & 0 \\ 0 & 0 & \beta_{63} & 0 & \beta_{65} & 0 \end{bmatrix} \times \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \\ \eta_6 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & 0 \\ 0 & 0 \\ \gamma_{31} & 0 \\ 0 & \gamma_{42} \\ 0 & \gamma_{52} \\ 0 & \gamma_{62} \end{bmatrix} \times \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \\ \zeta_5 \\ \zeta_6 \end{bmatrix}. \tag{1}$$

2. Measuring model

X is used to represent the vector of exogenous observable variable (5×1) and Y is used to represent the vector of endogenous observable variables (21×1). The mathematic form of the measuring model for customer satisfaction evaluation is as follows:

$$X = \Lambda_X \xi + \delta,$$
$$Y = \Lambda_Y \eta + \varepsilon.$$

Among which:

Λx is the regression coefficient or the loading matrix of X to ξ (5×2);
δ is the vector composed by the measurement error of X (5×1);
Λy is the regression coefficient or the loading matrix of Y to η (21×6);
ε is the vector composed by the measurement error of Y (21×1).
It is calculated from matrix X and Y that,

$$\begin{bmatrix} \chi_1 \\ \chi_2 \\ \chi_3 \\ \chi_4 \\ \chi_5 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \\ \lambda_{21} & \\ & \lambda_{12} \\ & \lambda_{22} \\ & \lambda_{32} \end{bmatrix} \times \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix}, \tag{2}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \\ y_{11} \\ y_{12} \\ y_{13} \\ y_{14} \\ y_{15} \\ y_{16} \\ y_{17} \\ y_{18} \\ y_{19} \\ y_{20} \\ y_{21} \end{bmatrix} = \begin{bmatrix} \lambda_{11} & & & & & \\ \lambda_{21} & & & & & \\ \lambda_{31} & & & & & \\ \lambda_{41} & & & & & \\ & \lambda_{12} & & & & \\ & \lambda_{22} & & & & \\ & \lambda_{32} & & & & \\ & \lambda_{42} & & & & \\ & & \lambda_{13} & & & \\ & & \lambda_{23} & & & \\ & & \lambda_{33} & & & \\ & & & \lambda_{14} & & \\ & & & \lambda_{24} & & \\ & & & \lambda_{34} & & \\ & & & & \lambda_{15} & \\ & & & & \lambda_{25} & \\ & & & & \lambda_{35} & \\ & & & & \lambda_{45} & \\ & & & & & \lambda_{16} \\ & & & & & \lambda_{26} \\ & & & & & \lambda_{36} \end{bmatrix} \times \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \\ \eta_6 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \\ \varepsilon_8 \\ \varepsilon_9 \\ \varepsilon_{10} \\ \varepsilon_{11} \\ \varepsilon_{12} \\ \varepsilon_{13} \\ \varepsilon_{14} \\ \varepsilon_{15} \\ \varepsilon_{16} \\ \varepsilon_{17} \\ \varepsilon_{18} \\ \varepsilon_{19} \\ \varepsilon_{20} \\ \varepsilon_{21} \end{bmatrix}. \tag{3}$$

2.4 Estimation of Model and Selection of Applied Software

The estimation of customer satisfaction model is mainly based on PLS (Partial Least Square) method and LISREL (Linear Structural Relationships) method. PLS is a causal modeling method combining principal component analysis with multiple regression analysis for iterative estimation. LISREL is a modeling method using the fitted model of structural estimation covariance $\Sigma(\theta)$ and sample covariance () for iterative estimation of model parameters, and is also named as covariance modeling method. Both methods have advantages and disadvantages, and are applicable to different situation. PLS is applicable to circumstances with insufficient theoretical knowledge comparatively and emphasizing the accuracy of forecast, while LISREL is applicable to circumstances with sufficient theoretical knowledge and emphasizing the accuracy of parameter estimation. Both methods are mutually complementary instead of contradictory. However, as data distribution hypothesis is not required, PLS is applicable to continuous variable and classified variable, and can estimate the weight of measuring variables. PLS methods are usually adopted by domestic and foreign satisfaction evaluation studies. Software used for PLS analysis includes LVPLS-PC and PLSGraph as well as S-PLUS and MATLAB programming. As for the software pack used for LISREL analysis, there are LISREL, EQS, AMOS, MPLUS, CALIS, etc.

3 Conclusion

Based on the core concept of CSI models such as SCSB, ACSI and ECSI, taking advantages of the research achievements on the customer satisfaction both in China and abroad, the author constructs a new CSI model. Its innovation mainly includes:

1. Basing on "Expectancy Disconfirmation", it takes into consideration the equity mode and need disconfirmation mode in addition to expectancy disconfirmation mode. It is introduced perceived equity variable, integrating need and need conformity into relevant structural variables. And it sets up a new mode of observation and analysis to evaluate customer satisfaction much more accurately;
2. It improves the narrow relationship from customer satisfaction to customer loyalty in the traditional CSI model. It is in favor of explaining the source of customer loyalty by building three paths: from customer satisfactioncorporate image and perceived value to customer loyalty;
3. It is the first time incorporating the observable variable of price expectation to the structural variable of customer expectation. It makes customer expectation much more completely and reasonably.

However, the new evaluation model of CSI is an idealized studied. Further study for leading in the related variable and the relationship between correlation variables is expected.

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Study of Customer Value Attribute System Based on Fuzzy Evaluation

Lizhong Tong and Huajun Luo

Abstract As a new source of creating competitive advantage, the measurement and evaluation of customer value has guiding significance to the practice of business administration. The system of customer value attributes is proposed based on a review of relevant researches, aims at solving the problem of the lack of quantitative measurement. Delphi method, Analytic Hierarchy Process and Fuzzy evaluation are taken into the calculation of the customer value in this research. Finally, a case of an electronic communication equipment enterprise is presented in order to guide management practice.

Keywords Customer value attribute · Fuzzy evaluation · Analytic hierarchy process

1 The Presentation of Question

Such as a saying of the master of management, Peter Drucker, the final purpose of enterprise management is to attract and retain customers. Driven by increasingly fierce market competition, traditional competitive mode centers for products assumed a gradual transition to one centers for customers. Porter [6] pointed out in his book *Competitive Advantage*, the competitiveness of enterprise, in the final analysis, stems from the exceeding value over the cost. Woodruff [10] clearly put forward that customer value will likely be the next major source to achieve and retain competitive advantage. Relevant studies have shown that customer value can lead to the creation of corporation competitive advantage by enhancing customer loyalty and satisfaction. The switching mechanism of customer value and competitive advantage is shown in Fig. 1.

L. Tong · H. Luo (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: lhj0629scu@163.com

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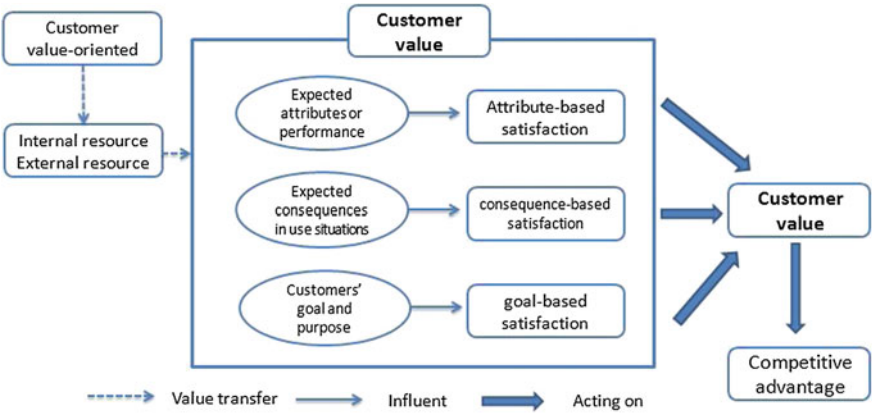

Fig. 1 Customer value and competitive advantage switching mechanism

Since the introduction of customer value, related researches revolved around the influencing factors or characteristics of value. However, there is a lack of systematic framework in the quantitative studies of customer value, which couldn't provide quantization basis for corporation in the process of strategizing enhancement.

2 Theoretical Analysis and Experimental Design

2.1 Customer Value

The promotion effect of customer value on corporation performance and customer satisfaction had been proposed since 1950s, but revolved researches started since the publish of Porter's Competitive Advantage [6], which pointed out that the exceeding value over the cost corporation creates is the new source of company competitiveness. Due to the difference in research object and perspective, the definition of customer value varies. Woodruff [10] held that, customer value is a customer's perceived preference for and evaluation of those product attributes, performance, and consequences arising from use that facilitate (to block) achieving the customer's goals and purposes in use situations. In the perceived customer value theory proposed by Zeithaml [11], enterprises should take consumers' value perception into consideration in the operation process to design, create and provide value for customers. Value is the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given [11]. Ravald [7] defined customer value in the perspective of relationship marketing, value is the emotional bond between a customer and a producer after the customer has used a salient product or service produced by that supplier and found the product provided an added value. More value and closed relationship could be created in the relation network than the nodes itself. In the mode, even the product or service is worse than other competitors, customer will still stick with the producers. The Kotler's delivered value theory [1] assumes customers always chase for the maximum of service value. Delivered value is defined from the perspective of customers satisfaction and their expected cost, which refers to the difference between the total customer value and total customer cost. The most widely recognized definition is set by Gale [5] from the perspective of quality, customer value is market perceived quality adjusted for the relative price of a company's product.

Domestic researches of customer value mainly focus on the composition or the internal driving factors of customer value. Dong [4] thought that customer value is a comprehensive evaluation between the product attributes, using effect and the input of the product in the whole consumption life-cycle based on his purchasing experience, knowledge and preference. He also holds that corporations improve their satisfaction and consumers' loyalty by providing higher perceived value for customer. Therefore, customer value lays the foundation of creating competitive advantage by acting on consumer behavior intension. In Bai's customer value driving factors research [2], he took product brand as a point of penetration, proposed that a better brand image can reduce purchasing risk and simplify the decision-making process, and can affect customers' preference and purchasing choices by improving customers' psychological expectation and social recognition besides the product function itself.

According to some relevant studies, this paper defines customer value as the subjective evaluation difference between the cost and the perceptual value including function value, experience value and social value gaining in the process of products using or service. It has features as follows: (1) perceptual subjectivity; (2) dynamic, owing to the subjectivity of customer value and benefits consumers get vary in different phase of product life-cycle, so does the value attributes system varies with time; (3) multi-level, multi-dimension (customer value involves every aspects of perceived attributes system, so its an item of multi-dimension and multi-level). In the view of this, customer value could be denoted as:

$$CV = A_1X_1 + A_2X_2 + A_3X_3 + \cdots + A_nX_n,$$

where, CV stands for customer value, X_n means the component attributes of customer value, A_n represents the corresponding weight coefficient of each attribute.

2.2 Value Measurement

The fundamental purpose of customer value research is to promote customer value and help create competitive advantage on the premise of ensuring company's profit. Therefore, quantitative researches should be carried out on the basis of qualitative studies like definition or characteristics of customer value. The quantitative data could be used to help decision make and establish enhancing strategies. Summarized by the literatures review, research contents of customer value measurement at home and abroad are roughly shown in Table 1.

Table 1 Customer value measurement research content summary

Model	Principle and content	Application method
Woodruff	Customer value is defined from concrete level to abstract level as attribute-based, consequence-based and goal-based. It provides a systematic framework for customer value research	Step 1, hackle the factors of customer value attributes system by interview. The system starts with the obvious attributes easy to be mentioned by consumers in the attribute-based level, then gradually deepen into more abstract level, and eventually form the whole system
		Step 2, measure customers' perceived degree of corporations' value performance
Gale	Measuring customer value from quality and price. Based on the measurement of market perceptual quality and price, there comes the graph of customer value. The market position of company itself and its competitors can be shown intuitively by the two-dimensional graph, then it can help make an improving strategy	$CV = \sum_{i=1}^{n} Q_i r_i + \sum_{i=1}^{n} P_i t_i$, in which, relative score of some fractional factor $= \frac{\text{competitors' score on this factor}}{\text{the research company's score on the factor}}$, $Q_i = \frac{Q'_E}{Q'_C}$, $P_\text{i} = \frac{P_E{}'}{P_C{}'}$, r_i, t_i means the score of quality and price of the i attribute. The scores are evaluated by customers. means the score of quality and price of the i attribute. The scores are evaluated by customers
Kotler	Value is measured in two perspectives, customer delivered value and satisfaction. Customers always seek to maximize value, hoping to get the maximum benefit with the lowest cost, in order to make their needs satisfied to the greatest degree	$TCDV$ stands for the customer delivered value. $\begin{cases} TCDV = f\,(Pd, S, P, I) - f\,(M, T, C) \\ \text{Absoluteway} \\ \text{or} \\ TCDV = f\,(Pd, S, P, I)\,/f\,(M, T, C) \\ \text{Relativeway} \end{cases}$ $TCV = f\,(Pd, S, P, I)$. TCV stands for total customer value, Pd stands for product value, S stands for service value, personnel value is P, image value is I. $TCC = f\,(M, T, C)$. TCC stands for total customer cost, monetary cost is M, T stands for time cost, E means physical and energy cost
Butz TR-TC model	Price is the only cost factor which has effect on the purchasing decision	$CV = TR - TC_P$
		TR stands for the total revenue, TC_P means price

(continued)

Table 1 (continued)

Model	Principle and content	Application method
Van.der Haar J.W DE-DV model	It focus on the creation process of value. Customer value is the difference expected value between corporation and customers in the process of developing, purchasing and using of the product	CV (customer value) = DV (companys design value)$-EV$ (customer's expected value) Sources of differences include, Developing—divergence between market survey and company's judgment. Design—the technique divergence between the original design and restriction of productive capability. Purchasing—divergences between market expectation and company expectation, customer expectation and the provided value. Using—divergence between customer expected value and provided value
Ulag.W	Using a multi-dimension equation to measure customer value	$CV = A_1X_1 + A_2X_2 + A_3X_3 + \cdots + A_nX_n$
		CV stands for customer value, X_n means the component attributes of customer value, A_n represents the corresponding weight coefficient of each attribute
Bao Wang	Measurement of customer value is divided into four types	
	First is the weight of each factors and the performance score measurement	
	Second is the measurement of the relationship between each attributes	
	Third is the measurement of how external factors affect customer value	
	Fourth is the dynamic measurement of how customer value changes with time	
Others	Related researches in customer value measurement scale construction	

Summarized by the table above, most of customer value measurement researches focus on some single parts of whole measurement process, there is a lack of systematic methodology and it's hard to provide quantitative basis for business administration. Simultaneously, previous researches use mathematics and statistical methods like factor analysis or validity and reliability analysis, ignoring the problem that the data of value factors are hard to be described and quantified.

Moreover, corporations should make certain of the improving object. Due to the resource restriction, a company couldn't manage to improve every attribute in the customer value system. Companies should pay special attention to the important factors or its shortcoming factors. So to break the limitation, it's necessary to calculate the importance coefficient and measure the performance of every attribute in the value system, which could help company make accurate enhancing strategies with choices.

2.3 Research Design

Based on the customer value dimensions proposed by Kotler, Treacy and Wiersema [8], the management practice of enterprises and interviews of experts, the research put forward a multi-dimension and multi-factor customer value attribute system by the combination of the SERVQUAL scale method. On the foundation of the attribute system, weight coefficient could be determined by AHP (Analytic Hierarchy Process), then factors that are hard to quantified can be measured by fuzzy evaluation. In the final section of the measurement, value attributes need to be improved can be found according to the maximum membership degree law. The consequence of the research can offer reference in company strategies making and can help company choose key factors to improve, rationalize the distribution of the resource and elevate the competitiveness in the resource capacity-constrained business circumstance and ensure profit in the meantime.

3 The Design and Measurement of Customer Value Attribute System

1. The Design of Customer Value Attribute Dimensions

The customer value dimension division researches home and abroad can be summarized in Table 2 through literature review. Based on the relevant researches, this study divides customer value into four dimensions as follow, function value (the quality and attributes of product), experience value (satisfaction of the experience of using product or service, the purchasing process and the after sale), social value (social status benefit that is offered by buying or using the product), cost (acquisition cost and use cost of products or service). Simultaneously, experience value is further subdivided into five dimensions as responsiveness, reliability, assurance, tangibles, empathy referring to the division standard of SERVQUAL scale.

The attribute system of customer value shown in Table 3 is proposed on the basis of records processing by methods of elements recognition and frequency statistics, the records include existing data and interview records acquired by qualitative research methods like expert interview, brainstorm and focus group interview of customer. The evaluation scale includes 9 dimensions, 37 items. It should be noted that the system here is universally applicable, detailed design and adjustment should be done considering the different features of product when it comes to a specific product in different industry.

2. The Measurement of Customer Value Attributes

Due to the subjectivity and multi-dimension of customer value, some attributes in the evaluation system couldn't or are hard to be quantified. So in this research, performance of value attributes are quantified by fuzzy evaluation, which can contribute to enhance customer value specifically. Method of the research is as follows.

Table 2 Customer value dimension division summary

Kotler	Product value, Experience benefit, Image value, Network effect
Parasuraman	Tangibles, Reliability, Responsiveness, Assurance, Empathy
Sheth	Functional, Social, Emotional, Epistemic, Conditional value
Butz	Product value, Value in use, Possession value, and overall value link together in a consumer's evaluation process
Sweeney	Price and cost, Quality value, Emotion value, Social value
Woodruff	Product attribute, Consequence, Using goal
Treacy, M	Price, Quality, Convenience, Reliability, After service
Eun-Ju	Utility value(dimension which describes the perceived value related to function, service, time cost, choice being provided)
	Experience value(evaluation of online shopping includes, entertainment of the website, visual effect, interaction between business and customer)
Holbrook	Extrinsic value versus Intrinsic value
	Self-oriented value versus Other-oriented value
	Active value versus Reactive value
Ruyter	External value, Internal value, System value

(1) Calculation of weight coefficient of each item in the customer value system

According to the incidence of each attributes have on customer value, a certain weight coefficient is given to a corresponding item to measure the importance of the item. That is to work out A_n set in $CV = A_1X_1 + A_2X_2 + A_3X_3 + \cdots + A_nX_n$. Coefficient of each item is set by analytic hierarchy process (AHP). The main step of the method is to build judgment matrix according to Satie's 1–9 scale table. Take factor A_k as an example, judgment matrix (shown below as U_{ij}) needs to be built after the relative importance comparison between factor A_k and any other factors $B_1, B_2, \ldots, B_n$ in the multi-level attributes system.

$$U_{ij} = \begin{bmatrix} u_{11} & u_{12} & u_{13} & u_{14} & \cdots \\ u_{21} & u_{22} & u_{23} & u_{24} & \cdots \\ u_{31} & u_{32} & u_{33} & u_{34} & \cdots \\ u_{41} & u_{42} & u_{43} & u_{44} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix}.$$

After the corresponding characteristic vector ω of the maximum eigenvalue λ max is obtained according to the judgment matrix, a consistency check needs to be done to check the rationality of the weight distribution using the formula $CR = CI/RI$. When $CR < 0.1$, the judgment matrix and weight distribution are considered to be rational [3].

Table 3 Customer value attribute system

Level	Dimension	Item
Function value	Attribute	1. Exterior Design of product. 2. Technique level comparing with competitors. 3. Simplicity of operation or comprehensiveness of instruction. 4. Market availability of product components. 5. Environmentalism in the process of production and use. 6. Complete functions 7. Key function can satisfy the daily needs. 8. Expansibility of the product function
	Quality	9. Durable years of the product. 10. Using stability in the product's service life
	Tangibles	1. There are entity channels for customers to experience or purchasing. 2. There are enough After-sale service channels and are easy to get in touch with. 3. The brand can be clearly identified and recognized. 4. The display of the entity channels or the lay out of the online website
	Responsiveness	5. Difficulty of contacting with the service staff. 6. Arrival speed of service staff to customers' need. 7. The responsiveness of customers' instant need in the trade. 8. Inventory can assure there is no stockout in the peak season of sales. 9. Customer can find service staff and get reply no matter when. 10. The time needed for product repair or return
Experience value	Reliability	11. Salesperson could recommend proper products according to different needs of customers. 12. Maintenance personnel is professional and can solve problem quickly. 13. The amount of attention paid to customers' opinions or feedback
	Assurance	14. There is a specific provision of warranty period and clause the guarantee. 15. There are feedback channels like "400" telephone or wechat, weibo or website for customers' complaint. 16. Repair fee is clearly defined. 17. Indemnity clause for product accident is clearly defined
	Empathy	18. Service staffs' attitude towards customer complaints. 19. Courtesy of maintenance personnel. 20. Courtesy of salesperson. 21. Staffs can provide some tips for product using and maintenance
Social value	Social value	1. Brand awareness. 2. Trustworthiness of the company. 3. Market acceptance of the brand
Cost	Cost	1. Price of products and other purchasing costs. 2. Cost of after-sale service. 3. Using cost

(2) The fuzzy evaluation of customer value

After the determination of item set and weight set W, remark set V and fuzzy evaluation matrix of attributes on each dimension R still need to be established to evaluate value. Based on the Likert scale principles, the remark set of this study is set as $V = v_1, v_2, v_3, v_4, v_5 =$ very good, good, fair, inferior, poor. On that basis, membership degree of evaluated item to each dimension needs to be quantified to get fuzzy relation matrix, after the fuzzy transformation, here comes the fuzzy evaluation matrix R.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \ddots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}.$$

Generally, membership degree is evaluated by expert or person familiar with the attributes. Owing to the subjectivity and particularity, however, the fuzzy subsets' membership degree in this study is calculated from data quantified in customer survey to ensure the genuineness and reliability.

Through the fuzzy operating and normalization of fuzzy evaluation matrix and weight vector set, the fuzzy comprehensive evaluation result set S is finally obtained by formula $S = W \times R$. Corporation's performance on each dimensions could be ascertained by the rule of maximum membership degree [9].

4 Application

The customer value measure system proposed in this study is applied in an electronic communication equipment corporation. Based on the value attribute system mentioned above, weight is ascertained by Analytic Hierarchy Process. Concrete scores are obtained by method of the multi-level fuzzy comprehensive evaluation to verify the whole measurement system, hoping to guide the enterprises' management practice.

1. Establishment of Evaluation Item Set U

Based on the customer value attributes system proposed in this study and the unique features of electronic communication device, evaluation item set is established as follows (shown in Table 4). It includes 9 first class indexes, $U =${Attribute, Quality, Tangibles, Responsiveness, Reliability, Assurance, Empathy, social value, cost}, while the fist class is divided into second items of 40.

2. Calculation of Value Attribute Weight

Take the attribute "quality" as example, after rounds of experts rating and adjustment by the method of "1–9 scale", the judgment matrix is obtained as follows,

$$U_2 = \begin{bmatrix} 1 & 2 & 3 & 3 & 5 \\ 1/2 & 1 & 2 & 2 & 4 \\ 1/3 & 1/2 & 1 & 1 & 3 \\ 1/3 & 1/2 & 1 & 1 & 3 \\ 1/5 & 1/4 & 1/3 & 1/3 & 1 \end{bmatrix}.$$

Table 4 Evaluation item set and its weight

Dimension	Weight[a]	Items	Weight[b]
Attribute U1	0.206	1. Exterior Design of product	0.236
		2. Technique level comparing with competitors	0.236
		3. Simplicity of operation or comprehensiveness of instruction	0.177
		4. Market availability of product components	0.096
		5. Environmentalism in the process of production and use	0.031
		6. Current functions are complete	0.118
		7. Expansibility of the product function	0.106
Quality U2	0.206	1. The satisfaction degree of product's basic function	0.405
		2. The satisfaction degree of product's extended function	0.248
		3. The abrasion resistant degree	0.144
		4. Whether there is some obvious quality defects	0.144
		5. Using stability in the product's service life	0.059
Tangibles U3	0.032	1. There are entity channels for customers to experience or purchasing	0.275
		2. There are enough After-sale service channels and are easy to get in touch with	0.545
		3. The brand can be clearly identified and recognized	0.117
		4. The display of the entity channels or the lay out of the online website	0.063
Responsiveness U4	0.094	1. Difficulty of contacting with the service staff	0.168
		2. Arrival speed of service staff to customers' need	0.306
		3. Customer can find service staff and get reply during the trade process and in after-sale service	0.052
		4. Inventory can assure there is no stock out in the peak season of sales	0.168
		5. The time needed for product repair or return	0.306
Reliability U5	0.047	1. Salesperson could recommend proper products according to different need of customers	0.333
		2. Maintenance personnel is professional and can solve problem quickly	0.334
		3. The amount of attention paid to customers' opinions or feedback.	0.333

(continued)

Table 4 (continued)

Dimension	Weight[a]	Items	Weight[b]
Assurance U6	0.064	1. There is a specific provision of warranty period and clause the guarantee	0.364
		2. There are feedback channels like "400" telephone or wechat, weibo or website for customers' complaint	0.207
		3. Repair fee is clearly defined	0.364
		4. Indemnity clause for product accident is clearly defined	0.065
Empathy U7	0.024	1. Service staffs' attitude towards customer complaints	0.397
		2. Courtesy of salesperson	0.397
		3. Courtesy of maintenance personnel	0.155
		4. Staffs can provide tips for product using and maintenance	0.051
Social value U8	0.121	1. Brand awareness	0.429
		2. Market acceptance of the brand	0.429
		3. Trustworthiness of the company	0.142
Cost U9	0.206	1. Price of products and other purchasing costs	0.383
		2. Cost of after-sale service	0.225
		3. Using cost	0.225
		4. Price of fittings	0.127
		5. Extended function cost	0.04

[a]Weight coefficient of dimension; [b]Weight coefficient of item

Then weight coefficient is calculated as:

$$\omega_2 = \{0.40476, 0.24841, 0.14374, 0.14374, 0.05935\},$$

$\lambda_{\max} = 5.0568$, through the consistency check knows that $CI = 0.0142$, when $n = 5$, RI is known as $RI = 1.12$, therefore, $CR = CI/RI = 0.01268 < 0.1$, which stands for the acceptable consistency of the judgment matrix. Similarly, other weight coefficients of value attributes are calculated and shown in Table 4.

3. Establishment of Fuzzy Judgment Matrix

Since evaluation is based on the perceived value customers have on the products and the company, so unlike the traditional way of establishing the fuzzy judgment matrix, this paper scores the performance of attributes by questionnaire survey among customers who has used the product of the company for over 3 months and has some certain understanding of the brand and company. Totally 100 questionnaires were sent out and 96 valid ones were retrieved. After data processing, 65 of the 96 interviewees regard the item in level 2, exterior design of product, as "very good", accounts for 67.7 %, 25 interviewees think it's good, accounts for 26.04 %; the number of people who thinks it's fair is 4, accounts for 4.2 %; the left 2 evaluate the product to be inferior, accounts for 2.1 %, no one votes for poor. So the remark set of the item, exterior design of product is $R_{11} = (0.677, 0.260, 0.042, 0.021, 0)$. Similarly, the remark set of technique level comparing with competitors is $R_{12} = (0.281, 0.417, 0.240, 0.052, 0.010)$, remark set of simplicity of operation is $R_{13} = (0.177, 0.219, 0.448, 0.094, 0.062)$, remark set of market availability of product components is $R_{14} = (0.406, 0.479, 0.115, 0, 0)$, remark set of environmentalism in the process of production and use is $R_{15} = (0.083, 0.146, 0.740, 0.031, 0)$, remark set of current functions is $R_{16} = (0.469, 0.427, 0.094, 0.010, 0)$, remark set of function expansibility is $R_{17} = (0.198, 0.354, 0.323, 0.073, 0.052)$.

Therefore, the fuzzy judgment matrix of attribute is:

$$R_1 = \begin{bmatrix} 0.667 & 0.260 & 0.042 & 0.021 & 0 \\ 0.281 & 0.417 & 0.240 & 0.052 & 0.010 \\ 0.177 & 0.219 & 0.448 & 0.094 & 0.062 \\ 0.406 & 0.479 & 0.115 & 0 & 0 \\ 0.083 & 0.146 & 0.740 & 0.031 & 0 \\ 0.469 & 0.427 & 0.094 & 0.010 & 0 \\ 0.198 & 0.354 & 0.323 & 0.073 & 0.052 \end{bmatrix}.$$

Shown in Table 4, the attribute weight vector is $w_1 = \{0.236, 0.236, 0.177, 0.096, 0.031, 0.118, 0.106\}$, According to the equation $S = W \times R$, the consequence of value evaluation is $S = W_1 R_1 = (0.375, 0.337, 0.225, 0.044, 0.019)$. In the same way, the fuzzy matrixes of index like quality, tangibles are as follows:

$$R_2 = \begin{bmatrix} 0.438 & 0.333 & 0.167 & 0.063 & 0 \\ 0.375 & 0.448 & 0.135 & 0.042 & 0 \\ 0.115 & 0.146 & 0.646 & 0.094 & 0 \\ 0.125 & 0.396 & 0.427 & 0.052 & 0 \\ 0.313 & 0.281 & 0.323 & 0.083 & 0 \end{bmatrix}, \quad R_4 = \begin{bmatrix} 0.104 & 0.271 & 0.365 & 0.188 & 0.073 \\ 0.094 & 0.156 & 0.396 & 0.24 & 0.155 \\ 0.073 & 0.104 & 0.156 & 0.521 & 0.146 \\ 0.155 & 0.177 & 0.299 & 0.299 & 0.25 \\ 0.167 & 0.198 & 0.323 & 0.271 & 0.042 \end{bmatrix},$$

$$R_5 = \begin{bmatrix} 0.469 & 0.417 & 0.083 & 0.031 & 0 \\ 0.125 & 0.135 & 0.49 & 0.188 & 0.063 \\ 0.094 & 0.177 & 0.208 & 0.281 & 0.24 \end{bmatrix}, R_6 = \begin{bmatrix} 0.406 & 0.406 & 0.146 & 0.042 & 0 \\ 0.083 & 0.115 & 0.51 & 0.229 & 0.063 \\ 0.135 & 0.261 & 0.177 & 0.302 & 0.125 \\ 0.073 & 0.344 & 0.385 & 0.104 & 0.094 \end{bmatrix},$$

$$R_7 = \begin{bmatrix} 0.146 & 0.281 & 0.354 & 0.156 & 0.063 \\ 0.417 & 0.354 & 0.198 & 0.031 & 0 \\ 0.073 & 0.292 & 0.385 & 0.167 & 0.083 \\ 0.031 & 0.302 & 0.427 & 0.135 & 0.104 \end{bmatrix}, R_8 = \begin{bmatrix} 0.948 & 0.042 & 0.01 & 0 & 0 \\ 0.917 & 0.052 & 0.031 & 0 & 0 \\ 0.865 & 0.094 & 0.042 & 0 & 0 \end{bmatrix},$$

$$R_9 = \begin{bmatrix} 0.104 & 0.177 & 0.26 & 0.302 & 0.156 \\ 0.073 & 0.135 & 0.375 & 0.24 & 0.177 \\ 0.094 & 0.167 & 0.354 & 0.281 & 0.104 \\ 0.063 & 0.146 & 0.229 & 0.406 & 0.156 \\ 0.115 & 0.198 & 0.292 & 0.271 & 0.125 \end{bmatrix}.$$

The remark set in this research is set as $V = \{v_1, v_2, v_3, v_4, v_5\} = \{$very good, fair, inferior, poor$\} = \{5, 4, 3, 2, 1\}$, by the rule of maximum membership degree, the

Table 5 Evaluation result

Evaluation system		Weight	Remark consequence					Score	Grade
Level 1	Level 2		Very good	Good	Fair	Inferior	Poor		
		0.206	0.375	0.337	0.225	0.044	0.019	4.005	Very good
Attribute U1	U11	0.236	0.677	0.26	0.042	0.021	0	4.594	Very good
	U12	0.236	0.281	0.417	0.24	0.052	0.01	3.906	Good
	U13	0.177	0.177	0.219	0.448	0.094	0.063	3.354	Good
	U14	0.096	0.406	0.479	0.115	0	0	4.292	Very good
	U15	0.031	0.083	0.146	0.74	0.031	0	3.281	Good
	U16	0.118	0.469	0.427	0.094	0.01	0	4.354	Very good
	U17	0.106	0.198	0.354	0.323	0.073	0.052	3.573	Good
		0.206	0.323	0.341	0.275	0.061	0	3.926	Good
Quality U2	U21	0.405	0.438	0.333	0.167	0.063	0	4.146	Very good
	U22	0.248	0.375	0.448	0.135	0.042	0	4.156	Very good
	U23	0.144	0.115	0.146	0.646	0.094	0	3.281	Good
	U24	0.144	0.125	0.396	0.427	0.052	0	3.594	Good
	U25	0.059	0.313	0.281	0.323	0.083	0	3.823	Good
		0.032	0.326	0.332	0.136	0.133	0.073	3.705	Good
Tangibles U3	U31	0.275	0.406	0.438	0.115	0.042	0	4.208	Very good
	U32	0.545	0.229	0.25	0.167	0.219	0.135	3.219	Good
	U33	0.117	0.448	0.458	0.083	0.01	0	4.344	Very good
	U34	0.063	0.583	0.344	0.052	0.021	0	4.49	Very good
		0.094	0.12	0.189	0.328	0.254	0.109	2.957	Fair
Responsiveness U4	U41	0.168	0.104	0.271	0.365	0.188	0.073	3.146	Good
	U42	0.306	0.094	0.156	0.396	0.24	0.115	2.875	Fair
	U43	0.052	0.073	0.104	0.156	0.521	0.146	2.438	Fair
	U44	0.168	0.115	0.177	0.229	0.229	0.25	2.677	Fair
	U45	0.306	0.167	0.198	0.323	0.271	0.042	3.177	Good
		0.047	0.229	0.243	0.26	0.167	0.101	3.332	Good

(continued)

Table 5 (continued)

Evaluation system		Weight	Remark consequence					Score	Grade
Level 1	Level 2		Very good	Good	Fair	Inferior	Poor		
Reliability U5	U51	0.333	0.469	0.417	0.083	0.031	0	4.323	Very good
	U52	0.334	0.125	0.135	0.49	0.188	0.063	3.073	Good
	U53	0.333	0.094	0.177	0.208	0.281	0.24	2.604	Fair
		0.064	0.219	0.289	0.248	0.179	0.065	3.418	Good
Assurance U6	U61	0.364	0.406	0.406	0.146	0.042	0	4.177	Very good
	U62	0.207	0.083	0.115	0.51	0.229	0.063	2.927	Fair
	U63	0.364	0.135	0.26	0.177	0.302	0.125	2.979	Fair
	U64	0.065	0.073	0.344	0.385	0.104	0.094	3.198	Good
		0.024	0.236	0.313	0.301	0.107	0.043	3.592	Good
Empathy U7	U71	0.397	0.146	0.281	0.354	0.156	0.063	3.292	Good
	U72	0.397	0.417	0.354	0.198	0.031	0	4.156	Very good
	U73	0.155	0.073	0.292	0.385	0.167	0.083	3.104	Good
	U74	0.051	0.031	0.302	0.427	0.135	0.104	3.021	Good
		0.121	0.923	0.054	0.024	0	0	4.899	Very good
Social value U8	U81	0.429	0.948	0.042	0.01	0	0	4.938	Very good
	U82	0.429	0.917	0.052	0.031	0	0	4.885	Very good
	U83	0.142	0.865	0.094	0.042	0	0	4.823	Very good
		0.206	0.09	0.162	0.304	0.295	0.148	2.751	Fair
U9 cost	U91	0.383	0.104	0.177	0.26	0.302	0.156	2.771	Fair
	U92	0.225	0.073	0.135	0.375	0.24	0.177	2.688	Fair
	U93	0.225	0.094	0.167	0.354	0.281	0.104	2.865	Fair
	U94	0.127	0.063	0.146	0.229	0.406	0.156	2.552	Fair
	U95	0.04	0.115	0.198	0.292	0.271	0.125	2.906	Fair
CE[a]			0.326	0.245	0.239	0.132	0.057	3.648	Good

[a]Comprehensive evaluation

specific scores of company's customer value are shown in Table 5, The performance scores show that the customer value comprehensive evaluation of the corporation is good, but there's still some improvement room in attributes like responsiveness and cost. The company can focus on some items which is important to customer and weak currently, like "cost", to enhance according to its own specific condition.

5 Conclusion

Quantified scores of corporations' performance on customer value could be obtained by fuzzy evaluation method, which can identify the strength and weakness in different factors that affect customer value. Thus, more accurate basis could be provided for enterprise optimization. Using the customer value system can not only enhance the scientificity and reliability of enterprise decision, but have some guiding significance for the creation of competitive advantage simultaneously.

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Proactive Scheduling Procedures for RCPSP with Beta Distributed Durations and Exponential Distributed Resources

Xuejuan Zhong and Zhe Zhang

Abstract In this paper, we address the resource-constrained project scheduling problem (RCPSP) with beta distributed durations and exponential distributed resources. Since the interruptions and resource breakdowns are common in practice, so the activity durations, whose start time deviates from the proactive scheduling start time, are considered as stochastic because of the influence of resource uncertainty. In the mathematical model, we aim to minimize the deviation of accumulative activity durations in the project and so as to minimize the expected instability costs from the perspective of robust scheduling. The resource interruptions will be considered essentially to make the time buffer to compensate for the tardiness of the start time as well as to get the minimum makespan of activities in the proactive phase. A procedure that combines Starting Time Criticality (STC) heuristic and a tabu search is designed as the solution method. Finally, a numerical example is presented to highlight the efficiency of the proposed model and solution method.

Keywords RCPSP · Proactive · Stochastic activity duration · Resource uncertainty

1 Introduction

The research on resource-constrained project scheduling problem (RCPSP) has achieved great progress over the last decades. The traditional RCPSP typically considered problems with deterministic schedule, which involves the deterministic activity durations and activity starting times. However, unexpected external events may happen in practical and disrupt the scheduling procedures, such as uncertain activity durations, resource breakdowns, equipment failures and so on. As a result, the uncertainty of resources and durations has drawn a growing attention of researchers. Herroelen et al. [8] reviewed the fundamental approaches for scheduling under

X. Zhong · Z. Zhang (✉)
School Economics and Management, Nanjing University of Science and Technology, Nanjing 210094, People's Republic of China
e-mail: zhangzhe@njust.edu.cn

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uncertainty and revealed their potentials for scheduling projects. Lambrechts et al. [10] also built a robust schedule considering the uncertain resource availabilities. Herroelen et al. also classified project scheduling problem with uncertain durations into four scheduling methods, including active, reactive, random and fuzzy schedule in 2005 [8]. Hence, an important research track—proactive scheduling procedure, has been identified in the field of project scheduling under uncertainty. Take the unexpected external events into consideration, a deterministic baseline schedule generated by proactive scheduling procedure should be employed to protect against possible interruptions. Typically, with robustness considered in the proactive scheduling, Van de Vonder et al. [13] proposed the quality robustness and solution robustness to increase schedule robustness. In this case, the random variables such as activity duration, the starting time of activities and scheduling policy are given for proactive schedule. The objective of proactive schedule usually focus on minimizing deviations from the baseline schedule, which is sometimes described as the stability objective [14]. In proactive scheduling procedures, the quality robustness was implemented in minimizing the expected instability costs [5]. He also proposed a stochastic methodology [6] for the determination of a project execution policy and a vector of predictive activity starting times with the objective of minimizing a cost function. Majority of these research discussed the proactive scheduling considering stochastic durations. On the basic of this, an increasing interest on resource availability [17] has been added to the proactive phase in RCPSP in recent years. As a NP-hard problem [3], randomness and variability of activities will be taken into account, and proactive scheduling will be implemented in the paper.

According to the description of RCPSP, project scheduling considers a variety of causes of uncertainty [16, 18], including the uncertain durations and uncertain resources. Hence, the activity duration distributions and resource constraint distributions can then be used to construct a project schedule. In recent research, taking the expected value of deterministic durations as the activity durations, Kolisch et al. [9] took the uniform distribution, exponential distribution and beta distribution into consideration according to different variance. Lambrechts et al. [10] set the instability weights w_i drawn from a discrete, triangularly shaped distribution between 1 and 10, which correspond to what can be expected in real-life projects. To assess the effectiveness of the proposed approach, Bruni et al. [4] tested two distributions under different conditions. They assumed that real activity duration is a uniform random variable in the continuous case, and in the discrete distributions, they have considered a poisson distribution with the mean d_i (activity durations). The more frequently used distribution is the beta distribution. Tsai et al. [12] proposed tabu search algorithm with uncertain activity duration subjecting to beta distribution. Van de Vonder et al. [15] also demonstrated that the real activity durations are all discretized values drawn from a right-skewed beta-distribution and the activity duration variability was divided into three level, that is low, high and random duration variability. To consider the resource constraint distributions, which include resource breakdowns, repairs and intervals between interruptions, researchers usually use exponential distribution to describe these situations. According to assumptions of Lambrechts et al. in [11], they chose exponential distributed to model times to failure and repair times, which is unambiguously defined by its expected value. Girault [7] believes that the times between failures will be exponentially distributed, which is analytically interesting and practically acceptable. This paper will combine the distribution of activity durations with resource, which respectively described by beta distribution and exponential distribution, to obtain the minimization of instability cost and makespan.

Considering the parameter distribution mentioned above, RCPSP is to be handled in the proactive phase to satisfied with both robust quality and robust solution. The remainder of this paper is organized as follows. In Sect. 2, we will present the problem description, including the brief explanation and introduction of these variables. Then the bi-objective model will be given as well, where assumptions and notation will be presented in detail. In Sect. 3, a combination of Starting Time Criticality (STC) heuristic and a tabu search is implemented to buffer the activity with the STC value to minimize the makespan and instability costs. Furthermore, in the Sect. 4, a numerical example will be presented to prove the efficiency of proposed model and solution method. Results will be evaluated and analyzed as concluding marks in the Sect. 5.

2 Research Problem and Modeling

In this section, the description of RCPSP with beta distributed durations and exponential distributed resources will be described, and then the bi-objective model will be developed for the proactive schedule.

2.1 Problem Description

Commonly, it can be found that most deterministic project scheduling models assumed that the activity durations are given and the scheduling procedure will be carried out in ideal conditions. However, in practice, unexpected factors such as resource breakdowns and repairs will be occurred and disturb the implementation of the schedule. Take these uncertain factors into account, this paper will discuss the impact these interruptions made on scheduling procedure. What's more, the proactive scheduling usually involves robust scheduling with deviation of the activity durations. While most of other research concentrate in minimize the makespan. Fawzan et al. [1] has ever proposed a bi-objective model with makespan minimization and robustness

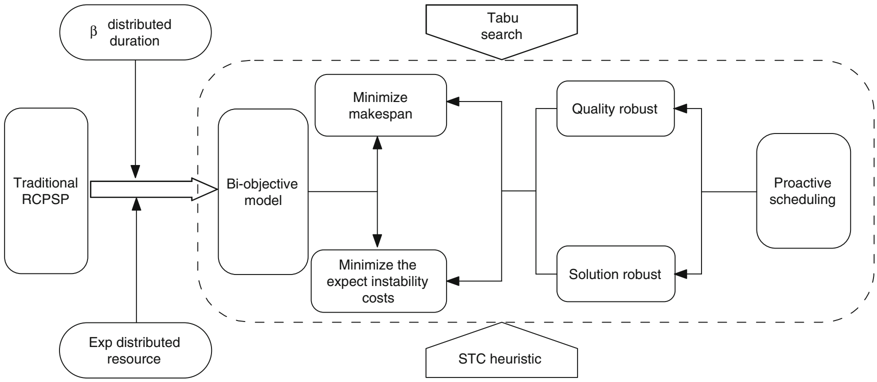

Fig. 1 Flow chart of the bi-objective model

maximization on the base of multi-objective framework. To optimize the objective, both of the expected instability costs and the makepan minimization will be combined together in the paper. To generate the proactive scheduling, the two objective can be respectively classified to solution robustness and quality robustness. The minimization of the makespan is connected to the completion of the project, equivalent to the quality robustness, while the stability attributed to the deviation of activities and the weight set to the activities. Therefore, a bi-objective model will be also applied in this paper for a proactive scheduling. We assume that the distribution of activity durations subject to beta distribution ($d_i \sim B(p, q)$). In the case of resource constraints, the time of the resource failure MTTF_k and repair MTTF_k are exponential distributed, k means the resource type. The flow chart of the model is shown in Fig. 1.

2.2 *Modeling*

In this subsection, for RCPSP considering beta-distributed durations and exponential-distributed resources, we will establish a bi-objective model with the pursuit of minimum deviation and the shortest makespan.

Cost Minimization Objective

As previously mentioned, to generate a proactive schedule to get a deterministic baseline schedule, we object to minimize the expected instability costs as follows. In the function, S_i means the the real start time of the activity i, while s_i means the planned start time. The cost C implicates the punishment of the delay in the start of the activity, and w_i means the weight of each activity.

$$\min C = \sum_{i \in N} w_i \times |E(S_i) - s_i| . \tag{1}$$

In this case, we assume that the real start time of the activity can never be earlier than the planned start time ($s_i \leq S_i$), and the resource allocations are fixed. However, the resource breakdowns can not be neglected. As demonstrated above, the interruptions occurs randomly and we have to take them into account. Referring to [11], resource failures and repairs are exponential-distributed. Thus, the objective function (1) can be converted into:

$$\min C = \sum_{j \in N} \sum_{i \in \mathrm{PRED}_j^*} w_j \max(0, s_i + d_i + LP_{ij} + E[\sigma_i] - s_j), \tag{2}$$

with

$$\begin{aligned} E[\sigma_i] &= \frac{\varphi_i}{(1-\varphi_i)\left(\sum_k \lambda_k r_{ik}\right)}\left(1 + \sum_k \frac{\lambda_k r_{ik}}{\mu_k}\right) - d_i, \\ \varphi_i &= 1 - e^{-d_i \sum_k \lambda_k r_{ik}}. \end{aligned} \tag{3}$$

The function are suitable for the preempt-repeat environment, and the function in preempt-resume environment can be easily deduced in the same way. In the function (2), r_{ik} means per period usage of resource type k for activity i, LP_{ij} means the length of the path between activities i and j, σ_i means the stochastic duration increase of i due to failures and repairs. According to the distribution of resource failures and repairs, λ is the parameter of the exponentially distributed time to failure of each resource unit. Its expected value can be calculated as follows:

$$E[F_i] = \frac{1}{\sum_k \lambda_k r_{ik}} - \frac{d_i(1-\varphi_i)}{\varphi_i}.$$

Then μ is the parameter of the exponentially distributed time to repair and the function is:

$$E[R_i] = \sum_k \frac{\lambda_k r_{ik}}{\sum_l \lambda_l r_{il}} \frac{1}{\mu_k}, l \neq k.$$

Let φ_i denote the probability the activity i is interrupted. Then according to the density distribution function of the frequency of the interruptions N_i, the expect value of N_i can be worked out as:

$$E[N_i] = \varphi_i / 1 - \varphi_i.$$

Obviously, $E[\sigma_i] = E[F_i]E[N_i] + E[R_i]E[N_i]$. F_i means the failures encountered by activity i, and R_i correspondingly means the repairs.

Makespan minimization objective

Apart from considering the stability of the schedule, the quality robustness objective is benefit to the proactive schedule. Here is another objective function.

$$\min M = S_n. \tag{4}$$

This function subjects to the same constraints in the cost minimization objective. It aims to calculate the minimization of the real start time and the duration of the last second activity, and the last second activity must be the precedence activities of the last activity. As the deviations between the real start time and the planned one regarded as the buffers inserted into the planned start time. The buffer should be considered in minimizing the makespan. Accordingly, what can be formulated as:

$$S_n = s_{n-1} + d_{n-1} + LP_{(n-1,n)} + E[\sigma_{n-1}]. \tag{5}$$

In order to represent the project, we choose a digraph $G = (N, A)$, which contains a set of nodes N and a set of arcs A. N represents the process of the activity and the A represents the connection of two continuous activity. To consider the order of activities, we set that activity j cannot start before activity i has finished.

$$s_i + d_i \le s_j, \forall (i, j) \in A. \tag{6}$$

d_i represents the planned activity duration. Here $(i, j) \in A$ means activity $i_{(i=1,\ldots,n)}$ is an immediate predecessor of activity j.

Take the renewable resource constraints into account, we assume that the resource requirements r_{ik} of resource type k of the processed activity in period t can be satisfied with resource capacity c_k. Busy$_t$ means the set of activities in progress during period t.

$$\sum_{i \in \text{Busy}_t} r_{ik} \le c_k, \forall t, \forall k. \tag{7}$$

The project has to be completed before the deadline δ. S_n means the start time of final activity as it is a virtual activity as well as the beginning activity.

$$S_n \le \delta. \tag{8}$$

Therefore, to combine Eqs. (2), (5), (6), (7) and (8), we can get:

$$\begin{aligned}
&\min C = \sum_{j \in N} \sum_{i \in \mathrm{PRED}_j^*} w_j \max(0, s_i + d_i + LP_{ij} + E[\sigma_i] - s_j) \\
&\min M = s_{n-1} + d_{n-1} + LP_{(n-1,n)} + E[\sigma_{n-1}] \\
&\text{s.t.} \begin{cases} s_i + d_i \le s_j, & \forall (i, j) \in A \\ \sum_{i \in \mathrm{Busy}_t} r_{ik} \le a_k, \forall t, \forall k \\ S_n \le \delta. \end{cases}
\end{aligned} \tag{9}$$

As demonstrated, we assume that the activity duration is subjected to a beta-distribution with parameter 2 and 5 [15]. It means low duration variability with the mean equal to $E(d_i)$, minimum and maximum values equal to 0.75 times and 1.625 times $E(d_i)$. And the activity durations are all discretized values. The interruptions described above can compensate for the shortness of the beta-distributed durations.

3 Solution Method

From the descriptions of the duration d_i and interruptions F_i of failures and repairs R_i, we can see that all the parameters should be considered into the buffers in the proactive phase. It is assumed that the list of the activities has already been ordered in a non-decreasing sequence with forward recursion procedure (SGS) [1]. What we need to do is to find the most suitable sequence of activities which generate the minimization of the cost of deviation and the makespan of the project.

To get the minimization of the instability cost, we have to suppose that the sequence of activities have been listed properly, and the distribution of durations, resources are known. Meanwhile it is supposed that the w_i subject to uniform distribution. The procedure should be processed as follows:

Step 1. According to the distribution of repairs and failures, we can get the output of one type of resource interfered with duration d_i,

$$E(N(i)) = \varphi_i/1 - \varphi_i,\ E(F_i) = 1/(\lambda \times r_i) - d_i \times (1 - \varphi_i)/\varphi_i,\ E(R_i) = 1/\mu_k.$$

Step 2. To sum all types of resources to generate the deviation cause by resource failures and repairs in the activity duration d_i.
Step 3. To calculate the deviation of each activity only if the deviation postpone the start time of the immediate successor and sum the deviation values.
Step 4. After the total cost of the neighborhood calculated, then get the minimization of the total cost.

Algorithm 1. Instability cost minimization

Initialization: $n = J, i = j - 1, s_1 = 0, S_1 = 0, r_i = 0$
For $j = 2 : 1 : n$
  $w_j =$ mean w_j
  $p =$ unifrnd(0,1)
  $d_i =$ betainv(p, 2, 5)
  $s_j = s_i + d_i + LP_{ij}$
  $E(S_j) - s_j = s_i + d_i + LP_{ij} + E(\sigma_i) - s_j$
  If $E(S_j) - s_j \leq 0$
    $E(S_j) - s_j = s_i + d_i + LP_{ij} + E(\sigma_i) - s_j$
  Else
    $E(S_j) - s_j = 0$
  End
  For $k = 1 : 1 : K$
    $\lambda r_i = \lambda r_i + \lambda_k r_{ik}, \quad \frac{\lambda r_i}{\mu} = \frac{\lambda r_i}{\mu} + \frac{\lambda r_i}{\mu_k}$
  End
    $E(\sigma_{(i)}) = E(F_i) \times E(N_i) + E(R_i) \times E(N_i)$
    $E(N_i) = \varphi_i / 1 - \varphi_i$
    $\varphi_i = 1 - exp(-\lambda \times r_i \times d_i)$
    $E(F_i) = 1/(\lambda \times r_i) - d_i \times (1 - \varphi_i)/\varphi_i$
    $E(R_i) = 1/\mu$
End
$C = \sum(w_j \times (E(S_j) - s_j))$

Considering the buffers inserted into the beginning of each activity, resource breakdowns will be considered in the minimization of makespan as well as instability cost. Therefore, the sequence of the scheduling list has to be rearranged. Hence, the start time of the last activity can derived from the list. According to the SGS, a backward recursion procedure can be applied by analogy with buffers.

Step 1. Get the initial feasible schedule.
Step 2. A tabu move swapping the positions of two activity subject to the precedence constraints and resource constraints to get the neighbourhood.
Step 3. The circulation terminates if it produces a solution which outperforms the best solution obtained so far.

Algorithm 2. Feasible schedule list with buffer insertion

Initialization: $UA = J$, $ES = \{S_n\}$, $q = 1$, $S(1) = S_n$
For i = n down to 1 do
  Select the activity $j = j_{(i)}$
  set $UA = UA \setminus \{j\}$
  for all $t \in ES$ do
    For $k = 1, \ldots, K$ do
      Compute $c_k(t)$
  $F_j^l = \min_{h \in SUCC_j} S_h^e$
  Let q be the index with $F_j^l = S_q$
  While $(\forall t \in [S_j^e, F_j^l], \forall k \in 1, \ldots, K, r_{jk} \leq c_k(t))$ is false do
    $q = q + 1$
    $F_j^l = S_q$
End
$S_j^l = F_j^l - d_j$
$ES = ES \cup S_j$, Update S
End
If $S_n > \delta$
  repeat For
Else
  break

In the Algorithm 2, UA denotes the set of unscheduled activities, $ES = \{S_j, j \notin UA\}$, $S_{(q)}$ means the list of the elements of ES ranked in a non-decreasing order, S_j^l means the latest finish time of activity j, and superscript e denotes the earliest as well as the finish time F_j. After generating the initial feasible schedule, the two activities of the project can be swapped as a tabu move. In each move, considering the weight probability the start time will be delayed, STC heuristic will be used to generate the most feasible buffers through iteration [2]. Sine then, suppose that

$$\min Y = \nu_1 \times \min C + \nu_2 \times \min M,$$

in which ν is the balance between instability cost and makespan, a combinition of the shortest makespan and the lowest instability cost can be generated.

4 Numerical Example

In order to display the procedure, a network diagram instance will be implemented with some parameters ever used by Lambrechts et al. [11]. In this example, another resource is added to the project with $c_{i2} = 10$ (Fig. 2).

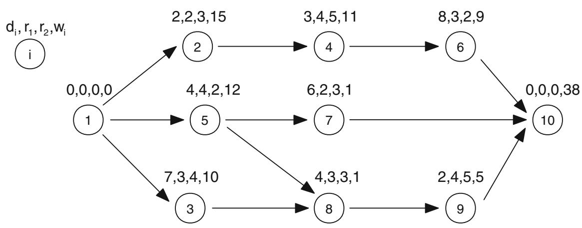

Fig. 2 The working procedure in RCPSP

Since the instability weights were drawn from a triangularly shaped distribution between 1 and 10, $w_i = \{0, 15, 10, 11, 12, 9, 1, 1, 5, 38\}$. Assuming that the parameter of resource failures λ and resource repairs μ are satisfied with $1/\lambda = 15$ and $1/\mu = 3$ respectively with both two resources [11]. We are able to calculate the value of φ and $E(\sigma_i)$, $\varphi = \{0, 0.49, 0.96, 0.83, 0.80, 0.93, 0.86, 0.80, 0.70, 0\}$ and $E(\sigma_i) = \{0, 2.84, 49.45, 8.22, 8.08, 34.18, 15.17, 8.08, 4.67, 0\}$. According to SGS, the unbuffered schedule of r_{ik} can be generated as Figs. 3 and 4.

Hence, LP_{ij} can be deduced from the sequence of activities with index of start time of it. Thus, we generate a processing line as Fig. 5, and the deviation of instability minimization is $\{0, 0, 3, 8, 0, 8, 8, 49, 15, 34\}$ with $E(\sigma_i)$ rounded to nearest integer. Considering the deadline, the last activities play an very important role the project completion, we assume that the weight of the last activity is 10 times of the weight of other activities. Therefore, the minimization of cost of the deviation with no buffers $\min C = 1614$. Meanwhile, the makespan is 15.

Once the deviation defined, buffers should be inserted in the beginning of each activity. From another perspective, the cost arising form the increase of the duration can be reduced. Through Algorithm 2, a new sequence of activities should be

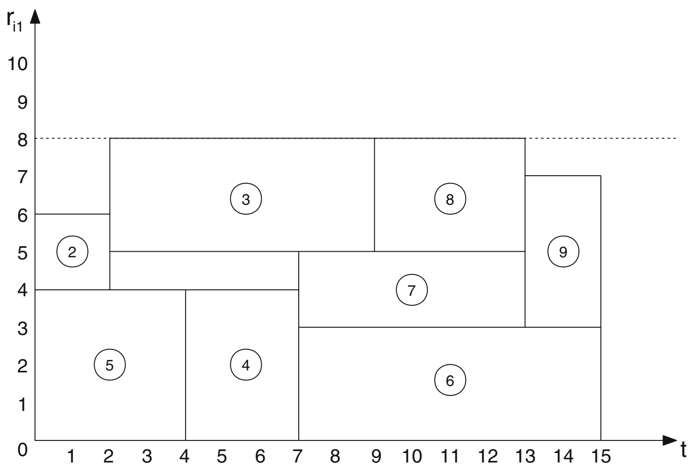

Fig. 3 Unbuffered schedule of r_{i1}

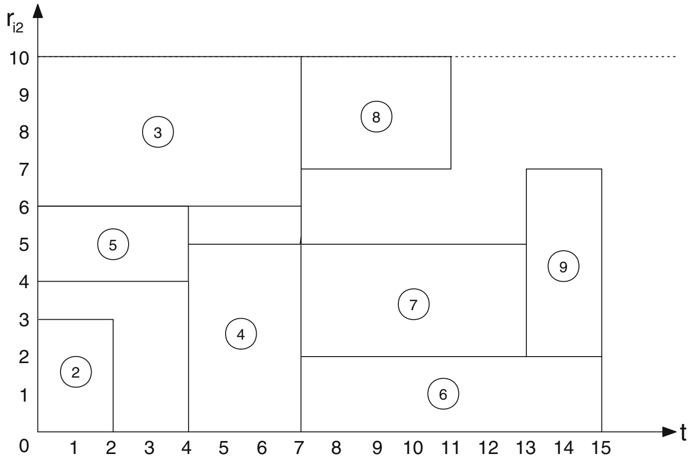

Fig. 4 Unbuffered schedule of r_{i2}

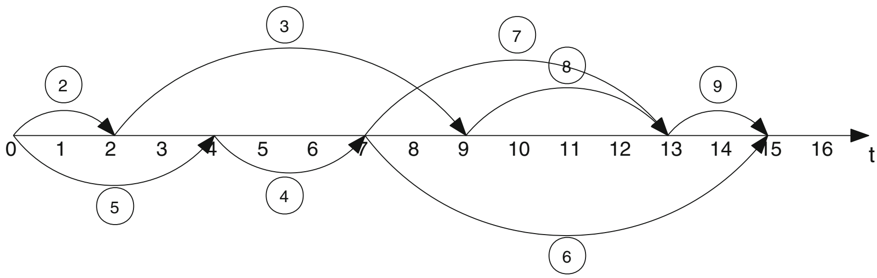

Fig. 5 Unbuffered schedule of r_{ik}

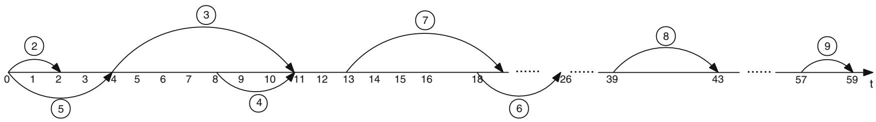

Fig. 6 Buffered schedule of r_{ik}

arranged. With regard to the rearranged schedule of r_{i1} and r_{i2}, we assume that a due date δ equal to 70 and $\nu = [1, 10]$. Through swapping the positions of two activities obey conditions in Algorithm 2, the buffered schedule can be displayed as Fig. 6.

In this case, we calculate the $\min C = 1159$ and $\min M = 59$ to get the minimization of Y. It depends on the significance that the project manager put on the makespan and the deviation, especially when it goes beyond the deadline.

5 Conclusions

In this paper, considering the interruptions of resources and the stochastic durations, a bi-objective model which satisfy both robust quality and robust solution is developed for the practical resource-constrained project scheduling problems. The proposed model employs the beta-distributed durations and exponential-distributed resources to hybrid the variation of durations, and this application makes the model is more suitable for describing interruptions in the real scheduling procedure. To generate a proactive schedule with robustness, a combination of Starting Time Criticality (STC) heuristic and tabu search is implemented according to the bi-objective model. For illustrating the effectiveness, the proposed model and algorithm are successfully applied to the numerical example.

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Real Estate Development Enterprises Dynamic Value Chain Model Building and Evaluation

Liling Huang and Guichuan Zhou

Abstract Based on the theories related to value chain and the features of real estate development enterprises, we have built real estate development enterprises dynamic value chain model. Through field investigation of real estate development enterprises in Sichuan province, using FAHP method to evaluate real estate development enterprises dynamic value chain model in Sichuan, we made the conclusion that the overall value of real estate development enterprises in Sichuan is at a medium level. This study aims to help real estate development enterprises to overcome the difficulties from complicated external environment which led to their own value chain fission, at the same time, provide ideas for real estate development enterprises in enhancing their competitive advantage and their own value. In the beginning, the article reviews the evolution and development of the value chain theory, which followed by the analysis of real estate development enterprises internal and external value points. In the next place, real estate development enterprises dynamic value chain model has been built. Finally we evaluate the level of the overall value of real estate development enterprises in certain area under the guidance of FAHP method after making the field research on real estate development enterprises in Sichuan.

Keywords Real estate development enterprises · Dynamic value chain · Fuzzy analytic hierarchy process (FAHP)

1 Introduction

At present, real estate industry is a pillar industry of national economy, which is directly related to whether the healthy development of the rise and fall of the

L. Huang · G. Zhou (✉)
Business School, Sichuan University, 610064 Chengdu, People's Republic of China
e-mail: zhouguichuan@vip.163.com

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national economy. Real estate industry's development has become one of the hot spots of economic development in China. However, with the trend of strengthened state macro-control and intensified industry competition, lots of small and medium-sized real estate enterprises have falled, even withdrawed from the market. The real estate industry gradually move towards rational and small profit. For the sake of sustainable competitive advantage, real estate development enterprises need to initiatively adjust the enterprises' internal resources and ability, making it match the external environment. The article choose values as research foundation and breakthrough point, build and evaluate the dynamic value chain of real estate development enterprises in order to guide real estate development enterprise to their direction in future.

2 Theoretical Basis

2.1 The Value Chain

Strategy of famous scientists Porter [6] put forward the value chain concept based on manufacturing enterprise features. In his book Competitive Advantage. The value chain includes two major parts of activities: auxiliary activities (human resource management, infrastructure construction, technology development, procurement) and basic activities (production and operation, external logistics, internal logistics, marketing and after-sales service).

Shank and Govin [8] extended the concept of value chain, defined it as the whole process of value production, which including the process from obtaining the raw materials of original suppliers to delivering the final product to the users, and it was widely useable to all enterprises.

Walters and Lancaster [9] emphasized that the value chain takes market as the guidance, it is a business system which creates user satisfaction and helps other partners to enhance their value. Using the perspective to find driver chain is used to determine the enterprise's position in the market.

Haines [3] on the basis of the former further stressed that the customer and raw material is part of the value chain, especially the customer demand should be the focus of production process, which create a new source of value. He proposed the value chain to adapt to the changing external environment so as to obtain competitive advantage.

Fearne [2] regarded value chain as a kind of thinking of its main goal is to increase revenues by adding value to the differentiated product. So, it demanded collaborative and focus on supply chain resilience and shared resource allocation, risk as well as benefits.

In general, the traditional value chain is profit-oriented which links production, logistics, finance and human resources activities, though they seems like independent division. The process of supply, production, sales are linked, which constitutes a chain system of efficient operation. It can reflect the enterprise's strategic type, the method of strategy implementation and the production and operation situation. However, the traditional value chain theory still exists defects, it limited to analyzing internal structure and internal resource, even ignored intergrating resource by using external market. So it is a static analysis method.

2.2 The Dynamic Value Chain

After Professor E. Porter put forward the concept of value chain, the domestic and foreign scholars have improved and extended the traditional value chain in the direction of internal and external.

Shank and Goindarajan [7] defines industry value chain, they pointed out the value chain not only exists in enterprise, but also exists among enterprises. A single enterprise can enhance its own competitive advantage through the decomposition and integration of the industry chain value.

Rayport and Sviokla [4] proposed the virtual value chain, they considered there are physical value chain made of the material world and virtual value chain composed of information in enterprise. At any stage of the virtual value chain involves five activities: collecting, sorting, filtering, integrated and delivering information.

Allee [1] raised the value network, he thought the process of network value creation and delivery is a complex dynamic process contains single or more enterprises, customers, suppliers and strategic partners. In fact, the value chain turn into a network chain.

Wang [10] defined the dynamic industry value chain, which emphasizes dynamic characteristics. He considered enterprise development as the dynamic development process within the scope of a specific industry.

Ju [5] considered the development of the value chain theory was in-depth study with the progress and innovation in the way of social production. So, in recent years, many scholars research the value chain theory from a perspective of dynamic and development.

Integrated utilization of virtual value chain, value network and dynamic industry value chain theory, focusing on a single enterprise, fully considering interactive relationship of internal value activities and external parties, we present the definition of enterprise dynamic value chain: Dynamic value chain is a dynamic, comprehensive, and profit-oriented value chain, basing on the theory of traditional value chain and value network, teasing out each enterprise internal value points including raw materials, production, operation, marketing, human resources, technology research and development, storage and other activities, at the same time, considering external value points such as the mutual relationship of the government, suppliers, partners, competitors and customers.

Obviously, the difference of dynamic value chain and traditional value chain is the output, the former outputs the overall value of the enterprise, however the latter chain focus on profits. The dynamic value chain emphasizes the characteristic of "dynamic", which highlights the important role of external value activities to achieving the goal of realizing the overall value and extending the business. The core of the dynamic value chain is enterprise value optimization, it reconsiders the process related to value added, modularize these process which possessing a comparative advantage, then integrates all modulars together. The concept of the dynamic value chain makes up the defect of Porter's tradional value chain theory, it is helpful for enterprises to realize resources integration through external market.

2.3 The Dynamic Value Chain of Real Estate Development Enterprises

Real estate development enterprises are engaged in real estate developing and operating, they are not only the product producer, also the operator of real estate commodity. The development and operation of real estate development enterprises is different of construction enterprises, which own characteristics, such as large investment, high risk operation, long period construction and complex development ways.

Therefore, it can be said that the real estate development enterprise is a "systems integrator", their commodity combine capital, land, engineering, property management, environment and other variable factors, so that they will maximize their market value through leasing, advertising, marketing and other services. Adopting the former theory dynamic value chain, we can summarize the dynamic value chain of real estate development enterprises. Compared with the manufacturing enterprise, the dynamic value chain of real estate development enterprises has the following distinctive features:

First, the dynamic value chain of real estate development enterprises is a collection of value activities. The added value of enterprises not only stems from the inside situation, even from the interaction with the external environment. Thus, the dynamic value chain of enterprises constitutes by both internal and external value.

Second, the chain takes enterprise comprehensive value optimal as the core, contributes to identify the effective value factors through the perspective of the customer and the staff, and help construct dynamic value chain model, rather than mechanical combined with all valuable activities and external related parties.

Third, the interconnectedness of value activities in this chain will bring competitive advantage by the way of optimization and coordination. For example, detailed market research and marketing planning may increase invested cost at an early stage, but they are helpful for avoiding making unexpected errors as to ensure market sales operating normally. At last, they can reduce the cost of market sales and property management. The phenomenon reflects enterprises make trade-offs to achieve the overall objectives.

3 Real Estate Development Enterprises Dynamic Value Chain Model

3.1 Analyzing Real Estate Development Enterprises Value Points

1. Real Estate Development Enterprises Internal Value Points
Based on Porter's traditional value chain theory, real estate development enterprises value chain is divided into two parts-basic activities and assistant activities as shown in Fig. 1.
(1) Basic Activities
Investment decision analysis. It is the first link in development process of real estate enterprises, even it is the most crucial link. Before real estate developers obtained land use right, they need to prove the selected plots, that is making detailed market research for the surrounding property on their competitive frame, in order to clear the main consumption, set an appropriate market location market positioning, study on project feasibility and other early activities.

Construction preparation. At this stage, it is responsible for specifying the professionals to design development area, in the meantime, it should be complied with the requirements of the city's overall planning. During the construction preparation period, controlling the project cost is particularly important, the reason is about 70 % of total cost of the project development is determined at this stage, and the quality of products will play a key role for customer satisfaction.

Construction implementation. This step usually includes bidding, contracts signing, projects implementation and acceptance. In the process of project construction,

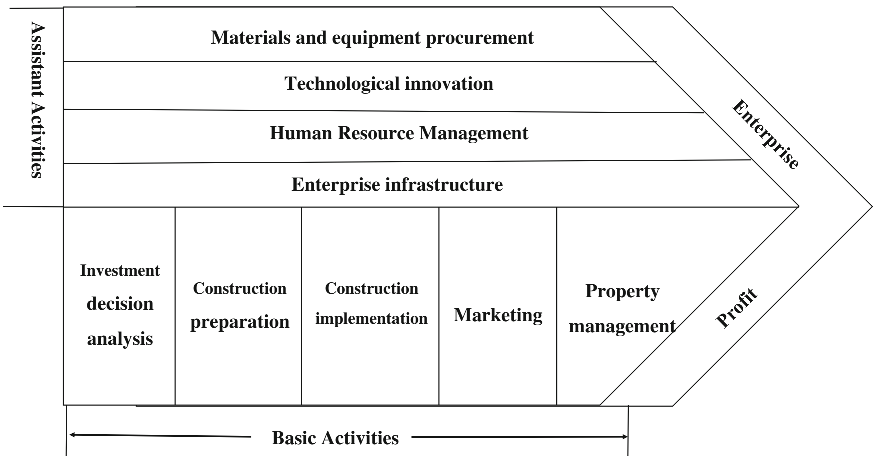

Fig. 1 Real estate development enterprises internal value chain

real estate developers should focus on the construction of engineering project management, such as quality control, schedule control and cost control. When real estate property entity construction and public facilities construction are completed, the project enters the completion acceptance stage.

Marketing. This stage directly determines whether enterprises would smoothly achieve the real estate development activities and commodity value. Marketing activities include pricing strategy, image promotion, advertising promotion, sales channels and sales team selection. At this point, closely cooperating with sales, planning department has become the key point to increase enterprise's value.

Property management. Referred to various services to increase or maintain the value of the product. Due to the increasingly competitive imitation in real estate market, it is very difficult for enterprises to gain sustainable competitive advantage only using technology or products. Therefore, high level property management service plays an important role in adding product value.

(2) Assistant Activities

Materials and equipment procurement. Refers to the purchase of various inputs used in enterprise value chain activities. Financing should be considered as well as land acquisition and funds reserving. The purchasing contents land use rights, construction funds, building materials, intermediary agency, office equipment and technology, and other supplies.

Technological innovation. A variety of activities refers to improving products and processes. Real estate development enterprises technological innovation present in all stages of basic activities, such as feasibility studies on early market development, the development process of construction and implementation, market research marketing stage, and sales of property management procedures.

Human Resource Management. These activities include all types of personnel involved in the recruitment, training and development, appraisal, remuneration and incentives. To some extent, it affects the competitive advantage size. Because it directly affects the enthusiasm and efficiency of staff, even the cost of hiring and training.

Enterprise infrastructure. Kinds of activities contents real estate investment planning system, financial accounting analysis, land management and urban planning department contact management and legal departments, government affairs management and so on. Under our current management system, relations with the government has become more important in the enterprise infrastructure.

2. Real Estate Development Enterprises External Value Points

Traditional real estate industry led to the developer, however, with the deepening of specialization, the importance national macro-control and the change of market demand, real estate development companies need to break the traditional thinking, make its value system naturally extend to outside. Analysis shows that the external value of real estate development enterprises are mainly related government, financiers, partners, competitors and customers as shown in Fig. 2.

Government. The real estate industry is characterized with extremely strong policy-oriented. National macroeconomic policy and relations of government for

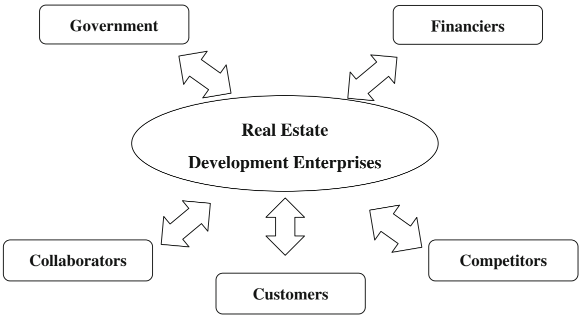

Fig. 2 Real estate development enterprises external value Ponits

the real estate is essential. Because land resources are the basis of the national economy, and the housing problem also involves the entire social stability. Additionally, due to the tax reform, local government largely dependent on local property taxes, so the rise and fall of real estate are closely connected with local finances. The impact of government on the real estate development business is the purchase of limited credit, tax policy, information disclosure, land supply, regulatory and other approvals.

Financiers. The real estate industry is a capital-intensive industry, the vast majority of them is debt management. Therefore, financing capability is a key element of assessing real estate enterprises competitiveness. Financiers is just a generic name in this paper, including financial institutions, capital markets, non-financial institutions and private lending, etc. What the impact of the financial institutions on real estate development enterprises is qualification examination, the loan amount, interest rate, loan term and other constraints.

Collaborators. Real estate development is a complex and long process that involves both a variety of technical and professional knowledge, but also involves a number of industries. In order to better play the core strengths of enterprises, real estate development companies will outsource most of their business, however, enterprise own are responsible for integration and cost control major resources. Generally collaborators include: material suppliers, design units, construction parties, advertising planning, marketing agents and property companies, etc.

Competitors. The gap between leading enterprises and small businesses is growing, the competitive situation of the real estate industry has been basically cured.For real estate development enterprises, the impact coming from their competitors include: the scramble for resources (capital and land, etc.), customer competition, trade barriers, price competition, strategic cooperation (including joint development, resource sharing and brand marriage, etc.).

Customers. Customer value is the value of real estate development enterprises the ultimate expression, to meet customer needs in the process is the process to achieve customer value, which is the process of delivering main value among design firms, construction units, and the amount of transfer agency. Real estate customer value is mainly reflected in four areas: economic value, using value, brand value and services value.

3.2 Building Real Estate Development Enterprises Dynamic Value Chain Model

Through the former analysis of internal and external value points in the real estate development business, we know the internal and external value of the real estate development enterprises have realized in the form of value activities, such as investment decision analysis, construction preparation, construction implementation, marketing and property management. These activities are affected by the external value parties, such as the government, financiers, collaborators, competitors and customers, while internal resources and capabilities also associate with the realization of these values activities. At the same time, enterprise value activities come from seven elements-land, capital, talent, corporate culture, brand, information and management. So, we will summarize an organic whole constituted by these seven elements. Through the interaction between the elements, achieve and improve the value of real estate development enterprises.

Therefore, build real estate development enterprise dynamic value chain model (Fig. 3) based on system integration concept. It made a total of four parts: First, external association, including governments, financiers, collaborators, competitors and customers; Second, factors affecting value activities achievement, including land, funds, talent, corporate culture, brand, information and management; Third, internal activities, including investment decision analysis, construction preparation, implementation, marketing, and property management; Fourth, the overall value of the real estate development enterprises, which is the chain's output finally.

The movement of dynamic value chain model:

(1) Those associated with the occurrence of an external change will have an impact on the internal capabilities and resources directly or indirectly.
(2) The internal abilities and resources change lead to causing changes in internal enterprise value activities.

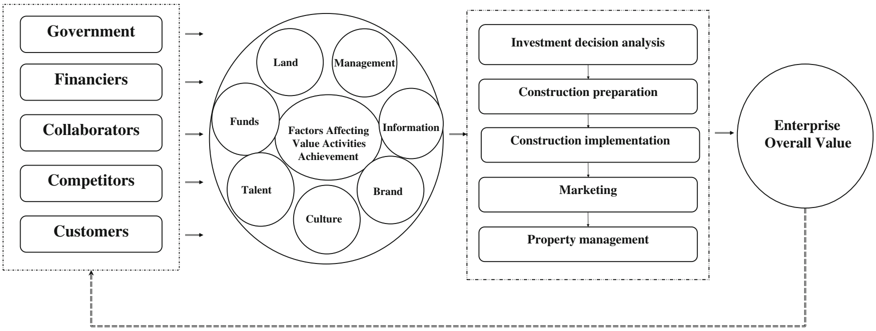

Fig. 3 Real estate development enterprises dynamic value chain Model

(3) According to Porter's traditional value chain theory, the internal value activities is undoubtedly a generator for enterprise value, so changes associated with those external parties will be reflected in the overall enterprise value.
(4) The overall value of the enterprise changed, inevitably have an impact on business decisions or action that were changed by an external association.

4 Evaluate Real Estate Development Enterprise Dynamic Value Chain Model Based on FAHP

4.1 Questionnaire Design and Implementation Research

In order to scientifically evaluate the dynamic value chain of real estate development enterprises, we design a questionnaire (due to limited space, not repeat them here) to do field research.

1. Research objects
All the data comes from 30 real estate development enterprises in Sichuan conducted by direct and indirect investigation. To ensure the objectivity of the findings, the investigators will be divided into three categories, first 129 real estate internal employees, including 74 staff functions, 55 business staff (35 people above manager level); Second 93 consultants work on related industry; Third 100 customers who have purchased commercial residential building.

2. Questionnaire form
Through setting certain problems, let respondents evaluate level of questions directly. About setting up the topic, we use Likert scale to itemize attitude scale in this article, scale dimensions from 5 scale, including the "very close association of 7", "close associate of 5", "associate degree in general of 3", "weak association of 1", "almost no association of 0".

3. Data collection
In this paper, we adopt sampling survey method, conducting field research and online research. The field investigation is mainly on-site interviews for 36 internal staff above manager level. The investigation lasted two months, issuing a total of 322 questionnaires, 277 were returned back, 210 questionnaires were obtained after screening, including internal staff of 63 in A enterprise, 76 real estate consultants, and 71 buyers.

4. Sample reliability and validity analysis
Using Baja Alpha clone to test the real estate dynamic value chain constitutes evaluation reliability co-efficient, and test content validity. Sample structure validity are analyzed to assess the quality of structure validity by a factor of load capacity. As the road factor of each question is greater than 0.5, let the same questions of each test variables into a single factor by factor analysis.

Sphere test statistics has passed significant test ($p < 0.001$) indicates that data are consistent with the conditions of factor analysis. Meanwhile, the factor loading coefficients were higher than 0.5, indicates that the real estate value chain dynamic factor rating scale has strong convergent validity.

4.2 Identify the Weights Base on AHP

1. Established the hierarchy structure.
Based on real estate development enterprises dynamic value chain, establish evaluation model of real estate development enterprise dynamic value chain (Fig. 4).

As is shown on the picture above, the first layer (A): optimal enterprise value, target layer. Through the establishment of real estate development enterprises dynamic value chain evaluation model, finally expect to arrive at a regional overall situation of real estate development enterprise value merits, or draw the merits of the value of real estate development enterprises; The second layer (B): value activities, criterion level. Including investment decision analysis, construction preparation, construction implementation, marketing and property management; The third layer (C): factors affecting value activities achieving, secondary criterion level. Including land, funds, talent, corporate culture, brand, information and management; The fourth layer (D): external related parties, indicator layer. Including the government, financiers, collaborators, competitors and customers.

2. Construct pairwise comparison judgment matrix.
Based on expert scoring, construct the structure of the various levels of pairwise comparison judgment matrix.

3. Single-level sorting and consistency checking.
Using MATLAB software programmed calculations obtain the weight of each matrix, the maximum characteristic root, consistency index and consistency ratio, finally the results of each test prove that the consistency of judgment matrix are acceptable.

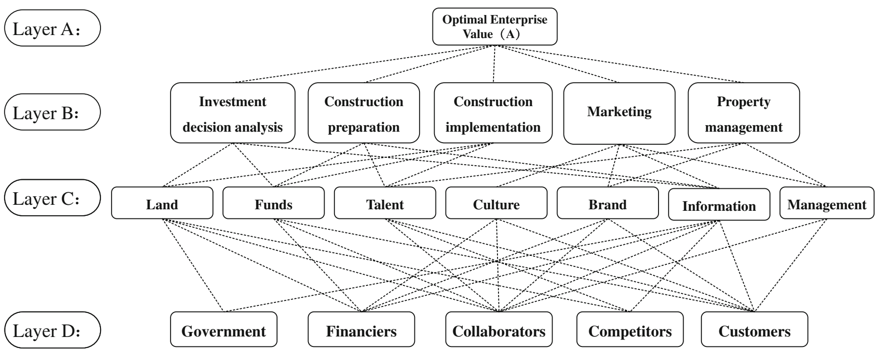

Fig. 4 Real estate development enterprises dynamic value chain evaluation model

4. Total sequencing.
From the calculation results, the weight of the second floor for the first layer is W_B = (0.2294, 0.1312, 0.3584, 0.1358, 0.1452), the weight of the second floor for the first layer is W_C = (0.2336, 0.1742, 0.1355, 0.0292, 0.0911, 0.2239, 0.1125). Therefore, considering AHP total sequencing theory, the weight of the fourth floor for the first layer is WD = (0.2371, 0.2245, 0.1810, 0.1595, 0.1979).

It is easy to see that the importance of the factors affecting the integrant parts of real estate development enterprises dynamic value chain of in Sichuan was: Land > Information > Funds > Talent > Management > Brand > Corporate culture, however the effect levels of external related parties successively was: government > financiers > customers > partners > competitors.

4.3 Using FAHP to Evaluate

(1) Establish evaluation factors set: U = (governments, financiers, collaborators, competitors, customers).
(2) Establish a weight set: centralized authority: conclude the factors weight by using AHP: $W = (0.2371, 0.2245, 0.1810, 0.1595, 0.1979)$.
(3) Establish reviews set: $v = \{$excellent, good, fair, poor, extremely poor$\}$.
(4) Single-factor fuzzy evaluation: After summarize the questionnaire feedback, come up with the single-factor evaluation matrix R of the value of real estate development enterprises as follows:

$$R = \begin{bmatrix} 0.12 & 0.19 & 0.29 & 0.22 & 0.18 \\ 0.19 & 0.17 & 0.37 & 0.16 & 0.11 \\ 0.07 & 0.20 & 0.50 & 0.13 & 0.10 \\ 0 & 0.47 & 0.30 & 0.20 & 0.03 \\ 0.26 & 0.18 & 0.30 & 0.17 & 0.09 \end{bmatrix}. \tag{1}$$

(5) Fuzzy comprehensive evaluation:

$$M = W \times R = \begin{bmatrix} 0.2371 & 0.2245 & 0.1810 & 0.1595 & 0.1979 \end{bmatrix} \times \begin{bmatrix} 0.12 & 0.19 & 0.29 & 0.22 & 0.18 \\ 0.19 & 0.17 & 0.37 & 0.16 & 0.11 \\ 0.07 & 0.20 & 0.50 & 0.13 & 0.10 \\ 0 & 0.47 & 0.30 & 0.20 & 0.03 \\ 0.26 & 0.18 & 0.30 & 0.17 & 0.09 \end{bmatrix}$$

$$= \begin{bmatrix} (0.237\wedge 0.12)\vee(0.2245\wedge 0.19)\vee(0.181\wedge 0.07)\vee(0.1595\wedge 0.00)\vee(0.198\wedge 0.26) \\ (0.237\wedge 0.19)\vee(0.2245\wedge 0.17)\vee(0.181\wedge 0.20)\vee(0.1595\wedge 0.47)\vee(0.198\wedge 0.18) \\ (0.237\wedge 0.29)\vee(0.2245\wedge 0.29)\vee(0.181\wedge 0.50)\vee(0.1595\wedge 0.30)\vee(0.198\wedge 0.30) \\ (0.237\wedge 0.22)\vee(0.2245\wedge 0.16)\vee(0.181\wedge 0.13)\vee(0.1595\wedge 0.20)\vee(0.198\wedge 0.17) \\ (0.237\wedge 0.18)\vee(0.2245\wedge 0.11)\vee(0.181\wedge 0.10)\vee(0.1595\wedge 0.03)\vee(0.198\wedge 0.09) \end{bmatrix}$$

$$= \begin{bmatrix} 0.1979 & 0.19 & 0.2371 & 0.22 & 0.18 \end{bmatrix}.$$

The M normalized rewritten as:

$$M = \left[0.1930\ 0.1854\ 0.2313\ 0.2147\ 0.1756 \right].$$

The comprehensive evaluation results:

$$\max M = \max\{0.19300.18540.23130.21470.1756\}.$$

As is seen from evaluation results, the overall value of real estate development enterprises in Sichuan Province is in the medium level. Specifically, the impact of government is the most largest for real estate development enterprises value in certain region. Such cases are quite normal in our country, it is China's socialist market economic system that determines this phenomenon. Obviously, the market is not a fully competitive market, in other words, the performance of government actions will determine the enterprise land acquisition and merchandise sales, for example the government's credit limit restriction policy will lead to the lag of the development of certain industries or enterprises. Next, financiers have a significant impact on real estate development enterprises value. Currently, real estate development enterprises in Sichuan move forward diversification of financing, such as public financing, bond financing, real estate funds, and etc., thus financing risks are rising. Whether the financing of real estate development enterprises can succeed is closely related to the real estate development enterprise value. Moreover, customers and partners have a greater impact on the value of real estate development enterprises. Effectively improving customer satisfaction for the enterprise undoubtedly contributes to increasing revenue, profits, and enhance enterprises value. As the development of real estate is a complex and long process, the pros and cons of operation partners and the cooperative way would have an impact on enterprises value activities. Finally, the competitor are with minimal impact on the value of the real estate development enterprises. Since this survey questionnaire mostly come from large companies, it shows a smaller impact on the enterprise value.

5 Conclusion and Outlook

Based on Porter's tradional value chain theory, we integrate internal and external parties, combine upstream with downstream construct, finally build real estate development enterprises dynamic value chain model which contains external related parties, factors affecting value activities achievement, internal value activities and the overall value of the enterprise. Then take an empirical analysis, using dynamic value chain model to assess the overall value of real estate development enterprises in Sichuan Province, and make a conclusion-the overall value of real estate development enterprises in Sichuan Province is in the medium level. Limited to time and energy, only the elements of real estate development enterprise dynamic value chain have been identified. Therefore further research is needed to assess mutual relations between the four parts as well as the mechanism of them all.

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Optimisation of Inclination for the Productivity in HTHP Slanted Well

Min Luo, Yuanyuan Zhuang, Jiancheng Hu, Shize Wang, Bin Qi and Zhiguo Qiao

Abstract A new mathematical model is set up to optimise the productivity in High temperature-High Pressure slanted well considering the effect of inclination in this paper. We constructed an optimisation method of the production calculated model based on the deviation value inclination and obtained the optimisation results. The simulation results are based on the historic calculation, using basic data of 'X Well' (HTHP well), 7100 m deep, located in Sichuan basin, South-West of China. The optimisation of the value in the model on wellbore inclination can efficiently enhance the production of slanted well, which can provide a theoretical guidance in well trajectory design.

Keywords Prediction · HTHP · Optimisation · Production

1 Introduction

In the mining process of oil and gas wells, the accuracy of productivity prediction and the productivity's optimisation are important content of the development program design and implementation. Many scientists had studied on improving the production of the oil well. In 1958, Aronofsky and Lee [19] for the first time studied on underlying finite homogeneous reservoir productivity optimisation problems using linear planning method. In 1975, Cinco-Ley [10] improved their work, gave the

M. Luo · J. Hu
College of Mathematics, Chengdu University of Information Technology, Chengdu 610225, People's Republic of China

M. Luo · J. Hu · Y. Zhuang (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 13922415@qq.com

S. Wang · B. Qi · Z. Qiao
Research School of Engineering Technology, China Petroleum and Chemical Corporation, Deyang 618000, People's Republic of China

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calculation formula of skin factor. In 1990, Cheng [9] compared the productivity in isotropic strata, but he did not put forward the inclined well deliverability equations corresponding to any variable angles. Besson [6] proposed a new method and gave the relevant calculation formula to calculate the skin factor in slanted straight wells. Since 2011, many studies have been conducted to study the optimization problems on perforation distribution in HTHP vertical wells [29–35].

In this paper, we considered the transient statement and established a simulation model to predict the production in slanted vertical wells according to percolation theory and Darcy law [15, 26, 27]. Based on the research of skin factor which impact on the prediction of producitivity [1, 3, 11–13, 16, 36], we made a reasonable choice of inclination for the correction model. For high temperature and high pressure oil and gas well completion string in the well testing process pressure and temperature changes rapidly, thus the status becoming difficult to use tools to measure, We use fluid dynamics, aerodynamics, unsteady heat conduction theory based on a comprehensive, systematic basic research [4, 14, 17, 18, 24] in fluid mechanism and different working conditions on completion, to establish the model to predict the pressure and temperature under different conditions of single-phase flow and two-way flow. Through the key parameters bottom hole pressure's prediction in production forecasting the model, we ultimately get the predicted results of production capacity, and the model parameters related to sensitivity analysis. Finally, the prediction model and the parameters established by the sensitivity analysis, use the theory of parameters to optimize the management of gradient wells.

The basic data of the model for the calculation are from X well, 7100 m of depth in Sichuan Basin, South-west of China. Through comparative results calculated by the optimisation model and the real measurements, we found that the model has great efficiency to improve the productivity of the slanted well. Under the given conditions, application to maximize the capacity to the best values would guide us to make the design in straight hole drilling mining process, and we also need to do the research to have the sensitivity parameters optimized, which would improve productivity of slanted wells in a higher degree.

2 Model Formulation

Considering the impaction of skin factor, we choose the efficent fomulas to calculate out the skin factor which based on Cinco lee fomula and Besson fomula. Given dimentionless corrected parameter $n = 0.7508$ in the calculation, we got the model of productivity based on Zhang's model [37]. According to Fig. 1, we got equations: $L_h = L_s \sin\theta$, $A_s = 2\pi r_\omega L$, $r_h = r_\omega / \sin\theta$, $\Omega = \Omega_h + \Omega_v$.

When the inclination is less than or equal to 75, in order to conveniently deal with the problem, we consider a horizontal well and vertical well into an equivalent straight well of radial inflow as shown in Fig. 1. According to Darcy equations, we got the productivity of the equivalent straight well as follows: $Q = (2\pi h K_h \Delta P)/\mu_0 B_0 \ln[r_c/(L_s \sin\theta/4 + r_\omega/\cos\theta)]$.

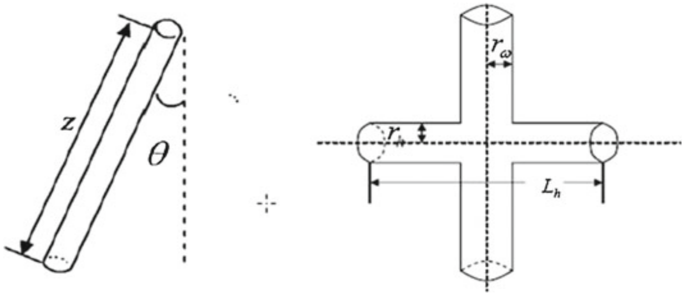

Fig. 1 The simple figure of slanted well

When the inclination is less than or equal to 75, without considering the influence of vertical well, but only the effect of the horizontal well, fluid in the horizontal plane way into the horizontal well potential as shown in the figure, can be look on as a confocal elliptic and hyperbolic system. Therefore, as we define

$$\begin{cases} x = Rch\phi \cos\psi \\ y = Rsh\phi \sin\psi. \end{cases}$$

We got the equipotential curve function and constant flow line function as follows:

$$\phi = ch^{-1}\left[\frac{x^2 + y^2 + R^2 + \sqrt{(x^2 + y^2 + R^2)^2 - 4R^2x^2}}{2R^2}\right]^{\frac{1}{2}},$$

$$\psi = \cos^{-1}\left[\frac{x^2 + y^2 + R^2 - \sqrt{(x^2 + y^2 + R^2)^2 - 4R^2x^2}}{2R^2}\right]^{\frac{1}{2}}.$$

Along the boundary of the X axis horizontal well, we got the boundary pressure:

$$P_c = ch - 1(\theta/R) = \ln\left[\alpha + \sqrt{(\theta^2 - R^2)/R}\right].$$

In this case, the pressure drop $\Delta P = P_c$, then the porous medium equation of Darcy formula:

$$Q_h = (2\pi K_h h\delta P)/\mu_0 B_0 \ln\left[\theta + \sqrt{(\theta^2 - R^2)/R}\right].$$

Between the wellbore and channel wall on vertical plane, the differential pressure:

$$\Delta P = -q_v \ln[h/(2r_\omega)].$$

So, the corresponding flow resistance:

$$\begin{aligned} \Omega_s &= \mu_0 B_0 \ln[r_c/(L_s \sin\theta/4 + r_\omega/\cos\theta)]/(2\pi K_h h), \\ Q_v &= \mu_0 B_0 \ln[h/(2r_h)]/(2\pi K_v L_h), \\ Q_h &= \mu_0 B_0 \ln[(\theta + \sqrt{\theta^2 - R^2})/R]/(2\pi K_h h). \end{aligned}$$

As we define:

$$\begin{cases} K_1 = (\mu_0 B_0)/(2\pi K_h h) \\ K_2 = [K_h h/L_s K_v \sin\theta] \ln[h \sin/(2r_\omega)] \\ r_\omega^{'} = L_s \sin\theta/4 + r_\omega/\cos\theta. \end{cases}$$

Then,

$$\Omega_s = \begin{cases} K_1 \ln[r_c/r_\omega^{'}] + K_2 f(\theta), \theta \leqslant 75^\circ \\ K_1 \ln[\theta + \sqrt{\theta^2 - R^2}/R^2] + K_2 f(\theta), \theta \leqslant 75^\circ. \end{cases}$$

Here, theta is the ratio of the remaining resistance in the horizontal direction on the whole vertical plane way into the wellbore. The ratio of flow resistance ($0 < f < 1$), is introduced to avoid the part of horizontal direction being repeated calculated.

$$Q_s = \begin{cases} \frac{(P_c - P_{wf})/K_1}{\ln[r_c/r'_\omega] + K_2 f(\theta) + S_{\theta C} - n}, & \theta \leq 75^\circ \\ \\ \frac{(P_c - P_{wf})/K_1}{\ln[\theta + \sqrt{\theta^2 - R^2}/R^2] + K_2 f(\theta) + S_{\theta B} - n}, & \theta \leq 75^\circ. \end{cases}$$

$$\begin{cases} K_1 = (\mu_0 B_0)/(2\pi K_h h) \\ K_2 = [K_h h/L_s K_v \sin\theta] \ln[h \sin/(2r_\omega)] \\ r'_\omega = L_s \sin\theta/4 + r_\omega/\cos\theta. \end{cases}$$

$$S_{\theta C} = -\left(\frac{\theta'}{41^\circ}\right)^{2.06} - \left(\frac{\theta'}{56^\circ}\right)^{1.865} \log\left(\frac{h_D}{100}\right), \ \theta' = \tan^{-1}\left[\sqrt{\frac{K_v}{K_h}}\right], \ h_D = \frac{h_\beta}{r_\omega},$$

$$\beta = \sqrt{\frac{K_v}{K_h}}, \ S_{\theta B} = \ln\left(\frac{4\cos\theta}{h_D \gamma}\right) + \frac{\cos\theta}{\gamma} \ln\left(\frac{2\gamma\sqrt{\gamma} h_D}{4\sqrt{\cos\theta(1+\gamma)}}\right),$$

$$\gamma = \sqrt{\cos^2\theta + \frac{1}{\beta^2}\sin^2\theta}.$$

Given the located position of inclination angel, which indicated to be the first measured position initiated from bottom of the well, the pressure and flow quantity at Nth measured position can be indicated as N dimensional vector: $P = (P_1, P_2, \cdots, P_N)^T$, $Q = (Q_{In,1}, Q_{In,2}, \cdots, Q_{In,N})^T$.

The constructed wellbore inclination and reservoir pressure is contained in the same system. Therefore, in the same position, the pressure drop of fluid in the wellbore is equal to the pressure drop of the reservoir fluids, the fluid in the wellbore flow is equal to the cumulative inflow. Thus, reservoir and wellbore all meet coupled condition, then we get the following coupled model.

$$\begin{cases} Q = AP \\ P = F[Q]. \end{cases}$$

For a string containing N inclination measurement positions in a slanted well, the coupled model contains 2 N unknown functions. Posed mathematical problems constitute a number of 2 N equations. We can solve the coupling problem by iterative format as follows.

$$\begin{cases} Q^{n+1} = AP^n \\ P^{n+1} = F[Q^{n+1}]. \end{cases}$$

Given initial data P, we can use this iterative format to calculate the pressure and quantity in the well. When the increasement is less than given control error, the iterative format is convergence. The total maximized production is the objective function Q. The variations of the optimization problem are the inclinations at the measurement position of the well, which satisfy the condition: $0 \leqslant Z_1 \leqslant \cdots \leqslant Z_i \leqslant \cdots \leqslant Z_N \leqslant H_P$.

In the actual process of generation, in order to reduce the amount of calculation we try to use the segmentation numerical method to reduce the number of optimization variables. The well is divided into J sections by $J - 1$ nodes z and each segment contains I measurement units. Finally, according to the optimized theory [2, 8, 23, 25, 28], we get the optimization model of inclination:

$$\min f(Z(\theta)) = -\sum_{i=1}^{N} [A(Z(\theta))P]$$

$$s.t. \begin{cases} P_i - P_d = 0 \ \ (i = 1, 2, \cdots, N) \\ Z_1 \geq 0 \\ Z_{j+1} - Z_j \geq 0 \ \ (j = 1, 2, \cdots, J - 1) \\ H_P - Z_j \geq 0. \end{cases}$$

3 Numerical Simulation and Discussion

In this simulation, we study a pipe in X well locating in Sichuan basin, South-West of China. Parameters of pipes are given in Table 1. Inclination, azimuth and vertical depth are given in Table 2. Through the algorithm and simulation, we can obtain series of results contained in tables and figures and analyze these results as below.

Table 1 Parameters of pipes

Diameter	Thickness	Weight	Expansion	Coefficient	Young	Modulus
88.9	9.53	18.9	0.0000115	215	0.3	1400
88.9	7.34	15.18	0.0000115	215	0.3	750
88.9	6.45	13.69	0.0000115	215	0.3	4200
73	7.82	12.8	0.0000115	215	0.3	600
73	5.51	9.52	0.0000115	215	0.3	150

Table 2 Parameters of azimuth, inclination and vertical depth

Number	Measured	Inclination	Azimuth	Vertical depth
1	0	0	120.33	0
2	303	1.97	121.2	302.87
3	600	1.93	120.28	599.73
4	899	0.75	126.57	898.59
5	1206	1.25	124.9	1205.45
6	1505	1.04	124.62	1504.32
7	1800	0.49	123.75	1799.18
8	2105	2.49	125.27	2104.04
9	2401	1.27	123.13	2399.91
10	2669	2.44	120.12	2667.79
11	3021	0.14	127.39	3019.63
12	3299	1.18	122.60	3297.50
13	3605	2.05	123.25	3603.36
14	3901	0.16	121.45	3899.22
15	4183	2.92	121.24	4181.09
16	4492	2.73	129.22	4489.95
17	4816.07	1.98	121.61	4813.87
18	5099.07	2.74	129.93	5096.74
19	5394.07	0.13	120.46	5391.61
20	5706.07	0.63	129.59	5703.47
21	5983.07	2.09	120.14	5980.34
22	6302.07	2.69	122.91	6299.19
23	6597.07	2.45	129.41	6594.06
24	6911.12	0.15	124.88	6907.96

To simplify the calculations, we divide the slanted well into several short segments from bottom to top. The length of each segment varies depending on the flow-rate variations, the fluid density inside and outside the pipe and the well's geometry. The model begins with a calculation at one particular position in the well: the bottom of the pipe. The detailed algorithm is as follows:

Step 1. Obtain each point's inclination: where i is a calculated inclination segment point, k is the measurement of the inclination angle depth.
Step 2. Calculate Reynolds number based on local flow-rate.
Step 3. Calculate out the turbulent friction factor f.
Step 4. Given the initial values guesses Pi (1) and tolerance respectively.
Step 5. Calculate the updated pressure and flow rate profile along the uniform slanted well applying iterative scheme. For an infinite conductivity wellbore, the pressure vector is constant, which can be applied directly.
Step 6. Calculate the optimal perforation distribution of an infinite conductivity well without a coning effect by solving optimisation model. As the model is a nonlinear programming problem, a sequential quadratic programming (SQP) algorithm is recommended. Nonlinear programming problem is equivalent to a series of quadratic programming sub-problem along research direction. At the kth iteration point, the quadratic programming sub-problem is determined from an approximation linear

Table 3 Pressure at different depth of different methods

Time Depth	300s	900s	1200s	3600s
0	42.55	46.62	50.24	51.34
300	43.23	47.53	50.64	52.67
600	44.86	48.71	50.46	53.47
900	45.87	49.13	51.41	54.69
1200	46.73	50.43	52.32	54.79
1500	48.46	51.24	53.36	55.53
1800	49.43	52.43	54.47	56.12
2100	50.34	53.83	55.42	57.37
2400	51.96	56.92	54.37	57.85
2700	53.53	57.22	55.45	58.97
3000	54.44	58.46	56.78	59.34
3300	55.24	59.97	57.47	60.95
3600	56.76	59.94	58.95	61.22
3900	57.33	60.98	59.04	62.29
4200	58.93	61.22	60.29	63.33
4500	59.34	62.45	61.24	64.48
4800	60.89	63.43	62.23	64.33
5100	61.56	64.19	63.22	64.78
5400	63.35	65.24	64.18	65.34
5700	64.69	65.45	65.12	66.34
6000	65.45	66.79	66.15	67.56
6300	66.99	67.49	67.11	67.47
6600	67.46	68.52	68.22	68.58
6900	69.28	69.46	69.92	69.55

research process and a positive definite matrix Z, the approximation Lagrange function Hessian matrix can be updated using the BFGS algorithm.

Step 7. Calculate the finite conductivity well optimal inclination distribution without a coning effect by solving model.

Step 8. Finally, calculate the productivity from the model by the optimal inclination distribution and other calculated results and index.

When the bottom pressure is 70 MPa, we use GRP methods which was introduced by Li and Artiz et al. [5, 7, 20–22] to calculate out the pressures at different depth. The results of the detail are shown in Table 3. When we got the data of pressure, we calculated the productivity of slanted well by production formula. The final result of this well's productivity is 34576 m^3/d, then we use the optimisation model to calculate out the optimised productivity, the result is 34671 m^3/d, which improve the production by 5.89 %.

4 Conclusion

In this paper, we constructed a new mathematical model to predict the production in High temperature-High Pressure slanted well considering the effect of skin factor. Then we constructed the optimised productivity model by inclination value. The basic data of the X Well (HTHP well), 7100 m deep in Sichuan basin, South-West of China, was used for case history calculations, and a sensitivity analysis is completed for the model. The result shows that the model can provide the technical reliance and dynamic analysis of production in high temperature-high pressure wells, and improve the production of slanted well in a great degree, which can provide a theoretical guidance in well trajectory design.

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Appendix

A : A total lenth of conduit (m^2)
C_J : Joule-Thompson coefficient (K/pa)
C_p : Heat capacity (J/kg·K)
D : A hydraulic diameter (m)
G : Acceleration constant of gravity (m/s^2)
K_e : Formation conductivity (J/m·K)
P : Pressure (KPa)
Q : Production (m^3/d)
r_D : Dimensionless radius

r_{to} : Outer radius of conduit (m)
T : Temperature (K)
t_D : Dimensionless time
T_e : Temperature of the stratum (K)
T_{wb} : Well-bore temperature (K)
T_{wbD} : Dimensionless well-bore temperature (K)
T_r : Temperature of the second surface (K)
T_{ei} : Initial temperature of formation (K)
V : Velocity (m/s)
Z : A total length of conduit (m)
z : The distance co-ordinate in the direction along the conduit
h_c : Heat transfer coefficient for natural convection based on outside tubing surface and the temperature difference between outside tubing and inside casin surface
h_r : Heat transfer coefficient for radiation based on the outside tubing surface and the temperature difference between the outside tubing and inside casing surface
U_{bo} : Overall-heat-transfer coefficient (W/m·K)
K_{cas} : Thermal conductivity of the casing material at the average casing temperature
K_{cem} : Thermal conductivity of the cement at the average cement temperature and pressure
K_e : Formation conductivity
K_h : The penitration in the horizontal direction
K_v : The penitration in the vertical direction
ρ : Density (Kg/m^3)
θ : Inclination angle flow conduit (°C)

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Based on Entropy Method Regional Innovation Capability Evaluation in Gansu Province

Lili He and Yanhua Liu

Abstract This paper established the applied value of entropy method in the field of regional innovation capability evaluation on the basis of the study on the range of applications, advantages and limitations. Then it selected 14 administrative areas as the research samples, and extracted the statistical data of 2010–2012 in these areas. The paper studies the key elements which form the regional innovative capacity, systematically explores the construction of influence factor model of regional innovative capability, using entropy method to evaluate the regional innovative capability, proposes countermeasures and put forward policy recommendations for regional capability in Gansu province.

Keywords Innovation capability evaluation · Regional · Entropy method · Gansu province

1 Introduction

Regional innovative capability is an important signal to measure whether the regional economy has been a decisive factor in the international competitive advantage, plays a central role in the process of long-run economic growth. Regional innovative capability was focused by experts and scholars. As a less developed areas in Gansu, it is of great practical significance to research its innovative capability.

Some literatures devote to define regional innovative capability [11, 18, 19, 21]. Porter and Furman (FP&S) considered that innovative capacity is also distinct from current national industrial competitive advantage or productivity, which results from many factors (such as the skills of the local workforce and the quality of physical infrastructure) that go beyond those important to the development and commercialization of new technologies [12]. A literature indicated that regional innovative

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L. He (✉) · Y. Liu
School of Management, Northwest University for Nationalities, Lanzhou 730030, People's Republic of China
e-mail: 1067543705@qq.com

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capacity was an important source to maintain the region competition ability and its advantage status [19]. A Chinese literature displayed that regional innovation capability is a capability to absorb the requisite knowledge and skills, master and improve existing technology, and create new technology [18]. In this paper, regional innovative capability defined as a capacity related with technological innovation and interaction in a region.

Some studies on the factors of regional innovative capability were from the macro-level the national innovation system (NIS), in the study of technology innovation ability [1, 5, 8–10, 15]. Stern, Porter and Furman (FP&S) introduced the concept of national innovative capacity, indicated that Country-level R&D intensity, public policy and international patenting activity played an important role in shaping a country's national innovative capacity among 17 OECD countries [12]. Based on the research of FP&S, Mei-Chih Hu and John A. Mathews arrived at the same conclusion by drawing into the indicator of public R&D expenditures among the east Asian tigers, had further concluded that building of R&D manpower, in targeting certain industrial sectors and specializing their innovative activities in these sectors, and in promoting and effecting public R&D were focused as a means of enhancing national innovative capacity [17]. Some researches indicated the factors of Chain's regional innovative capability, such as five elements [6, 17, 24], four elements [16].

Innovation evaluation has become a significant and critical concern for both practitioners and researchers, as well as for public authorities [4, 12]. Some studies verified propositions for measuring the innovation management of companies and identifying the conditions of a successful innovation process [7, 13, 14, 22, 23]. Measures of technological capability have typically involved three major aspects [26]. There are many differences in evaluation indicators and methods between different regions [3, 25]. In order to reduce the impact of the uncertain subjectivity on the determination of weights, the present study adopts entropy value method to determine the weights of indexes.

In the present study, based on regional innovation capacity behavior main body is different, the point of views, in the Chinese regional innovation capacity report indicated by China science and technology development strategy group, are adopted:

1. Knowledge creation capability,
2. Innovation cooperation and transformation capability,
3. The technological innovative capability of enterprises,
4. Technology innovation environment,
5. Technological innovation performance.

By focusing on the quantitative analysis of innovation capability, this paper helps to bridge the gap between the actual and planned of regional capability in Gansu province, and seek more advantageous the macro-adjustment by government of in Gansu.

2 System of Evaluation Indexes and Data Access

In the present study, due to do some statistical analysis of the technology innovation capability of Gansu region, 15 indicator variables are selected from five aspects: knowledge creation capability, innovation cooperation and transformation capability, the technological innovative capability of enterprises, technology innovation environment and technological innovation performance (Table 1).

In the study 14 regions in Gansu province from year 2010 to 2012 are selected. All original data come from Gansu province Statistical Yearbook and the yearbook of science and technology of Gansu province. The 14 regions are Lanzhou, Baiyin, Jinchang, Jiayuguan, Tianshui, Jiuquan, Zhangye, Wuwei, Dingxi, Longnan, Pingliang, Qingyang, Linxia and Gannan. The original data are analyzed by using MATLAB 2012.

3 Analysis Model and Empirical Calculation

There are m evaluation objects and n evaluation indicators, X_{ij} presents index value $(i = 1, 2, 3, \cdots, m;\ j = 1, 2, 3, \cdots, n)$, In the study, $m = 45$, $n = 15$.

1. Data Dimensionless Processing

For being inconsistent indicators unit, evaluating indicator system will not be useful without applying dimensionless method to the data. There are some kinds of method to dimensionless method. According to the actual research question, Eq. (1) is used to method to dimensionless method.

$$Y_{ij} = \frac{X_{ij}}{\bar{X}_j}(i = 1, 2, 3, \cdots, m;\ j = 1, 2, 3, \cdots, n). \tag{1}$$

In the Eq. (1), Y_{ij} presents dimensionless value of the jth indicators on the ith samples. X_{ij} presents average of the jth indicators.

2. Calculating Entropy of Indicators

$$a_{ij} = \frac{Y_{ij}}{\sum\limits_{i=1}^{m} Y_{ij}}(i = 1, 2, 3, \cdots, m;\ j = 1, 2, 3, \cdots, n), \tag{2}$$

$$E_j = -K\sum_{i=1}^{m} a_{ij}\ln a_{ij}(0 \leqslant E_j \leqslant 1)(i = 1, 2, 3, \cdots, m;\ j = 1, 2, 3, \cdots, n). \tag{3}$$

In the Eq. (2), $K = \frac{1}{\ln m}$. In the study, $m = 45$, $k = 0.236$. Entropy of indicators are following Table 2.

Table 1 Evaluation index system on the regional innovation capability in Gansu province

First class indicators	Second class indicator	Third class indicators
The regional innovation capability	Knowledge creation capability (A_1)	Internal R&D expenditure (A_{11})
		The number of technology development institutions (A_{12})
		The number of science-technology papers published per ten thousand people (A_{13})
	Innovation cooperation and transformation capability (A_2)	Ratio of technological market in the transaction contract to GDP (A_{21})
		Ratio of R&D expenditure invested in the business R&D to spending on R&D of university scientific research institution (A_{22})
		Expenditures purchased domestic technology by large and medium-sized industrial enterprises (A_{23})
	The technological innovative capability of enterprises (A_3)	Original R&D equipment cost per S&T personnel (A_{31})
		Ratio of internal R&D expenditure to prime operating revenue (A_{32})
		The number of patents possessed by enterprises (A_{33})
		The average expenditure of technical transformation (A_{34})
	Technology innovation environment (A_4)	The new GDP one hundred million yuan investment (A_{41})
		Highway has several per ten thousand people (A_{42})
		Ratio of educational investment to GDP (A_{43})
	Technological innovation performance (A_5)	Ratio of hi-tech exports to GDP (A_{51})
		Scientific and technological achievements project (A_{52})

The greater the entropy value of indicators of regional innovation, it can reflect the more the amount of information small, also the less weight. In Table 2, the top 5 the order of entropy are ratio of R&D Expenditure invested in the business R&D to spending on R&D of university scientific research institution (A_{22}), highway

Table 2 Entropy of all indicators

Second class indicators	Third class indicators	Entropy
A_1	A_{11}	0.806
	A_{12}	0.743
	A_{13}	0.825
A_2	A_{21}	0.865
	A_{22}	0.903
	A_{23}	0.766
A_3	A_{31}	0.883
	A_{32}	0.776
	A_{33}	0.691
	A_{34}	0.723
A_4	A_{41}	0.795
	A_{42}	0.887
	A_{43}	0.827
A_5	A_{51}	0.765
	A_{52}	0.834

has several per ten thousand people (A_{42}), original R&D equipment cost per S&T personnel (A_{31}), ratio of technological market in the transaction contract to GDP (A_{21}), scientific and technological achievements project (A_{52}).

3. Determining Evaluation Indicators Weight

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} (j = 1, 2, 3, \cdots, n). \tag{4}$$

Table 3 indicated that the greater the evaluation indicators weights, it can reflect the greater the impact on innovation capability. Influencing degree of innovation capability on different factors ranked as follows: the number of patents possessed by enterprises (A_{33}), the average expenditure of technical transformation (A_{34}), the number of technology development institutions (A_{12}), ratio of hi-tech exports to GDP (A_{51}), expenditures purchased domestic technology by large and medium-sized industrial enterprises (A_{23}), ratio of internal R&D Expenditure to prime operating revenue (A_{32}), the new GDP one hundred million yuan investment (A_{41}), internal R&D Expenditure (A_{11}), the number of science-technology papers published per ten thousand people (A_{13}), ratio of educational investment to GDP (A_{43}), scientific and technological achievements project (A_{52}), ratio of technological market in the transaction contract to GDP (A_{21}), original R&D equipment cost per S&T personnel (A_{31}), highway has several per ten thousand people (A_{42}), ratio of R&D Expenditure invested in the business R&D to spending on R&D of university scientific research institution (A_{22}).

Table 3 Evaluation indicators weights

Second class indicators	Third class indicators	Entropy
A_1	A_{11}	0.067
	A_{12}	0.088
	A_{13}	0.060
A_2	A_{21}	0.046
	A_{22}	0.033
	A_{23}	0.080
A_3	A_{31}	0.040
	A_{32}	0.077
	A_{33}	0.106
	A_{34}	0.095
A_4	A_{41}	0.070
	A_{42}	0.039
	A_{43}	0.059
A_5	A_{51}	0.081
	A_{52}	0.057

4. Calculating Evaluation Indicators Index

$$P_{ij}^k = \sum w_j^k X_{ij}^k (i = 1, 2, 3, \cdots, m; \ j = 1, 2, 3, \cdots, n), \tag{5}$$

$$P_j^l = \sum_{j=1}^{n} P_{ij}^k (i = 1, 2, 3, \cdots, m; \ j = 1, 2, 3, \cdots, n). \tag{6}$$

In the Eq. (5) and (6), expresses third class indicators, and presents second class indicators. In Table 4, it is obvious that different region has different innovation capability. Lanzhou has the most powerful innovation capability, following by Tianshui, Baiyin, Jiayuguan, Jinchang, Wuwei, Zhangye, Jiuquan, Qingyang, Dingxi, Longnan, Pingliang, Linxia and Ganlan. Ethnic regions has lower innovation capability, especially has more lower the technological innovative capability of enterprises (A_3).

4 Discuss and Conclusions

The empirical analysis used entropy method, there are some conclusions as following:

(1) Lanzhou has the most powerful innovation capability, in Gansu province. The main reason is that lanzhou is the most intensive region concerning research institutions, universities and colleges, large and medium-sized industrial enterprises and high-tech enterprises. And, regional innovation environment is constructed best.

Table 4 Evaluation indicators index

Reigion	The years	A_1	A_2	A_3	A_4	A_5	A
Lanzhou	2010	0.932	0.189	1.596	0.665	0.509	3.891
	2011	1.002	0.192	1.601	0.672	0.513	3.980
	2012	1.006	0.194	1.611	0.684	0.526	4.021
Baiyin	2010	0.139	0.403	0.592	0.579	0.352	2.065
	2011	0.142	0.410	0.597	0.586	0.354	2.089
	2012	0.145	0.417	0.601	0.591	0.362	2.116
Jinchang	2010	0.109	0.040	0.541	0.598	0.521	1.809
	2011	0.113	0.042	0.547	0.601	0.526	1.829
	2012	0.118	0.046	0.551	0.609	0.531	1.855
Jiayuguan	2010	0.348	0.281	0.347	0.560	0.361	1.897
	2011	0.352	0.283	0.349	0.562	0.364	1.910
	2012	0.356	0.286	0.352	0.567	0.368	1.929
Tianshui	2010	0.161	0.524	0.532	0.369	0.503	2.089
	2011	0.163	0.529	0.534	0.371	0.509	2.106
	2012	0.167	0.531	0.537	0.374	0.513	2.122
Jiuquan	2010	0.221	0.273	0.220	0.319	0.283	1.316
	2011	0.224	0.274	0.227	0.322	0.286	1.333
	2012	0.227	0.276	0.230	0.326	0.291	1.350
Zhangye	2010	0.156	0.002	0.339	0.448	0.394	1.339
	2011	0.158	0.003	0.342	0.453	0.398	1.354
	2012	0.161	0.007	0.347	0.457	0.392	1.364
Wuwei	2010	0.169	0.432	0.298	0.359	0.338	1.596
	2011	0.171	0.435	0.302	0.361	0.341	1.610
	2012	0.174	0.437	0.306	0.364	0.346	1.627
Dingxi	2010	0.178	0.195	0.180	0.301	0.117	0.971
	2011	0.179	0.199	0.183	0.307	0.119	0.987
	2012	0.183	0.201	0.184	0.311	0.121	1.000
Longnan	2010	0.051	0.087	0.037	0.359	0.365	0.899
	2011	0.053	0.089	0.039	0.362	0.368	0.911
	2012	0.057	0.091	0.041	0.365	0.371	0.925
Pingliang	2010	0.083	0.147	0.165	0.238	0.183	0.816
	2011	0.085	0.148	0.168	0.241	0.185	0.827
	2012	0.089	0.151	0.171	0.245	0.187	0.843
Qingyang	2010	0.087	0.092	0.379	0.231	0.248	1.037
	2011	0.089	0.096	0.382	0.235	0.250	1.052
	2012	0.092	0.099	0.387	0.238	0.254	1.070
Linxia	2010	0.060	0.232	0.082	0.131	0.119	0.624
	2011	0.062	0.237	0.091	0.134	0.210	0.734
	2012	0.064	0.241	0.097	0.137	0.214	0.753
Gannan	2010	0.012	0.252	0.000	0.159	0.134	0.557
	2011	0.017	0.257	0.000	0.160	0.138	0.572
	2012	0.021	0.261	0.001	0.163	0.140	0.586

(2) Tianshui and Baiyin, belongs to the strong innovation capability area.
(3) Jiayuguan, Jinchang, Wuwei, Zhang Ye, Jiuquan and Qingyang, belongs to the innovation ability is weak.
(4) Pingliang, Linxia and Gannan have poorer overall innovation capability. These conclusions are consistent with previous researches [2, 20].

From the analysis, we can conclude that the conditions promoting innovation or economic growth for different parts of the technology industries fall into the following pathways:

(1) To having the obvious advantages of regional innovative ability in the whole province area, such as Lanzhou and Tianshui, we can make this kind of region play the leading and creative role as the pioneers in the province-wide. To accomplish this, some measures may be taken: increasing original research input to, improving capability of scientific and technological achievement transforming to market, strengthening ability of digesting and absorbing introduce technologies and accelerating development of high-tech industries.
(2) To undeveloped areas, such as Gannan and Linxia, we should promote economic growth and to create loose innovation environment. At the same time, by vigorously promoting marketization process, cultivating innovative talent and accelerating the growth rate of absorption of foreign investment improve economic growth of undeveloped areas.
(3) All regions of Gansu province should establish status of enterprise independent innovation. The approach of industry-university-research must be strived in Gansu, especially in Pingliang, Linxia and Gannan. The government should reduce the interference to the enterprise government, and make enterprise as innovative subject.

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Catastrophe Theory-Based Water Quality Evaluation Model Under Uncertain Environment, Case in Chaohu Lake

Jingneng Ni, Fangqing Ding and Haifeng Yu

Abstract Water quality evaluation is an important item in water resource management. However, water quality evaluation is a complex system problem, fuzzy uncertainties and random uncertainties both exist in it. In this research, fuzzy random variables are employed to deal with the complex uncertainty. Then, according to the five essential features of water quality systems, a new model for water quality evaluation named catastrophe theory-based water quality evaluation model under uncertainty (CT-based WQEMU) was proposed. And, a new calculation method was designed to solve the model. The proposed model was applied to an actual case: Chaohu lake, China. According to the calculation results of the model, some analysis about the actual situation of water pollution in Chaohu lake was made. Then, the policy recommendations are provided to the local water management department.

Keywords Water quality · Evaluation · Catastrophe theory · Model · Uncertainty

1 Introduction

Water plays a key role public health and economic-social sustainable development [2]. Rapid urbanization and industrial growth makes the surface water quality seriously deteriorated. Which has affected the human life security and sustainable development of social. It has reported that in developing countries over three million people (90 % are children under 5) die every year because of waterborne diseases [15]. Thus, water quality assessment is a crucial element in water resources management [3, 4].

Due to the water quality is identified in terms of its physical, chemical and biological parameters [11], a variety of water quality index (WQI) has been established to quantitatively express the quality of water [5, 9]. Based on which, large number of mathematical models have been developed to evaluate the quality of various types

J. Ni (✉) · F. Ding · H. Yu
Department of Mathematics and Physics, Hefei University, Hefei 230601, People's Republic of China
e-mail: nijn@hfuu.edu.cn

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of water [6, 10]. However, these models assessed the water quality according to its static index only, without taking into account the role of the water body itself. Because of its taking into account both the system indices and the system's own internal effect, catastrophe theory was widely used in the environmental assessment [1]. In the role of pollutant concentrations, flow rate, temperature, microorganisms and aquatic algaes, the water quality suddenly changed from one steady-state to another. Catastrophe theory model can exactly describe this kind of mutation phenomenon of water quality [12].

However, uncertainty exists widely in water quality management [14]. It makes the water quality modeling beyond the traditional mathematical methods. Stochastic and fuzzy approaches have been proposed to deal with random uncertainty and fuzzy uncertainty [17, 19]. These uncertainties have most often been looked at separately, but there is another form of uncertainty which has both randomness and fuzziness, such as the water pollutant content. Therefore, to deal with this situation, new water quality evaluation model should be established.

In order to describe the parameters of the water body objectively, fuzzy random variables were employed to express the uncertainty of the water quality index. According to the number of control variables, three catastrophe theory-based evaluation models under uncertain environment were built to evaluate water quality. Then, the proposed models were applied to an actual case: Chaohu lake, China. Based on the evaluation results, a scheme was developed to guide the decision-makers to protect the water quality of Chaohu lake.

The rest of this paper was organized as follows. In Sect. 2, the motivation of employing fuzzy random variables and some preliminaries of catastrophe theory were given. Then, the catastrophe theory-based water quality evaluation model under uncertainty (CT-based WQEMU) was established for evaluating the water quality. The proposed model was applied to an actual case, and some analysis were presented based on the model results in Sect. 3. The paper was concluded in Sect. 4.

2 Methodology and Modeling

Some necessary preliminary work were made in Sects. 2.1 and 2.2, then the catastrophe theory-based water quality evaluation model under uncertainty (CT-based WQEMU) was established in Sect. 2.3.

2.1 Uncertainty Processing Method

Because of the impact of microorganisms, algae, flow rate, temperature and pollutant emissions, etc., the concentration of pollutants in the water is not a constant value. Therefore, pollution data of real-time monitoring can not be directly used for water quality assessment. NH_3-N concentration was used as an example to explain the

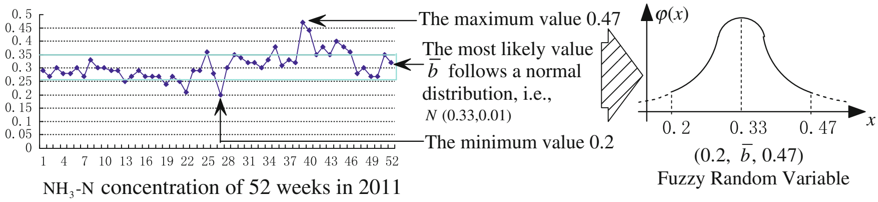

Fig. 1 The process of converting NH_3-N concentration in a fuzzy random variable. Data derived from Binghu monitoring point, Hefei, Anhui Province

processing method for uncertainty. NH_3-N concentration in real-time monitoring data obtained from China environmental monitoring center were 0.32 and 0.33 mg/L at am 08:00:00, October 25 and October 30, 2014, respectively. Obviously it's not a definite value. Weekly average value of NH_3-N concentration of 2011 was extracted for observing the characteristics of the data. It can be found that the maximum and minimum values are 0.47 and 0.2 respectively, and the most likely value (Denoted by $\bar{b}$) is a random variable. $\bar{b}$ is normally distributed with mean value 0.33 and variance 0.01. Thus, NH_3-N concentration can be converted into a Kwakernaaks' fuzzy random variable [7], written as $(0.2, \bar{b}, 0.47)$, where $\bar{b} \sim N(0.33, 0.01)$. In this way, the uncertainty of NH_3-N concentration is described as a fuzzy random variable. The conversion process is shown in Fig. 1. Other indicators of uncertainty, similarly.

2.2 Essential Catastrophe Model

The catastrophe theory is widely applied to various evaluation systems because it has the following advantages: (1) without knowing the internal laws of the system, (2) simultaneously dealing with uncertainty and uncertainty, (3) giving the mathematical description and quantitative processing of the system. When the system state is affected by no more than 4 control variables, the catastrophe theory provides 4 essential models for the evolution of the system under natural conditions [12, 13]. Using x denotes state variable, a, b, c, d denote control variables and, $f(x)$ is the potential function of x, these 4 essential models can be written as follows.

The fold catastrophe model:

$$f(x) = x^3 + ax. \tag{1}$$

The cusp catastrophe model:

$$f(x) = x^4 + ax^2 + bx. \tag{2}$$

The swallowtail catastrophe model:

$$f(x) = x^5 + ax^3 + bx^2 + cx. \tag{3}$$

The butterfly catastrophe model:

$$f(x) = x^6 + ax^4 + bx^3 + cx^2 + dx. \tag{4}$$

If a system has the five essential features summarized by Zeeman [18], then the catastrophe model is applicable to the system. However, two principles named "complementation principle" and "non-complementation principle" should be complied with during the operation of the catastrophe model. Complementation principle: When the control variables are interrelated obviously, the "complementation principle" should be followed. In this case, the state variable x takes the mean of controlling variable values. Non-complementation principle: When the control ariables are not interrelated obviously, the "non-complementation principle" should be followed. In this case, the state variable x takes the minimum value among of controlling variable values.

2.3 Catastrophe Theory-Based Water Quality Evaluation Model Under Uncertainty

Surface water system meets Zeeman's [18] five essential features.

(1) Mutation: The changing of the water body from one steady state to another is instantaneous, for example, blue-green algae outbreak.
(2) Hysteresis: Mutation results will continue after the incentive eliminated, for example, after the elimination of eutrophication, algae outbreak phenomenon will continue for some time.
(3) Multimodal: The system has two or more stable states, for example, pollution and clean.
(4) Unreachable: The system has an unstable equilibrium position, it is unreachable in practice, for example, the critical point between pollution and clean.
(5) Divergent: In some situation, a slight change of the control variables will induce the system state change, for example, the effect of temperature on algae outbreak.

Therefore, catastrophe theory can be employed for modeling of the water quality evaluation.

Index set of the control variables that affect the water quality state should be established, when applying catastrophe theory to evaluate the water quality. According to the National Quality Standards of People's Republic of China: *Environmental quality standards for surface water* (GB 3838-2002), *Standards for Drinking Water Quality* (GB 5749-2006) and, *Technical Specifications Requirements for Monitoring*

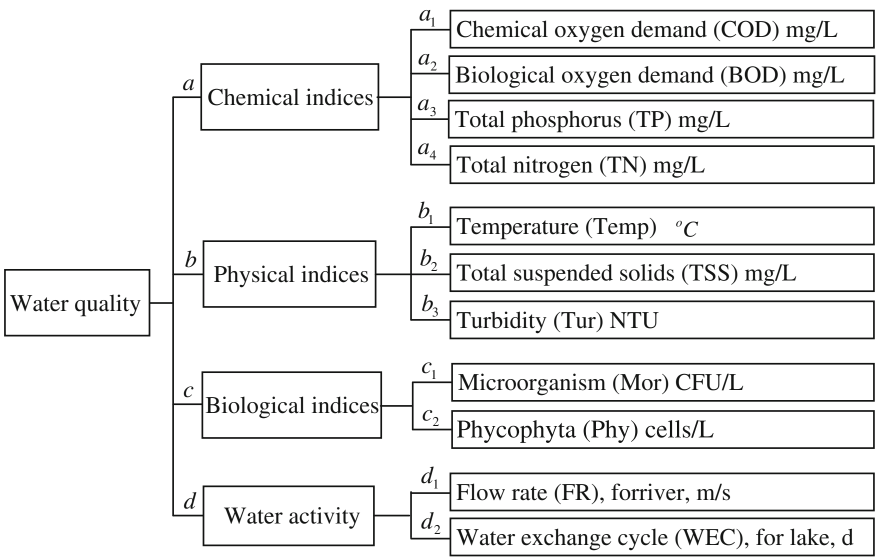

Fig. 2 Index set of control variables

of Surface Water and Waste Water (HJ/T 91-2002), 11 major indicators of four categories were selected as control variables, as shown in Fig. 2.

When the evaluating objectives are influenced by 1, 2, 3 or, 4 indices, the fold catastrophe model, the cusp catastrophe model, the swallowtail catastrophe model, or the butterfly catastrophe model can be selected as the evaluation model, respectively. Furthermore, generally the more important controlling variables are written in front of the less important controlling variables. According to Sect. 2.1, the monitoring data of indices was converted into fuzzy random variables. Thus, based on the index structure shown in Fig. 2, the catastrophe theory-based water quality evaluation model under uncertainty (CT-based WQEMU) can be established as follow:

$$f(x) = x^6 + \tilde{\tilde{a}}x^4 + \tilde{\tilde{b}}x^3 + \tilde{\tilde{c}}x^2 + \tilde{\tilde{d}}x$$
$$\begin{cases} \varphi_1(a) = a^6 + \tilde{\tilde{a}}_1 a^4 + \tilde{\tilde{a}}_2 a^3 + \tilde{\tilde{a}}_3 a^2 + \tilde{\tilde{a}}_4 a \\ \varphi_2(b) = b^5 + \tilde{\tilde{b}}_1 b^3 + \tilde{\tilde{b}}_2 b^2 + \tilde{\tilde{b}}_3 b \\ \varphi_3(c) = c^4 + \tilde{\tilde{c}}_1 c^2 + \tilde{\tilde{c}}_2 c \\ \varphi_4(d) = \begin{cases} d^3 + \tilde{\tilde{d}}_1 d, & \text{for river} \\ d^3 + \tilde{\tilde{d}}_2 d, & \text{for lake,} \end{cases} \end{cases} \tag{5}$$

where x denotes the state of water quality, $f(x)$ is the potential function of x; a, b, c, d denote the state of the chemical indices, physical indices, biological indicators and water activity, respectively. $\varphi_1(a)$, $\varphi_2(b)$, $\varphi_3(c)$, $\varphi_4(d)$ are the potential functions of a, b, c, d. $\tilde{\tilde{}}$ is the symbol for fuzzy random variable.

In CT-based WQEMU (i.e. Eq. (5)), due to $\tilde{\tilde{a}}_1 \sim \tilde{\tilde{a}}_4$, $\tilde{\tilde{b}}_1 \sim \tilde{\tilde{b}}_3$, $\tilde{\tilde{c}}_1$, $\tilde{\tilde{c}}_2$, $\tilde{\tilde{d}}_1$ and $\tilde{\tilde{d}}_2$ are fuzzy random variables, they make $\tilde{\tilde{a}}$, $\tilde{\tilde{b}}$, $\tilde{\tilde{c}}$ and $\tilde{\tilde{d}}$ are also fuzzy random variables. Therefore, the calculation of CT-based WQEMU goes beyond the traditional mathematical methods. The chance measure and expected value of fuzzy random variable proposed by Xu [16] can be used to handle this situation very well. Thus, Eq. (5) can be rewritten into Eq. (6):

$$
\begin{aligned}
&Ch\{f(x)\} = Ch\{x^6 + \tilde{\tilde{a}}x^4 + \tilde{\tilde{b}}x^3 + \tilde{\tilde{c}}x^2 + \tilde{\tilde{d}}x\} \\
&\begin{cases}
\varphi_1(a) = EV\{a^6 + \tilde{\tilde{a}}_1 a^4 + \tilde{\tilde{a}}_2 a^3 + \tilde{\tilde{a}}_3 a^2 + \tilde{\tilde{a}}_4 a\} \\
\varphi_2(b) = EV\{b^5 + \tilde{\tilde{b}}_1 b^3 + \tilde{\tilde{b}}_2 b^2 + \tilde{\tilde{b}}_3 b\} \\
\varphi_3(c) = EV\{c^4 + \tilde{\tilde{c}}_1 c^2 + \tilde{\tilde{c}}_2 c\} \\
\varphi_4(d) = \begin{cases} EV\{d^3 + \tilde{\tilde{d}}_1 d\}, \text{ for river} \\ EV\{d^3 + \tilde{\tilde{d}}_2 d\}, \text{ for lake,} \end{cases}
\end{cases}
\end{aligned}
\tag{6}
$$

where $Ch\{\cdot\}$ and $EV\{\cdot\}$ denote the chance measure and expected value of fuzzy random variable $\cdot$ respectively.

For solving CT-based WQEMU (i.e. Eq (6)), the development of the normalized formula can be obtained as follow. Taking potential function $f(x)$ as an example, It is similar to the potential function $\varphi_1(a)$, $\varphi_2(b)$, $\varphi_3(c)$ and $\varphi_4(d)$. The balance point set and singular point set of function $f(x)$ can be obtained by solving equations $f'(x) = 0$ and $f''(x) = 0$ respectively. Thus, the bifurcation set of function $f(x)$ was obtained by canceling the state variable x in equations $f'(x) = 0$ and $f''(x) = 0$. It means that the catastrophe is happened in the time when all the controlling variables satisfy the bifurcation point set equation. In this way, the development of the normalized formula of CT-based WQEMU was deduced as follow:

$$
\begin{aligned}
&x_a = (\tilde{\tilde{a}})^{1/2},\ x_b = (\tilde{\tilde{b}})^{1/3},\ x_c = (\tilde{\tilde{c}})^{1/4},\ x_d = (\tilde{\tilde{d}})^{1/5} \\
&\begin{cases}
a_{a_1} = (\tilde{\tilde{a}}_1)^{1/2},\ a_{a_2} = (\tilde{\tilde{a}}_2)^{1/3},\ a_{a_3} = (\tilde{\tilde{a}}_3)^{1/4},\ a_{a_4} = (\tilde{\tilde{a}}_4)^{1/5} \\
b_{b_1} = (\tilde{\tilde{b}}_1)^{1/2},\ b_{b_2} = (\tilde{\tilde{b}}_2)^{1/3},\ b_{b_3} = (\tilde{\tilde{b}}_3)^{1/4} \\
c_{c_1} = (\tilde{\tilde{c}}_1)^{1/2},\ c_{c_2} = (\tilde{\tilde{c}}_2)^{1/3} \\
\begin{cases} d_{d_1} = (\tilde{\tilde{d}}_1)^{1/2}, \text{ for river} \\ d_{d_2} = (\tilde{\tilde{d}}_2)^{1/2}, \text{ for lake,} \end{cases}
\end{cases}
\end{aligned}
\tag{7}
$$

Furthermore, Ccombining the two principles: "complementation principle" and "non-complementation principle", the common calculation structure of CT-based WQEMU is shown in Fig. 3.

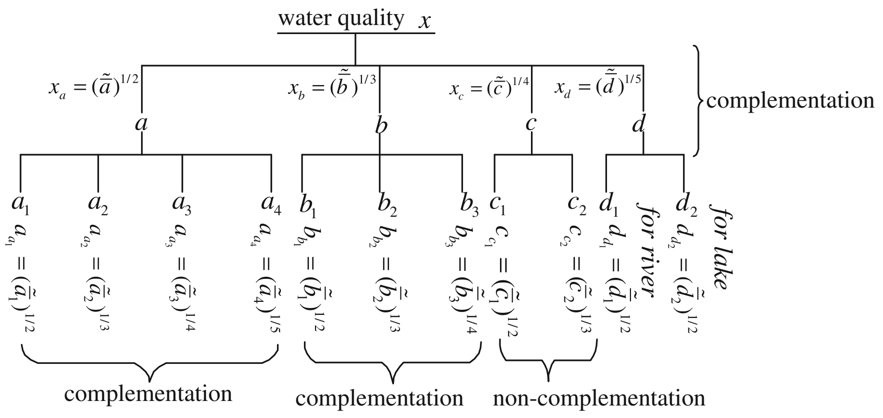

Fig. 3 The common calculation structure of CT-based WQEMU

3 Case Study

Chaohu lake, one of the five largest freshwater lakes in China, is located at 31°N and 117°E. The Chaohu lake watershed has an area of 13,486 km^2, with at the end of 2000, a catchment population of 9.854 million. In the past 20 years, with rapid economic development and an increase in the industrial population, urban life sewage and industrial wastewater emissions have also increased rapidly. Without processing, pollutants are discharged into the nearby rivers, and finally flow into Chaohu lake [8]. Increasing pollution pressure has become a serious threat to the regional economy and ecology coordinated development. So, an accurate evaluation of chaohu lake water quality is an important basis for decision-makers to coordinate the development regional economic and ecological environment.

3.1 The Original Data Acquisition

In China, according to the index values of water quality, surface water is divided into five categories. If the index value exceeds the maximum limit, the surface water is called inferior fifth category water. Surface water classification and the interval of the index value limit are derived from the National Quality Standards of People's Republic of China: *Environmental quality standards for surface water* (GB 3838-2002), as shown in Table 1. The monitoring data of all indices of Chaohu lake water quality from 2009 to 2013, are obtained from Binghu and Yuxikou monitoring points, which are the two real-time monitoring point of China environmental monitoring center (http://58.68.130.147, Binghu and Yuxikou monitoring points,

Table 1 Surface water index limits and classification

Index	I	II	III	IV	V	V bad
COD (mg/L)	<15	<15	15–20	20–30	30–40	>40
BOD (mg/L)	<3	<3	3–4	4–6	6–10	>10
TP (mg/L)	<0.01	0.01–0.025	0.025–0.05	0.05–0.1	0.1–0.2	>0.2
TN (mg/L)	<0.15	0.15–0.5	0.5–1.0	1.0–1.5	1.5–2.0	>2.0
Temp (°C)	$-2 \leq$ human-caused change in water temperature ≤ 1					
TSS (mg/L)	<20	20–25	25–30	30–60	60–150	>150
Tur (NTU)	<5	5–10	10–20	20–50	50–80	>80
Mor ($\times 10^2$CFU)	<2	2–20	20–100	100–200	200–400	>400
Phy ($\times 10^5$ cells/L)	<1.0	1.0–2.0	2.0–3.3	3.3–4.6	4.6–6.0	>6.0
WEC (days)	40–80	80–120	120–200	200–360	360–540	>540

Note Data derived from *Environmental quality standards for surface water of China*

Hefei, Anhui Province). Using the processing method for uncertainty introduced in Sect. 2.1, monitoring data were converted into fuzzy random numbers, as shown in Table 2.

3.2 The Calculation Results

The index dimensional difference exists in the multi-factor input system. Therefore, in order to realize the calculation, dimensionless should be done firstly. In this research, the upper/lower limit of the index value of the fifth category water and the lower limit of the index value of the first category water were used as benchmark to realize dimensionless quantity. Standardization formulas are as follows.

$$X_{std}^j = \frac{X^j}{X_{V_{sup}}^j}, \quad j = 1, 2, \cdots, 10, \tag{8}$$

$$X_{std}^j = \frac{X_{I_{inf}}^j}{X^j}, \quad j = 1, 2, \cdots, 10, \tag{9}$$

where j, X_{std}^j and X^j denote the jth index, the normalized and monitoring value of the index j, respectively. $X_{V_{sup}}^j$ denotes the upper limit value of the index j of the fifth category water. $X_{I_{inf}}^j$ denotes the lower limit value of the index j of the first category water. If the index j is a positive indicator of pollution, Eq. (8) is adopted, conversely, using Eq. (9).

Based on the calculation structure shown in Fig. 3, when the fuzzy random variables in Eqs. (6), (7) were replaced with crisp variables, the catastrophe theory-based

Table 2 The monitoring data of all indices from 2009 to 2013

Index	2009	2010	2011	2012	2013
COD (mg/L)	$(27, \overline{CO}, 45)$	$(25, \overline{CO}, 43)$	$(24, \overline{CO}, 48)$	$(24, \overline{CO}, 46)$	$(26, \overline{CO}, 44)$
	$\overline{CO} \sim N(36, 4)$	$\overline{CO} \sim N(34, 3)$	$\overline{CO} \sim N(36, 3)$	$\overline{CO} \sim N(35, 4)$	$\overline{CO} \sim N(35, 3)$
BOD (mg/L)	$(7.6, \overline{BO}, 9.4)$	$(6.8, \overline{BO}, 8.8)$	$(6.4, \overline{BO}, 8.2)$	$(6.6, \overline{BO}, 8.8)$	$(5.9, \overline{BO}, 7.7)$
	$\overline{BO} \sim N(8.5, 0.5)$	$\overline{BO} \sim N(7.8, 0.6)$	$\overline{BO} \sim N(7.3, 0.4)$	$\overline{BO} \sim N(7.7, 0.6)$	$\overline{BO} \sim N(6.8, 0.3)$
TP ($\times 10^{-2}$ mg/L)	$(9, \overline{TP}, 12)$	$(8, \overline{TP}, 12)$	$(7, \overline{TP}, 11)$	$(7, \overline{TP}, 9)$	$(8, \overline{TP}, 10)$
	$\overline{TP} \sim N(10.5, 1.1)$	$\overline{TP} \sim N(10.0, 1.3)$	$\overline{TP} \sim N(9.0, 1.1)$	$\overline{TP} \sim N(8.0, 0.9)$	$\overline{TP} \sim N(9.0, 1.3)$
TN ($\times 10^{-1}$ mg/L)	$(15, \overline{TN}, 21)$	$(14, \overline{TN}, 20)$	$(15, \overline{TN}, 19)$	$(16, \overline{TN}, 22)$	$(15, \overline{TN}, 19)$
	$\overline{TN} \sim N(18, 5)$	$\overline{TN} \sim N(17, 5)$	$\overline{TN} \sim N(17, 4)$	$\overline{TN} \sim N(19, 5)$	$\overline{TN} \sim N(17, 3)$
Temp (°C)	$(0.5, \overline{Te}, 1.3)$, $\overline{Te} \sim N(0.90, 0.07)$				
TSS ($\times$10 mg/L)	$(13, \overline{TS}, 17)$	$(15, \overline{TS}, 21)$	$(14, \overline{TS}, 20)$	$(14, \overline{TS}, 18)$	$(14, \overline{TS}, 18)$
	$\overline{TS} \sim N(15, 3.7)$	$\overline{TS} \sim N(18, 4.2)$	$\overline{TS} \sim N(17, 4.1)$	$\overline{TS} \sim N(16, 3.3)$	$\overline{TS} \sim N(16, 3.5)$
Tur ($\times$10 NTU)	$(5.5, \overline{Tu}, 8.5)$	$(6.3, \overline{Tu}, 8.9)$	$(6.7, \overline{Tu}, 9.1)$	$(6.5, \overline{Tu}, 8.9)$	$(6.5, \overline{Tu}, 8.3)$
	$\overline{Tu} \sim N(7.0, 0.9)$	$\overline{Tu} \sim N(7.4, 1.1)$	$\overline{Tu} \sim N(7.9, 1.1)$	$\overline{Tu} \sim N(7.7, 0.9)$	$\overline{Tu} \sim N(7.4, 0.8)$
Mor ($\times 10^4$ CFU)	$(1.9, \overline{Mo}, 2.7)$	$(2.1, \overline{Mo}, 2.9)$	$(2.2, \overline{Mo}, 3.4)$	$(2.1, \overline{Mo}, 3.3)$	$(2.0, \overline{Mo}, 2.8)$
	$\overline{Mo} \sim N(2.3, 0.07)$	$\overline{Mo} \sim N(2.5, 0.09)$	$\overline{Mo} \sim N(2.8, 0.11)$	$\overline{Mo} \sim N(2.7, 0.10)$	$\overline{Mo} \sim N(2.4, 0.09)$
Phy ($\times 10^5$ cells/L)	$(5.3, \overline{Ph}, 6.3)$	$(4.6, \overline{Ph}, 6.8)$	$(4.8, \overline{Ph}, 6.2)$	$(4.7, \overline{Ph}, 6.5)$	$(5.3, \overline{Ph}, 6.9)$
	$\overline{Ph} \sim N(5.8, 0.51)$	$\overline{Ph} \sim N(5.7, 0.73)$	$\overline{Ph} \sim N(5.5, 0.45)$	$\overline{Ph} \sim N(5.6, 0.53)$	$\overline{Ph} \sim N(6.1, 0.57)$
WEC ($\times 10^2$ days)	$(5.1, \overline{WE}, 5.5)$	$(5.2, \overline{WE}, 5.8)$	$(5.3, \overline{WE}, 5.9)$	$(5.2, \overline{WE}, 5.6)$	$(5.1, \overline{WE}, 5.9)$
	$\overline{WE} \sim N(5.3, 0.3)$	$\overline{WE} \sim N(5.5, 0.4)$	$\overline{WE} \sim N(5.6, 0.4)$	$\overline{WE} \sim N(5.4, 0.3)$	$\overline{WE} \sim N(5.5, 0.5)$

Note Data derived from Binghu and Yuxikou monitoring points, Hefei, Anhui Province

Table 3 The catastrophe theory-based category set

Category	I	II	III	IV	V	V bad
Catastrophe value interval	[0.00, 0.15)	[0.15, 0.35)	[0.35, 0.60)	[0.60, 0.80)	[0.80, 1.00)	≥1

category set can be deduced by using the index values shown in Table 1. The new category set is shown in Table 3.

The monitoring data in Table 2 were standardized according to Eqs. (8) or (9). Then, using Eq. (7), referring to the two principles, the catastrophe value of each year can be calculated out based on the the calculation structure in Fig. 3. The calculation process of the catastrophe value of 2009 is shown as follows.

Step 1. Input index monitoring data
$\overset{\eqsim}{a}_1 = (27, \overline{CO}, 45)$, $\overline{CO} \sim N(36, 4)$; $\overset{\eqsim}{a}_2 = (7.6, \overline{BO}, 9.4)$, $\overline{BO} \sim N(8.5, 0.5)$;
$\overset{\eqsim}{a}_3 = (9, \overline{TP}, 12)$, $\overline{TP} \sim N(10.5, 1.1)$; $\overset{\eqsim}{a}_4 = (15, \overline{TN}, 21)$, $\overline{TN} \sim N(18, 5)$;
$\overset{\eqsim}{b}_1 = (0.5, \overline{Te}, 1.3)$, $\overline{Te} \sim N(0.90, 0.07)$; $\overset{\eqsim}{b}_2 = (13, \overline{TS}, 17)$, $\overline{TS} \sim N(15, 3.7)$;
$\overset{\eqsim}{b}_3 = (5.5, \overline{Tu}, 8.5)$, $\overline{Tu} \sim N(7.0, 0.9)$; $\overset{\eqsim}{c}_1 = (1.9, \overline{Mo}, 2.7)$, $\overline{Mo} \sim N(2.3, 0.07)$;
$\overset{\eqsim}{c}_2 = (5.3, \overline{Ph}, 6.3)$, $\overline{Ph} \sim N(5.8, 0.51)$; $\overset{\eqsim}{d}_2 = (5.1, \overline{WE}, 5.5)$, $\overline{WE} \sim N(5.3, 0.3)$.

Step 2. Standardized index data
$\overset{\eqsim}{a}_1^{std} = (0.675, \overline{CO}, 1.125)$, $\overline{CO} \sim N(0.900, 0.083)$; $\overset{\eqsim}{a}_2^{std} = (0.760, \overline{BO}, 0.940)$, $\overline{BO} \sim N(0.850, 0.043)$;
$\overset{\eqsim}{a}_3^{std} = (0.450, \overline{TP}, 0.600)$, $\overline{TP} \sim N(0.525, 0.049)$; $\overset{\eqsim}{a}_4^{std} = (0.750, \overline{TN}, 1.050)$, $\overline{TN} \sim N(0.900, 0.027)$;
$\overset{\eqsim}{b}_1^{std} = (0.250, \overline{Te}, 0.650)$, $\overline{Te} \sim N(0.450, 0.023)$; $\overset{\eqsim}{b}_2^{std} = (0.867, \overline{TS}, 1.133)$, $\overline{TS} \sim N(1.000, 0.191)$;
$\overset{\eqsim}{b}_3^{std} = (0.688, \overline{Tu}, 1.062)$, $\overline{Tu} \sim N(0.875, 0.093)$; $\overset{\eqsim}{c}_1^{std} = (0.475, \overline{Mo}, 0.657)$, $\overline{Mo} \sim N(0.575, 0.018)$;
$\overset{\eqsim}{c}_2^{std} = (0.883, \overline{Ph}, 1.050)$, $\overline{Ph} \sim N(0.967, 0.073)$; $\overset{\eqsim}{d}_2^{std} = (0.727, \overline{WE}, 0.784)$, $\overline{WE} \sim N(0.756, 0.053)$.

Step 3. Normalized index data
$\overset{\eqsim}{a}_1^{nom} = (0.822, \overline{CO}, 1.061)$, $\overline{CO} \sim N(0.949, 0.144)$; $\overset{\eqsim}{a}_2^{nom} = (0.913, \overline{BO}, 0.980)$, $\overline{BO} \sim N(0.947, 0.116)$;
$\overset{\eqsim}{a}_3^{nom} = (0.819, \overline{TP}, 0.880)$, $\overline{TP} \sim N(0.851, 0.118)$; $\overset{\eqsim}{a}_4^{nom} = (0.944, \overline{TN}, 1.010)$, $\overline{TN} \sim N(0.979, 0.097)$;
$\overset{\eqsim}{b}_1^{nom} = (0.500, \overline{Te}, 0.806)$, $\overline{Te} \sim N(0.671, 0.076)$; $\overset{\eqsim}{b}_2^{nom} = (0.954, \overline{TS}, 1.043)$, $\overline{TS} \sim N(1.000, 0.192)$;

$\overset{\simeq nom}{b_3} = (0.911, \overline{Tu}, 1.015), \overline{Tu} \sim N(0.967, 0.138)$; $\overset{\simeq nom}{c_1} = (0.689, \overline{Mo}, 0.811), \overline{Mo} \sim N(0.758, 0.067)$;
$\overset{\simeq nom}{c_2} = (0.959, \overline{Ph}, 1.016), \overline{Ph} \sim N(0.989, 0.139)$; $\overset{\simeq std}{d_2} = (0.853, \overline{WE}, 0.885), \overline{WE} \sim N(0.869, 0.115)$.

Step 4. The integrated index values of Chemistry, Physics, Biology and Activity
$\tilde{\tilde{a}} = (0.875, \overline{a}, 0.983)$, $\overline{a} \sim N(0.932, 0.119)$; $\tilde{\tilde{b}} = (0.788, \overline{b}, 0.955)$, $\overline{b} \sim N(0.879, 0.135)$;
$\tilde{\tilde{c}} = (0.689, \overline{c}, 0.811)$, $\overline{c} \sim N(0.758, 0.067)$; $\tilde{\tilde{d}} = (0.853, \overline{d}, 0.885)$, $\overline{d} \sim N(0.869, 0.115)$.

Step 5. Normalized the integrated index
$\overset{\simeq nom}{a} = (0.935, \overline{a}, 0.992)$, $\overline{a} \sim N(0.965, 0.172)$; $\overset{\simeq nom}{b} = (0.924, \overline{b}, 0.985)$, $\overline{b} \sim N(0.958, 0.171)$;
$\overset{\simeq nom}{c} = (0.911, \overline{c}, 0.949)$, $\overline{c} \sim N(0.933, 0.127)$; $\overset{\simeq nom}{d} = (0.969, \overline{d}, 0.976)$, $\overline{d} \sim N(0.972, 0.130)$.

Thus, the catastrophe value of CT-based WQEMU in 2009 is $x = (0.935, \overline{x}, 0.968)$, $\overline{x} \sim N(0.957, 0.150)$. Similarly, the catastrophe values from 2009 to 2013 can be calculated out, see Table 4.

According the catastrophe interval values shown in Table 3, and using the results in Table 4, the chance measure of the water quality of Chaohu lake from 2009 to 2013 can be calculated out by Eq. (6). The calculated results are shown in Table 5, The first, second number in number pair $(*, \cdot)$ denote the probability, possibility level of the chance measure, respectively.

3.3 The Results Analysis

From Tables 4 and 5, it can be known that Chaohu lake water pollution is serious in 2009–2013. The water quality in Chaohu lake mainly belongs to the fifth and inferior

Table 4 The catastrophe values from 2009 to 2013

Years	2009	2010	2011
Catastrophe values	$(0.935, \overline{x}, 0.968)$	$(0.907, \overline{x}, 0.953)$	$(0.896, \overline{x}, 0.937)$
	$\overline{x} \sim N(0.957, 0.150)$	$\overline{x} \sim N(0.933, 0.143)$	$\overline{x} \sim N(0.919, 0.135)$
Years	2012	2013	
Catastrophe values	$(0.857, \overline{x}, 0.896)$	$(0.873, \overline{x}, 0.915)$	
	$\overline{x} \sim N(0.869, 0.117)$	$\overline{x} \sim N(0.895, 0.153)$	

Table 5 The chance measure of the water quality of Chaohu lake from 2009 to 2013

Category	Year				
	2009	2010	2011	2012	2013
III	(0.80, 0.00)	(0.80, 0.07)	(0.80, 0.22)	(0.80, 0.37)	(0.80, 0.31)
	(0.90, 0.00)	(0.90, 0.00)	(0.90, 0.15)	(0.90, 0.25)	(0.90, 0.21)
IV	(0.80, 0.13)	(0.80, 0.19)	(0.80, 0.37)	(0.80, 0.73)	(0.80, 0.53)
	(0.90, 0.08)	(0.90, 0.11)	(0.90, 0.20)	(0.90, 0.61)	(0.90, 0.39)
V	(0.80, 0.21)	(0.80, 0.35)	(0.80, 0.69)	(0.80, 1.00)	(0.80, 0.71)
	(0.90, 0.17)	(0.90, 0.26)	(0.90, 0.41)	(0.90, 0.91)	(0.90, 0.55)
V bad	(0.80, 1.00)	(0.80, 1.00)	(0.80, 0.91)	(0.80, 0.67)	(0.80, 0.86)
	(0.90, 1.00)	(0.90, 0.93)	(0.90, 0.83)	(0.90, 0.59)	(0.90, 0.79)

fifth category. From 2009 to 2013, the most serious water pollution appeared in 2009. Pollution situation has been reduced year by year from 2010 to 2012, but it began to deteriorate in 2013. According to Table 5, The change diagram in water quality situation of Chaohu lake can be drawn, as shown in Fig. 4. From Fig. 4, it can be seen visually, whether under 0.8 or 0.9 probability level, the possibility levels of the water quality belonging to "V bad" grade are high up to 0.9, but belonging to "V" grade

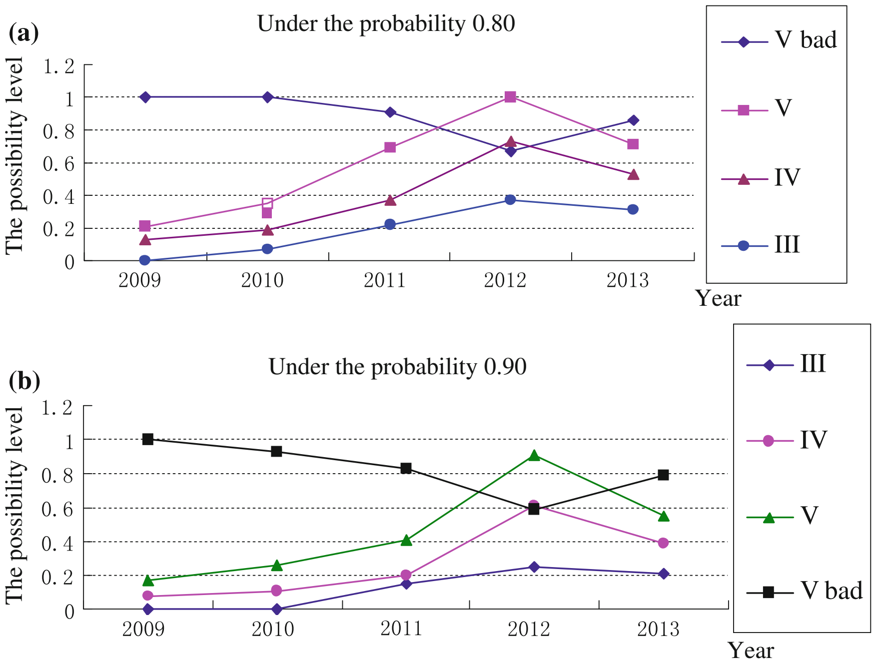

Fig. 4 The change diagram in water quality situation of Chaohu lake

are low down to 0.4 in 2009 and 2010. Therefore, taking the necessary measures to protect the chaohu lake water quality, improve the water environment is the first task of the local administrative department.

4 Conclusion

In this research, Fuzzy random variables are employed to deal with the complex uncertainty in water quality. A new model for water quality evaluation named catastrophe theory-based water quality evaluation model under uncertainty (CT-based WQEMU) was proposed. And, a new calculation method was designed to solve the model. The proposed model was applied to an actual case: Chaohu lake, China. According to the calculation results of the model, some analysis about the actual situation of water pollution in Chaohu lake was made. Then, the policy recommendations are provided to the local water management department.

Water quality assessment is a complex system problem, and a variety of different uncertainty exists widely in water quality. Therefore, in order to exactly and objectively evaluate water quality, new mathematical model needs to be created, new uncertainties approach needs to be found. These all will be the authors' future research work.

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The Research of Influence Relationship Between Third-Party Rating and Micro-Financial Institution Performance

Xiaorui Zhou and Li Yang

Abstract Effective company management and performance control are crucial for successful Micro-Finance Institutions (referred as MFIs). Capital and output would be better coordinated under an efficient performance control system. An efficient performance control system is also the key for the development of a company and a well-yielded benefit. Given the truth of the crucial role of third-party rating to financial institutes, this paper is focusing on the model of third-party rating results in connection with the performance control system of MFIs, to provide a reference for the establishment a comprehensive evaluation system for MFIs institutions.

Keywords Micro-financial institution (MFI) · Performance · Third party rating

1 Introduction

The third-party valuation agency plays a crucial role in the capital market [8]. It guides institutional investors and private capital for an unrestricted allocation of assets worldwide under the balance of risks and benefits. MFIs are rated by valuating their financial performances. Investors such as banks could make investment decisions according to the rating level of an institution. Third-party valuation agencies assess the performance of an institution based on the information collected and reported. Up to 2010, there are about twenty difference agencies that make assessment on rating Microfinance Institution. There are traditional rating agencies such as Standard & Poor's and Fitch Rating, specialized rating agencies such as PlaNet Rating, Micro-Finance Rating and M-CRIL. Top five agencies including PlaNet Rating, Micro-Finance Rating, MicroRate, M-CRIL and PCR take 80 % of market share [11].

X. Zhou (✉)
Chengdu Jin-Kong Financing Guarantee Co., Ltd, Chengdu 610064,
People's Republic of China
e-mail: 21327769@qq.com

L. Yang
Southwest Jiaotong University, Chengdu 610064, People's Republic of China

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However, there are few researches emphasizing on the connection between third-party rating results and the performance control system of MFIs. Conclusions of these researches are summarized as below:

(1) The development of microfinance industry needs the professional rating agencies. In the absence of the stock and bond market for MFIs, the information provided by these independent agencies could highly improve the efficiency of capital [10].
(2) The size of the organization, financial sustainability, amount of total assets, number of active customers and Institutional continuity are widely mentioned as the factors of the third-party rating [4]. These factors not only have a positive impact on the rating, they also play significant roles on the sustainable development of MFIs.
(3) Domestic rating tends to primarily focus on rural financial institution, especially the establishment of a comprehensive business performance evaluation system. They combine fuzzy comprehensive evaluation method with analytic hierarchy process [3].

Therefore, this paper establishes an econometric model to test the impact of the third-party rating on both financial and social performance of the MFIs. 154 MFIs screened by PlaNet Rating are selected as our samples.

2 Relational Model

Performance of MFIs' is divided into financial performance and social performance, which are the independent variables. Then relevant variable factors are designed to measure two independent variables. Based on this analysis, this paper establishes the relational model between third party rating results and MFIs.

2.1 Model Construction

Hartarska and Nadolnyak [7] constructed the empirical models which are designed to test relativity impact of ratings results on MFIs financing scale. The models are constructed econometric models to test MFIs rating results with their financial performance and social performance.

Econometric model which tests the impact on financial performance is as following:

$$F_{It} = C + \alpha A_t + \beta B_t + \phi R_t + \varepsilon_t. \tag{1}$$

In Eq. (1), F is a description of MFI financial performance variable. A is a variable to describe the characteristics of MFIs, including the size of the organization, operation period, organization type, etc. B is a variable to indicate state of operation, including capital structure, credit structure, credit risk, operational efficiency and so on. R is a dummy variable to determine whether institution participated ratings or not.

Econometric model which tests the impact on social performance is as following:

$$S_{It} = C + \alpha A_t + \beta B_t + \phi R_t + \varepsilon_t. \tag{2}$$

In Eq. (2), S is a variable describing social performance of MFIs. Other variables remain unchanged as in Eq. (1).

2.2 Variable Definition

According to the characteristics of the microfinance industry and its special social purpose, independent variables and dependent explanatory variables are defined.

1. Financial performance variables
   According to characteristics of MFIs, financial performance dependent and independent variables are listed in Table 1.
2. Social performance variables
   This paper uses the number of borrowers with active loans and average amount loaned per borrower to evaluate the social performance of MFIs. The number of borrowers with active loans measures the breadth of services. The higher the value, the more services are provided by the institution to customers who are excluded by formal financial system, which means the better social performance. The average amount loaned per borrower measures the depth of services. The smaller average amount loaned per borrower, the lower of social class of them is serviced by MFIs.
3. The explanation of variables

(1) Total assets
This study uses total assets to measure the size of a MFIs. The larger the size of an MFI generally means a better profitability and a stronger anti-risk capability. This study uses the LnA as alternative indicator of total assets.

(2) Length of years in operation
This study categorizes the length of years in operation into three groups: newly founded (less than 4 years), young (4–8 years) and fully developed (more than 8 years), respectively referred as −1, 0 and 1.

(3) Organization type
MFIs are classified as Bank, Credit Union: Cooperative, Non-bank financial institution (referred as NBFI), Non-government organization (referred as NGO) and other organization according to Microfinance Information Exchange (referred as MIX). The objective of NGO and NBFI to involve in capital allocation is

Table 1 Definition of financial performance dependent variables

Type	Index and abbreviation	Definition
Dependent variables	ROA—return on asset	Adjusted net income/adjusted average total assets
	ROE—return on equity	Adjusted net income/adjusted average shareholder equity
	OSS—operating self—financed ratio	Operating income/(operating expense + provision for loan losses + admin expenses)
	NAB—number of active borrower	The number of customers need to repay the loan after write-offs
	ALPB—average loan per borrower	Adjusted loan balance/(adjusted active accounts × GNI per capita)
Independent variables	A—total asset	Adjusted total asset after loan loss reserves, write-offs, and inflation adjustment
	Age—institution age	How long do institutions last
	ST—institution type	Dummy variable: if institution is NGO or NBFI, ST = 0, or ST = 1
	Capital—capital ratio	Adjusted total capital / Adjusted total asset
	Loan—loan ratio	Loan/total asset
	P30—risk loan ratio	Loan overdue for more than 30 days/total loan
	Liquid—current ratio	Cash and bank balance/total asset
	Cost—administration efficiency	Administration expense/total asset
	R—rating participation	Dummy variable: if participate rating, R = 1, or R = 0

different from other types of organizations [5]. As NGO and NBFI are more socially focused, the type of organization will affect the performance of MFIs. This study introduces dummy variables, with 0 represents NGO and NBFI and 1 represents other types of organizations.

(4) Capital ratio
The profit of MFIs is primarily from granting loans. A larger the proportion of loans to total assets indicates a stronger ability to create profits.

(5) P30
P30 is defined by MIX as the proportion of loan overdue for more than 30 days (including the overdue loans renegotiated) to total loan. It is a key indicator for a Microfinance Institution to measure its risk.

(6) The ratio of cash and bank deposits to total assets
This study uses this ratio to measure the liquidity risk of MFIs. A cash and bank deposit surplus means the capital has not been allocated reasonably, while a cash and bank deposit deficit indicates a payment risk. The ratio of cash and bank deposits to total assets has impact on both financial and social performance.

(7) The proportion of administrative expenses to total assets
The proportion of administrative expenses to total assets measures the efficiency of administrative expenses. It is also an important factor of financial and social performance.

(8) Whether to accept rating
Sample institutions are rated by PlaNet Ratings after 2–3 years operation. This study introduces the dummy variables: institutes accept ratings are referred as 1, else 0. AR (1) indicates the average amount of institutes accepting ratings.

3 Analysis of Sample Selection

This study not only selects native MFIs, but also includes a large number of international MFIs. The purpose is to completely reveal the correlativity between third party rating results and MFIs performance.

1. Sample Selection
   Selected MFIs need to conform to the following two standards:

   (1) Being assessed by professional rating agency—PlaNet Rating.
   (2) Submitting statistics to MIX.

   The selection process is first to determine the scope of study period beginning 2003–2010. Then 218 MFIs, which assessed by PlaNet Rating during this period, are filtered as analysis objects.
   Second, those 218 MFIs are designated as the target sample and relevant indicators are looked up on MIX database. There are 37 MFIs do not disclose their statistics, which are removed from target sample.
   Finally, MFIs operating less than 2 years need to be removed from the sample. The selected sample includes 154 MFIs.
2. Sample Analysis
   Selected samples are mainly spread in five districts: Africa, Eastern Asia and the Pacific, Eastern Europe and Central Asia, Latin America and the Caribbean, the Middle East and North Africa, South Asia. Among them, there are 51 institutions in Africa, accounting for 33.1 %. There are 48 institutions come from Latin America and the Caribbean, accounting for 31.2 %. There are 26 institutions in Eastern Europe and Central Asia, accounting for 17 %. Thus, the samples are reasonably distributed with good regional representation.
   The 154 samples include 5 different types of MFIs which has good representation of type diversification. NBIFs take 28.9 % proportion, credit unions take 16.4 %, non-governmental organizations (NGO) take 47.4 %, and others take 13 %. Such MFIs mainly rely on donations and government grant. Therefore, compared to commercial MFIs, these organizations need to be more aware by investors that they are under excellent operation condition. Participation in the rating process is undoubtedly a significant way to convey information.

Table 2 Characteristic analysis of sample

Year	2003					2011				
Profit/loss	MFIs number	Ratio (%)	Supervised			MFIs number	Ratio (%)	Supervised		
Profit	21	22.60	Yes	No	N/A	33	27.70	Yes	No	N/A
			21	0	0			29	4	0
Loss	72	77.40	Yes	No	N/A	86	72.30	Yes	No	N/A
			36	36	0			35	49	2
Total	93	100	57	36	0	119	100	64	53	2

There are obvious differences among samples rest on whether institutions can get profit, or whether they are under supervision. These characteristics will affect their financial and social performance. Table 2 shows the analysis results of samples in 2003 and 2011.

The result of this analysis shows that profitability and regulatory environment of MFIs have changed over time. For example, in 2011, there were 21 profitable companies of total 93 organizations, accounting for 22.6 %; while 33 companies made profit among 119 ones, accounting for 27.7 %. Moreover, all profitable MFIs were regulated in 2003; however 87.77 % of profitable MFIs were regulated in 2011.

In addition, the result shows the ratio of profitable MFIs which were supervised is higher than that of defective ones. In 2011, taking 119 MFIs as the sample, 87.88 % of profitable MFIs were supervised while 40.70 % of defective ones were supervised.

Finally, non-profitable MFIs account for higher proportion among unsupervised organizations. Among 79 supervised MFIs, profitable ones and defective ones separately account for 44.3 and 54.4 %. Among 64 unsupervised MFIs, defective ones account for 90.6 %.

4 Empirical Test

4.1 Unit Root Test

The stability of statistics is significantly crucial to analyze economic data. Unit root test which aims to verify stationary of time series is the basis for the establishment of economic model. This study chooses five different unit root test methods: Levin- Lin-Chut test (LLC), Im-Pesaran-Shin test (IPS), ADF-Fisher chi-square test, P-Fisher chi-square test and Hadri-stat test, to verify the stability of data used by regression model.

Table 3 Results of dependent variable unit root test

Variables	Method	LLC	IPS	ADF-Fisher	P-Fisher	Hadri Z-stat
LnA	Statistic	−19.49	−2.41	324.16	504.73	18.29
	Prob	0.00	0.01	0.0	0.00	0.0
	Obs	669.00	669.00	669.00	717.00	867.00
Capital	Statistic	−20.54	−5.98	402.60	457.06	15.91
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	664.00	664.00	664.00	717.00	867.00
Loan	Statistic	−36.77	−6.48	374.48	448.87	14.37
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	669.00	669.00	669.00	717.00	867.00
P30	Statistic	−26.65	−4.89	365.38	363.46	15.66
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	620	620	620	661	826
Liquid	Statistic	−92.92	−11.31	391.83	446.24	14.67
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	647	647	647	686	844
Cost	Statistic	−20.42	−4.45	359.19	482.94	15.08
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	656.00	656.00	656.00	693.00	845.00

Table 4 Results of dependent variable unit root test

Variables	Method	LLC	IPS	ADF-Fisher	PP-Fisher	Hadri Z-stat
ROA	Statistic	−39.6	−30.98	383.41	453.27	14.22
	Prob	0.00	0.01	0.0	0.00	0.0
	Obs	661	661	661	712	862
ROE	Statistic	−106.73	−19.04	370.79	440.64	16.98
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	661	661	661	712	862
OSS	Statistic	−37.34	−6.96	386.77	436.91	13.67
	Prob	0.00	0.00	0.0	0.00	0.0
	Obs	670	670	670	717	867

1. Dependent Variable Unit Root Test
   The Table 3 shows observations of dependent variables are basically stable during 2003 and 2011, which are used to do regression analysis.
2. Independent Variable Unit Root Test
   The Table 4 shows observations of independent variables are stable to do regression analysis.

Table 5 Correlative results of dependent variables

Variables	Age	ST	LnA	Capital	Loan	R	Liquid	P30	Cost
Age	1.00	–	–	–	–	–	–	–	–
ST	0.29	1.00	–	–	–	–	–	–	–
LnA	0.65	0.12	1.00	–	–	–	–	–	–
Capital	−0.02	−0.31	−0.34	1.00	–	–	–	–	–
Loan	−0.48	−0.03	−0.80	0.41	1.00	–	–	–	–
Liquid	0.63	0.49	0.32	0.15	−0.31	1.00	–	–	–
P30	0.66	0.42	0.20	0.20	0.07	0.48	1.00	–	–
Cost	0.00	0.20	0.03	−0.07	−0.22	0.40	−0.11	1.00	–
R	0.17	0.32	0.10	0.03	0.00	0.13	0.32	−0.11	1.00

4.2 Correlation Analysis of Variables

1. Correlation Analysis of Dependent Variables

As the Table 5 shows:

(1) The correlative analysis results between Age and LnA, Age and Liquid, and Age and P30 are all above 0.5. Therefore, Age can be removed from the regression model to improve accuracy.
(2) The maximum correlation coefficient between LnA and Loan is −0.8, meaning one of those two variables should be removed. However, technically speaking, organization size and proportion of loan to total assets are both significant factors to influence MFIs financial and social performance. In order to improve accuracy of research, this study uses index LgE instead of LnA to measure organization size of MFIs.
(3) Age is correlative to Loan. ST is correlative to Liquid and P30. Liquid is correlative to P30 and Cost, and the degree of correlation is acceptably less than 0.5. They all can be used in the regression model.

2. Correlation Analysis between Dependent and Independent Variables

As the Table 6 shows:

(1) Removing variable Age from regression model is to avoid autocorrelation. The analysis results in Table 6 indicate that Age is not correlative to MFIs financial performance, neither social performance. The effect of removing index Age in the regression model can be ignored.
(2) Size of organization and return on equity are negative correlative. The coefficient is −0.78 possibly resulting from high proportion of non-profitable MFIs in sample. Because the objectives of NGOs are to diffuse financial service and to provide service to poor people instead of seeking profit, their profit will be remained stable after financial sustainability. Moreover, while profits remain stable, enlarging institution will decrease the return on equity.

Table 6 Correlation analysis between dependent and independent variables

Variables	ROA	ROE	OSS	NAB	ALPB
Age	−0.07	0.06	−0.2	−0.04	0.03
ST	0.01	−0.21	−0.13	−0.49	0.86
LnA	0.23	−0.78	0.27	0.19	0.12
Capital	0.06	−0.58	0.34	0.16	−0.22
Loan	0.05	−0.6	0.1	0.25	0.1
Liquid	−0.37	−0.38	−0.15	−0.23	0.34
P30	−0.19	−0.37	−0.33	0.07	0.29
Cost	−0.33	0.34	−0.07	−0.07	−0.42
R	0.07	0.12	−0.12	−0.08	0.15

(3) For institutional solvency indicators, the indicators of Liquid and P30 measuring risk are negative correlative to financial performance, which is consistence with theory analysis. However the degree of effect is verified by regression model.

4.3 Regression Result

In order to reduce the impact of lack of statistics on the regression result, this study deletes the samples which are lack of partial data. Finally, the regression analysis is based on 128 MFIs with 877 series data.

1. Regression Result between Rating and Financial Performance
   As shown in Table 7, at 15 % significant level, R is positive correlative to ROE. This indicates that participation rating is helpful to improve the ration of return on equity. The principle is that through evaluation of MFIs performance in last financial year, financial information is more transparency than that before. Furthermore MFIs pay more attention on financial performance.
   To further validate the relationship between ratings and financial performance of MFIs, the various rating indicators and rating results are lagged to next period to do regression analysis. The result is shown as Table 8.

(1) At 15 % significant level, R_t is positive correlative to ROE_t and OSS_{t+1}. This result means that participation rating is conducive to increase ROE in current financial period, while improve MFIs operation profitability.
(2) At 5 % significant level, ROE_{t-1} is positive correlative to R_t, which proves that the higher ROE, the more probability that MFIs accepting rating.
(3) Rating results and financial performance of MFIs are mutually reinforcing.

2. Regression Result between Rating and Social Performance
   As shown in Table 9, at 5 % significant level, R is negative correlative to NAB.

Table 7 Regression result between rating and MFIs financial performance

Variables and test statistics	ROA	ROE	OSS
C	−362.51*	−22.64	109.31***
	(198.52)	(18.51)	(25.83)
AR(1)	1.15***	0.55***	0.38***
	(0.01)	(0.04)	(0.08)
ALPB	0.58***	0	0.02
	(0.28)	(0.03)	(0.04)
LnE	40.81*	4.28**	0.08
	(19.76)	(2.03)	(2.73)
ST	−751.15***	12.03*	1.42
	(268.08)	(6.61)	(8.13)
Capital	1.26	0.36***	0.54***
	(1.36)	(0.1)	(0.13)
Loan	0.84	0.13	0.16
	(1.29)	(0.12)	(0.18)
P30	−7.99*	−1.35***	−1.78***
	(2.75)	(0.24)	(0.37)
Cost	−1.99	−2.49***	−1.32
	(4.00)	(0.38)	(0.57)
R	−22.64	4.36	−1.32
	(28.18)	(2.77)	(4.47)
F-statistic	651.59*	23.799*	11.599
Adjusted R-squared	0.94	0.36	0.2
No of observations	454	454	454
DW	1.52	1.84	1.9

*at 15% significant level; **at 10% significant level; ***at 5% significant level; ****at 1% confidence level

Table 8 Regression analysis of lagging statistics

Period	ROA	ROE	OSS
R(−1)	1.74	0.75	5.86*
	(23.86)	(2.37)	(3.95)
R	−22.64	4.36*	−1.32
	(28.18)	(2.77)	(4.47)
R(1)	−6.76	5.87***	0.73
	(25.07)	(2.61)	(4.41)

*at 15 % significant level; **at 10 % significant level; ***at 5 % significant level; ****at 1 % confidence level

Table 9 Regression result between rating and MFIs social performance

Variables and test statistics	NAB	ALPB
C	−3674.27****	2.9
	(145)	(28.59)
AR(1)	0.01****	0.87****
	(0.00)	(0.01)
ROE	0.22**	−0.08****
	(0.13)	(0.03)
ALPB	−0.20*	0.00***
	(0.14)	(0.00)
LnE	16.04*	3.4
	(10.8)	(3.14)
ST	−120.62	83.86****
	(224.94)	(26.48)
Capital	−2.56****	83.86****
	(0.61)	(0.17)
Loan	1.35***	0.27**
	(0.57)	(0.16)
P30	−0.31	−0.69
	(1.05)	(0.50)
Cost	−0.16	−0.69
	(1.81)	(0.50)
R	−19.91***	0.64
	(8.33)	(2.29)
F-statistic	1159.56*	492.43*
Adjusted R-squared	0.95	0.88
No of observations	666	666
DW	0.95	2.71

*at 15 % significant level; **at 10 % significant level; ***at 5 % significant level; ****at 1 % confidence level

This indicates that rating result can lead the number of active borrowers decreased. Even at 15 % significant level, R is not correlative to ALPB. To further validate the relationship between ratings results and social performance of MFIs, the various rating indicators and rating results are lagged to next period to do regression analysis. The result is shown as Table 10:

Firstly, rating results influence the number of active loan borrowers in current and next periods. At 5 % significant level, R_t is negative correlative to NAB_t, but is positive correlative to NAB_{t+1}. This results means that participation rating leads the number of active borrowers decreased in current period, but increased in next period. At 15 % significant level, there is no correlation between NAB_{t-1} and Rt. Hence, the number of active borrowers does not encourage institutions to accept rating.

Table 10 Regression analysis of lagging statistics

Period	NAB	ALPB
R(−1)	19.03***	−4.29***
	(9.05)	(1.86)
R	−20.03***	1.04
	(8.34)	(2.28)
R(1)	−3.85	−1.31
	(8.70)	(2.53)

*at 15 % significant level; **at 10 % significant level; ***at 5 % significant level; ****at 1 % confidence level

Secondly, rating result is negative correlative to the average loan per borrower. At 5 % significant level, R_t is negative correlative to $ALPB_{t+1}$, which means after rating, the average loan per borrower is not influenced in current period, but this will be decreased in next period.

5 Conclusion and Discussion

1. Mutual Promotion

   Overall, the third part rating results of MFIs and their financial performance can promote each other. Improvement of organization's financial performance is conducive to encourage participation in rating. Meanwhile rating results are contributed to the improvement of financial performance.

   However, regarding to diverse financial indicators, the impact by rating results are different.

(1) There is no correlation between the results and ROA. The experimental result shows that even at a 15 % significance level, the correlation coefficient between R(−1), R(1) and ROA is 0. Hence, participation in third party rating does not affect current ROA, also the next one.

(2) ROE and rating result interrelate. At 15 % significance level, R(−1), R, and ROE are positive correlated. This result indicates that the promotion of ROE can encourage participation of rating. Meanwhile, participation of rating can enhance MFIs current ROE.

(3) Rating results can influence MFIs business sustainability. At 15 % significance level, R and OSS are positive correlated, which means if MFIs participate rating in period T, then business sustainability can increase in the next $T + 1$ period.

2. Evaluation Function

   The rating results have certain impact on the achievement of social goals of MFIs. When MFIs accept third party assessment in period T, current NAB will decrease, but increase in next $T + 1$ period. This means that MFIs involved in the rating is detrimental to their social objectives, but the social performance in next period will be significantly improved. To some extent, rating plays a supervisory role on MFIs to implement their social goals.

3. Modification
   Rating results can promote MFIs performance development. The results are not only helpful to improve MFIs financial performance, but also play an important role on supervising them and achieving their social objectives.

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The Study on Path Model of China's SMEs Development Strategy Based on Life Cycle

Dechao Mi, Ping Zhang and Pu Chen

Abstract Small medium-sized enterprises (SMEs) are important strength in the development of national economy, its healthy and sustainable development has been plagued the development of China's economy and society. Therefore, SMEs must have a clear development strategy, namely, to clear development direction, determine development goal, and promote development ability. This paper, based on the Life Cycle Theory (LCT) in biology, relying on the enterprise's internal resources, focusing on the enterprise's external resources, establish the three-dimensional model aboutinternal resources, brand status, and the enterprise life cycle (LC). By integrating internal and external factors of SMEs into a model, systematically analyze the path and wayof enterprise development strategy at different stages.

Keywords SMEs · LC · Development strategy · Path model · Internal resources · Brand status

1 Introduction

SMEs, as a heterogeneous group in terms of size and sector diversity, are the basic power to promote national economic development, build the main body of market economy, and promote social stability, and they are increasingly recognized as central contributors to play a pivotal role in the national economies of countries all around the world [2]. In all kinds of industrial and commercial enterprises in our country, the proportion of SMEs is as high as 99 %, but its LC is only 3 to 5 years, which is far shorter than 6–8 years in the Western countries. Statistically, the LCof 68 % of SMEs in our country is not more than 5 years, these enterprises tend to die at a certain stage. To investigate its reasons, the solidification of development strategy is an important factor, which may prevent them from engaging proactively in the innovation process [8]. Therefore, the development of SMEs in China must solve its

D. Mi · P. Zhang(✉) · P. Chen
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zpscu1@163.com

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problems in the development direction, development goal, and the focus, that is to solve its problem of development strategy. While facing the huge challenges brought about by the current international and domestic economic reform, SMEs needs to formulate development strategy of the enterprise according to the change of internal and external environment, and seek adjustment of enterprise development strategy. Analysis of enterprise's LC can not only enable management to identify critical LC steps of the enterprise, but also help managers improve business performance in the areas of development strategy, further, to develop better and more fact-based strategies to meet future market challenges [3]. This paper, based on the perspective of LC, combine the intensity of internal resources of SMEs with external brand status, to study the path of development strategy in each stage of LC, and help enterprises to better formulate and implement development strategy. Hence, the paper mainly discusses from the following parts,literature review, enterprise development strategy analysis in each stage of LC, and the path model analysis of the enterprise development strategy.

2 Literature Review

American scholar Haire [7] put forward the concept of "Enterprise Life Cycle", he thought that the development of the enterprise conformed to the biological growth curve, and the enterprise should not only grasp the whole development process, but also pay attention to a specific stage of LC. Another Adizes [1] brought up the Enterprise Life Cycle Theory, he illustrated the traits of different LC stages, and summarized the basic rule of the enterprise LC as well, the theory mainly suggested there relationship about development and stagnation during the process of enterprise development. Afterwards, the similar research occurred in 1990s in China, Chen [5] thought that the enterprise generally had two forms after the recession stage, namely, renaissance and death. Through the above literature review, the study about LCT mainly concentrated on the traits of different LC stages, ignored the specific path of the enterprise development strategy at different stages.

The study about enterprise development strategy mainly focuses on three aspects. Firstly, American scholar Chandler [4] put forward "the Organization Structure is Followed byStrategy", he argued that the development strategy should bead justed timely according to the changes of the organization structure. Secondly, the study about elements of the enterprise development strategy. For example, Kenichiohmae [13] put forward viewpoint of "Strategy 3C", he argued that the enterprise should consider competition, consumer, corporation when faced on the dramatic changes of environment. Thirdly, the study about resource of the enterprise development strategy, Wernerfelt [10] brought up "The resource-based theory of the enterprise", he thought that enterprise was a collection of resources, which could make good use of the development strategy to be in pursuit of equilibrium point via the internal and external resources, further, by which the enterprise could grow constantly.

The foreign study about development strategy of SMEs mainly represents two aspects. Firstly, the development strategy of SMEs comes from macroscopic view, the government provides superior policy to solve the outside condition of the enterprise. For examples, The United States launched the rapid loan for the development of SMEs. Besides, Singapore introduced the development plan to enhance the capacity of SMEs. The British government launched a series of measures to solve the finance, moreover, support start-up funds to help new high-tech companies. Secondly, the development strategy of SMEs comes from firm level. This view is from the nature of SMEs development strategy, the development strategy is actually a kind of competitive strategy, which affects long-term objective of enterprise, and supplies the path of achieving the established objectives [9].

The domestic study about development strategy of SMEs mainly represents three aspects. Firstly, the development strategy of SMEs comes from industry integration. For example, The report "The Development Strategyof SMEsin China" put forward a viewpoint of "small and medium enterprises should shrink the body", the benign development of SMES mainly relies on industry consolidation, link integration, zone concentration. Secondly, the development strategy of SMEs comes from the perspective of humanity, the development strategy of SMEs based on the humanistic orientation of Chinese characteristics, the theory suggested that the enterprise development strategy was consisted of the overall progress of enterprises and all-round development of staff [11]. Thirdly, the study about traits of the SMEs development strategy, concluded as follows: integrity, long-term, fundamental, ploy, etc. [12].

In conclusion, domestic and foreign scholars have a relatively thorough study about the enterprise LCT and enterprise development strategy, but few combine LCT, the path of enterprise development strategy, internal and external resources of enterprise, and do the systematical research. Due to the existence of SMEs individual differences and differences in each stage of LC, this paper has its certain theoretical significance, which mainly relies on the perspective of LC, explores the path of development strategy and strategy conversion about SMEs on the basis of the integration of enterprise resources.

3 Enterprise Development Strategy Analysis in Each Stage of LC

This paper mainly use the simplified LC four stages model, they are: start-up stage, growth stage, maturity stage, recession stage. As is shown in Fig. 1.

The development path of each enterprise is not entirely as shown in Fig. 1, some enterprises in recession stage may return to growth stage successfully by organization reform, or some enterprises enter recession stage in advance due to the failure of reform in growth stage. Along with the changes of organization's internal and external environment, enterprise sat different stages of LC will present different characteristics.

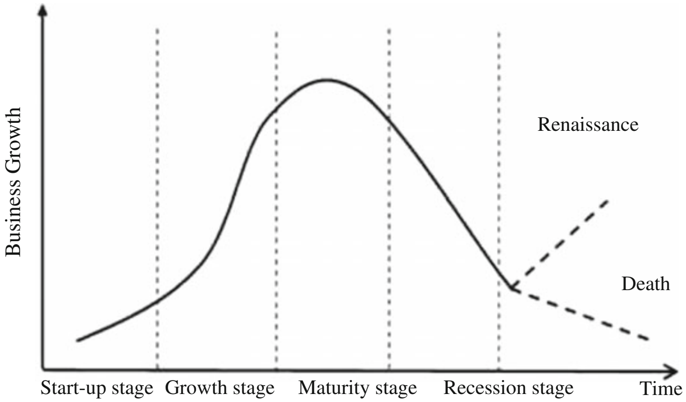

Fig. 1 Life cycle of the enterprise

(1) **Start-upstage**
When SMEs is founded in the early, it is in a period of groping, learning and seeking survival. As the organization system has not yet fully formed, the capacity of internal resources of enterprises is very short, the brand image has not yet been built, and the profitability is very limited, therefore, the overall competitiveness of enterprise is weak. In this condition, the focus of enterprise development strategy is to enter the market quickly on a higher starting point by implementing management innovation and technology innovation [6], ensure the number of customers, and improve enterprise recognition, thus prompt the accumulation of internal resources and the building of brand status.

(2) **Growth stage**
Along with initial business development and market operation, SMEs have been gradually adapted to the laws of market development, the organizational system begins to improve gradually, and there are significant improvements in the overall product scale, product competitiveness, market accumulation, capital operation and brand status. In this condition, SMEs should focus on internal resources and implement specialized management by selecting segment markets, to establish competitive advantage. Besides, by adopting complementary strategy, SMEs can establish strategic alliance with others to realize mutualism. Hence, the focus of enterprise development strategy in growth stage is to expand the business scale and enhance the core competitiveness to quickly occupy the market, at the same time,ensure customer quality and product quality, constantly update enterprise internal resources and strengthen brand status.

(3) **Maturity stage**
Through the early accumulation of enterprise development, the organization system tends to be complete, and the overall internal resource capacity, brand status have reached a relatively mature level, the overall competitiveness of enterprises enhance continuously. But later as competitors enter constantly, all enterprises compete against each other, and the weak imitate the strong, product

function gradually converges, and the homogenization is serious. Hence, the focus of enterprise development strategy in this stage is to gather resources through the integration of internal resources, and increase the scope of business to expand the market. Besides, by implementing the expansion strategy, to see knew sources of business growth, and reinforce the brand status.

(4) **Recession stage**
When enterprises enter recession stage, big changes have taken place in competitive environment, competitors imitate and innovate at an ever-accelerating pace, the resources of enterprise lose the original uniqueness, market competitiveness decline rapidly, and market demand begin to shrink, the overall benefit is reduced, some even appear negative growth. In this condition, the focus of enterprise development strategy is to seek new point of growth by resources liquidation and cut. At the same time, carry out brand re-position on the basis of the original brand to seek new customers.

All in all, enterprise should combine the capability of internal resource with the condition of external resources according to the characteristics of different stage of LC, constantly adjust enterprise development strategy, and promote healthy and sustainable development of enterprises.

4 The Path Model Analysis of the Enterprise Development Strategy

4.1 The Path Model of the Enterprise Development Strategy

The enterprise development strategy, namely, according to the status of the enterprisere source competence, to seek survival and long-term stable development, and gain new competitive edge constantly, which is general plot of the development goal of the enterprise and the way to realize the development strategy. Because the status of the enterprise internal resources are influence by all kinds of factors, such as technology resources, human resources, financial resources, information resources, etc., those above can reflect the competence of the enterprise internal resources comprehensively. However, it is difficult to focus on a specific superior resource. Therefore, the factors above are summarized abstractly as the enterprise internal resources in this paper. The external stake holders of the enterprise mainly assess the external resource capacity on the basis of brand status, so enterprise's external resource can be focus on the enterprise brand status. Hence, the brand status represents the enterprise's external resource in the following part of paper.

The development of the enterprise is not only influenced by its own internal resource capacity, but also external resource capacity, so is the formulation of enterprise development strategy. The internal resources capacity makes the enterprise can react consciously to critical incidents, opportunities and external threats, and help

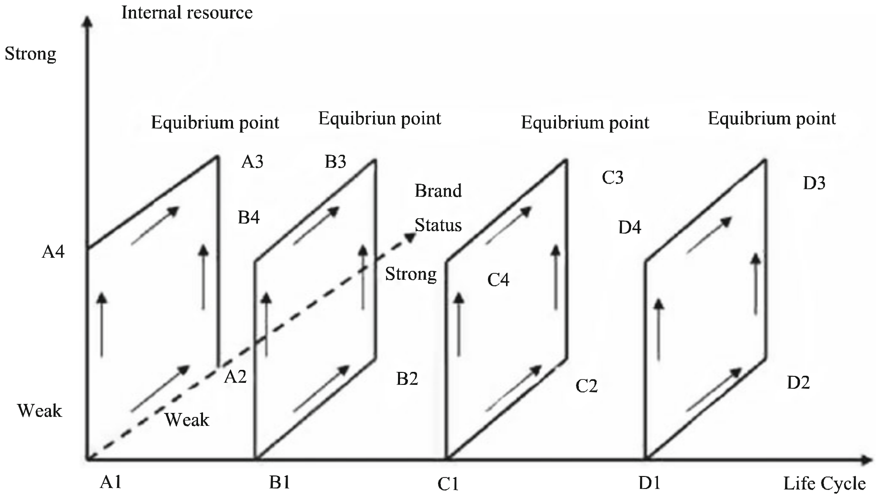

Fig. 2 The path model of the enterprise development strategy

enterprise to gain and keep the competitive edge, so the internal resource capacity can enhance the efficiency of the internal resource, further, make the enterprise development strategy be implemented better. The mechanism is that the external resource competence, especially, the brand status in industry, will be conditioned by both shortage of the internal resources and lacking of data collections about market and consumers, these will affect the formation of brand equity, the external capacity will also influence the inhibition of the internal resources capacity inversely. The enterprise internal resources and brand status are playing parallel collaborative roles in promoting the enterprise development and carrying out innovation activities, and what status the enterprise stays in will affect the development strategy [10]. Hence, the enterprise development strategy should take account of what LC stage the enterprise stays in. On the basis of the above view, this paper, from the perspective of the LCT, mainly establish the model "Internal resources-Brand status-Enterprise LC" by combining enterprise's internal resources and external resource. By integrating internal and external factors of SMEs into a model, systematically analyze the path and way of enterprise development strategy at different stages.

The paper classifies enterprise LC into four stages, and divides the enterprise internalresources and enterprise brand status into two levels (strong, weak), The model has $2 \times 2 \times 2 = 16$ state points totally by three spatial combination of variables, each state point represents the competitive edge of the enterprise (Fig. 2). Via the model, the enterprise can analyze current LC stage, internal resources ability and brand status comprehensively, ensure current specific state, further, to seek the development strategy direction, development goal, development ability. Eventually, it can provide corresponding countermeasures for the SMEs development strategy.

4.2 The Path Choice of the Enterprise Development Strategy

In Fig. 2, the path of the enterprise development strategy in different LC stages can be shown as follows:

(1) Start-up stage: A1–A2–A4, A1–A3–A4;
(2) Growth stage: B1–B2–B4, B1–B3–B4;
(3) Maturity stage: C1–C2–C4, C1–C3–C4;
(4) Recession stage: D1–D2–D4, D1–D3–D4.

Therefore, there are mainly two types about enterprise development strategy of the four stages of LC. One is "internal resource- external brand status-equilibrium point", this is a kind of enterprise development strategy from internal resource to equilibrium point, and we call it "endogenous strategic path". Another is "external brand status-internal resource- equilibrium point", it is a kind of enterprise development strategy from external brand status to equilibrium point, and we call it "exogenous strategic path". Though from different starting points, both can reach a relative equilibrium point through the path conversion, and prompt enterprise to transform to the next stage.

(1) **Start-upstage**
Since the internal resources and brand position are not strong, SMEs need to make full use of existing internal resources, enter the market quickly and build brand. In this stage, the exogenous strategic path is "brand position-resource aggre-gation-equilibrium point". That is to strengthen brand planning, shape brand attributes, form brand position, facilitate brand communication, build brand cognition, and build brand status, thus absorb and gather more advantageous resources, to reach equilibrium point of enterprise development strategy. The endogenous strategic path of this stage is "resource aggregation-brand position-equilibrium point". That is, through the enterprise internal resource aggregation, to drive the establishment of the enterprise external brand status, ultimately reach equilibrium point of enterprise development strategy.
(2) **Growth stage**
Through accumulation of early development, enterprise awareness is constantly improved, and enterprise begins to make profit. In this stage, the exogenous strategic path is "brand strengthening-resource update-equilibrium point". That is to strengthen the brand continuously, achieve the internalization of brand resources, build brand asset, enhance the brand status, and thus make enterprise continuously update internal resources, ultimately reach equilibrium point of enterprise development strategy. The endogenous strategic path in growth stage is "resource update-brand strengthening- equilibrium point". That is, by constant upgrading of enterprise internal resources, to meet the need of enterprises' rapid development, drive the improvement of brand status, prompt enterprise development strategy to reach equilibrium point, and thus propel the enterprise transform to the maturity stage.

(3) **Maturity stage**
Through the early accumulation of enterprise development, the overall management have reached a comparatively mature level, and enterprise environment is relatively stable, internal resources advantage has reached maximization, brand status is comparatively high, to some extent this can withstand the challenge of competitors. But later as enterprise internal resources capacity reach saturation point, competitors imitate and innovate at an ever-accelerating pace, product homogenization is serious. Hence, the exogenous strategic path of this stage is "brand diversification-resource reorganization-equilibrium point", by implementing the strategy of brand diversification tomeet the diversified demand of customers, improve the efficiency of internal resource utilizing, and ultimately reach equilibrium point of enterprise development strategy. The endogenous strategic path in maturity stage is "resource reorganization—brand diversification—equilibrium point". That is to re-organize internal resources capability, continuously optimize enterprise internal resources, and prevent resource redundancy, thus consolidate brand status, and make efforts to prolong the maturity stage.

(4) **Recession stage**
The enterprise environment and core competitiveness are comparatively poor, which need enterprises to integrate the internal resources. In this condition, the exogenous strategic path is "brand reposition-resources liquidation and cut-equilibrium point". Through the brand reposition, enable consumers to have a new understanding of the brand, prompt internal resources and external brand

Table 1 Enterprise development strategy based on life cycle

Life cycle stage	Strategic objective	Strategic type	
		Exogenous strategic path	Endogenous strategic path
Start-up stage	(1) Enter the market quickly, build brand (2) Achieve equilibrium between internal resources and external brand status, prompt enterprises to transform to the next stage	Brand position	Resource aggregation
Growth stage	(1) Strengthen brand recognition, build brand asset (2) Achieverapid development of enterprises, the market share rapidly ascend (3) Achieve new equilibrium point, prompt enterprises to transform to the next stage	Brand strengthen	Resource update
Maturity stage	(1) The enterprise develop stably, brand diversification, explore new markets (2) Achieve new equilibrium, prompt enterprises to transform to the next stage	Brand diversification	Resource reorganization
Recession stage	(1) Reduce cost, squeeze residual values of brand (2) Achieve new equilibrium and the recovery of enterprise	Brand reposition	Resources liquidation and cut

status to be a new equilibrium point. From the point of endogenous strategic path, it is mainly "resources liquidation and cut—brand reposition—equilibrium point". By resources liquidation and cut, optimize efficiency of internal resource utilizing, focus on enterprise superior resources, quickly convert market, seek enterprises'new development point, thus prompt enterprise to reach new equilibrium point. According to the above analysis and research, we can conclude and form Table 1.

5 Conclusion

Enterprise development strategy is a complex organization innovation activities, SMEs should take full account of the various internal and external resources factors, and choose appropriate path and way of development strategy, further to promote the healthy and sustainable development of the enterprise. This paper, based on the LCT, systematically analyze the path and way of enterprise development strategy at different stages by combining enterprise's internal resources and external brand status, which achieve a shift from traditional two-dimensional static development strategy to three-dimensional dynamic development path. Via the path model of enterprise development strategy, SMEs can find the location of the enterprise and analyze the characteristics of the each space point. Besides, by effective combination of path model, SMEs can clear the direction of transformation path and choose effective competition strategy to better improve the competitive strength of the enterprise. There are some shortcomings in the paper, for instance, lack of quantitative analysis, the strength of the enterprise's internal resources and brand status is abstractly measured in two dimensions, the path selection of enterprise development strategy is relatively simple and so onand all these needto improve inthe follow-up study.

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Wholesale Price Contract Under Bilateral Information Asymmetry

Xinhui Wang, Hongmei Guo and Xianyu Wang

Abstract This paper investigates the impacts of bilateral asymmetric information in a supply chain. More specifically, we consider a supply chain consisting of one risk-neural manufacturer and one risk-averse retailer who have their private information regarding the manufacturing cost and risk aversion degree, respectively. We first construct a model under the bilateral asymmetric information case using M-V approach. There exists a pair of threshold values of cost and risk aversion degree such that the optimal trading quantity holds. We then give a wholesale price contract under bilateral asymmetric information case to examine the information revealing. We find that the manufacturer and the retailer both announce a lower information type to gain more opportunistically individual profit. This damages the supply chain's performance.

Keywords Supply chain management · Contingent contract · Bilateral asymmetric information · Risk aversion

1 Introduction

The decisions of supply chain's member often depend on the firm's private information. These informed firms may act independently and opportunistically to optimize their own benefit by misreporting their private information. In a supply chain consisting of a manufacturer and a retailer, when the informed parties do their decisions, the manufacturer may announce a higher production cost [16], or the retailer pretend to

X. Wang (✉)
School of Computer Science and Technology, Southwest University for Nationalities, Chengdu 610041, People's Republic of China
e-mail: wxh-865@163.com

H. Guo · X. Wang
Business School, Sichuan University, Chengdu 610064, People's Republic of China

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be less risk aversion [19]. In this symmetric information case, how will the manufacturer and the retailer behave when they both have private information, what results these behaviours will lead?

So in this paper, we consider a supply chain consisting of one manufacturer and one retailer who have private production cost and risk aversion degree respectively. We investigate the manufacturer and retailer's behaviours and analyze the loss of the efficiency of the supply chain.

The unilateral asymmetric information problem in supply chain are widely studied, such as the manufacturer's private information of production cost [11], retailer's types of volume [13], asymmetric risk aversion [19].

The supply chain models under the bilateral asymmetric information scenario have aroused some researcher's interests. Chatterjee and Samuelson [3] considered the commodity prices are asymmetric in a seller-buyer structure, Zhang and Luo [22] explored the trade credit in coordinating supply chain under bilateral information senior. In the proposed model the manufacturer possesses the private information regarding its own capital cost while the retailer has the private information about the budget constraint or capital cost. Pavlov [16] considered a bilateral asymmetric case that the supplier and the retailer both have their private costs information. Esmaeili and Zeephongsekul [7] considered a supply chain, in which the buyer and seller have the private information about demand information and purchase costs respectively. Some bilateral asymmetric information problem can be seen in the analysis of auction [2, 4, 6, 9].

However, those papers mostly concentrate on the risk neutral case without considering the risk aversion's impacts. In fact, the risk aversion has an important impact on the supply chain parties' decisions. In summary, these effects of the risk aversion have several aspects, such as order quantity [21], retail price and optimal service level [20], bargaining power [14], supply chain performance [10], manufacturer-retailer relationship [17]. If the risk aversion of retailer is private information, the retailer pretends to be less risk aversion [19] to get more individual profit. Thus it is necessary to consider the risk aversion's impacts in supply chain with asymmetric information.

In order to depict problem of supply chain with a risk-aversion retailer, we firstly construct a model using M-V method. Then we give the commodity quantity under symmetric information as a bench mark and discuss the commodity quantity under the asymmetric information environment. To investigate the supply chain parties' behaviours, we apply the simplest wholesale price contract to the supply chain model. The wholesale price contracts are still widely discussed in recently years [5, 15, 18]. In our paper, we have different focus, we concentrate the bilateral information. The wholesale price contract contingents on the announced information. Such a contingent contract implies an incomplete information game in which parties decide cost or risk aversion to reveal.

Our contributions to the literature will be two aspects: first, in contrast to the existing literature, we first construct the model of bilateral asymmetric information of production cost and risk aversion degree. Second, we investigate the wholesale price contract under bilateral asymmetric information case.

The remainder of this paper is organized as follows. Section 2 describes the model. Section 3 analyzes the wholesale price contract with bilateral asymmetric information. Section 4 concludes this paper and presents directions for future research.

2 The Model

2.1 Assumption and Notations

Consider a two-firm supply chain consisting of one retailer (risk aversion) and one manufacturer (risk neutral) for an innovation product. Prior to production, the manufacturer and the retailer commit a wholesale price contract (formal agreement) to ensure the latter trading. It contingents on the announced information and contain the corresponding transfer payments. When the sample product is finished, the true production cost can be obtained by the manufacturer and the risk aversion degree can be determined by investigating the market. Then they share their information to determine the trading quantity according to the ex ante informal agreement. Then the retailer sells it to a market in which demand is stochastic. In order to simplify notation, without loss of generality, we also assume the goodwill cost and the salvage cost are both zero. (The sequence of events can be seen in Fig. 1).

p is selling price per unit and w is wholesale price per unit. $q^{\circ}(\cdot)$ and $q^{*}(\cdot)$ are Optimal commodity trading quantity in the symmetric and asymmetric information cases; $t_1(\cdot)$ and $t_2(\cdot)$ are transfer payments to the manufacturer and the retailer, respectively. c_s, $\hat{c}_s$ are manufacturer's true unit manufacturing cost and announcing unit manufacturing cost, belong to $[\underline{c}_s, \bar{c}_s]$; k_r, $\hat{k}_r$ are retailer's true unit risk aversion and announcing risk aversion, belong to $[\underline{k}_r, \bar{k}_r]$, $\underline{k}_r > 0$. $F_1(\cdot)$, $f_1(\cdot)$ are strictly increasing distribution function and corresponding density function of c_s; $F_2(\cdot)$, $f_2(\cdot)$ are strictly increasing distribution function and corresponding density function of k_r. $E_{k_r}(\cdot)$ and $E_{c_s}(\cdot)$ are expectation function with respect to $F_1(\cdot)$ and $F_2(\cdot)$; $E_{c_s,k_r}(\cdot)$ is expectation function with respect to $F_1(\cdot)$ and $F_2(\cdot)$. $y > 0$ denotes the market stochastic demand during the selling season; $G(\cdot)$, $g(\cdot)$ are strictly increasing distribution function and corresponding density of stochastic demand; $S(q(\cdot))$ is expected sales for retailer, equals $E\min(q(\cdot), y)$; $Var(\min(q(\cdot), y))$ is variance of

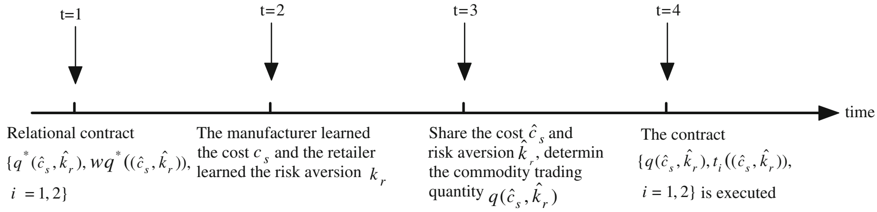


Fig. 1 Timing of the contracting game

stochastic demand. $\Pi(\cdot)$ is the profit function of the total supply chain; $\Pi_1(\cdot)$ and $\Pi_2(\cdot)$ are manufacturer's profit function and retailer's profit function respectively.

As usual, we assume that $\partial q(\cdot)/\partial \hat{c}_s < 0$, $\partial q(\cdot)/\partial \hat{k}_r < 0$, which means that the commodity trading quantity is decreasing in the production cost and the risk aversion. Also, $\partial^2 q(\cdot)/\partial \hat{c}_s^2 < 0$ and $\partial^2 q(\cdot)/\partial \hat{k}_r^2 < 0$, which means that the commodity trading quantity rate of the change in cost or risk aversion are increasing.

2.2 The Model

Let π_r be the retailer's random profit, thus

$$\pi_r = p \min(q(\hat{c}_s, \hat{k}_r), y) + t_2(\hat{c}_s, \hat{k}_r). \tag{1}$$

To analyze decision making problems with the risk-averse retailer, we adopt the meanCvariance (MV) approach [1, 8, 12, 17]: $u(\pi_r) = E(\pi_r) - k_r Var(\pi_r)$. Here $E(\pi_r)$ is the expected profit of the retailer, $Var(\pi_r)$ is the corresponding variance.

k_r denotes the retailer's degree of risk aversion and it belongs to the interval $[\underline{k}_r, \bar{k}_r]$, the larger the k_r, the more conservative retailer's behaviour will be. It is obvious that in our model $Var(\pi_r)$ equals to $p^2 Var(\min(q(\hat{c}_s, \hat{k}_r), y))$. Here

$$\begin{aligned} Var(\min(q(\hat{c}_s, \hat{k}_r), y)) &= E(\min(q(\hat{c}_s, \hat{k}_r), y)^2) - (E \min(q(\hat{c}_s, \hat{k}_r), y))^2 \\ &= 2q(\hat{c}_s, \hat{k}_r) \int_0^{q(\hat{c}_s, \hat{k}_r)} G(y)dy - 2 \int_0^{q(\hat{c}_s, \hat{k}_r)} yG(y)dy \\ &\quad - \left(\int_0^{q(\hat{c}_s, \hat{k}_r)} G(y)dy \right). \end{aligned}$$

Let $\Pi_2(q(\hat{c}_s, \hat{k}_r), k_r) \equiv u(\pi_r)$ and $Var(\min(q(\hat{c}_s, \hat{k}_r), y)) \equiv \xi(q(\hat{c}_s, \hat{k}_r))$, the risk-averse retailer's profit can be expressed as

$$\Pi_2(q(\hat{c}_s, \hat{k}_r), k_r) = pS(q(\hat{c}_s, \hat{k}_r)) - k_r p^2 \xi(q(\hat{c}_s, \hat{k}_r)) + t_2(\hat{c}_s, \hat{k}_r). \tag{2}$$

Here, $S(q(\hat{c}_s, \hat{k}_r)) = E \min(q(\hat{c}_s, \hat{k}_r), y) = q(\hat{c}_s, \hat{k}_r) - \int_0^{q(\hat{c}_s, \hat{k}_r)} G(y)dy$.

Also the manufacturer's profit is given by

$$\Pi_1(q(\hat{c}_s, \hat{k}_r), c_s) = -c_s q(\hat{c}_s, \hat{k}_r) + t_1(\hat{c}_s, \hat{k}_r). \tag{3}$$

From the perspective of the system, the supply chain's ex post profit can be written as:

$$\Pi(q(\hat{c}_s, \hat{k}_r), c_s) = pS(q(\hat{c}_s, \hat{k}_r)) - \hat{c}_s q(\hat{c}_s, \hat{k}_r) - \hat{k}_r p^2 \xi(q(\hat{c}_s, \hat{k}_r)). \tag{4}$$

In order to analyze our model and put insight into the impacts of asymmetric information on the supply chain, we first present the complete information case, as a benchmark. So Eq. (4) can be written as:

$$\Pi(q(c_s, k_r), c_s) = pS(q(c_s, k_r)) - c_s q(c_s, k_r) - k_r p^2 \xi(q(c_s, k_r)). \tag{5}$$

Proposition 1 *Under the complete information case, if* $k_r \le (1 - c_s/p)\big/2p \int_0^{q(c_s,k_r)} G(y)dy$ *holds, there exists an optimal commodity trading quantity of the supply chain satisfies the following equation:*

$$G(q^\circ(c_s, k_r)) = 1 - \frac{c_s}{p\big(1 - 2pk_r \int_0^{q^\circ(c_s,k_r)} G(y)dy\big)}. \tag{6}$$

In Proposition 1, the condition $k_r \le (1 - c_s/p)\big/2p \int_0^{q(c_s,k_r)} G(y)dy$ means the following conclusion.

Proposition 2 *(1) There exists* $k_r^\circ \in [\underline{k}_r, \bar{k}_r]$ *such that* $k_r = (1 - c_s/p)\big/2p \int_0^{q(c_s,k_r^\circ)} G(y)dy$*, when* $k_r \in [k_r^\circ, \bar{k}_r]$*,* $k_r^\circ \in [\underline{k}_r, \bar{k}_r]$ *holds.*
(2) There exists $c_s^\circ \in [\underline{c}_s, \bar{c}_s]$ *such that* $c_s^\circ = p\big(1 - 2pk_r \int_0^{q(c_s^\circ,k_r)} G(y)dy\big)$*, when* $c_s \in [c_s^\circ, \bar{c}_s]$*,* $c_s \le p\big(1 - 2pk_r \int_0^{q(c_s,k_r)} G(y)dy\big)$ *holds.*

Combining the part (1) and part (2) of Proposition 2, we can get that there exists c_s° and k_r° such that $k_r^\circ = (1 - c_s^\circ/p)\big/2p \int_0^{q(c_s^\circ,k_r^\circ)} G(y)dy$.

Proposition 1 and 2 state that the optimal commodity trading quantity exists only if the information c_s and k_r belong to the intervals $[c_s^\circ, \bar{c}_s]$ and $[k_r^\circ, \bar{k}_r]$, respectively.

Now we consider the bilateral asymmetric information case. From (4), for any $c_s \in [c_s^\circ, \bar{c}_s]$ and $k_r \in [k_r^\circ, \bar{k}_r]$, if their announced information $\hat{c}_s \in [c_s^\circ, \bar{c}_s]$ and $\hat{k}_r \in [k_r^\circ, \bar{k}_r]$ also hold, we will examine the existence of the optimal commodity trading quantity under bilateral asymmetric information case.

Proposition 3 *If* $\hat{c}_s \in [c_s^\circ, \bar{c}_s]$ *and* $\hat{k}_r \in [k_r^\circ, \bar{k}_r]$*, the optimal trading quantity* $q^*(\hat{c}_s, \hat{k}_r)$ *exists and satisfies Eq. (7).*

$$G(q^*(\hat{c}_s, \hat{k}_r)) = 1 - \frac{\hat{c}_s}{p\big(1 - 2p\hat{k}_r \int_0^{q^*(\hat{c}_s,\hat{k}_r)} G(y)dy\big)}. \tag{7}$$

Proposition 3 states that c_s° and k_r° are threshold values that can achieve the optimal commodity trading quantity $q^*(\hat{c}_s, \hat{k}_r)$ of supply chain. From Eq. (7), we know that $q^*(\hat{c}_s, \hat{k}_r)$ is an action plan that contingents on the manufacturer and retailer's announced information. If the announced information $\hat{c}_s \notin [c_s^\circ, \bar{c}_s]$ or $\hat{k}_r \notin [k_r^\circ, \bar{k}_r]$, the asymmetric optimal commodity trading quantity does not exist. Consequently, the maximum supply chain's profit can not be achieved.

Since the left side of Eq. (7) increases in $q^*(\hat{c}_s, \hat{k}_r)$, and the right side of Eq. (7) decreases in $q^*(\hat{c}_s, \hat{k}_r)$, thus $q^*(\hat{c}_s, \hat{k}_r)$ is a sole solution to Eq. (7). Also, $q^\circ(c_s, k_r)$ is a sole solution to Eq. (6). So only when $\hat{c}_s = c_s$, $\hat{k}_r = k_r$, the $q^\circ(c_s, k_r)$ can be achieved.

In this paper, in order to analyze the impacts of the bilateral asymmetric information we restrict mainly our analysis on the intervals $[c_s^\circ, \bar{c}_s]$ and $[k_r^\circ, \bar{k}_r]$.

3 The Wholesale Price Contract

Now we consider the wholesale price contract, and examine the features that whether it can stimulate the manufacturer and retailer to reveal their true information or not.

If the transfer payment $t_1(\hat{c}_s, \hat{k}_r)$ equals to $wq(\hat{c}_s, \hat{k}_r)$, the contract can be seen as the wholesale price contract under bilateral asymmetric information case. With the transfer payments, the manufacturer and the retailer's expected profits are given by

$$\begin{aligned} E_{k_r}(\Pi_1(q(\hat{c}_s, \hat{k}_r), c_s)) &= E_{k_r}[-c_s q(\hat{c}_s, k_r) + t_1(\hat{c}_s, k_r)] \\ &= E_{k_r}[(w - c_s)q(\hat{c}_s, k_r)], \end{aligned} \tag{8}$$

$$\begin{aligned} E_{c_s}(\Pi_2(q(\hat{c}_s, \hat{k}_r), k_r)) &= E_s[pE\min(q(c_s, \hat{k}_r), y) - k_r p^2 \xi(q(c_s, \hat{k}_r)) + t_2(c_s, \hat{k}_r)] \\ &= E_{c_s}[pS(q(c_s, \hat{k}_r)) - wq(c_s, \hat{k}_r) - k_r p^2 \xi(q(c_s, \hat{k}_r))]. \end{aligned} \tag{9}$$

Now we examine the incentives of the transfer payments, and investigate the information revealing.

Proposition 4 *With the wholesale price contract under bilateral asymmetric information case, the manufacturer and retailer will announce a lower information type, i.e.,* $\hat{c}_s < c_s$, $\hat{k}_r < k_r$.

Proposition 4 states that with the wholesale price contract, both parties prefer to announce a lower cost, thus they can benefit from their misreporting. From Eq. (8), we can see that $\partial E_{k_r}\Pi_1(q(c_s, k_r))/\partial \hat{c}_s$, so the manufacturer will announce his private information as $\hat{c}_s(\hat{c}_s = c_s^\circ < c_s)$. The conclusion for the manufacturer is different from the work of Pavlov [16]. In his research, the manufacturer may announce a higher cost.

From Eq. (9), one main observation can be obtained that $\partial E_{c_s}\Pi_2(q(c_s, k_r))/\partial \hat{k}_r < 0$ holds, this means that the retailer chooses to announce a lower risk aversion degree $(\hat{k}_r = k_r^* < k_r)$. Meanwhile, for $\hat{k}_r = k_r^*$, it holds that $\partial^2 E_{c_s}\Pi_2(q(c_s, k_r^*))/\partial \hat{k}_r^2 < 0$. That is to say, announcing a lower risk averse degree k_r^* will maximize his expected profit, while telling truthful information $(\hat{k}_r = k_r)$ will decrease his expected profit.

If any one party of the supply chain reveals the false information, the optimal commodity trading quantity will be affected by the announcing information, i.e. $q^*(\hat{c}_s, \hat{k}_r) > q^\circ(c_s, k_r)$ (That is because $\partial q(\cdot)/\partial k_r < 0$, $\partial q(\cdot)/\partial c_s < 0$ holds). Because the supply chain's profit is concave in the trading quantity, any case $q^*(\hat{c}_s, \hat{k}_r) = q^\circ(c_s, k_r)$ damages the total supply chain profit in the cooperative relationship (see in Fig. 2).

Fig. 2 The relationship between the supply chains profit and the trading quantity

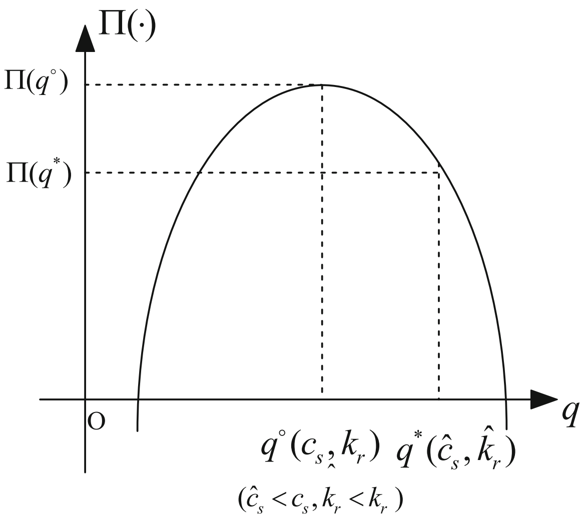
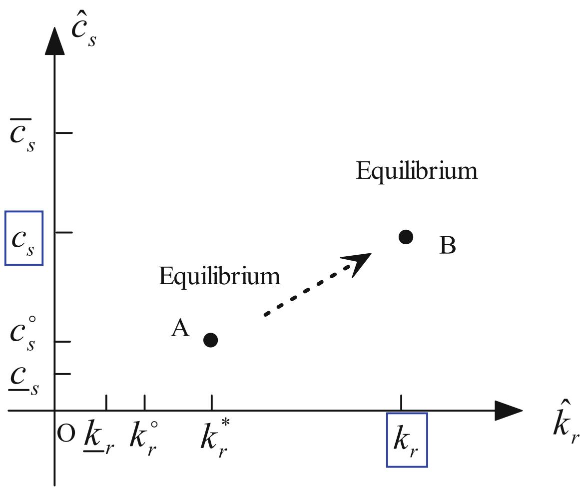


Fig. 3 Nash equilibrium



The main reason of the contract inefficiency is that the transfer payments in the contract can not provide sufficient incentives for sharing information truthfully and align the individual objective and the system objective.

For the wholesale price contract under bilateral asymmetric information case, it is clear that the Nash equilibrium, i.e. $(\hat{c}_s = c_s^\circ, \hat{k}_r = k_r^*)$ is not dominant strategies for the two parties (see in Fig. 3, the point A). To induce the true information revealing, designing a contract should ensure that each party has a unique dominant strategy, i.e. $\{\hat{c}_s = c_s, \hat{k}_r = k_r\}$. (See in Fig. 3, the point B.) Since $q^*(\hat{c}_s, \hat{k}_r)$ is decreasing monotonically with and increasing monotonically with $\hat{c}_s$, so there exists a unique dominant equilibrium, only if $\hat{c}_s = c_s$ and $\hat{k}_r = k_r$ hold simultaneously.

4 Conclusions and Future Research

In this paper, we address the contract mechanism designing of the supply chain consisting of a risk-neural manufacturer and a risk-averse retailer under bilateral asymmetric information case.

We firstly construct a model under the bilateral asymmetric information case using M-V approach. In the model, the system optimal commodity trading quantity is related to the manufacturer and retailer's announcing information. We find that there exists a pair of threshold values of risk aversion degree and production cost such that the optimal trading quantity exists under bilateral asymmetric information case.

We then give a basic wholesale price contract to examine the information revealing. We find that with the wholesale price contract, the manufacturer and the retailer do not concern about the whole supply chain's profit, but they pay much more attention on their individual expected profit. More important, they both understate their information type for gaining more opportunistically profit. This has a difference from the result that the manufacturer may overstate his production cost [16]. However, the conclusion that the retailer pretends to be less risk aversion is consistent with Wei and Choi [19].

Our research may yield some key managerial insights to the bilateral asymmetric information environment. Further research can extend our model to design the coordinating contract to reveal information truthfully and improve the supply chain performance.

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Study on the Relationship Between E-Commerce and Industrial Structure in Sichuan Province Based on Gray-Relation Analysis

Rui Wang, Ye Yang and Jiao Tang

Abstract With the rapid development of electronic commerce, its impact on "transformation of the pattern of regional economic development, regional economic restructuring" is increasingly growing, causing research on the relationship between e-commerce and the regional industrial structure is becoming increasingly important. In this paper, we firstly establish an index system to estimate the development of regional e-commerce, then use some industry-related indicators to make a comprehensive measure of regional industrial structure. On this basis, we use gray correlation theory to calculate the linkage between regional e-commerce development and industrial structure evolution processes. An empirical study of Sichuan Province conducted a discovery that e-commerce have a strong linkage between some industry, such as: scientific research, technical services and geological exploration industry, wholesale and retail industry, residential services and other services industry, manufacturing industry, accommodation and catering industry, renting and business services, and electricity, gas and water production and supply industry and so on. We can make use of the great development of e-commerce as an opportunity to accelerate the development of these industries.

Keywords E-commerce · Industrial structure · Gray-relation analysis

1 Introduction

The Global Information Infrastructure Committee (GIIC) define electronic commerce (e-commerce) as "an economic activity using electronic communications as the means, in this way, one can conduct propaganda, purchase and settlement of products and services with economic value". Location or whether enough funds or the ownership of retail channel has little effect on this transaction mode [6].

R. Wang · Y. Yang (✉) · J. Tang
Business School, Sichuan University, 610065 Chengdu, People's Republic of China
e-mail: 49275328@163.com

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E-commerce in China originated in the early 1990s, started in the late 1990s. During this period, Yun Ma built the first B2B (business to business) electronic commerce website in China-Alibaba, following that there also appeared a batch of B2C (business to consumer), C2C (consumer to consumer) e-commerce service websites. After the year of 2000, with the establishment of the taobao.com, e-commerce has been well known in China. After just ten years of development, China's e-commerce transaction scale in 2013 amounted to 10.2 trillion, with the number of employees in December 2013 that directly employed by e-commerce service enterprises reached more than 235 million, and by the indirect e-commerce, has reached more than 1680 million [3].

Industry refers to a collection composed by enterprises producing and selling products or services which can be mutually substituted and buyers purchasing such products or services [7]. The industrial structure of a region plays an important role in the region's economic development. Study on the correlation between the development of regional e-commerce and evolution process of industry structure has great significance for making use of the great development of e-commerce as an opportunity to accelerate development of some industry.

Researching on the relationship between e-commerce and industrial structure, most scholars are from a qualitative point of view to analyze, such as Ming [9] put forward, the combination of e-commerce and modern logistics eventually led to the formation of a regional economic range which is rational; Wu [12] concluded that there were four motive forces to promoting formation of a regional e-commerce: seeking internal and external economies of scale, regional industrial characteristics and brand promotion, reducing the risk of innovation, and government advocacy and support. Mustaffa and Beaumont [10] studied various aspects of e-commerce by using statistical methods to analyze the data of Australian small and medium-sized enterprise (SMEs), then pointed out the advantages of e-commerce in marketing, customer relations, supply chain management, e-commerce and so on, also pointed out the shortcomings.

Owing to the turnovers of e-commerce and online retail trading volumes have not been included in the national and local governments Statistical Yearbook, related index of the e-commerce or retail e-commerce associated with other industries is not covered under input-output tables. In that case, researching and analyzing the actual influence of e-commerce on industrial structure has a certain theoretical and practical value.

The gray-relation analysis is based on the development trend for analysis, therefore either the sample size or the typical distribution did not demanding much when we use this method [5], which may fit in nicely with existing state of affairs that the e-commerce-related statistical indicators in our country is not much or incomplete. In this paper we use gray correlation theory to calculate linkage between regional e-commerce development and industrial structure evolution processes from the quantitative angel, taking the province of Sichuan for instance. Firstly, establish an index system to estimate the development of regional e-commerce, during this process, due to the lack of data, we will use smooth ratio to generate new data to fill the vacancy. Secondly, use the output and the number of employees in 18 major industry as indicators to make a comprehensive measure of regional industrial structure evolution, and finally use gray correlation theory to calculate linkage between regional e-commerce development and industrial structure evolution processes.

2 Index System of E-Commerce Evaluation

For e-commerce in China is still in the process of development, statistical standards of e-commerce data are being constantly explored. “Alibaba e-commerce development index” was proposed by Alibaba in the year of 2013 to replace “network business development index” proposed in the first half of 2010. For the “Alibaba e-commerce development index” exists for only one year, we will still choose the “network business development index” as an indicator of the evaluation index system of e-commerce. Considering the changing of the statistical standard in 2013, related data of 2013 is missed, resulting in vacancy in data columns. We choose smooth ratio to generate new data to fill sequence when the hole exist at the terminus of sequence.

The original index data of e-commerce is shown in Table 1 [1].

Smooth ratio of sequence is $\rho(k) = x(k)/\sum_{i=1}^{k-1} x(i)$.

We now use $x(n) = x(n-1)(1 + \rho(n-1))$ to generate new data, as Table 2 shows.

Table 1 The original index data of e-commerce

Year	Turnovers of E-commerce	Network business development index	Network ecological index	Popularity index	Growth trend index	Management level index
2010	1524	30.11	100	12.45	63.18	62.5
2011	3200	30.06	53.39	9.73	57.05	76.94
2012	5300	23.93	61.21	12.52	12.35	73.62
2013	8800.9					

Table 2 The new index data of e-commerce

Year	Turnovers of E-commerce	Network business development index	Network ecological index	Popularity index	Growth trend index	Management level index
2010	1524	30.11	100	12.45	63.18	62.5
2011	3200	30.06	53.39	9.73	57.05	76.94
2012	5300	23.93	61.21	12.52	12.35	73.62
2013	8800.9	33.45	85.64	19.59	13.62	112.49

3 Estimate the Development of Regional E-Commerce

1. Establish Evaluation Index System of E-Commerce

In this paper, we select some index that can represent the level of e-commerce sellers to estimate the development condition of the e-commerce. We build an index system constituted by a two-stage indicators, with e-commerce composite index as the level indicator. The composite, which is a weighted index derived from secondary indicators, is used to evaluate the overall development of the e-commerce. There are six secondary indicators, which are Turnovers of E-commerce, Network Business Development Index, Network Ecological Index, Popularity Index, Growth Trend Index and Management Level Index. Specific indicators and their weight division are shown in Table 3.

2. Calculation Steps of E-Commerce Composite Index

In this paper, we take the year of 2010 as the base year, in other words, we take the secondary indicators of Sichuan province in 2010 as a benchmark.

The calculation steps to calculate e-commerce composite index of each year are as follows [8]:

Step 1. Take the secondary indicators of Sichuan province in 2010 as a benchmark, then note the secondary index value divided by the reference value as the single index value. Recorded as:

$$A^{'}(t) = \frac{A(t)}{A(t_0)} \quad t_0 = 2010 \quad t = 2010, 2011, 2012, 2013, \tag{1}$$

$$F^{'}(t) = \frac{F(t)}{F(t_0)} \quad t_0 = 2010 \quad t = 2010, 2011, 2012, 2013. \tag{2}$$

Here A'(2010) on behalf of the A index's single index value of Sichuan Province in 2010.

Step 2. Calculate the e-commerce composite index of each year. We use:

$$E(t) = \sum_{J=A}^{F} w_J \times J(t) = 0.3 \times A(t) + 0.14 \times B(t) + \cdots + 0.14 \times F(t) \tag{3}$$

Table 3 Indicators of the development of electronic commerce

Symbol	Level indicator	Symbol	Secondary indicators
H	E-commerce	A	Turnovers of e-commerce (0.3)
	Composite	B	Network business development index (0.14)
	Index	C	Network ecological index (0.14)
		D	Popularity index (0.14)
		E	Growth trend index (0.14)
		F	Management level index (0.14)

Table 4 The result of e-commerce index

Year	E-commerce composite index	Turnovers of E-commerce	Network business development index	Network ecological index	Popularity index	Growth trend index	Management level index
2010	1	1524	30.11	100	12.45	63.18	62.5
2011	1.2526	3200	30.06	53.39	9.73	57.05	76.94
2012	1.5733	5300	23.93	61.21	12.52	12.35	73.62
2013	2.5103	8800.9	33.45	85.64	19.59	13.62	112.49

to calculate the e-commerce composite index of each year as:

$$H(2010) = 1,\ H(2011) = 1.2526,\ H(2012) = 1.5733,\ H(2013) = 2.5103.$$

The result of e-commerce composite index and secondary indicators are shown in Table 4.

4 Calculation of the Industrial Structure

In this paper, we divide all industry into 18 major industry, and consider the total industry as a whole to analysis, which means, there are 19 objects to be analyzed, as is shown in Table 5.

In view of the above 19 objects, we weighted average by such indicators as fixed assets investment of the whole society, the number of legal entities, the number of employed persons in urban units, gross domestic product (GDP) and total payroll employment to generate a new comprehensive index, which is used to measure the development of the industry. As a result of the missing data, in order to ensure the authenticity and reliability of correlation effect, the weight of the missing part will be distributed to the remaining indicators according to their own weight proportion. The specific weight of each index are shown in Table 6.

According to the method of calculating the e-commerce composite index above, we get the development level of each industry for each year [2, 4, 11], as shown in Table 7.

5 Method

We set up a sequence of system behavior as follows:

$$X_0 = (x_0(1), x_0(2), \cdots, x_0(n)),$$
$$X_1 = (x_1(1), x_1(2), \cdots, x_1(n)),$$

Table 5 Main industry category

Serial number	Name of the industry
1	Total industry
2	Agriculture, forestry, animal husbandry and fishery
3	Mining
4	Manufacturing industry
5	Electricity, gas and water production and supply industry
6	Building industry
7	Transportation, storage and postal services
8	Information transmission, computer services and software industry
9	Wholesale and retail industry
10	Accommodation and catering industry
11	Financial industry
12	Renting and business services
13	Scientific research, technical services and geological exploration industry
14	Water conservancy, environment and public facilities management
15	Resident, services and other services
16	Education
17	Health, social security and social welfare
18	Culture, sports and entertainment
19	Public management and social organization

Table 6 Industry-related indicators and their weights

Index name	Weight
Fixed assets investment of the whole society	0.25
Number of legal entities	0.15
Number of employed persons in urban units	0.15
Gross domestic product (GDP)	0.2
Total payroll employment	0.25

$$\begin{aligned} &\cdots \quad \cdots \quad \cdots \\ X_i &= (x_i(1), x_i(2), \cdots, x_i(n)), \\ &\cdots \quad \cdots \quad \cdots \\ X_m &= (x_m(1), x_m(2), \cdots, x_m(n)). \end{aligned}$$

For $\xi \in (0, 1)$, we have:

$$\gamma(x_0(k), x_i(k)) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \xi \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \xi \max_i \max_k |x_0(k) - x_i(k)|}, \tag{4}$$

Table 7 The development level of each industry for each year

Name of the industry	2010	2011	2012	2013
Total industry	1	1.1483	1.3164	1.7012
Agriculture, forestry, animal husbandry and fishery	1	1.0043	1.2136	1.0707
Mining	1	1.0806	1.2915	1.1629
Manufacturing industry	1	1.1819	1.3003	1.9425
Electricity, gas and water production and supply industry	1	1.1003	1.2441	2.0337
Building industry	1	1.0942	1.2778	1.7382
Transportation, storage and postal services	1	1.1554	1.1539	1.867
Information transmission, computer services and software industry	1	0.9993	1.1979	1.6725
Wholesale and retail industry	1	1.261	2.9076	2.5139
Accommodation and catering industry	1	1.1326	1.3927	3.26
Financial industry	1	1.6202	2.2413	2.9847
Renting and business services	1	1.1641	1.1413	2.066
Scientific research, technical services and geological exploration industry	1	1.2912	1.5306	1.6288
Water conservancy, environment and public facilities management	1	1.0428	1.2554	1.6614
Resident, services and other services	1	1.257	1.4216	1.5646
Education	1	0.9997	1.1108	1.3038
Health, social security and social welfare	1	1.0598	1.2684	1.4779
Culture, sports and entertainment	1	1.0266	1.2306	1.5122
Public management and social organization	1	1.0259	1.0151	1.1587

$$\gamma(X_0, X_i) = \frac{1}{n}\sum_{k=1}^{n}\gamma(x_0(k), x_i(k)), \tag{5}$$

$\gamma(X_0, X_i)$ is the gray correlation between X_0 and X_i.

6 The Gray Correlation Between the E-Commerce-Related Indicators and the Development of Industry

Take the e-commerce composite index for instance, we set up a sequence of system behavior as follows:

$$X_1 = (x_1(2010), x_1(2011), x_1(2012), x_1(2013)),$$

$$X_2 = (x_2(2010), x_2(2011), x_2(2012), x_2(2013)),$$
$$\ldots$$
$$X_{19} = (x_{19}(2010), x_{19}(2011), x_{19}(2012), x_{19}(2013)).$$

The calculation steps to calculate the gray correlation between the e-commerce-related indicators and the development level of industry are as follows:

Step 1. Calculate the initial value of each sequence. We have:

$$X_i^{'} = \frac{X_i}{x_i(2010)} = (x_i^{'}(2010), x_i^{'}(2011), x_i^{'}(2012), x_i^{'}(2013)), \tag{6}$$

among them $i = 0, 1, \ldots, 19$.

Step 2. Calculate the difference value of each sequence. Note that:

$$\begin{aligned} &\Delta_i(t) = \left| x_0^{'}(t) - x_i^{'}(t) \right|, \\ &\Delta_i = (\Delta_i(2010), \Delta_i(2011), \Delta_i(2012), \Delta_i(2013)), \end{aligned} \tag{7}$$

among them $i = 1, 2, \ldots, 19$. We have the results:

$$\begin{aligned} &\Delta_1 = (0, 0.1043, 0.2569, 0.8091), \\ &\Delta_2 = (0, 0.2483, 0.3597, 1.4396), \\ &\ldots \\ &\Delta_{19} = (0, 0.2267, 0.5582, 1.3516). \end{aligned}$$

Step 3. Find the maximum and minimum difference values among those different values. Note that:

$$\begin{aligned} &M = \max_i \max_t \Delta_i(t),\ m = \min_i \min_t \Delta_i(t), \\ &M = 1.4396,\ m = 0. \end{aligned}$$

Step 4. Calculate the gray correlation value:

$$\Upsilon_{0i}(t) = \frac{m + \xi M}{\Delta_i(t) + \xi M}, \tag{8}$$

among them, $\xi \in (0, 1)$.

In this paper, we take $\xi = 0.5$, then:

$$\Upsilon_{0i}(t) = \frac{0.776}{\Delta_i(t) + 0.776}. \tag{9}$$

Table 8 Main industry category

Name of industry	Gray correlation
Total industry	0.77
Agriculture, forestry, animal husbandry and fishery	0.686
Mining	0.718
Manufacturing industry	0.799
Electricity, gas and water production and supply industry	0.778
Building industry	0.753
Transportation, storage and postal services	0.76
Information transmission, computer services and software industry	0.715
Wholesale and retail industry	0.833
Accommodation and catering industry	0.787
Financial industry	0.696
Renting and business services	0.783
Scientific research, technical services and geological exploration industry	0.836
Water conservancy, environment and public facilities management	0.732
Resident, services and other services	0.813
Education	0.681
Health, social security and social welfare	0.725
Culture, sports and entertainment	0.714
Public management and social organization	0.668

What's more:

$$\gamma_{0i} = \frac{1}{n} \sum_{t=2010}^{2013} \gamma_{0i}(t), \tag{10}$$

among them $t = 2010, 2011, 2012, 2013$, $i = 1, 2, \ldots, 19$.

At last we have the gray correlation between the e-commerce composite indicator and the development level of industry in Sichuan province, which have been shown in Table 8.

Similarly, we can calculate the gray correlation between the development level of each industry and turnovers of e-commerce, network business development index, network ecological index, popularity index, growth trend index and management level index, and the details are shown in Table 9.

Table 9 Gray correlation between the other e-commerce-related indicators and the development level of industry

Name of the industry	Turnovers of economic commerce	Network business development index	Network ecological index	Popularity index	Growth trend index	Management level index
Total industry	0.65	0.799	0.72	0.839	0.736	0.757
Agriculture, forestry, animal husbandry and fishery	0.631	0.919	0.808	0.821	0.794	0.776
Mining	0.638	0.892	0.781	0.807	0.773	0.775
Manufacturing industry	0.655	0.774	0.703	0.797	0.723	0.753
Electricity, gas and water production and supply industry	0.65	0.789	0.71	0.805	0.733	0.742
Building industry	0.646	0.81	0.726	0.845	0.743	0.75
Transportation, storage and postal services	0.648	0.802	0.723	0.837	0.738	0.761
Information transmission, computer services and software industry	0.638	0.846	0.747	0.888	0.764	0.745
Wholesale and retail industry	0.74	0.644	0.597	0.625	0.642	0.685
Accommodation and catering industry	0.68	0.716	0.652	0.7	0.691	0.708
Financial industry	0.736	0.606	0.578	0.592	0.615	0.645
Renting and business services	0.651	0.788	0.712	0.812	0.73	0.756
Scientific research, technical services and geological exploration industry	0.663	0.764	0.697	0.81	0.712	0.753
Water conservancy, environment and public facilities management	0.642	0.83	0.738	0.873	0.755	0.747
Resident, services and other services	0.657	0.785	0.713	0.839	0.724	0.766
Education	0.631	0.905	0.789	0.873	0.787	0.768
Health, social security and social welfare	0.641	0.846	0.75	0.867	0.76	0.757
Culture, sports and entertainment	0.638	0.853	0.754	0.886	0.765	0.753
Public management and social organization	0.628	0.941	0.814	0.871	0.798	0.785

7 Conclusion

Introducing the gray correlation can reflect the relationship between the research objects, and the greater the degree of correlation is, the relationship between the two is more closely. If the correlation degree equals 1, it means that the two changed on the same way and the two had a direct correlation between them.

We can figure out from Table 8 that there exist some industry that has higher correlation degree on the e-commerce composite index than the total industry's average degree (0.770), such as: scientific research, technical services and geological prospecting industry (0.836), wholesale and retail trade (0.833), resident services and other services (0.813), manufacturing (0.799), accommodation and the food and beverage industry (0.787), leasing and business services (0.783) and electric power, gas and water production and supply industry (0.778).

The development of e-commerce can provide greater impetus and more effectively promote the rapid and healthy development of these industries. Specific factors that promote the development can be analyzed from Table 9.

The gray correlation degree of scientific research, technical services and geological prospecting industry, wholesale and retail trade and accommodation and catering industry and electric total transactions are 0.663, 0.740 and 0.680, which are higher than the total industry's average degree (0.650), indicating that during the process of the development of e-commerce, strive to improve the volume of e-commerce and the turnovers of e-commerce can more effectively promote the rapid and healthy development of such three industries.

Similarly, from the table of gray correlation between network ecological index and the development level of industry, we can conclude that, improve the regional social economic ecological environment would be more powerful driving force to conducive the development of such industry as the resident services and other services, leasing and business service industry, electric power, gas and water production and supply industry development. Specifically, we could improve the social economic ecological environment from three aspects as follows: (1) promote the self-organization connection between network operators, such as the cooperation between network operators, or the alliances between them; (2) improve the network support service system, including logistics, electronic payment and so on; (3) improve the entire environment of the social and economic.

Promoting the management ability and capacity for sustainable development of the network sellers can be more effective in promoting the development of the scientific research, technical services and geological prospecting industry, resident services and other services, leasing and business services. Specifically, we can enhance the shop operating ability and the ability of sustainable development from three aspects: (1) Products: focus on the quality and function of products as a unique selling point to apart from other competing products; (2) Price: enterprises should analyze seriously on brand strategy and market situations in the case of determining the prices of products; (3) Promotion: merchants could carry out promotional activities during the holidays, such as profit sharing, buy one get two, etc., to boost its popularity and promote sales growth.

And the way may be picked to promote the development of manufacturing industry effectively is to promote the development of the trend of regional network business scale and the turnover of network transactions. In order to achieve the development of network business scale and the turnover of network transactions, some new products may be introduced on the premise of that sales of existing products kept steady growth. At the same time, network operators could explore the wholesale business, not being limited to the retail business.

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A Hybrid Evolutionary Algorithm Framework and Its Applications to Multiobjective Scheduling Problems

Wenqiang Zhang, Jiaming Lu, Hongmei Zhang, Zhan Qian and Mitsuo Gen

Abstract Scheduling plays a very important role in intelligent manufacturing system, where it can have a major impact on the productivity of a production process. However, it is very difficult to find an optimal solution for scheduling problems since most of them fall into the class of NP-hard problem. Evolutionary algorithm (EA) is a generic population-based meta-heuristic optimization algorithm, which can find compromised optimal solutions well for complicated scheduling problem. Moreover, multiobjective evolutionary algorithm (MOEA) has attracted attention with respect to multiobjective scheduling problems because ofthe global and local search abilities. This paper designs a multiobjective hybrid evolutionary algorithm (MoHEA) framework which combines vector evaluated genetic algorithm and a new archive maintenance strategy to preserve both the convergence rate and the distribution performance. The MoHEA is applied to solve the most import practical scheduling problems such as multiobjective process planning and scheduling (MoPPS) problem and multiobjective assembly line balancing (MoALB) problem. Numerical experimental results show that the MoHEA could get the better efficacy and efficiency than existing MOEAs.

Keywords Hybrid evolutionary algorithm (HEA) · Process planning and scheduling (PPS) · Assembly line balancing (ALB) · Multiobjective optimization problem (MOP)

W. Zhang (✉) · J. Lu · H. Zhang
College of Information Science and Engineeering, Henan University of Technology, Zhengzhou, People's Republic of China
e-mail: zhangwq@haut.edu.cn

Z. Qian
Zhengzhou VCOM Science and Technology Co. Ltd., Zhengzhou 450000, People's Republic of China

M. Gen
Fuzzy Logic Systems Institute and Tokyo University of Science, Tokyo, Japan

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1 Introduction

In many real world applications in intelligent manufacturing system, a scheduling problem involves determining an effective optimal solution, which decide a production facility what to make, when, with which staff, and on which equipment, to process the products effectively. Unfortunately, determination of such a solution is a difficult combinatorial optimization problem. Seeking an optimal solution rapidly and effectively from all of the permutations, combinations of all of the tasks, manufacturing resources and human resources according to specified criteria is very intractable to the traditional approaches. Evolutionary algorithm (EA) is a meta-heuristic optimization algorithm, which can find compromised optimal solutions with short computing time and acceptable quality for complicated scheduling problem.

In practical scheduling problem, more than one objective need to be optimized together and in most cases objectives are conflicting. Multiobjective optimization problem (MOP) is such a practical, important but very intractable optimization problem in which two of more conflicting objectives should be considered together, and many Pareto-optimal solutions with incommensurable quality are generated for decision makers. Most single objective optimization problem concerns with more problem-dependent considerations and one global optimal solution as well as less computation time are desired. However MOP needs additional cares in convergence mechanism and distribution mechanism much more. Moreover, reduction of computation time becomes more difficult accordingly.

Multiobjective Evolutionary algorithm (MOEA) has been recognized to be well-suited for solving MOPs [1, 3, 5, 6]. The first MOEA, vector evaluated genetic algorithm (VEGA), divides the population into *m* sub-populations (*m* is number of objectives), each of which evolves toward a single objective [8]. Weight sum methods transform MOP into single-objective problem by assigning different weight for each objective and aggregating them. However, fixed weight or random weight could cause search bias in evolving process. Gen and Cheng [3] proposed an adaptive weights genetic algorithm (AWGA) which utilizes some useful information from current population to readjust weights in order to obtain a search pressure towards to positive ideal point [4]. Lin et al. [6] proposed an interactive adaptive weight GA (i-AWGA) by using AWGA and Pareto ranking based approach to classify the difference among non-dominated solutions (or dominated solutions) clearly.

As two classical MOEAs, NSGA-II [2] and SPEA2 [15] have been proven to get better quality in solving MOPs. Zhang and Fujimura proposed an improved vector evaluated genetic algorithm with archive (IVEGA-A) that combined VEGA and Pareto-based scale-independent fitness function (GPSI-FF)-based archive mechanism [10]. Zhang et al. [13] improved the IVEGA-A and proposed a Hybrid sampling strategy-based multiobjective evolutionary algorithm (HSS-MOEA) by combining two different mechanisms to improve the convergence and distribution performances.

The paper is organized as follows: Sect. 2 reviews the literature of recent re-search works; Sect. 3 presents the detailed multiobjective hybrid evolutionary algorithm (MoHEA); Sect. 4 gives a discussion and analysis of numerical experiments results for two practical multiobjective scheduling problem: process planning and scheduling and assembly line balancing problems; finally, the conclusion and future work are given in Sect. 5.

2 Literature Review

The VEGA just selects individuals into mating pool for one objective in selection phase. The benefit of VEGA is the strong ability to converge to the edge region of the Pareto front by its simple sampling strategy and less time complexity, hence the qualities (especially, diversity) of VEGA are not good because of the selection bias.

The AWGA calculates the approximate objective function value interval according to the current population to define the positive ideal point and negative ideal point. The weight for each objective can be defined by ideal point that it can be changed with the evolving process. AWGA uses these adaptive weights to normalize objective values and accumulate them as fitness value. As a result, AWGA has tendency towards center region of Pareto front because the individuals locating at center area have bigger fitness value than edge area.

The i-AWGA combines the AWGA based fitness value and Pareto ranking strategy to improve the AWGA.The fitness value is calculated normally, and dominating and dominated relationship of each individuals are calculated accordingly. For minimization problem AWGA fitness value is added 1 if the individual belongs to nondominated solution; otherwise, only add 0 to the AWGA fitness value. Obviously, the fitness values of individuals locating at center area of Pareto front are bigger than edge area and all of nondominated individuals are allocating along Pareto front with rank 1.

The NSGA-II calculates the Pareto ranking considering the dominating and dominated relationship, then sorts these individuals according to ranking value by ascending. When updating the archive, the individuals with rank 1 should be inserted first, then rank 2. If rank r cannot be fully inserted into archive, insert the individuals in the descending order of the crowding distance until the archive is full. However, calculation of rank and crowding distance need much CPU time.

The SPEA2 first calculates the individual's strength, which is the number of individuals it dominates in population and archive. Then calculates the individual's raw fitness, which is the total strengths value of individuals dominate it. Also need to calculate the individual's distance for each individual. When updating the archive, both of the raw fitness and the distance are considered. Since the complicated computation of distance value and pruning scheme when updating archive cause that SPEA2 need much CPU time than NSGA-II but better distribution performance than NSGA-II.

Ho et al. [7] proposed a generalized Pareto-based scale-independent fitness function (GPSI-FF) to solve the large parameter optimization problem. The GPSI-FF can obviously speed up the convergence rate [10], especially around the central area of the Pareto front. The aforementioned VEGA has preference for the edge region of Pareto front. Therefore it is reasonable to hybridize these two methods to achieve better convergence performance approaching to central and edge areas of whole Pareto font. According to these ideas, Zhang and Fujimura propose IVEGA-A in which both VEGA and GPSI-FF-based archive not only preserve the convergence rate but also guarantee better distribution performance. However, the difference between nondominated and dominated individuals can be decreased by GPSI-FF values. This disadvantage causes that more dominated individuals could be held in archive (external population) while nondominated ones would be removed from archive. It reduces the performance of archive, unless an enough large size of its archive is set to store a sufficient number of individuals. The HSS-MOEA provide an effective hybrid evolutionary algorithm framework to solve the multiobjective scheduling problem by combining two different mechanisms. One is the sampling strategy of VEGA with a preference for the edge region of the Pareto front, and the other is the sampling strategy based on an improved fitness function with tendency converging toward the central area of the Pareto front. These two mechanisms not only preserve the convergence rate, but also guarantee the better distribution performance.

3 Hybrid Evolutionary Algorithm Framework

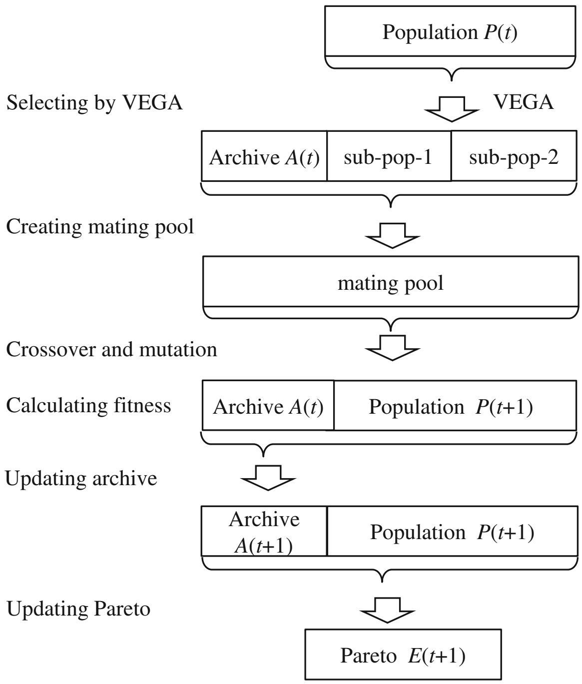
1. Fitness Function
Pareto dominating and dominated relationship-based fitness function (PDDR-FF) is proposed to evaluate the individuals. The PDDR-FF of an individual s_i is calculated by the following function:

$$\mathrm{eval}(s_i) = q(s_i) + 1/(p(s_i) + 1), \quad i = 1, 2, \ldots, \mathrm{popSize}, \tag{1}$$

where $p(s_i)$ is the number of individuals, that can be dominated by the individual s_i, $q(s_i)$ that can dominate the individual s_i. The smaller value is better.
According to the above equation, the fitness values of nondominated individual will not exceed one and the dominated one will exceed one. Moreover, ones with different numbers of dominating are also given the different fitness values even though they are all nondominated individuals. The nondominated individuals locating around the central region of Pareto font with bigger domination area will have smaller values (near to 0) than the edge points (near to 1). The PDDR-FF can set the obvious difference values between the nondominated and dominated individuals.Moreover, ones with different numbers of dominating are also set as different fitness values even though they are all nondominated individuals. The individuals locating around the central region of Pareto font will have smaller values than the edge points.

2. Framework of HEA
The evolving process of one generation of MoHEA is shown in Fig. 1. $A(t)$ represents the archive as an external population at generation t and $P(t)$ represents the population at generation t.

Fig. 1 The framework of MoHEA



The solution procedure of one generation includes 6 steps.

Step 1. Selecting individuals into sub populations by VEGA.
In this step, for two objectives optimization problem, individuals are selected with replacement according to objective 1 into sub population 1 while ignoring objective 2 until the size of the sub population 1 (half of population size) is reached. In the same manner, individuals are selected for objective 2 into sub population 2 without considering objective 1 until sub population 2 is full. As a result, the individuals locating at edge areas of Pareto front have higher probability to be selected into sub populations.
Step 2. Creating mating pool by combining the sub populations and archive.
In this step, the sub populations and $A(t)$ are combined to form a mating pool. In the mating pool, sub-pop-1 stores the good individuals for one objective, and sub-population 2 holds the good individuals for the other objective. These two sub populations ensure that the solutions approach to edge areas of true Pareto front. The archive saves the individuals with good PDDR-FF values that guarantee the solutions converge to center area of true Pareto front. These three parts of the mating pool make the solutions converge to the true Pareto front evenly.

Step 3. Reproducing the new individuals by crossover and mutation.
The crossover and mution can be applied according to problem-dependent encoding and decoding strategy.
Step 4. Calculating the objectives values and fitness values by PDDR-FF.
Since only calculation dominating and dominated relationship among individuals without calculating distance makes PDDR-FF much faster than other approaches with diversity preservation mechanism.
Step 5. Updating the archive according to the PDDR-FF values.
The individuals of $A(t)$ and $P(t)$ are combined to form a temporary archive $A'(t)$. Thereafter, the PDDR-FF values of all individuals in $A'(t)$ are calculated and sorted in a ascending order. The smallest $|A(t)|$ individuals in $A'(t)$ are copied to form $A(t+1)$. This archive updating mechanism likes a elitist sampling strategy to keep the better individuals with better PDDR-FF values.
Step 6. Updating the Pareto set.
Because the archive size can not store all nondominated individuals and the archive maintenance strategy could remove some nondominated ones, the Pareto set has been save for each generation.

The implementation structure of MoHEA is described in Fig. 2.

In selection phase of HEA, the PDDR-FF based selecting strategy has the advantage with the tendency converging toward the center area of the Pareto front, but drawback

```
procedure: MoHEA for multiobjective scheduling problem
input: data set of problem, EA parameters
output: Pareto optimal solutions E
begin
  t ← 0;
  initialize P(t) by random key-based encoding routine;
  calculate two objectives by decoding routine;
  calculate fitness eval(P) by PDDR-FF approach;
  create Archive A(t) by PDDR-FF based updating routine;
  create Pareto E(P) by nondominated routine and keep best Pareto optimal solution;
   while (not terminating condition) do
    create mating pool M'(t) from P(t) by binary tournament selection routine;
    combine mating pool M'(t) and Archive A(t) as mating pool M(t);
    create P(t+1) from M(t) by crossover routine;
    create P(t+1) from M(t) by mutation routine;
    calculate objectives by decoding routine;
    calculate fitness eval(P+1) by PDDR-FF approach;
    update Archive A(t+1) from P(t+1) and A(t) by PDDR-FF based updating routine;
    update Pareto E(P) by nondominated routine and update best Pareto optimal solution;
    t ← t + 1;
    end
  output Pareto optimal solutions E(P)
end;
```

Fig. 2 The procedure of MoHEA

to the edge region. It causes bad distribution performance. The selection strategy of VEGA prefers the edge rather than center regions of Pareto front that it causes VEGA cannot achieve better distribution performance. So it is natural, reason-able and possible to combine these two methods to improve the overall performance and reduce the computation time of the algorithm. The strong convergence capability of VEGA and PDDR-FF ensures that the MoHEA has the ability to converge to the true Pareto front both in central and edge regions. The preferences for the edge area of the Pareto front in VEGA and the central area of the Pareto front in PDDR-FF guarantee that the MoHEA distributes along the Pareto front evenly. Moreover, MoHEA has less computing time.

4 Experiments and Discussion

4.1 Multiobjective Process Planning and Scheduling Problem

Processing planning and scheduling PPS is to process a set of prismatic parts into completed products effectively and economically in a manufacturing system. Process planning (PP) is the determination of optimal process plans, i.e. operations (machine, tool, tool access direction) and their sequences. The scheduling is determination of the most appropriate moment to execute each operation with competitive resources.

The mathematical model of MoPPS is expressed in the following notations.

Indices

i, k : Indices of part, $(i, k = 1, 2, \ldots, I)$;
j, h : Indices of operation for part i, $(j, h = 1, 2, \ldots, J)$;
m : Index of machine, $(m = 1, 2, \ldots, M)$;
l : Index of tool, $(l = 1, 2, \ldots, L)$;
d : Index of TAD, $(d = 1, 2, \ldots, D)$.

Parameters

I : Number of parts;
J_i : Number of operations for part i;
M : Number of machines;
L : Number of tools;
D : Number of TADs;
O_i : Set of operations for part i; $O_i = \{o_{ij} | j = 1, 2, \ldots, J_i\}$;
o_{ij} : The jth operation of part i;
m_m : The mth machine;
t_l : The lth tool;
a_d : The dth TAD;

M_{ij} : Set of machines that can process o_{ij};
A_m : Set of operations that can be processed on machine m;
r_{ijh} : Precedence constraints. if o_{ij} is predecessor of o_{ih}, $r_{ijh} = 1$; Otherwise, 0;
t^M_{mij} : Machining time of o_{ij} by machine m;
t^{MC} : Machine change time. It is needed when two adjacent operations belong to (1) Different parts, or (2) Same part and different machines;
t^{TC} : Tool change time. It is needed when two adjacent operations belong to (1) Different parts, or (2) Same part and different machines, or (3) Same part, Same machine and different tools;
t^{SC} : Set-up change time. It is needed when two adjacent operations belong to (1) Different parts, or (2) Same part and different machines, or (3) Same Part, same machine and different TADs;
t^{PRE}_{mij} : Preparation time of operation o_{ij} by machine m.
The preparation time for an operation consists of machine change time, tool change time and set-up time for the operation; $t^{PRE}_{mij} = t^{MC} + t^{TC} + t^{SC}$.
t^P_{mij} : Processing time of operation o_{ij} by machine m. The processing time for an operation consists of the preparation time and the machining time for the operation; $t^P_{mij} = t^{PRE}_{mij} + t^M_{mij}$.
u_m : Workload of machine m. $u_m = \sum_{i=1}^{I} \sum_{j=1}^{J_i} t^M_{mij} x^M_{mij}$.
$\overline{u}$: Average workload of machine. $\overline{u} = 1/M \sum_{m=1}^{M} u_m$.
t^C_{mij} : Completion time of o_{ij} By machine m.

Decision variables

$$x^M_{mij} = \begin{cases} 1, & \text{if } o_{ij} \text{ is performed by machine } m, \\ 0, & \text{otherwise,} \end{cases}$$

$$x^T_{lij} = \begin{cases} 1, & \text{if } o_{ij} \text{ is performed by tool } l, \\ 0, & \text{otherwise,} \end{cases}$$

$$x^D_{dij} = \begin{cases} 1, & \text{if } o_{ij} \text{ is performed by TAD } d, \\ 0, & \text{otherwise,} \end{cases}$$

$$y_{ijkh} = \begin{cases} 1, & \text{if } o_{ij} \text{ is performed directly before } o_{kh}, \\ 0, & \text{otherwise.} \end{cases}$$

Mathematical Model:
The mathematical model for minimization of makespan and variation of workload can be formulated as the following bicriteria nonlinear mixed integer programming (B-NMIP) model:

$$\min \ t_M = \max_{m,i,j} \{t^C_{mij}\} \tag{2}$$

$$\min\ w_P = \sqrt{1/M \sum_{m=1}^{M} (u_m - \overline{u})^2} \tag{3}$$

$$s.t. (t^C_{mkh} - t^P_{mkh} - t^C_{mij}) x^M_{mij} x^M_{mkh} y_{ijkh} \geq 0,\quad \forall (i,j),(k,h),m \tag{4}$$

$$r_{ijh} y_{ihij} = 0,\quad \forall (i,j),h \tag{5}$$

$$y_{ijij} = 0,\quad \forall (i,j) \tag{6}$$

$$\sum_{m=1}^{M} x^M_{mij} = 1,\quad \forall (i,j) \tag{7}$$

$$x^M_{mij} = 0,\quad \forall (i,j) \notin A_m,\quad \forall m \tag{8}$$

$$y_{ijkh} \in \{0,1\},\quad \forall (i,j),(k,h) \tag{9}$$

$$x^M_{mij} \in \{0,1\},\quad \forall m,(i,j) \tag{10}$$

$$t^C_{mij},\quad \forall m,(i,j). \tag{11}$$

Equation (2) describes the one objective of minimization of makespan. Minimization of variation of workload is defined as Eq. (3). Equation (4) imposes that any machine cannot be selected for one operation until the predecessor is completed. The precedence constraint is defined as Eq. (5). Equation (6) ensures the feasible operation sequence. The feasible resource selection are defined as Eqs. (7) and (8). Equations (9), (10) and (11) impose nonnegative condition.

The minimizing makespan and minimizing variation of workload for each machine are used as the two objectives in PPS problems and 4 parts (each part has 20, 16, 14 and 7 operations, respectively) problem are used as simulation experimental data (see [10, 13] for details).

The adopted parameters are listed as follows:population size, 100; maximum generation, 500; archive size, 50; crossover probability, 0.70; mutation probability, 0.30. MoHEA, IVEGA-A,VEGA, AWGA, i-AWGA, NSGA-II, and SPEA2 are run 30 times to compared the results with each other.

Let S_j be a solution set for each method. $PF*$ is a known reference Pareto solutions. In this study, $PF*$ in this study comes from combining all of the obtained Pareto set with 30 runs by 7 methods.

The following two performance measures coverage C and spacing SP are considered [9, 14]. The C is used to verify convergence performance while SP is used to check the distribution performance.

The Fig. 3 shows the numerical comparison of the box-and-whisker plots for C and SP and the CPU times by 7 methods. From Fig. 3f, it is easy to see that the MoHEA is better than other 6 methods on C measure.Therefore, MoHEA is better than IVEGA-A, VEGA, AWGA, i-AWGA as well as famous NSGA-II, and SPEA2.

The distribution performance SP (as shown in Fig. 3g) indicates that MoHEA is slightly better than SPEA2, and obviously better than left 5 methods (IVEGA-A, VEGA, AWGA, i-AWGA, NSGA-II).

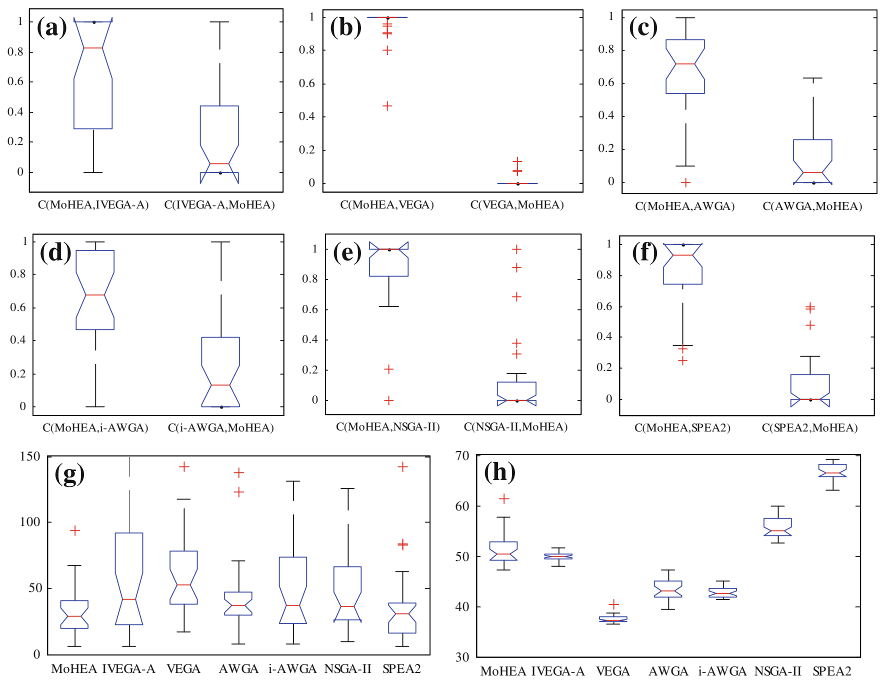


Fig. 3 C, SP and CPU times by 7 methods for MoPPS problem. **a** Coverage for MoHEA and IVEGA-A. **b** Coverage for MoHEA and VEGA. **c** Coverage for MoHEA and AWGA. **d** Coverage for MoHEA and i-AWGA. **e** Coverage for MoHEA and NSGA-II. **f** Coverage for MoHEA and SPEA2. **g** Spacing. **h** CPU time

From the comparisons of CPU time as shown in Fig. 3h, it is clear that MoHEA is much faster than NSGA-II and SPEA2 while close to IVEGA-A, and much computational time than VEGA, AWGA and i-AWGA.

In general, the convergence and distribution performance of MoHEA is better than IVEGA-A, VEGA, AWGA, i-AWGA as well as famous NSGA-II and SPEA2, and the efficiency is obviously better than NSGA-II and SPEA2.

4.2 Multiobjective Assembly Line Balancing Problem

The assembly line balancing (ALB) problem determines the assignment of various tasks to an ordered sequence of stations, while optimizing one or more objectives without violating restrictions imposed on the line in a manufacturing system. How to allocate the proper workers to proper stations to obtain the best efficiency of the line and reduce the total cost is also a problem in multiobjective assembly line balancing with worker capability (MoALB-WC).

The notation used in the mathematical model can be summarized as follows:
Indices:

j, k : Indices of task ($j, k = 1, 2, \ldots, n$);
i : Indices of station ($i = 1, 2, \ldots, m$);
w : Indices of worker ($w = 1, 2, \ldots, m$).

Parameters:

n : Number of tasks;
m : Number of stations/workers;
d_{jw} : Worker cost of worker w process task j;
t_{jw} : Processing time of task j by worker w;
$\mathrm{Suc}(j)$: Set of direct successors of task j;
$\mathrm{Pre}(j)$: Set of direct predecessors of task j;
S_i : Set of tasks assigned to station i;
$t(S_i)$: Processing time at station i, $t(S_i) = \sum_{j=1}^{n} \sum_{w=1}^{m} t_{jw} x_{ij} y_{iw},\ \forall i$;
u_i : Utilization of the station S_i, $u_i = t(S_i)/\max_{1 \le i \le m}\{t(S_i)\}$;
u : Average utilization of all stations,$u = 1/m \sum_{i=1}^{m} u_i$.

Decision Variables:

$$x_{ij} = \begin{cases} 1, & \text{if task } j \text{ is assigned to station } i, \\ 0, & \text{otherwise,} \end{cases}$$

$$y_{iw} = \begin{cases} 1, & \text{if task } w \text{ is working in station } i, \\ 0, & \text{otherwise.} \end{cases}$$

Mathematical Model:

$$\min\ c_T = \max_{1 \le i \le m} \{\sum_{j=1}^{n} \sum_{w=1}^{m} t_{jw} x_{ij} y_{iw}\} \tag{12}$$

$$\min\ d_T = \sum_{i=1}^{m} \sum_{j \in S_i} \sum_{w=1}^{m} d_{jw} y_{iw} \tag{13}$$

$$s.t. \sum_{i=1}^{m} i x_{ij} \ge \sum_{i=1}^{m} i x_{ik},\quad \forall\, k \in \mathrm{Pre}(j), \forall j \tag{14}$$

$$\sum_{i=1}^{m} x_{ij} = 1,\quad \forall j \tag{15}$$

$$\sum_{w=1}^{m} y_{iw} = 1,\quad \forall i \tag{16}$$

$$\sum_{i=1}^{m} y_{iw} = 1, \quad \forall w \tag{17}$$

$$x_{ij}, y_{iw} \in \{0, 1\}, \quad \forall i, j, w. \tag{18}$$

The first objective (12) of the model is to minimize the cycle time of the assembly line. The second objective (13) is to minimize the total worker cost. Inequity (14) states that all predecessor of task j must be assign to a station, which is in front of or the same as the station that task j is assigned in. Equation (15) ensures that task j must be assigned to only one station. Equation (16) ensures that only one worker can be allocated to station i. Equation (17) ensures that worker w can be allocated to only one station and Eq. (18) represents the nonnegative restrictions.

The MoALB-WC problem concerns with the assignment of the tasks to stations and the allocation of the available workers for each station in order to minimize the cycle time and minimize the total cost under the constraint of precedence relationships (see [11, 12] for details).

We employed Gunther's problem data with 35 tasks and 6 stations and all the simulations are performed on Pentium Dual-Core processor (2.70 GHz clock) and 2GB memory. The adopted parameters are listed as follows: population size, 100;

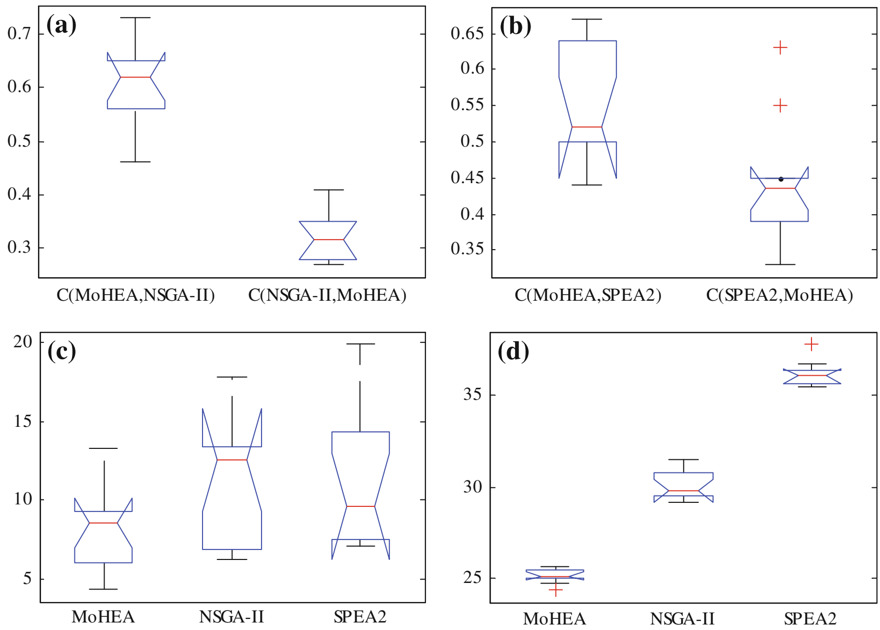


Fig. 4 C, SP and CPU times by 3 methods for MoALB problem. **a** Coverage for MoHEA and NSGA-II. **b** Coverage for MoHEA and SPEA2. **c** Spacing. **d** CPU time

maxi-mum generation, 500; archive size, 50; crossover probability, 0.80 and 0.30; mutation probability, 0.40 and 0.10.

The Fig. 4 shows the numerical comparison of the box-and-whisker plots for C, SP and the CPU times by 3 methods. From Fig. 4 we can see that the convergence and distribution performance of MoHEA is better than famous NSGA-II and SPEA2, and the efficiency is better.

5 Conclusions

In this study, a MoHEA (multiobjective hybrid evolutionary algorithm) framework was proposed to solve multiobjective scheduling problems such as multiobjective process planning and scheduling (MoPPS) problem and multiobjective assemble line balancing (MoALB) problem.

A Pareto dominating and dominated relationship based fitness function was proposed to evaluate the individuals. PDDR-FF (Pareto dominating and dominated relationship-based fitness function) could provide a clear classification between non-dominated solution and dominated solution, but also a clear difference among solutions locating along the Pareto front.The proposed method combined the advantages of VEGA and PDDR-FF based archive updating strategies. The selection strategy of VEGA has a preference for the edge region of the Pareto front and the PDDR-FF-based sampling strategy has the tendency converging toward the center area of the Pareto front. The MoHEA could preserve that the solutions approached to the true Pareto front as close as possible in various directions.

Numerical comparisons for two practical multiobjective scheduling problems indicated that MoHEA was better than IVEGA-A in efficacy while the efficiency was closely equivalent, and both convergence and distribution performance were also better than NSGA-II and SPEA2 as well as VEGA, AWGA and i-AWGA, furthermore, the efficiency was obviously better than NSGA-II and SPEA2. Especially, MoHEA can also keep diversity evenly without special distribution mechanisms like NSGA-II and SPEA2.

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Studying Key Factors to Creating Competitive Advantage in Science Park

Alireza Aliahmadi, M. Ebrahim Sadeghi, Hamed Nozari, Meisam Jafari-Eskandari and Seyed Esmaeil Najafi

Abstract Science parks are known tools for development of high technologies. In recent years, much attention has been given to these institutions in all countries and also in Iran. This paper attempts to provide a framework for evaluating the potential of creating competitive advantages by science and technology parks in Iran using foreign models and studies in this field and also considering the local dimensions of the issue. In considered model some aspects have been determined such as human resources, R&D and technology transfer, market development and facilities that are main effective aspects on potential of creating competitive advantages in science and technology parks. The Fuzzy decision making trial and evaluation laboratory (DEMATEL) method is proposed in order to find the cause and effect aspects and determining the priorities of planning in science and technology parks. The proposed framework applied to Pardis Technology Park in Iran and then key aspects of competitive advantage were examined.

Keywords Science parks · Industrial clusters · Competitive advantages · Knowledge based companies · Fuzzy dematel

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A. Aliahmadi
Industrial Engineering Department, Iran University of Science and Technology,
15614 Tehran, Iran

M.E. Sadeghi
Department of Science and Technology Policy, Tehran University,
15614 Tehran, Iran

H. Nozari (✉)
Industrial Engineering Department, Islamic Azad University Centeral
Tehran Branch, 15614 Tehran, Iran
e-mail: ham.nozari.eng@iauctb.ac.ir

M. Jafari-Eskandari
Industrial Engineering Department, Payam Noor University of Shemiranat,
15614 Tehran, Iran

S.E. Najafi
Industrial Engineering Department, Islamic Azad University Science
and Research Branch, 15614 Tehran, Iran

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1 Introduction

Many studies have expressed that science parks are important tools in the development of high-tech industries [1]. These parks were originally established in Western countries. Silicon Valley and rout 128 can be noted as successful examples of these parks in USA [2]. These successful experiences of the USA became an important factor in the modeling of scientific park model in other countries.

In developed countries, establishing a science park usually creates the expectation of the reindustrialization of area and eliminating undeveloped areas. In developing economies, a science park is expected to act as a development catalyst and promote new firms in high technology in a way that they create more innovation in their products and processes [3]. The assessing of academic knowledge and expertise by businesses located on-site is a key principle of Science Parks [4]. Research links may take many forms, from formal contracts for research to more informal contracts as well as the transfer of personnel between academia and industry. Science Parks provide an important resource network for new technology-based firms (NTBFs). The importance of NTBFs on Science Parks is related to their performance: they are expected to "perform better" than the average firm. So the main purpose of this study is to identifying and ranking factors causing for competitive advantage in science parks. Therefore in this study, after reviewing the literature on the second part, The theoretical framework of research will be discussed. Then the rank of key factors ti creating competitive advantage in this park can be obtained using fuzzy DEMATEL.

2 Literature Review

Institutions such as science parks and industrial clusters, are trying to improve competitive power of companies. The difference between them is that science parks operate in high tech industries but clusters cover various industries. Because of the similar missions of these institutions and the tools they use to achieve their goals, in many studies, these two topics explore in the same field. For example Lai and Shyu [5] compared the innovation capacity of two science parks by the innovation orientatation of national industry clusters model of Furman et al. Also, Lin and Tzeng [6] has investigated the value created of the Science and Technology Parks, by determining the factors that affect on industrial clusters. Moreover, it should be noted that one of the most effective strategies to increase the competitiveness of companies in science parks is clustering them that is used as a factor, in performance measurement of many parks. In this study, by using literature of industrial clusters and other studies in the field of science and technology parks, we identified critical factors which create competitive advantages for the companies located in the science Parks.

Lin et al. [7] explained the effects of industrial clusters in viewpoint of system dynamics and suggests that 4 factors of human resources, technology, money and market as the main influencing factors of industrial clusters. Sun et al. [8] introduced 6 factors as factors that contribute industrial clusters to achieving national competitive advantage and searched the effect of these factors in Hesincho park. The six factors are: Input conditions, local demand conditions, related and supporting industries, competition, corporate strategy and structure, government support and culture. Thus, they concluded that these factors have played a key role in increasing the competitive advantage in science and technology parks.

Fukugawa [9] expressed the most important assistant that science parks could provide for new technology based firms is creation of connection with higher education institutes and research institutes. The science parks have combined functions of the traditional industry parks and incubation centers, and thus NTBF could obtain research resources and desired technologies from the assistance of R&D institutes. Therefore, NTBF could easily find suitable strongholds to commercialize their technologies [6]. Since science and technology parks are interface between universities and R&D organizations, So can have very significant role in the economic development of the country. Therefore, understanding the factors determining the competitive advantage and prioritization of them can facilitate the convergence rate of growth.

3 Theoretical Framework

According to the above mentioned studies and factors mentioned in other studies, factors that create competitive advantages in science parks were identified and are listed in Table 1.

To determine the major factors in Iranian science parks, a questionnaire consisting of 18 factors was prepared. The questionnaires were sent to a number of experts (science and technology policy makers, managers of science parks and managers of located firms). In the questionnaire, the five level Likert scale (1 means no importance,

Table 1 Effective factor identified by literature review

High quality scientist and engineer	Proper domestic market share
High quality human resource in field of management and marketing and entrepreneurship	Supporting culture of innovation
Access to reference laboratory communication with universities and R&D institutes	Access to required market information
	Access to high quality suppliers
Cooperation with similar companies	Existence of rivalry
Access to required technology information customs and tax exemptions	The quality of local demand
	Expected local demand
Financial support	Supporting environment for Investment
Provision of physical infrastructures	Export power

Table 2 Effective factor identified by experts opinions

Human resources	H1: High quality scientist and engineer
	H2: High quality human resource in field of management and marketing
R&D and technology transfer	R1: Access to reference laboratory
	R2: Communication with universities and R&D institutes
	R3: Cooperation with similar companies
	R4: Access to required technology information
Facilities	F1: Customs and tax exemptions
	F2: Financial support
	F3: Provision of physical infrastructures
Market development	M1: Proper domestic market share
	M2: Export power
	M3: Access to required market information

to 5 means very significant important) was used. According to the results of 32 questionnaires that came to us, 12 factors as shown in Table 2 were identified as influencing factors in science and technology parks then using expert opinion these factors were placed in 4 categories that are: human resources, research and development and technology transfer, facilities and market development. In the following, we describe an overview of these factors.

4 The DEMATEL Method

DEMATEL method was first created at Science and Human Affairs Program of the Battelle Memorial Institute of Geneva and it is used to study complicated phenomena [10]. It has been used widely in many field of studies such as, evaluating core competencies, decision-making, knowledge management, operations research and technology research [11]. The structure of DEMATEL and its calculation procedures are summarized as fallow:

Step 1. Establishing the direct-relation matrix. In order to measure the relationship between factors i and j requires that the comparison scale to be designed according to the following four levels (No influence (0) up to Very high influence (4)). The integer score x_{ij}^{k} is given by the kth expert and shows the degree to which the criterion i affects the criterion j. The $n \times n$ matrix A is calculated in Eq. (1) by averaging individual expert's scores,

$$a = \frac{1}{H}\sum_{k=1}^{H} x_{ij}^{k}, \tag{1}$$

where H is the number of experts.

Step 2. Normalizing the direct-relation matrix. On the basis of the direct-relation matrix A, the normalized direct-relation matrix X can be obtained through the following equations:

$$s = \max\left(\max_{1\leq j\leq n}\sum_{j=1}^{n} a_{ij},\ \max_{1\leq j\leq n}\sum_{i=1}^{n} a_{ij}\right), \tag{2}$$

$$X = \frac{A}{s}. \tag{3}$$

Step 3. Calculating the total-relation matrix. Once the normalized direct-relation X is obtained, the total-relation matrix T can be calculated by following equation, where I is the identity matrix.

$$T = X(I - X)^{-1}. \tag{4}$$

Step 4. Building a causal diagram. The sum of rows and the sum of columns are respectively denoted as vector D and vector R. The horizontal axis vector $(D + R)$, named Prominence, represents the importance of the criterion. Similarly, the vertical axis $(D - R)$, named Relation, divides criteria into a causal group and an effect group. According to the previous statements, the factor is causal, if $(D - R)$ is positive, and the factor is effect when $(D - R)$ is negative. Thus, the causal diagram can be acquired by mapping the dataset of $(D + R, D - R)$.

$$T = [t_{ij}]_{n\times n}, i, \mathrm{j} = 1, 2, \cdots, n, \tag{5}$$

$$D = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = [t_i]_{n\times 1}, \tag{6}$$

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]'_{1\times n} = [t_j]_{n\times 1}. \tag{7}$$

Step 5. Determine the threshold value. In many cases, it is necessary to set a threshold value α for explaining the structural relation among factors while simultaneously keeping the complexity of the whole system to a manageable level. Threshold value α is determined by experts in order to set up the minimum value of influence level. An influence relationship between two elements will be excluded from the map if their correlative value in the matrix T is smaller than α.

5 Fuzzy Logic

In the real world, many decisions include imprecision because goals, constraints, and possible actions are not known precisely [12]. When we are making a decision in a fuzzy environment, the result of decision-making is highly influenced by subjective judgments that are vague and imprecise. The sources of imprecision are unquantifiable information, incomplete information, non-obtainable information, and partial ignorance [13]. In order to find a way to solve the problem of imprecision, Zadeh [14] introduced fuzzy set theory as a mathematical way to represent and handle vagueness in decision-making.

It is very hard to express reasonably the situations that are very complex or difficult to define, by using conventional quantification; so using the linguistic variable concept is necessary in such situation. Linguistic variable are variables that their values are words or phrases in a natural language [15].

In calculations procedures, linguistic values can be replaced by fuzzy numbers. In this study we use triangular fuzzy numbers (TFN). A triangular fuzzy number $\tilde{A}$ is shown as $[(L, M, U)]$ where L and U are respectively top and bottom boundary of $\tilde{A}$ as shown in Fig. 1. The membership function is defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-L)\big/(M-L), & L \le x \le M \\ (U-x)\big/(U-M), & M \le x \le U \\ 0, & \text{otherwise.} \end{cases} \tag{8}$$

The operational laws of two triangular fuzzy numbers are as fallow:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (L_1, M_1, U_1) + (L_2, M_2, U_2) = (L_1 + L_2, M_1 + M_2, U_1 + U_2), \tag{9}$$

$$\tilde{A}_1 - \tilde{A}_2 = (L_1, M_1, U_1) - (L_2, M_2, U_2) = (L_1 - U_2, M_1 - M_2, U_1 - L_2), \tag{10}$$

$$\tilde{A}_1 \otimes \tilde{A}_2 = (L_1, M_1, U_1) \otimes (L_2, M_2, U_2) = (L_1 L_2, M_1 M_2, U_1 U_2), \tag{11}$$

$$\tilde{A}_1 \,\varphi\, \tilde{A}_2 = (L_1, M_1, U_1)\,\varphi\,(L_2, M_2, U_2) = (L_1\big/U_2, M_1\big/M_2, U_1\big/L_2), \tag{12}$$

$$\tilde{A}_1^{-1} = (L_1, M_1, U_1)^{-1} = (1\big/U_1, 1\big/M_1, 1\big/L_1). \tag{13}$$

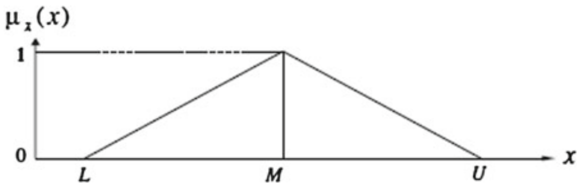

Fig. 1 Membership function of triangular fuzzy numbers

Table 3 The fuzzy linguistic scale

Linguistic terms	Triangular fuzzy numbers
Very high influence (VH)	(0.75, 1.0, 1.0)
High influence (H)	(0.5, 0.75, 1.0)
Low influence (L)	(0.25, 0.5, 0.75)
Very low influence (VL)	(0, 0.25, 0.5)
No influence (No)	(0, 0, 0.25)

6 Procedure of Fuzzy DEMATEL

In order to use fuzzy logic in DEMATEL method in the first step in measuring the relationship between criteria, a decision group of p experts were asked to make sets of pair-wise comparisons in terms of defined linguistic terms (as shown in Table 3).

Hence, p fuzzy matrices were obtained.

Following equation is used to calculate the average fuzzy matrix.

$$\tilde{z} = {(\tilde{z}^1 + \tilde{z}^2 + \cdots + \tilde{z}^p)}\Big/{p}. \tag{14}$$

We call this matrix, initial direct-relation fuzzy matrix which shows as below.

$$\tilde{z} = \begin{bmatrix} 0 & \tilde{z}_{12} & \cdots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \cdots & \tilde{z}_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n2} & \tilde{z}_{n2} & \cdots & 0 \end{bmatrix}, \quad \text{where } \tilde{z}_{ij} = (l_{ij}, m_{ij}, r_{ij}). \tag{15}$$

Now by using a deffuzication method we can obtain initial direct-relation matrix.

In order to transform TFN numbers to crisp values we use CFCS defuzzication method [16]. Four steps of the CFCS method described as follows:

1. Normalization:

$$xl_{ij} = (l_{ij} - \min l_{ij})/\Delta_{\min}^{\max}, \tag{16}$$
$$xm_{ij} = (m_{ij} - \min l_{ij})/\Delta_{\min}^{\max}, \tag{17}$$
$$xl_{ij} = (r_{ij} - \min l_{ij})/\Delta_{\min}^{\max}, \tag{18}$$

where

$$\Delta_{\min}^{\max} = \max r_{ij} - \min l_{ij}. \tag{19}$$

2. Compute right (rs) and left (ls) normalized values:

$$xls_{ij} = xm_{ij}/(1 + xm_{ij} - xl_{ij}), \tag{20}$$
$$xrs_{ij} = xr_{ij}/(1 + xr_{ij} - xm_{ij}). \tag{21}$$

3. Compute total normalized crisp values:

$$x_{ij} = [xls_{ij}(1 - xls_{ij}) + xrs_{ij}xrs_{ij}]/[1 - xls_{ij} + xrs_{ij}]. \tag{22}$$

4. Compute crisp values:

$$z_{ij} = \min l_{ij} + x_{ij}\Delta_{\min}^{\max}. \tag{23}$$

The remaining calculation procedure of fuzzy DEMATEL is like the normal DEMATEL.

7 Results

In this study a questionnaire sent to all located firms in Pardis Technology Park that 43 firms answered the questionnaire. At the first step, linguistic variables transformed to triangular fuzzy numbers. Then average matrix calculated and the initial direct relation fuzzy matrix obtained. This matrix is shown in Table 4.

The CSCF method was used to calculate the initial direct matrix obtained. This matrix is shown in Table 5. In this step we calculated the normalized initial direct-relation matrix D; and it is shown in Table 6.

Table 4 Initial direct-relation fuzzy matrix of Pardis Technology Park

	H	R	F	M
H	(0, 0, 0)	(0.395, 0.645, 0.849)	(0.308,0.558, 0.779)	(0.378, 0.628, 0.820)
R	(0.192, 0.419, 0.657)	(0, 0, 0)	(0.244, 0.488, 0.733)	(0.384, 0.622, 0.831)
F	(0.145, 0.331, 0.564)	(0.285, 0.483, 0.686)	(0, 0, 0)	(0.442, 0.692, 0.872)
M	(0.262, 0.494, 0.733)	(0.349, 0.587, 0.820)	(0.494, 0.738, 0.895)	(0, 0, 0)

Table 5 Initial direct-relation matrix of Pardis Technology Park

	H	R	F	M
H	0	0.624	0.545	0.606
R	0.423	0	0.485	0.605
F	0.347	0.482	0	0.665
M	0.492	0.576	0.708	0

Table 6 The normalized initial direct-relation matrix of Pardis Technology Park

	H	R	F	M
H	0	0.333	0.291	0.323
R	0.225	0	0.259	0.322
F	0.185	0.257	0	0.355
M	0.262	0.307	0.377	0

Table 7 Total relation matrix of Pardis Technology Park

	H	R	F	M
H	1.3287	1.9077	1.9476	2.0578
R	1.357	1.4623	1.728	1.8446
F	1.3208	1.6527	1.5098	1.8498
M	1.5247	1.8788	1.9869	1.8028

Table 8 The prominence and relation axis for causal diagram

Aspect	D	R	(D + R)	(D − R)
H	7.2418	5.5312	12.773	1.711
R	6.3919	6.9015	13.293	−0.51
F	6.3331	7.1723	13.505	−0.839
M	7.1932	7.555	14.748	−0.3618

Total relation matrix was calculated by using Eq. (4) as shown in Table 7.

Based on Eqs. (5) and (6) the prominence and relation values calculated as shown in Table 8.

The calculation procedure for each aspect is the same. The causal diagram for Pardis Technology Park is shown in Fig. 2.

Regarding to the outcomes of DEMATEL method following results acquired:

Market development aspect has the most prominence and human resource aspect has the less importance between quadruple aspects. But the human resource aspect is the sole causal aspect, and other three aspects include R&S and technology transfer, facilities and market development are effect aspects.

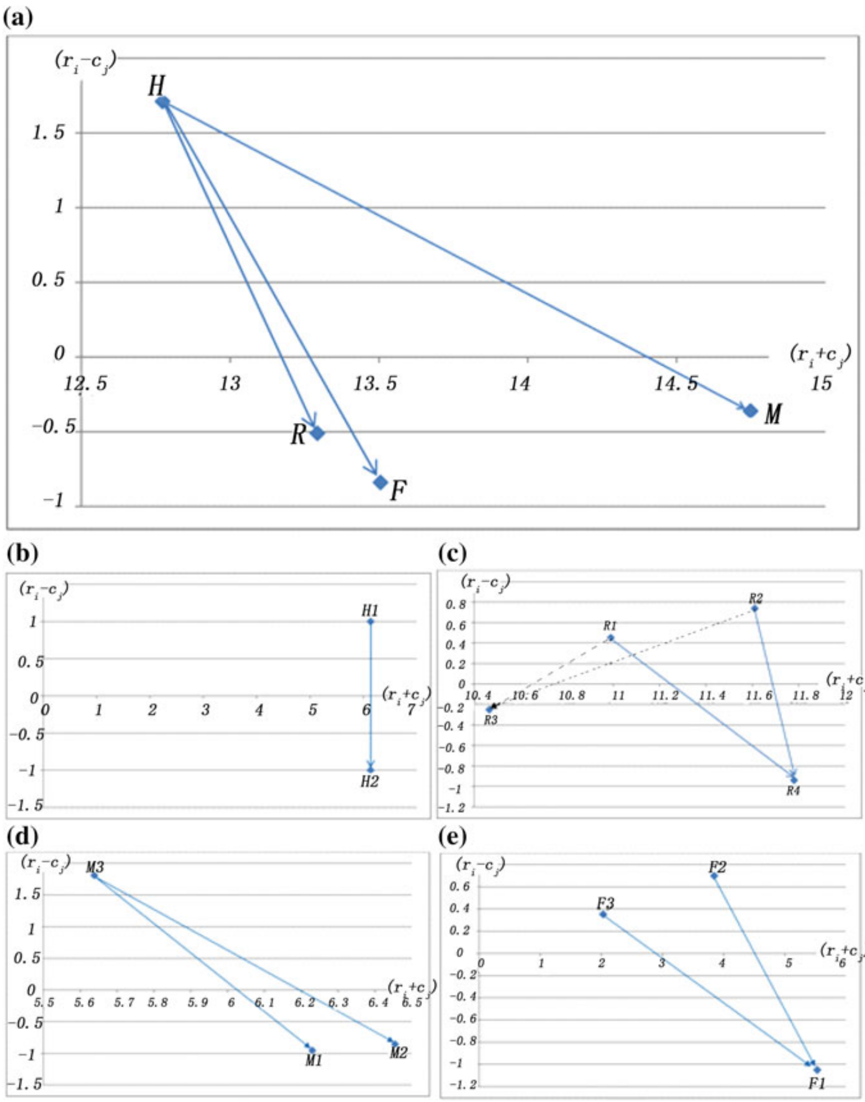

Fig. 2 **a** Initial direct-relation fuzzy matrix of Pardis Technology Park **b** Initial direct-relation matrix of Pardis Technology Park **c** The normalized initial direct-relation matrix of Pardis Technology Park **d** Total relation matrix of Pardis Technology Park **e** The prominence and relation axis for causal diagram

8 Conclusion

Conclusion Many factors affect the performance of the firms that located on science parks. Depending on the general state of the country these factors will change. In this study we explored most important factors which affect the firms in a developing country. Science parks in Iran provide different kind of services for their firm that will improve their performance and create competitive advantages for them. Base on a comprehensive survey of literature in this field and many interviews and questionnaires, twelve effective factors identified and categorized in four aspects, by the opinion of a group of experts. These four aspects are human resource, R&D and technology transfer, facilities and market development. The proposed framework applied in Pardis Technology Park and the following results obtained. According to the DEMATEL method promoting the human resource aspect can improve all other three aspects and help to increase the total performance of the Pardis Technology Park. So the management of the Pardis Technology Park should focus on the human resource aspect.

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Part VI
Project Management

Application of Scenario Approach to Optimal Choice of Feedback Coefficients in Trading Strategy Using PI-Controller

Aleksandra Kornivetc and Oleg Granichin

Abstract In a number of recent papers, new approaches devoted to financial mathematics in sphere of stock exchange were discovered. The most recent one considers using a PI Controller. The main point here is that under idealized market conditions, with non-trivial Geometric Brownian Motion, a combination of as static as dynamic linear feedbacks leads to implementation of "robust positive expectation property". The positive expected value does not guaranteed a profit; however, it showed good results in simulations. Considering such theory, it is necessary to analyze which new features will bring introduction of a probabilistic basis. When we talk about probability, especially in such spheres as stock exchange, we cannot ignore the word "compromise". For this purpose, in this article we are going to consider the realization of "compromise" through the scenario approach. This approach was already applied to the portfolio theory. Portfolio selection was considered as the result of minimax optimization of function constructed basing on previous data-scenarios. These approaches were chosen by author with purpose for its further connection. Thus, in this article the problem is formulated and scenario approach is considered as effectively choice of feedbacks coefficients of trading strategy.

Keywords Scenario approach · Stock exchange · Adaptive strategy · Feedback · PI-controller

1 Introduction

In the last few years, the number of works devoted to financial mathematics, especially to stock exchange, increased dramatically. It could be justified by growing interest of traders, who want to receive winning strategy. In addition, developing market made

A. Kornivetc (✉) · O. Granichin
Department of Mathematics and Mechanics, Saint-Petersburg State University,
Saint-Petersburg 198504, Russia
e-mail: alexandra_91@inbox.ru

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its contribution. There are many different methods of stock exchange analysis. Two of them we will consider later. The main problem here is an attempt to describe the mathematical part of stock exchange without including human factor or other factors, which are almost impossible to analyze. However, in practice especially these factors influence the market a lot. Human factor, for example, includes gossips, expectations and forecasts of analysts. It is important to mention, that except human factor, there are many others-force majeure, politics etc. All these factors are hard to forecast or somehow to include in a model. In addition, when we are talking about the stock exchange, it is impossible to build the so-called model, which includes all factors. Thus, we could made a conclusion, that stock exchange's model does not exist. Moreover, most of the methods, that are existing right now, do not describe the great part of stock exchange's "life".

Nowadays different methods, which are trying to solve this problem, are developed. They are looking on it other way around. Some of them try to include the factors by including uncertainty in their model, for example scenario approach, see [8]. Briefly about this approach, it was developed, as it is now, see [4, 8], quiet recently. However, it has already found the application in different spheres. It is important to mention, that the keystone of this approach is compromise.

Usually, we consider solving control problems as optimization of some function. Such function, for example cost function, includes variables used for uncertainty simulation. The value of this function we could guarantee only with some probability. However, by increasing probability, we receive worse value of function and vice versa. Thus, as it was said before, it is necessary to reach a compromise. Of course, it also depends on task formulation and a goal, which we want to reach.

The second set of methods, unlike the first one, does not try to consider uncertainty a priory, but constantly updates the so-called "model" with help of feedbacks and adaptive strategies. One of those strategies considers PI-controller (proportional-integral controller), see [1–3, 6, 7], as a control tool for investment function. The main point here is an absence of price dynamics model used to determine an amount of investments $I(t)$. Instead, the amount of investments is managed with help of adaptive feedbacks, which constantly update such data, as cumulative profit and losses. The main result, which was received in [1–3, 6, 7], could be rephrased as: under idealized market conditions with prices governed by nontrivial Brownian Motion, the combination of two static feedbacks, one-"long" and one-"short", leads to positive value of expectation for trade profit $g(t)$ for all $t > 0$. As this statement holds independently from parameters, which underlie in geometric Brownian Motion (GBM), it receives the name of "robust positive expectation property". In [7], within the same conditions, the results of static feedback were expanded to dynamic. For this purpose, the PI-controller was considered for investment function $I(t)$, and then the stochastic equations for expectation $g(t)$ were reduced to the classical systems the second order. With help of analytic solution it was proved, that out magical property still holds.

The purpose of this article is to consider two different approaches, which were briefly considered in introduction to use one of them as efficiency improvement for other. The article consists of three parts. In the next two, we will consider these approaches. In the fourth part, the problem is formulated. In conclusion, some future works will be listed.

2 Trading Strategy Under Idealized Market Conditions with Using Proportional-Integral Controller

The main feature of this strategy is absence of price dynamic model to determine the amount of investments $I(t)$. Instead, it is governed and generated in "free-model" manner with help of adaptive feedbacks, which update the data about cumulative profit or losses $g(t)$. Thus, instead of determining the amount of investments $I(t)$, which could be evaluated from time to time, based on some parameterized model, some controllers (in our case PI-controller) could govern productivity, that means, that $I(t)$ is constantly updating based on cumulative profits and losses $g(t)$ to the time moment t without further price forecasting.

For the better understanding, it is also important to mention, that authors have determined some definitions to describe trading on stock exchange:

- "long" linear feedback, which is characterized with amount of investments $I(t)$ at time moment $t : I(t) = I_0 + Kg(t)$, where $I_0 > 0$—initial investments, and $K \geq 0$—data that we had received in process of feedback or feedback coefficient.
- "short" linear feedback, here the amount of investments $I(t)$ is described with the same formula, however in this case we suppose that $I(t) < 0$, which could be received by initial investments $I_0 < 0$ and $K \leq 0$.

The last version of this approach considers a combination of both types of feedback and introduce one more notation-SLS (Simultaneous Long-Short) controller. This controller has unique property: under idealized market conditions with prices governed by GBM, with drift $\mu \neq 0$, non zero feedback K, and volatility $\sigma \neq 0$, independently from sign and value of μ and σ, SLS controller leads to trading gain with positive value of expectation $E[g(t)]$ for all $t > 0$.

In the previous works for static case it was found, that:

$$E[g(t)] = I_0/K[e^{K\mu t} + e^{-K\mu t} - 2], \tag{1}$$

which is obviously more than zero for all $t > 0$. Thus, this property received the name: "robust positive expectation property".

The same property was also proved for dynamic case. Further Barmish and co-authors adjusted control action to investment function $I(t)$ under ILS condition.

Further the expectation of trading gain $E[g(t)]$, which is associated with PI-controller, was analyzed. The conditions are the same: idealized market and prices $p(t)$ generated by GBM. Then the stochastic differentiation equality was received:

$$\frac{d_p}{p} = \mu dt + \sigma dZ, \tag{2}$$

where $Z(t)$ is a standard Wiener process, μ is a drift parameter, and σ − *volatility*.

Theory allows us to consider three scenarios: Initially Long, Initially Short, and Initially Long-Short (ILS). Adjective "initially" in scenario describing is used because of fundamental difference between static and dynamic cases. Thus, in static case with $K_I = 0$, as it is shown in previous works, the sign of $I_{L(t)}$ and $I_{S(t)}$ is constant during all trading. However, when we include the process of integration with $K_{I \neq 0}$, the trading could be finished with $I_{L(t)}$, or $I_{S(t)}$ changing its sign; for example, Initially Long position could be changed in Initially Short. In conclusion, in case of ILS, control, as a sum of "long" and "short" position, could be reduced to:

$$I(t) = K_p (g_L(t) - g_S(t)) + K_I \int_0^t (g_L(\tau) - g_S(\tau)) \, d\tau. \tag{3}$$

The task was also formulated in vector-space and the examples of this approach application were also demonstrated.

3 Scenario Approach

The second approach was already adapted to stock exchange. However, the main object here is a portfolio optimization, see [4].

It should be mentioned, that this approach has already found different spheres of application. The main idea, that is the keystone of this approach, is compromise.

Usually we consider the control problem solving as an optimization of some function. Such function (it could be, for example, cost function) consist of some variables, which are used for uncertainty simulation and we could guarantee its value only with some probability. Moreover, when we increase the probability, the function value becomes worse, and vice versa. That is why it is a question of necessity to reach a compromise. Of course, it also depends on problem formulation and our goals.

Uncertainty could emerge in different cases. For example, structure uncertainty could be attributed to the situation, when we do not have exact data about system dynamic, and in the same time, the input data uncertainty is connected with some unknown exogenous signals. Scenario approach is some kind of tool in solving such type of cases.

In this part of article we will briefly consider this approach for better understanding of its adjustment to the first one. Let us introduce some denotations, which are used in scenario approach, and which we will use further:

- elements attributed with uncertainty we will denote as δ, when Δ is a specified range for δ,
- let us define $\theta \in R^d$ as variable vector, which we could measure. Thus, unlike δ, $\theta$is chosen by user. For example, θ could be parameters of some controller,
- and, finally, function, which we want to optimize $\zeta(\theta, \delta)$.

The simultaneous existence of θ and δ means only partial knowledge about final results of optimization is accessible because of θ. The reason is dependence of results from uncertainty δ.

Such conditions bring us to the problem optimization with uncertainty, which looks like:

$$\min_{\theta \in R^d} \ell\left(\theta, \delta\right), \delta \in \Delta. \tag{4}$$

However, this problem is not fully formalized, because Eq. (4) does not describe the way, how we could take into consideration δ, when we optimize function. The solving of such problem requires more detailed information about uncertainty type. That is why there are different types of approach, emerging depending on different formulations. Among these is scenario approach.

It looks like a symbiosis of worst-case approach and method of averaging. In addition, it uses probability to find out the chances, that some level of productivity will be reached. Moreover, this approach considers optimization problems, where the level of robustness is modulated.

When we consider some example, the problem formulation is sounded as minimizing of maximum cost with maximum taken from reduced set $\Delta_\varepsilon \subset \Delta$ with probability $Pr\Delta_\varepsilon = 1 - \varepsilon$:

$$\min_{\theta \in^d, \Delta_\varepsilon} [\max_{\delta \in \Delta_\varepsilon} \ell\left(\theta, \delta\right)]. \tag{5}$$

Defining optimal solution in Eq. (5) as θ^*, and optimal function value as ζ^*, it is possible to combine these two parameters:

$$\ell_\varepsilon^* = \max_{\delta \in \Delta_\varepsilon} \ell\left(\theta, \delta\right). \tag{6}$$

Thus, the value ζ_ε^* is guaranteed independently from all issues of uncertainty from Δ_ε with probability $1 - \varepsilon$.

The reason, why we reduce the set, is the wish to receive a smaller optimal function value in comparison with worst-case approach. The level of robustness depends on ε, and, for received ε, the set Δ_ε must be chosen so, that we could reduce the optimal value as far as possible. Parameter ε could be varied and adjusted according to user preferences: the bigger value of ε the better system works, but the higher risk of error emerging. It is also important to mention, that level of robustness could be controlled.

In conclusion, it is important to notice, that this approach is unique tool in compromise gain process.

4 Problem Formulation

Let us consider the trading strategy under idealized market conditions with using PI-controller, which we have already considered in the first part of this article. Thus, assume that our trading strategy is looks like:

$$I(t) = K_p\left(g_L(t) - g_S(t)\right) + K_I \int_0^t \left(g_L(\tau) - g_S(\tau)\right) d\tau, \tag{7}$$

where $I(t)$ is the amount of further investments, g_L and g_S are the trading "long" or "short" gains, according to the chosen case and K_P and K_I are the feedback coefficients.

We still work under the same idealized market conditions:

- continuously transactions, by this we understand, that the amount invested can be continuously updated;
- perfect liquidity-no gap between bid and ask;
- the trader is price taker or transactions that are undertaken by user do not influence the market;
- zero transaction costs-no taxes, no fees and no commissions;
- adequacy of resources-there are enough resources, which allow to trader to make a necessary maneuvers;
- no interest and margin charges neither for our bank account, where we hold our money for further investment, nor for received trading gain.

Assume, that the market situation is governed by non-trivial GBM and stock prices behave accordingly:

$$\frac{dp}{p} = \mu dt + \sigma dZ, \tag{8}$$

where $Z(t)$ is a standard Wiener process, μ is a drift parameter, and $\sigma -$ volatility. In addition, we are going to consider the stochastic differential equation for the trading gain g. Here we will consider the equation for the "long" position, however the same could be applied for the "short" case:

$$dg_L = \frac{dp}{p} \times I = (\mu dt + \sigma dZ)(I_0 + K_p g_L(t) + K_I \int_0^t g_L(\tau)\, d\tau). \tag{9}$$

Returning to the Eq. (7), we have a function ζ of g_L, g_S , K_P and K_I:

$$\ell\left(g_L, g_S, K_P, K_I\right). \tag{10}$$

Further, we are going to use scenario approach to reach a goal. Thus, we will draw similarities between it and current trading strategy.

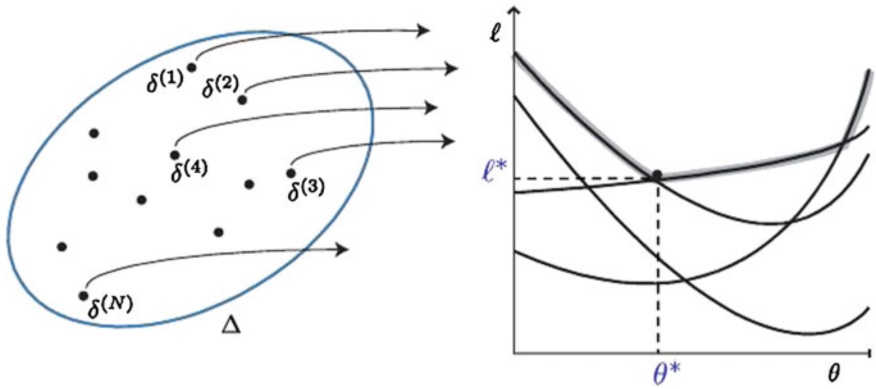

Fig. 1 The "scenario paradigm"

Thereby:

- elements attributed with uncertainty, and which were previously denoted as δ, now are attributed as K_P and K_I,
- and we have parameters, which we could evaluate: g_L is a θ_1 and g_S is a θ_2,
- and, finally, our function, which we want to optimize: $I(g_L, g_S, K_P, K_I)$ (we want to minimize the amount of investments I, given that we want to maximize trading gain g).

Further, we are going to consider the part of scenario approach. Figure 1 was borrowed from the presentation of EECI International Graduate School (graduate course on the Scenario approach, Care et al. [5]). It shows schematically the main principal of scenario approach. Here we can see $\delta^1, \delta^2, \delta^3 \ldots$ (or in our case the feedback coefficients), which we are going to pick from our hole set. Then we are searching for optimal solution with the definite amount of scenarios. The question is, how many scenarios school we take?

Next, we are going to consider the theorem of scenario approach, which will give us the answer. It has a name of ε-robustness, see Eq. (8).

Theorem 1 (ε-robustness)
Fix $\varepsilon \in (0, 1)$ (risk parameter) $\beta \in (0, 1)$ (confidence parameter). If

$$N = \frac{2}{\varepsilon}\left(\ln\frac{1}{\beta} + d\right), \tag{11}$$

then, with probabilit $y \geq 1 - \beta$, ζ^* is ε-risk guaranteed.

Here N is a number of scenarios or models and d is the number of θ, in our case it equals to 2.

Let us consider the "family" of $\{K_P, K_I\}$: $\left\{K_P^1, K_I^1\right\}, \left\{K_P^2, K_I^2\right\} \cdots \left\{K_P^n, K_I^n\right\}$. In addition, its corresponding outputs: $I_1, I_2, \ldots I_n$. By applying "$\varepsilon-$robustness" theorem, we receive, that:

Theorem 2 *If $n = N$ and we fix $\varepsilon \in (0, 1)$ and $\beta \in (0, 1)$, then the optimal value of the investment function ζ^* is ε-risk guaranteed, with probability $\geq 1 - \beta$.*

5 Conclusion

In this chapter, the consideration of two approaches was made for its further proper combination. The problem was briefly formulated. Scenario approach is used to define the coefficients of PI- controller optimal choice. In future works the problem formulation will be considered more detailed, and it is the question of necessity to consider a simulation of this case.

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A New Condition Monitoring Approach for Maintenance Management in Concentrate Solar Plants

Carlos Quiterio Gómez Muñoz , Fausto Pedro García Marquez, Cheng Liang, Kogia Maria, Mohimi Abbas and Papaelias Mayorkinos

Abstract The concentrated solar energy is one of the most important renewable energy source. It is crucial to ensure that the solar receivers work properly to avoid failures, and to increase the reliability, availability, safety and maintainability. Non-destructive testing (NDT) is used in structural health monitoring systems for fault detection and diagnosis (FDD). The main purpose of this paper is to present a novel approach for FDD based on long range ultrasonic technology, together with a signal processing of ultrasonic waves (Shear waves) employing wavelet transforms using a variable window size. A new electromagnetic acoustic transducer (EMAT) generates high frequency waves that flow through the material. A similar transducer is also employed as a sensor to collect the guided wave. These waves have a particular behaviour according to the condition of the material. It is analyse the influence of the temperature in the propagation of an ultrasonic pulse through the material. This information is very useful to carry out a proper signal analysis in order to find cracks or failures on the pipes, the correct operation of the system, etc.

Keywords Maintenance management · Concentrated solar plants · Wavelet transform · Electromagnetic acoustic receiver · Parabolic through receiver · High temperature ultrasonic signals

1 Introduction

Non-destructive testing (NDT) for fault detection in structures have gained relevant attention in recent years due to significant advances in instrumentation technology and digital signal processing. Techniques for Structural Health Monitoring (SHM)

C.Q. Gómez Muñoz(✉) · F.P. García Marquez
Ingenium Research Group, Castilla-La Mancha University, Ciudad Real, Spain
e-mail: carlosquiterio.gomez@uclm.es

C. Liang · K. Maria · M. Abbas
Brunel Innovation Centre, Brunel University, London, UK

P. Mayorkinos
University of Birmingham, Birmingham, UK

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permit to identify and diagnose the fault and its location on the basis of changes in static and dynamic structure features. In addition, these techniques can be remotely controlled and they may work online saving important costs associated to manual inspections and warning times. The capability of NDT to prevent faults is one of their main advantages, which typically achieve a better reliability, availability, maintainability and a cost reduction of the system [7, 13].

Within the NDT field, guided waves are a common technique employed for SHM. These waves are particularly useful in geometries such plates or tubes. This technology is based on the excitation of low frequency ultrasonic waves flowing along the pipeline over long distances and allowing inspections of large areas without any relocation of the actuator, as it occurs in classical ultrasonic methods [3]. This technology may be used in pipelines under working conditions and it can be inspected from a single position, what is particularly indicated when monitoring inaccessible areas, e.g. isolated materials, partially buried structures, corrosive atmospheres or structures under the sea [15]. Since these signals can be recorded and processed, novel methodologies are arising so as to perform predictive analysis in real time.

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The temperature can cause structural problems in the medium and long-term. Note that this study is crucial since the cost of PTR can reach the 30 % of the overall solar field cost. Therefore, the correct maintenance of the receivers is of paramount importance to assure that CSP plants work properly [6, 10]. The average annual PTR replacement rate from 1997–2001 was about 5.5 % [14]. Nowadays, it has been reduced to 3.37 % [10] and forecasts indicate that the replacement rates should decrease up to 0.5 % for a near future [14].

The FDD proposed is able to detect faults or structural modifications, e.g. scratches, cuts, changes in thickness or edges by identifying pattern changes in the input-ouput signals [11]. The signal processing is based on system identification techniques in discrete time to estimate potential changes, employing Wavelet Multisignal Analysis in one dimension will be employed to identify the structure at different temperatures.

2 A New Electromagnetic Acoustic Transducer for Condition Monitoring

The Electromagnetic Acoustic Transducer (EMAT) (Fig. 1) is a transducer for non-contact sound generation and reception using electromagnetic mechanisms. It has been widely used in non-destructive testing in the generation of Shear and Lamb waves [2]. A new EMAT has been developed specifically for this purpose, with a specific configuration of coil and magnets.

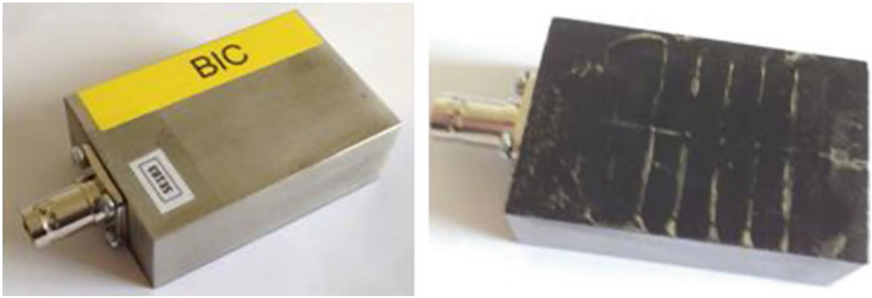

Fig. 1 Picture of 1st generation EMAT transducer

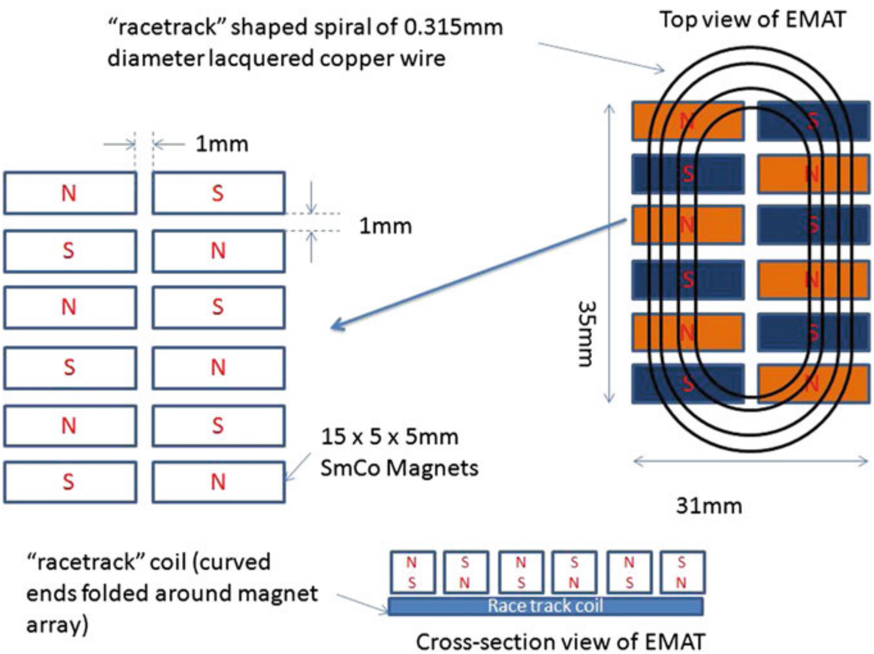

Fig. 2 First generation EMAT transducer

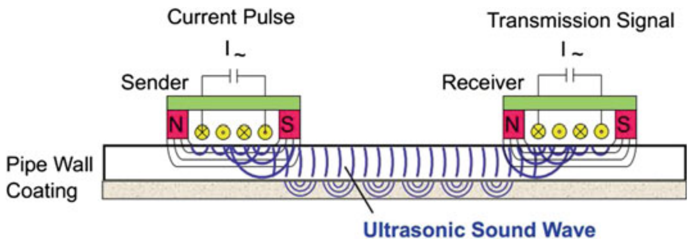

Fig. 3 Principle of EMAT transmitter and receiver for longitudinal inspection

Considering the dimension of the pipe (outer radius 35 mm) and the review on EMAT configuration, a design of the EMAT transducer for this application is shown in Fig. 2, using PPM and race track coil to generate SHO mode in a plate or equivalent $T(0, 1)$ mode in a pipe. The dimension of each magnet is 15 mm × 5 mm × 5 mm. The distance between magnets is 1 mm. In addition, the magnetic strength of each magnet is $0.3T$. The diameter of coil is 0.315 mm and the width and length are 15 and 35 mm respectively with a lift-off distance 0.1 mm to the sample.

The type of EMAT configuration shown in Fig. 3 is mainly to detect transversal defects (spiral cracking, blowout holes, circumferential cracking, bell splitting, etc.). In this case, Lorentz forces are generated normal to the tube wall, and so that the compressive forces produce ultrasound propagating along longitudinal direction through the tube/pipe for inspection.

3 Experiments

An experimental platform that comprises a high power pulser-receiver and a condition monitoring system based on electromagnetic acoustic transducers placed on an austenitic stainless steel plate is designed in order to illustrate the results (Fig. 4). The

Fig. 4 Placement of the EMAT on austenitic steel plate

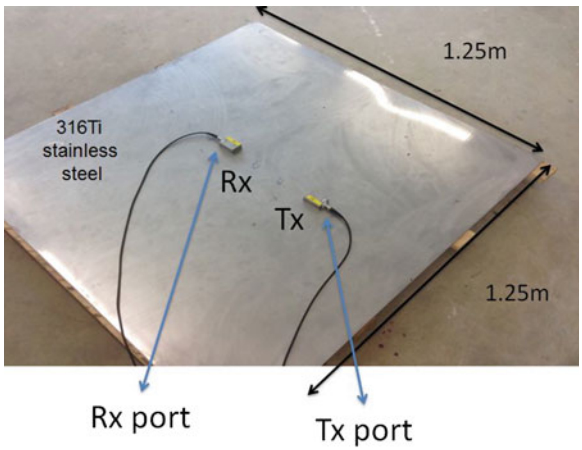

Table 1 Physical properties of $316Ti$ steel and the influence of temperature

Thermal expansion	$10e^{-6} \times Ke^{-1}$		16.5	17.5	18	18.5	19
Modulus of elasticity	longitudinal Gpa	200	194	186	179	172	165
Poisson number	μ	0.3					
Electrical resistivity	$\Omega mm^2/m$	0.75	0.79	0.87	0.94	0.98	1.02
Electrical conductivity	$Siemens \cdot mm^2/m$	1.33					
Specific heat	J/(kg K)	500	500	520	530	540	540
Density	kg/dm^3	8					
Thermal conductivity	W/mK	15	16	17.5	19	20.5	22
Relative magnetic permeability	$\mu \gamma$	1.02					
Temperature (°C)		20	100	200	300	400	500

plate material is the same as that used in the solar concentration pipes ($316Ti$, standard carbon 3116 Type with titanium stabilisation). The properties of this material and the influence of temperature thereon is found in Table 1.

The plate is heated with a heater pad for the tests of emission and reception of ultrasonic pulses by the EMAT from 40 to 180 °C (see Fig. 5). Each test was performed when the temperature increased 10 °C. It has been used a 6 cycles Hanning pulse with a frequency of 256 kHz to excite the EMAT.

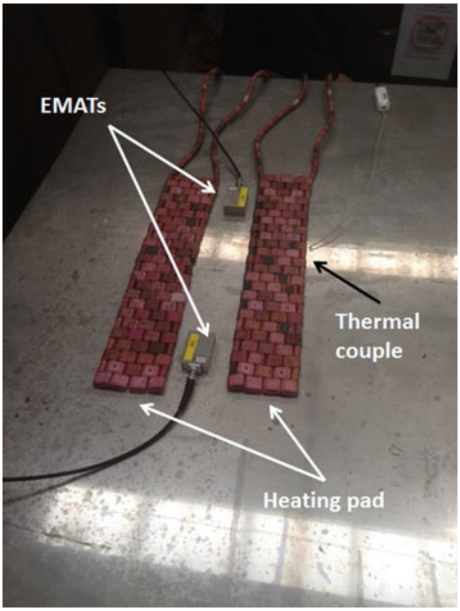

Fig. 5 Heater pad on the plate

4 Wavelet Transform

Wavelet transform (WT) improves the limitations of resolution and the loss of information presented by the Short-Time Fourier Transform or the Fast Fourier Transform [5]. This technique uses a variable window size, using large windows where it is required accuracy in low frequencies, and using small windows where the information is in the high frequencies (Fig. 6). Other way to understand the operating mode of the WT is to think that the signal passes through a low pass filter and high pass filter. The resulting signal from low pass filter is the approximations A_i, and the resulting signals from the high pass filter are the details D_i (Fig. 7), where c is the subsampling. For discrete signals it can be applied single-level or multi-level filters. The sum of the approximations and details should be given as a result the original signal.

Wavelet transforms are commonly categorized as Continuous Wavelet Transforms (CWT), Discrete Wavelet Transforms (DWT), Wavelet Packet Transforms (PWT) among others [4, 8]. The mother wavelet, which is given by the Eq. (1).

$$\Psi_{s,T}(t) = \left(\frac{1}{\sqrt{s}}\right)\Psi\left(\frac{t-T}{s}\right), \tag{1}$$

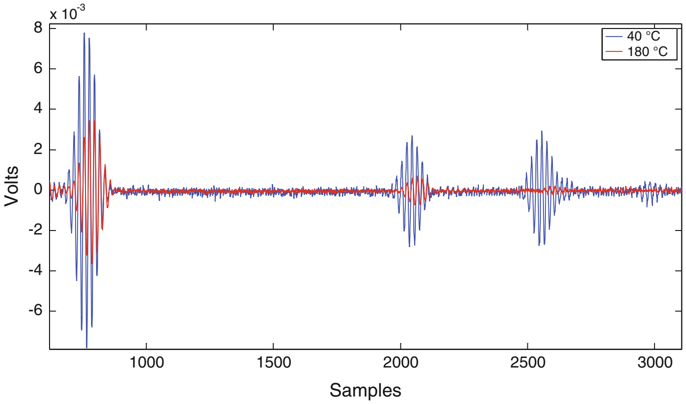

Fig. 6 Signals obtained by the EMAT with the plate at 40 and 180 °C

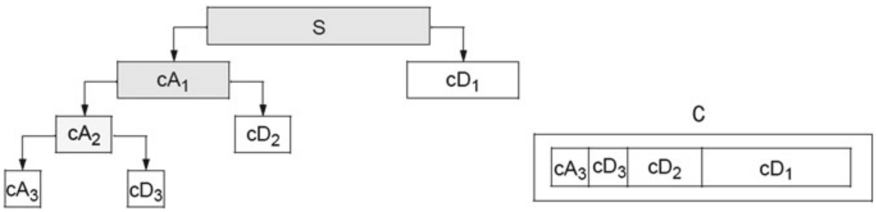

Fig. 7 Wavelet decompositions levels with subsampling

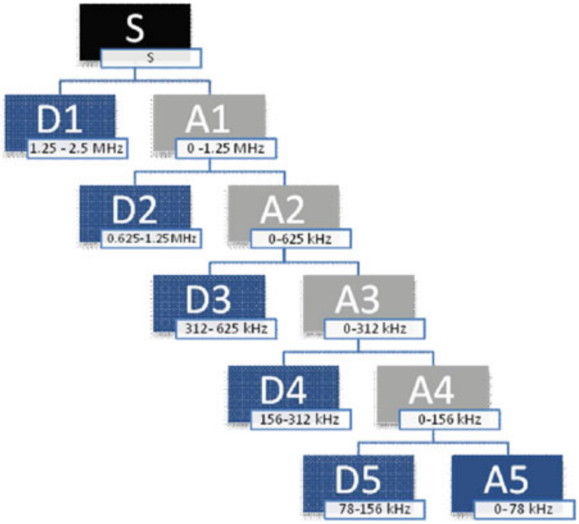

Fig. 8 Wavelet decompositions levels for ultrasonic signals received by the EMAT

where s is the scale factor, and τ is the translational factor. The wavelet transform $W_{f(s,\tau)}$ of a function $f(t)$ is the decomposition of $f(t)$ in a set of functions forming a base with the conjugate of the mother wavelet $(\psi^{*}s, \tau_t)$. It is defined in Eq. (2):

$$W_{f(s,T)} = \int f(t)\psi^{*}_{s,T}(t)dt. \tag{2}$$

The most recurrent families of wavelet transforms are Haar, Daubechies, Biortogonal, Coiflets, Morlet or Symlet transforms. The selection of a particular family can be set by the application where the wavelet is introduced [12].

It was used a multi-signal analysis, to analyse different scenarios together, and it is obtained the energy of each signal. On the other hand it is obtained the percentage of information of the decompositions in each signal. It was used the daubechies wavelet family, which according to [9] are the most suitable for this type of signals, because it are more sensitive to sudden changes. The number of levels that reports best results was five. Figure 8 shows the five levels of decompositions with their respective frequencies for the signals obtained in the experiments.

5 Results

Table 2 shows the results after the analysis of the signals for each temperature of the steel plate. It is showed the resulting energy for each signal according to the chosen wavelet decomposition, and it is also presents the percent of information of each of the five decompositions (approximation and details). In all cases the D4

Table 2 Wavelet decompositions and energy of the signals at different temperature

Wavelet Decompositions							
Temperature (°C)	D1 (%)	D2 (%)	D3 (%)	D4 (%)	D5 (%)	A5 (%)	Energy
40	0.48	0.47	8.16	89.64	0.14	1.10	2.82E-03
50	0.10	0.26	7.56	90.44	0.10	1.55	2.35E-03
60	0.13	0.37	7.39	89.82	0.25	2.04	1.84E-03
70	0.14	0.42	7.19	89.31	0.49	2.45	1.49E-03
80	0.17	0.50	7.04	89.14	0.68	2.47	1.19E-03
90	0.20	0.65	7.03	88.87	0.74	2.51	9.96E-04
100	0.24	0.76	6.95	89.01	0.79	2.25	8.32E-04
110	0.28	0.94	6.86	89.34	0.64	1.94	6.98E-04
120	0.35	1.03	6.68	89.74	0.47	1.73	5.76E-04
130	0.37	1.09	6.61	89.88	0.30	1.74	5.32E-04
140	0.38	1.11	6.68	90.05	0.17	1.62	5.11E-04
150	0.40	1.09	6.79	90.17	0.14	1.41	5.13E-04
160	0.39	1.09	6.61	90.55	0.18	1.19	5.15E-04
170	0.49	1.14	6.61	90.40	0.17	1.18	5.04E-04
180	0.49	1.14	6.61	90.40	0.17	1.18	5.04E-04

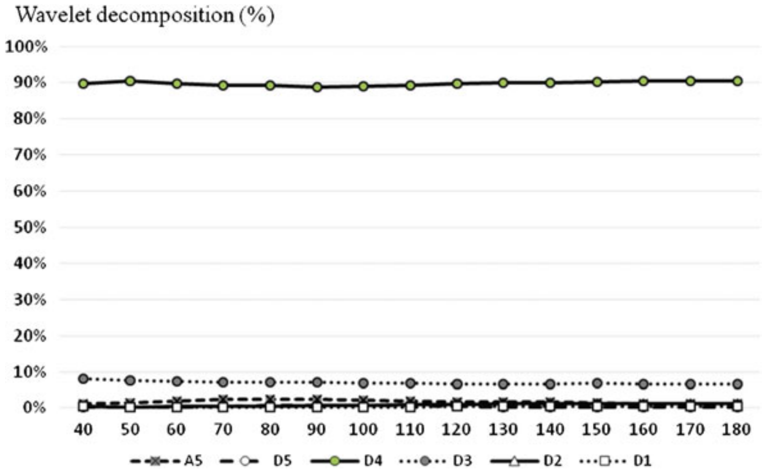

Fig. 9 Percentage of signal information in each decomposition

decomposition contains the highest percentage of information of the original signal ant it is associated with the frequency range 156–312 kHz. And it is consistent with the excitation frequencies of the Hanning pulse used in the actuator (256 kHz). This allowed study the frequencies of interest from other frequencies.

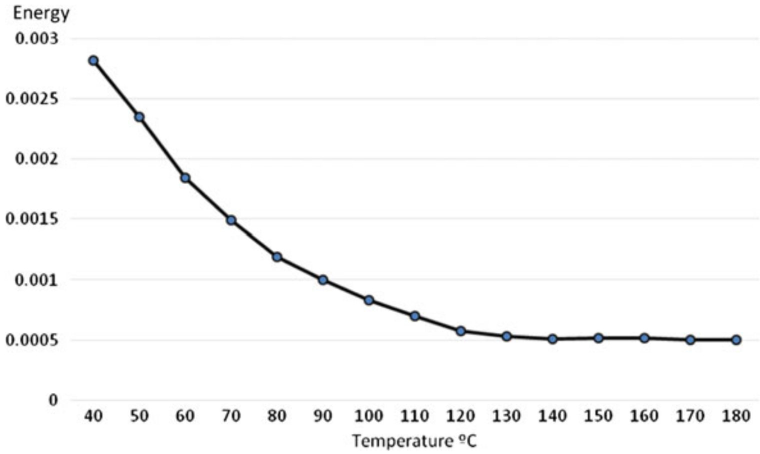

Fig. 10 Energy of ultrasonic signals for each temperature

Figure 9 shows that D4 wavelet decomposition present the main percentage of energy of the signal in the frequency range of 156–312 kHz, which is consistent since the excitation ultrasonic pulse is 256 kHz. Finally a multi-signal processing analysis employing wavelet transforms is done, providing a value of energy for each signal.

Figure 10 shows that the energy decreases exponentially with increasing temperature. This is due to, although the frequency remains constant, the signal amplitude decreases as the temperature increases because it changes the parameters such as Young's modulus and Poisson's ratio and this affects the velocity of wave propagation.

6 Conclusions

The development of condition monitoring techniques together with the use of advanced signal processing approaches to reduce the failure rate of Parabolic Trough Receivers (PTR) has been done in order to increase the reliability, availability and investing returns in the generation of electricity by means of solar energy. PTR works at high temperatures where the properties of the ultrasonic inspection is affected. This work reports a novel methodology to control the condition of the PTR steel part by means of ultrasounds and digital signal processing. Particularly, a method for identifying changes in the ultrasonic signals due to changes in temperature is crucial to detect any anomaly in the pipes with greater efficiency.

Significant discrepancies between the energy measurements can work as an alarm signal to activate maintenance operations. Case studies based on laboratory experiments have been done in order to demonstrate this novel approach.

Acknowledgments This work has been supported by the EU project INTERSOLAR (Ref.: FP7-SME-2013-605028), the MINECO project WindSeaEnergy (Ref.: IPT-2012-0563-120000) and Sonemat for manufacturing the transducers.

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Research on the Resource Utilization of Soft Sandstone in the Mu Us Sand Land Region During the Land Consolidation Project

Lintao Luo and Huanyuan Wang

Abstract This paper presents research on the technological transition of soft sandstone from a single control object to a comprehensive resource utilization object and proposes a feasible resource utilization method for soft sandstone in the Mu Us Desert based on the Land Consolidation Project practice and experimental analysis. The research showed that remixing the soil with soft sandstone and sand was an effective measure to achieve soft sandstone resource utilization. This technology improved the adverse nature of the sand, so that it both retains water and nutrients, allowing the sand to become high-quality arable land and significantly improve crop yields. Further, the soft sandstone and complex soil have a significant effect on sand fixation. These research findings have already shown significant economic, social and ecological benefits in the pilot application in the land development and demonstration project at Dajihan village in Yuyang district, Yulin City, Shaanxi Province, where there has been a quality improvement of 2100 ha land and an new arable land increase of 1573.3 ha. Resource utilization soft sandstone has important theoretical and practical significance to soil erosion control and the comprehensive utilization of desertified land in this area.

Keywords Soft sandstone · Remixing soil · Land reclamation · Resource utilization · Mu Us sandland

L. Luo (✉)
Institute of Water Resources and Hydrology-Electric Engineering,
Xi'an University of Technology, Xi'an 710048, People's Republic of China
e-mail: 12600357@qq.com

L. Luo · H. Wang
Shaanxi Provincial Land Engineering Construction Group CO., LTD., Shaanxi Province Land Reclamation Engineering Technology Research Center, Key Laboratory of Degraded and Unused Land Consolidation Engineering, The Ministry of Land and Resources of China, Xi'an 710075, People's Republic of China

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1 Introduction

Soft sandstone is ancient Permian, Mesozoic Triassic, Jurassic and cretaceous layered thick sandstone, with a sand shale interbed and argillaceous sandstone rocks [10]. Soil and water loss in the soft sandstone areas is serious because of soil erosion hazards and leaching [17]. Soft sandstone is mainly distributed east of the Yellow River, west of the Hangjinqi fault line, from northwest to southeast long the northeastern edge of the Mu Us Desert, south of the city of Shenmu County, Shaanxi Province, and on the northern edge of the Kubuqi desert, at latitudes $38°10' \sim 40°10'$ and longitudes $108°45' \sim 111°31'$, with a total area of about 16,700 km^2 [18]. According to the survey, there are also over 3600 km^2 of distribution in Yuyang District and Jia county, Yulin City, Shaanxi province.

Soft sandstone is an important part of the coarse sand in the Yellow River Basin area, which is characterized by small thickness, low pressure, a low degree of diagenetics, and a low degree of cementation between the sand and the structural strength level. Soft sandstone when dry can be as hard as stone, but when wet, can become like mud, can be easily eroded by wind, and becomes loose like sand after rain and freezing. Rainfall runoff makes soft sandstone the main source of coarse sediment in a flood in a soft sandstone area [8]. Further, as a storm center in the Loess Plateau region, the soft sandstone area has complex erosion because of the storms and sparse vegetation [25], and suffers greatly from erosion [11]. Part of the local ecology is extremely fragile and some areas has become barren and uninhabitable. This area is known for having some of the world's most serious soil erosion [17].

There have been many attempts using plant management [2, 22], project management [1, 13], and comprehensive management [12], to change the landscape features of the soft sandstone area [19–21]. Results have confirmed that the weathered red sandstone is useful as an impermeable material [9], and the arsenic sandstone can also be used in such areas as road construction, pigsties and cellars [23]. These studies, however, have not resolved the problems of the ecological environment nor optimized the use of the resources in the soft sandstone areas.

To curb the sharp drop in China's cultivated land area, the strategic restructuring of rural land is being promoted to improve agricultural production, so the edge regional resources of the Mu Us Desert are being developed to make full use of the soft sandstone to improve guaranteed cultivated land quantity. Since 2009, the author's research team has been conducting in-depth research focusing on the reconstruction of the plow layer in the Mu Us Desert. Through field investigation and sampling, indoor simulation experiments, plot trials, field demonstrations and project promotion tests, the research team has conducted systematic experiments and research on technical rationality, feasibility and safety in the reconstruction of the plow layer through soft sandstone renovation. In addition, combined with the land reclamation project, we have developed a new technical utilization for the soft sandstone by developing the sand into farmland [4, 15, 16].

2 Sand Control and the Reconstruction of Magnetic Arsenic Sandstone Properties Research

The focus of this research was to determine whether sandstone could be a new important material for the Mu Us Desert development and reconstruction. Sandstone and sand mixed together were assessed as to whether they were able to provide a suitable soil for crops and whether they had suitable characteristics such as water retention, organics, nutrients and sustainability.

2.1 Arsenic Sandstone Investigation

Sand is the main soil type in the Mu Us Desert. Sand has no structure and is extremely porous. The most common means of improving sand is to mix it with heavy clay soils to change the texture so as to allow the soil to retain water and nutrients. Sandstone consists of quartz, calcium montmorillonite, feldspar and calcite and other minerals [14]. Among these, calcium montmorillonite swells in water and has strong water retention n. From a particle composition perspective, sandstone silt is 50 % or more of the content, but with a clay content higher than sand, the bulk density is generally between 1.2–1.7 g/cm^3, and compacts easily. There is little organic matter, N, P, K or other nutrients in sandstone so sandstone by itself is unable to provide a suitable habitat for crops.

The key to land remediation engineering resources is sandstone and sand earth technology [3], which is a method of crushing the sandstone into different sizes and thoroughly mixing it in proportion with the sand. In this study, we set different proportions (0 : 1, 1 : 5, 1 : 2, 1 : 1, 2 : 1, 5 : 1, 1 : 0) for the sandstone and sand mixtures for the compounded soil. From the complex measurement results on the physical and chemical properties of the soil, the soil rendering "Sand-sandy loam-loam-Pink soi" appeared as the proportion of sandstone increased, as shown in Table 1. As shown in Table 1, after the sandstone was mixed with the sand, the structural properties of the sandy soil showed a significant improvement. The saturated hydraulic conductivity decreased significantly compared to the total sediment. A mixing ratio of 1 : 5 to 1 : 2 was found to be the point at which the mixed samples' saturated hydraulic conductivity decreased from fast to slow.

The proportional range was in an ideal hydraulic conductivity range. The sandstone content increase had a positive effect on improved synthesis soil structure, but if the "degree" was too much, the complex soil permeability was affected. At the same time, capillary porosity increased from 26.33 to 44.94 % with an increase in the sandstone in the mixing ratio. These results were sufficient to prove that after the sandstone was mixed with the sand, the non-capillary porosity changes to capillary porosity, and as capillary porosity increases, more water was retained, which ensured a good environment for crop growth. However, complex organic matter content was still very low, with a change only in the range of 0.42∼1.06 g/kg, which was far

Table 1 Compound feldspathic sandstone and sand soil physical properties at different ratios

Item	Sand (0.05–2 mm)	Silt (0.002–0.05 mm)	Clay (<0.002 mm)	Texture (USDA)	SOM (g/kg)
Mixing Ratio (Feldspathic sand stone: Sand)	0 : 1	95.31	4.45	Sandy	0.53
	1 : 5	83.33	14.97	Loamy sand	0.43
	1 : 2	60.70	35.09	Sandy loam	0.48
	1 : 1	52.65	42.26	Sandy loam	0.42
	2 : 1	50.37	44.4	Sandy loam	0.77
	5 : 1	42.44	51.51	Silt loam	1.05
	1 : 5	83.33	14.97	Loamy sand	0.43

Classification of soil texture was according to USDA

below the normal nutrient indicators to ensure crop growth. Therefore, the use of organic fertilizers was going to be needed [5].

However, after one cropping season, the physical and chemical properties of the sandstone and sand mixed soil at the ratios of 1 : 2 and 1 : 5 were more complex, with the average organic matter content increasing by 0.465 and 0.695 g/kg. This increase in organic matter showed an increasing trend with the number of crop seasons. The water stability content aggregates were greater than 0.25 mm in the complex soil after cropping in the second quarter and reached 20.82 and 22.82 % respectively, an increase of 1.38 and 2.44 % compared to before the mixed planting. The soil aggregate size was found to be distributed more evenly and the soil structure gradually improved. Therefore, after the sandstone and sand mixed soil, soil quality standards not only met crop cultivation standards such as soil fertility, but the crop production was very impressive. Corn and potato yields were 9.9, 8.25 t/ha and 22.5, 35.24 t/ha in the 1 : 2 and 1 : 5 complex soil, respectively. Corn yields were higher in the 1 : 2 complex soil, and potato yields were higher in the 1 : 5 complex soil [26].

2.2 Analysis of the Complex Soil's Water Retention and Water Holding Capacity

Sandy soil has poor water retention, and is prone to overall water shortages. Therefore, Mu Us Desert sandstone water retention could be improved with the use of the complex soil.

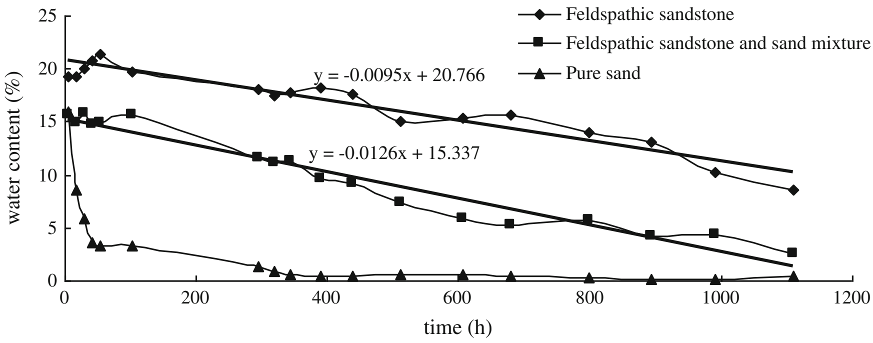

Fig. 1 Water content changes in the feldspathic sandstone, sand and compound soil along with time

With sand as the control substance, the sandstone rock, and the soft rock and sand mixture trends are shown in Fig. 1 after 1110 h of observations. As can be seen, the changes in the sand moisture content were divided into three phases: in the first phase, the sand moisture content quickly reduced from 15.90 to 3.26 % within the first 54 h. In the second phase, the water content gradually decreased from 3.26 to 0.64 % from 54 to 342 h. In the third phase, the moisture content reached a minimum and stabilized. However, compared with the changes in the moisture content of the sand, the sandstone rock, soft rock and sand mixture moisture content had the same trends over time, decreasing by 10.73 and 13.06 % when the slope was 0.0095 and 0.0126. This demonstrated that the sandstone had strong water retention and permeability was slow. The change in the water content of the soft rock could also be divided into two stages: Within the first 54 h, the soft rock absorbed moisture, increasing from 19.29 to 21.39 % [26]. After 54 h, the water content continued to decline. The water content of the mixture of sandstone and sand was divided into two stages, with the water content remaining between 14.76 to 15.87 % within the first 54 h; and then the water content continued to reduce. Several sets of experimental data were obtained. The water retention properties of the sand was poor, the mixture of sandstone rock and sand, the soft rock equivalent of an “absorbing agent” and insurance agent, was able to absorb and store water when the mixture was wet and soil moisture was steady in the soft rock and sand mixture. 54 h later, the sandstone and sand mixture still slowly released water but the sand had no ability to release water. In conclusion, the sandstone had significant water retention characteristics and when combined with sand, released water slowly [4, 15].

2.3 Analysis of Soil Quality

The quality of the soil determined whether it could be used for agricultural production. In the test analysis of the heavy metal content of the complex soil, sandstone and sand in addition to the Hg element it was found that complex soil > arsenic Sandstone > sand, and for the other seven elements, the arsenic sandstone > the complex soil > sand. Besides exceeding the national average environmental quality concentration for Cd by of 0.27 times, the average level of the other heavy metals in were within the natural background value, indicating that all soil types would have no adverse effects on agricultural production.

The average content of Cr, Ni, Cu, Zn, As, Cd, Hg and Pb in the Arsenic sandstone was 24.93, 15.80, 8.70, 9.81, 12.52, 0.406, 0.063 and 20.84 mg/kg. The average content of Cr, Ni, Cu, Zn, As, Cd, Hg and Pb in the compounded soil was 21.73, 9.37, 4.86, 4.97, 6.28, 0.253, 0.074 and 17.91 mg/kg, except for Hg, which , compared with the Arsenic sandstone's, Ni, Cu, Zn, As, Cd and Pb in the compound soil fell 0.13 times, 0.41 times, 0.42 times, 0.49 times, 0.50 times, 0.38 times and 0.14 times, respectively, which indicated that the compounded soil could reduce the soil pollution.

Using a single factor pollution index method and a comprehensive pollution index method to evaluate the pollution levels in the arsenic sandstone and compounded soil, it was found that each single contaminate index for heavy metals in the compounded soil and the arsenic sandstone and soil was less than 1, indicating that none of the three soil types had any heavy metal pollution.

2.4 Sand Stabilization

Dust emission is closely related to agricultural use. Sandy soil has bigger particles, so when the wind is strong, it tends to be lifted easily, causing dust and sand storms. However, dry cohesive soil has small particles, so can be lifted easily when the wind speed is slight. After the arsenic sandstone was compounded with the sand, because the arsenic sandstone had a silt content as high as 58.09 %, the compounded soil particles blocked the surface sand pores when wet, and formed a physical crust of about 0.9 mm. Wind tunnel tests showed that this physical crust could significantly increase the speed at which wind begins to cause dust, meaning that the crust protected the soil from wind erosion [6], and it also allowed for the formation of soil micro biotic crusts.

The three soil types's abilities to maintain moisture were also different, with the cohesive soil being the best, and the sandy soil the worst. In sandy soil, moisture easily evaporates and therefore is easily eroded in strong winds. When bound with the clay soils, however, the water retention was found to be higher and the risk of wind erosion lower because the sand was tightly bound between the soil particles. Surface soil water content and snow or ice surfaces in the sand are known to affect wind abrasion quantity and with an increase in humidity decreased dramatically, so wind abrasion quantity was found to be negatively correlated with soil moisture. In the winter, there is snow in this region, and because the soil thermal conductivity of arsenic sandstone and Shafu is lower than in sand, the distribution of the snow on the soil's surface was found to melt more slowly than on sandy soil. From the field measurements in Yuyang district in the winter of 2012 to the spring of 2013, the sandy ground is frozen to a soil depth of 98 cm. The non-farming arsenic sandstone and the Shafu soil mixed in ratios of 1 : 1, 1 : 2 and 1 : 5 had maximum frozen soil depths of 101, 101 and 100 cm respectively, and the farmed arsenic sandstone and Shafu soil mixed in ratios of 1 : 1, 1 : 2 and 1 : 5 had maximum frozen soil depths of 116, 108 and 112 cm respectively. During the growing season, the vegetation cover reduced soil erosion significantly and in the fallow season, the soil's physical crust, snow or the frozen soil layer on the surface formed two to three protective layers, which also significantly reduced the soil wind erosion.

3 Engineering Design

From readings in energy research, the factors affecting the implementation of the engineering solution were GDP, population, industrial structure and urbanization levels.

3.1 Principles of Industrial Design

The Mu Us area is an ecologically fragile area, so when seeking to successfully implement the arsenic sandstone, it was important to ensure adequate project site selection, construction technology, facilities and comprehensive management. Using sound scientific engineering practice, we needed to decide on a rational utilization of the desert resources to ensure the development of good arable land without destroying the local ecological environment, thus realizing a win-win situation between man and nature. The construction needed to follow the following principles.

1. Comprehensive Consideration of the Factors for Project Location
When selecting the project site, there were many factors that needed to be considered.

(1) Priority was given to the natural resources and reserve resources. As arsenic sandstone was the main raw material, to reduce quantities, the site selection needed to be in or near an arsenic sandstone and sandy terrain, and have reasonable topography, materials distribution, and materials reserves.
(2) The natural and social resources of the project site were required to match the farming needs. Light and heat resources in the desert are abundant, but water and water resource utilization were important factors when considering project location.
(3) The project site needed to consider local land use planning policies and the availability of surrounding facilities.

As farmland ecosystems and human activities are closely connected, the site selection had to consider local land use planning restrictions. At the same time, convenient

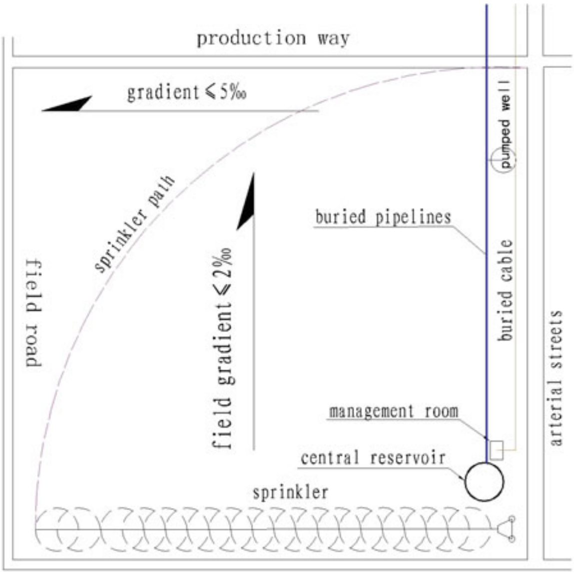

Fig. 2 Typical plots layout chart

access to existing production areas, labor, transportation, electric power and other facilities was necessary. In the Yuyang district, Yulin city, Xiaojihan village and Dajihan village land development project for example, the project site selection mainly considered the distribution of arsenic sandstone resources.

2. Optimization Principle to Determine the Distribution of Soil Construction Technology and Irrigation Systems

(1) The distribution of farmland soil construction technology was required to meet standard farmland norms of a field gradient control within 20 %, a wide edge direction grade control within the scope of 50 %, and an irrigation uniformity and other related technical requirements (see Fig. 2).
(2) Distribution of soil grain size and mixing proportions needed to be strictly controlled. The arsenic sandstone used for the farming layer required a particle size in an optimal gradation range of 2–4 cm and the soil mix distribution needed to be in proportion with the target crops. A sand dune needed to be built to a default height during the construction (see Fig. 3).
(3) The selection and determination of a reasonable water preservation irrigation system. Drip irrigation, sprinkler irrigation and other water-saving irrigation technology can reduce water waste and soil erosion. Further, the well location needed to be carefully planned to support a single well controlled irrigation area, and well spacing was included in the design parameters (see Fig. 4).

3. Scientific Planning Biological Protective Principle

Biological forest design protection is also an important part of desert land engineering designs.

Fig. 3 Feldspathic sandstone and sand compound soil construction figure

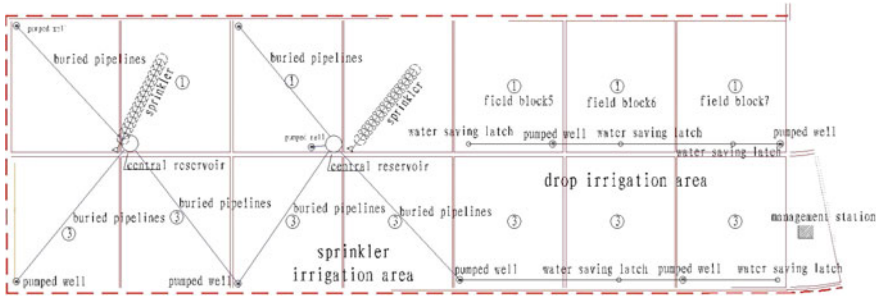

Fig. 4 Field irrigation design

(1) Strengthening biological protection measures, such as increasing the biodiversity of the sand, improving the layouts of the field, using ecological tillage techniques, and preparing for windbreaks and sand-fixation in the fallow periods, were all important to avoid secondary farmland desertification.
(2) The selection of tree and plants species needed to be suitable to the climate and geography to adapt to the desert environment.
(3) Development of the soil crust, and the frozen soil layer and mixed soil surface spraying method for arsenic sandstone area were needed to ensure an immediate effect.

4. Strengthen the Sustainable Fertilizer Training Principles
Soil distribution not only needed to meet the standards required, but also needed to meet the stable-water aggregate retention and required nutrient levels. However, from the sample soil survey, it was found that there was only about 0.22 % organic matter, and total nitrogen and available phosphorus were at level 6, so while the heavy metal content was in accord with crop planting standards, other nutrients needed improvement. Therefore strengthening the use of fertilizer was seen to be a key point in the sustainable utilization (Fig. 5).

(1) The principle of "soil testing formula, balanced fertilization"was strictly adhered to to ensure that the nutrients necessary for crop supply were available, monitored and regulated, to meet the crop growth and development needs.

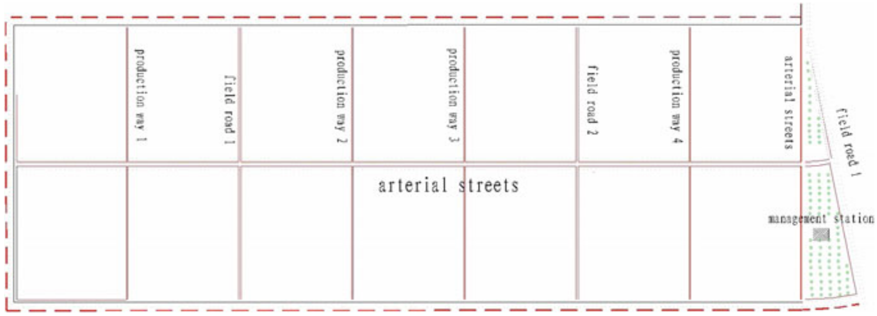

Fig. 5 Agricultural protection forest design

(2) Along with opening of the land to grazing and planting grass, wide fertilizer use was needed to improve irrigation and drainage because of the rapid increase in organic matter content.
(3) The scope of the use of straw was expanded as far as possible and land use was shared between agriculture and animal husbandry.
(4) Green manure and chemical fertilizers were promoted along with the use of organics. Fertilizer use was adjusted to local conditions, as was the planting structure to improve land productivity and soil fertility.

3.2 Application Examples

An engineering pilot program which applied the arsenic sandstone and ShaFu oil blending technology was established in the Yu Yang district, yulin city xiaojihan village dajihan village land development project. The project area was located on the southern margin of the Mu Us Desert sandy lands, 30 km north of the Great Wall, at east longitude 109°29′50 ∼ 109°31′44" and north latitude 38°26′ ∼ 38°27′02"23". The area is a typical dune landscape with groundwater buried at a depth of 1.2 to 2.9 m. The total project total size was 2419.44 mu. Construction was from April 2010 to December 2010 (Figs. 6 and 7).

The project focused on land changes and involved major activities such as arsenic sandstone and sand consolidation engineering, irrigation engineering, road engineering, and a shelter forest project. The flat land area of 161.2959 ha was divided into 28 plots, with each single block being about 85 mu. The arsenic sandstone excavation areas, which has a total of 155,200, was 25 km from the project area. The arsenic sandstone was used in the field and had a uniform coverage, with the thickness of top layer being an average of 10 cm.

From the water resources survey, there was an average of 13.33 ha for the digging of motor-pumped wells. A total of 17 agricultural motor-pumped wells were dug for the 60 m deep groundwater and a buried low pressure pipeline of 5784.5 m was laid.

Fig. 6 Landforms in the project area before the beginning of development

Fig. 7 Potatoes were planted after the land reclamation of project area

Lateral moving sprinkler irrigation was selected for the crop growth conditions to control irrigation time and quantity.

A 5m road was constructed to allow for large-scale machinery operation with the roadbed being compacted with a thickness of 0.3 m and a compaction degree of 0.93 or higher. The project design windbreak forest area width was 8 m, and more than 2 plant species were planted from suitable species such as bluegrass, hippophaerhamnoides, Xinjiang Yang, Pinussylvestris, Amorphafruticosa and others.

After the engineering demonstration projects were completed, crops were planted which slowly improved the ecological environment. From the 2011 $\sim$ 2013 farming results compared to the Jianping Li [7] survey in 2008–2010, the grain yield was the highest at 4308 kg/ha. The potato and maize yields in the demonstration project reached 37.5–45.0 t/ha and 13.5–14.25 t/ha. From the normal market price, the demonstration project annual net income was more than 4 million yuan, indicating that this demonstration project had remarkable economic, social and ecological benefits (Fig. 8).

Fig. 8 Graph of demonstration project

4 Conclusion and Discussion

Comprehensive land management work is an important way to insure our country's economic and social development in agricultural and city supporting rural areas. This paper presented the results of a comprehensive research project which focused on the Shanxi, Shaanxi and Inner Mongolia soft rock areas, which have ecological fragility, severe wind erosion and low soil fertility. This paper presented a mechanism whereby arsenic sandstone was converted to usable land, and the feasibility of land reclamation engineering was demonstrated. Yu Yang district's Xiaojihan township Dajihan village was developed as an engineering demonstration project site, the results of which showed that the demonstration project achieved remarkable economic, social and ecological efficiency.

Arsenic sandstone areas have serious soil erosion, but arsenic sandstone compounded with a certain percentage of sand was shown to increase land resource utilization. When arsenic sandstone was compounded with sand, the quality of the sand was improved and the compounded soil had good water and air permeability. After cropping, the compounded soil structure was further improved and as soil fertility improved, crop yields increased steadily. Arsenic sandstone has good water and nutrient retention and can effectively store water when there is abundant water. Further, when there is a lack of water, the arsenic sandstone releases moisture ensuring a sustainable soil moisture distribution. Arsenic sandstone is also harmless with the average heavy metal content in the compounded soil being below the national secondary standard. Finally, the sand-fixation effect was remarkable after the arsenic sandstone was compounded with sand. The formation of a soil crust and the increased thickness of snow and the frozen layer all demonstrated that this soil distribution had a more prominent sand-fixation.

In this project, we not only considered the comprehensive improvement of the sandy lands, but also sought to develop high standard farmland in the Mu Us Desert farmland demonstration project, which represented a paradigm shift from a "passive unitary governance" to an "active comprehensive utilization". This project not only improved the proportion of arable land in the demonstration area, but also reduced soil erosion, and achieved a win-win economic and ecological restoration result. The arsenic sandstone compounded with sand technology was proved to be a sustainable way to comprehensively improve the Mu Us land, which demonstrated that this technology could solve land management problems [24]. This research has important theoretical significance and practical significance in the Mu Us arsenic sandstone area in terms of soil improvement and water loss control.

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Venture Capital and the Corporate Performance After IPO: Based China GEM Market

Yingkai Tang, Li Zeng, Chenguang Li and Kun Li

Abstract Compared with the general investors, Venture Capital can influence the generating of operating strategies of the invested company once they offer the fund for future development; thus, Venture Capital can have effects on corporate performance. This paper takes the 153 companies listed between 2009 and 2010 as samples to do empirical study. The result shows that though the existence of declining performance, participation of Venture Capital is relatively helpful in maintaining the performance after IPO. This paper also provides new evidences for the study of the relation between Chinese Venture Capital and corporate performance.

Keywords Venture capital · GEM · IPO · Corporate performance

1 Introduction

The developing of Chinese Venture Capital (VC) can date back to the end of last century. Just after the setting of small and medium-sized enterprises board in 2004 and GEM in 2009, VC began to develop rapidly. The number of Venture Capital Institution (VCI) and private equity firm increase from 500 in 2005 to 6290 in 2012. Since 2005, Li and Chen [13] proposed that the fund raised by VCI in China has been increasing at a compound annual growth rate of up to 13 %. In theory, by offering fund, VCI can efficiently guarantee the lasting of R&D and rapid development of start-up technology companies. Besides, by using their professional ability to improve the management and operate efficiency and build a system to inspire the company's creativity, VCI can help to transfer and disperse part of the risks. In reality, though the active participation of VCI, corporate performance decline year by year. From 2010 to 2013, price earning ratio, net return on equity, average growth rate of operating revenue and average growth rate of net profit all kept decreasing, and are lower than that of main board and small and medium-sized board.

Y. Tang (✉) · L. Zeng · C. Li · K. Li
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: likun@scu.edu.cn

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Broad experts had made some researches about VCI influence on corporate performance in different capital markets, and they reached to different conclusions. Barry's Supervision and screening hypothesis [9] says that VCI can select the corporate with the best quality. By offering management advices and supervising the exposure of information, it can help to relieve the problem of information asymmetry between corporate and VCI. A similar theory is Megginson and Weiss's certificate hypothesis, which says that VCI is the financial organization that is the most familiar with corporate management condition. Owing the corporation stocks is a signal to the market that the corporation is worthy of being invested. The above two theories were supported by many scholars [10]. Another kind of theory is adverse selection [2] and grandstanding hypothesis [18]. Grandstanding hypothesis says that VCI has to take the responsibility of raising new funds to maintain operating. In China, the same problem has completely different answers. By doing empirical study, this paper will draw a conclusion about this problem and make profound analysis about VCI influence on corporate performance after IPO.

2 Literature Review

As early as in 1990, Barry, Muscarella and Peavy did empirical study. The result showed that every sample company is supported by 3 VCI on average. Two of the board of directors or board of supervisors came from VCI. This study proved that VCI can efficiently supervise company's operation and management. Gompers [6] divided the target companies into two groups, one supported by VCI and the other not. They found that IPO effect, which means that all the listed companies' performance kept declining after IPO was obvious, whereas, performance of companies supported by VCI is better than those without VCI. Besides, the result showed that the number of VCI of the company can affect the performance after IPO. In the long run, effects from VCI weakened and the difference between the two group's performances disappear.

VCI taking part in corporate governance of the invested company has become a worldwide phenomenon and arouses lots experts' attention. Chien-Hsun Hui-Tzu [3] did a deep analysis about creative research projects in American small business (SBIR). The result showed that sales growth rate of VCI backed companies is obviously better than that of companies without VCI. Li [15] checked the VCI in German capital market. They divided the 166 sample companies into two groups, one were supported by VCI and the other not. It was proved that corporate performance after IPO of VCI backed companies is better than that of those without. By way of Propensity Score Match, Tang and Tan [22] studied the companies supported by VCI in Austria. The empirical result proved says that VCI backed companies do better in the aspects of creativity, develop speed and technology creativity.

Stewart [20] studied the 123 listed companies in mainland. The result showed that quality of VCI backed companies is better that that of those without. Wu [24] proved that performance of before and after IPO of VCI backed companies are worse than that of those without, while IPO effect of the former is not so obvious.

Above all, for the fund they had offered, we think that VCI will try their best to supervise and improve the management and operating condition of the invested company. Based on this saying, quality of VCI backed companies are better than that of those without. Besides, after the certification the third party, namely VCI, companies that are not so famous before can improve their reputation. VCI becomes the shareholder of the companies with greater reputation, which will strengthen investor's confidence and improve IPO behavior.

3 Research Design

There are various of standards for selecting the index for corporate performance. Dupont system of analysis, which takes return on net assets as the main index, is one of the most uses. Another one is EVA [5], which has become one of the index for central enterprises to compute corporate performance. Balanced score card is also a useful system and invented by Robert Kaplan and David Norton in 1992. Besides, for high-tech business in particular, Antti Lonnqvist, a Verronica expert, stressed the importance of human resource and intelligence for enterprises.

Based on the modern financial analysis system and the above studies, this paper takes profitability, operating efficiency and developing ability as the indexes for evaluating corporate performance. Table 1 shows this in detail.

In the further analysis model, we take the change of return on net asset as dependent variable. Independent variables are VC, PE ratio, IPO under-pricing rate, turnover on total asset, net profit margin on sales and growth rate of profit. Table 2 shows this in detail.

4 Data Resource and Descriptive Statistics

This paper studies the GEM of China mainland. By organizing the financial data of companies 1 year before and 2 years after IPO, we take the 153 companies listed between 2009 and 2010 as samples. Most of the financial data come from Csmar and RESSET. Corporate prospectuses come from www.Cninfo.com.cn. in terms of the mistaken and missed data, we searched it from Flush. This paper omits the corporations that were obviously owned by internal staff. Table 3 is IPO condition of different years.

Table 1 Index system for corporate performance

Profitability	Operating efficiency	Developing ability
Return on net assets, gross profit rate	Turnover of total capital	Growth rate of net profit

Table 2 Explanation for variables

	Types of variables	Name	Meaning
Dependent variables	Variation of return on equity of IPO	ROE0	ROE0 = ROE of IPO−ROE of 1 year before IPO
	Variation of return on equity 1 year after IPO	ROE1	ROE1 = ROE of 2 years after IPO−ROE of 1 year before IPO
	Variation of return on equity 2 years after IPO	ROE2	ROE1 = ROE of 2 years after IPO ROE−ROE of 1 year before IPO
Independent variables	VC	VC	Dummy variable, for VC backed ones. It equals to 1
Controlling variables	IPO behavior-PE ratio	PE	PE = stock price/profit after tax per share of the last year
	IPO behavior-IPO under-pricing rate	IPO under	IPO = close price of the first day-issuing price/issuing price
	IPO behavior-IPO total fund	under IPO	IPO raise is the total fund, (0.1 billion)
	Profit ability-net profit on sales	raise NPM	NPM = net profit/operating revenue (1 year before IPO)
	Operating efficiency-turnover on total assets	TAT	TAT = sales revenue/average assets (1 year before IPO)
	Developing ability-growth rate of net profit	NPGR	NPGR = (net profit of 1 year before profit of last year)/IPO-net profit of 1 year before IPO

Table 3 IPO condition of different years

Year	Shareholding ratio of VCI backed	Ratio (%)	Shareholding ratio without VCI	Ratio (%)	Total
2009	29	80.56	7	19.44	36
2010	74	63.25	43	36.75	117
Total	103	67.32	50	32.68	153

Data source Prospectuses of GEM companies are collected from www.Cninfo.com.cn. The author organized it

Seen from the above table, 80 percent of the listed companies in 2009 and 60 percent in 2010 are supported by VCI. Taken together, there are about 70 percent (67.32 %) GEM companies are supported by VCI before IPO in 2009 and 2010.

Using the industry statistical method of CSRC, we classified the 153 samples into 11 groups, which consist of manufacturing, services, biotechnology, information technology, medicine, chemical energy, electronic technology, culture, film and television, agriculture, food, etc. The detailed information is showed in Table 4.

Seen from the above, companies in manufacturing, information technology, electronic technology and medicine are supported by the most VCI; while in terms of

Table 4 Distribution of industries

	Shareholding of VCI backed		Shareholding without VCI		Total	
	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Manufacturing	32	71.11	13	28.89	45	100
Information technology	19	65.52	10	34.48	29	100
Electronic technology	13	68.42	6	31.58	19	100
Medicine	9	90	1	10	10	100
Others	9	90	1	10	10	100
Services	6	75	2	25	8	100
Chemical energy	6	37.5	10	62.5	16	100
Biotechnology	4	80	1	20	5	100
Film and television	3	60	2	40	5	100
Agriculture	2	50	2	50	4	100
Food	0	0	2	100	2	100
Total	103		50		153	100

the ratio, the rapidly developing medicine, biotechnology and services had the most VCI. Compared with the above, VCI in agriculture, chemical energy and food are relatively small in both number and ratio.

5 Empirical Study

5.1 VCI and Corporate Performance After IPO

According to VCI backed or not, the samples are divided into two groups. Based on the 3 years' financial data after IPO, we did significance testing about the related indexes by using SPSS. We mainly used Mann-Whitney test. The result is showed in Table 5 in detail.

Financial data of the two groups had no difference in this test. That is to say, VCI had no influence on listed companies 3 years after IPO. But a new problem came along: during these 3 years, whether VCI had influence or not. To test the existence of IPO effect, namely if corporate performance decline after IPO, we will identify the role VCI played.

In theory, listed companies should have the better corporate performance and better development. Their financial conditions are expected to increase fast. It is not real in practice. After Jain and Kini found the declining performance after IPO, many

Table 5 Influence of VCI on corporate performance after IPO

	Average of shareholding of VCI backed	Average of shareholding without VCI	Average of the total sample	Value Z of Mann-Whitney
Return on equity (%)	6.41	7.31	6.7	−0.55
	6.27	6.3	6.29	
Gross profit margin (%)	37.95	37.4	37.77	−0.263
	35.35	34.65	35.11	
Turnover of total capital	0.45	0.51	1.08	−0.996
	0.4	0.44	0.96	
Growth rate of net profit (%)	−15.15	1.9	−9.58	−0.383
	2.24	5.26	4.34	

Table 6 Test of the variation of performance of before and after IPO

		IPO − 1	IPO	IPO + 1	IPO + 2
Return on equity (%)	Total sample	35.08	8.30[a]	7.48[a]	6.70[a]
	Shareholding of VCI backed	34.04	8.52[a]	7.37[a]	6.41
	Shareholding of those without VCI	37.23	7.85[a]	7.72	7.31
Gross profit margin (%)	Total sample	42.9	42.68	39.75[a]	37.77[a]
	Shareholding of VCI backed	43.53	43.2	40.25[a]	37.92[a]
	Shareholding of those without VCI	41.61	41.62	38.71[a]	37.40[c]
Turnover of total capital	Total sample	1.08	0.55[a]	0.44[a]	0.47[a]
	Shareholding of VCI backed	1.01	0.53[a]	0.42[a]	0.45[b]
	Shareholding of those without VCI	1.22	0.59[a]	0.46[a]	0.51[a]
Growth rate of net profit (%)	Total sample	47.4	31.42[a]	10.85[a]	−9.58
	Shareholding of VCI backed	48.06	32.27[a]	9.12[a]	−15.15
	Shareholding of those without VCI	46.02	29.65[a]	14.42[b]	1.9

Note [a]symbolizes that it is significant under 1 % under, [b]is under 5 % and [c]is under 10 %

domestic scholars find that this phenomenon exist in different capital markets, which is the so-called IPO effects.

There are many ways to test IPO effects. For instance, single factor analysis of Kaplan and Norton [11], ANOVA of Lerner [12], MNR and Panel of Christopher et al. [4], T match of Tang [21] and Li and Chen [13] and PCA of Li [14].

This paper used T match. The result is showed in Table 6.

Seen from the above table, we can know that average return on equity, gross profit margin, turnover on total asset and growth rate of net profit of the total samples and

VCI backed samples varies in the same way. Average return on equity is as high as 35 % 1 year before IPO, and keeps declining in the following 3 years. Average gross profit margin is high in the first 2 years and decreased greatly then. Above all, these two indexes of VCI backed companies are higher than that of those without, while the former decline faster. Different from the first two indexes, average turnover on total asset of VCI backed companies is higher than that of those without, and begin to increase in the 3rd year. Average growth rate of net profit decrease greatly after IPO, and is even below zero. Scale of decrease of companies with no support of VCI is great but smooth, whereas, that of VCI backed companies slide accelerate and become negative in the 3rd year.

We can now understand that IPO effects exist widely in China. But we are still not clear if VCI relieve the IPO effects or just exacerbated. Thus we had the following further study.

5.2 Further Study

To identify VCI role in IPO effects, we use the same financial data as above to do empirical analysis. Performance of companies 1 year before IPO is the base. Variation of the following 3 years is classified by having VCI support or not.

We still use Mann-Whitney test and average in the analysis. The detailed result is showed in Table 7.

To test the explaining ability of variables and multicollinearity, correlation of other indexes is under 0.5. ROE0, ROE1, ROE2 are obviously related with total fund, net profit margin on sales, turnover on total asset and growth rate of net profit (Table 8).

Based on the selected variables, we did analysis of regression about equity return in different time periods one by one. The three models are as following:

$$\mathrm{ROE0} = \alpha_0 + \beta_1 VC + \beta_2 \mathrm{IPOunder} + \beta_3 \mathrm{IPOraise} + \beta_4 NPM + \beta_5 TAT + \beta_6\ \mathrm{NPGR} + \varepsilon_0,$$
$$\mathrm{ROE1} = \alpha_1 + \gamma_1 \mathrm{IPOunder} + \gamma_2 \mathrm{IPOraise} + \gamma_3 NPM + \gamma_4 TAT + \gamma_5 \mathrm{NPGR} + \varepsilon_1,$$
$$\mathrm{ROE2} = \alpha_2 + \delta_1 \mathrm{IPOunder} + \delta_2 \mathrm{IPOraise} + \gamma\delta_3 NPM + \gamma\delta_4 TAT + \delta\gamma_5 \mathrm{NPGR} + \varepsilon_2.$$

VC is omitted in model 2 and model 3. The result is showed in Table 9.

Table 7 VCI influence on corporate performance

Changing rate of average (%)	From −1 to 0		From −1 to 1		From −1 to 2	
	VC	Non-VC	VC	Non-VC	VC	Non-VC
Return on equity	−77.4	−79.23	−77.47	−79.47	−79.62	−80.09
Gross profit margin	−0.26	0.75	−5.95	−6.76	−11.02	−11.66
Turnover on total asset	−48.45	−51.61	−59.43	−62.11	−56.18	−58.77
Growth rate of net profit	−15.03	−13.62	−29.71	−32.9	−33.74	−39.36

VC refers to companies supported by VCI, and Non-VC refers to the rest

Table 8 Pearson correlation test of VCI and performance indexes

		VC	PE	IPO under	IPO raise	NPM	TAT	NPGR
ROE0	Pearson	0.143	−0.056	0.197[a]	−0.479[b]	−0.407[b]	−0.315[b]	−0.523[b]
	Sig.	0.077	0.491	0.015	0	0	0	0
ROE1	Pearson	0.102	−0.057	0.132	−0.429[b]	−0.360[b]	−0.358[b]	−0.525[b]
	Sig.	0.208	0.485	0.104	0	0	0	0
ROE2	Pearson	0.074	−0.031	0.164[a]	−0.425[b]	−0.317[b]	−0.315[b]	−0.485[b]
	Sig.	0.363	0.702	0.043	0	0	0	0
VC	Pearson	1	0.044	0.138	0.1	0.061	−0.192[a]	0.023
	Sig.		0.591	0.089	0.221	0.457	0.017	0.782
PE	Pearson	0.044	1	0.507[b]	0.180[a]	0.109	−0.039	0.249[b]
	Sig.	0.591		0	0.026	0.178	0.632	0.002
IPO under	Pearson	0.138	0.507[b]	1	−0.256[b]	−0.028	0.023	0.038
	Sig.	0.089	0		0.001	0.731	0.774	0.644
IPO raise	Pearson	0.1	0.180[a]	−0.256[b]	1	0.272[b]	−0.022	0.338[b]
	Sig.	0.221	0.026	0.001		0.001	0.786	0
NPM	Pearson	0.061	0.109	−0.028	0.272[b]	1	−0.383[b]	0.041
	Sig.	0.457	0.178	0.731	0.001		0	0.616
TAT	Pearson	−0.192[a]	−0.039	0.023	−0.022	−0.383[b]	1	0.285[b]
	Sig.	0.017	0.632	0.774	0.786	0		0
NPGR	Pearson	0.023	0.249[b]	0.038	0.338[b]	0.041	0.285[b]	1
	Sig.	0.782	0.002	0.644	0	0.616	0	

Note [a]and [b]refers that it is significant under 0.05 and 0.01 in two-tailed test

In Table 9, R^2 of the three models are 0.64, 0.59 and 0.5 respectively. The declining explaining ability says that factors affecting performance keeps growing. All of the three models pass the statistical significant test under 1 % level. And there is no existence of mulicollinesrity.

Based on the regression result, we had the following two conclusions.

Firstly, in the three models, total fund, net profit margin on sales, turnover on total asset and growth rate of net profit of 1 year before IPO have significant negative influence on ROE. Thus we can conclude that, first, the greater performance 1 year before IPO, the greater decrease of ROE. This reflects that companies do better in IPO decline greater than those do bad. Second, the more funds VCI provide, the greater decrease. This paper measures performance decline by ROE decline.

Secondly, VCI influence corporate performance mainly in the IPO year. VCI is positively related with equity return. Equity return decrease of VCI backed companies is lower than that of those without under 5 % level. This happens only in the IPO year. Generally speaking, VCI stays in the capital market for only 1 year, during which it plays the role of supervisor. 1 year after IPO, VCI can exit the market by selling the stocks. Shareholding ratio of VCI will have no influence on companies then.

Table 9 Regression result of ROE variation in different time period

	Intercept	VC	IPO under	IPO raise	NPM	TAT	NPGR	R^2	F-value	P
ROE0	1.12	2.89	0.04	−0.59	−0.6	−9.71	−0.1	0.64	43.27	0
	−2.84	(1.39)[b]	(0.02)[b]	(0.15)[a]	(0.07)[a]	(1.42)[a]	(0.02)[a]			
ROE1	3.83		0.03	−0.49	−0.59	−11.38	−0.1	0.59	41.96	0
	−2.92		(0.02)[c]	(0.17)[a]	(0.08)[a]	(1.53)[a]	(0.02)[a]			
ROE2	2.1		0.04	−0.59	−0.56	−10.93	−0.1	0.5	28.92	0
	−3.6		(0.02)[b]	(0.20)[a]	(0.09)[a]	(1.88)[a]	(0.02)[a]			

Note [a]symbolizes that it is significant under 1 % under, [b]is under 5 % and [c]is under 10 %

6 Conclusion

By collecting the information of 153 companies listed between 2009 and 2010, we studied the relation between VCI and change of corporate performance after IPO. The regression result shows that performance decline of VCI backed companies is obviously smaller than that of those without in the IPO year. The 3rd year after IPO, VCI had no influence on the decline no longer. Thinking of the real condition of China GEM, we believe that supervision is more appropriate for explaining this phenomenon. The major defects of this paper are that we just take 3 years' performance into account; and the shareholding ratio of VCI is collected from prospectus by hand. For all of these reasons, there may be some deviation. We will better these problems in the future study.

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Frame-Working Harmonious Labor Relations Evaluation Index System with Human Resources Ecosystem Perspective

Yulong Li, Yajie Song and Xiaoyun Zhang

Abstract Since the reform and opening up, Chinese economy has been moving forward rapidly. However, the issues of labor relations have become more and more important in recent years, especially frequent labor management conflict. In this paper, an index system of harmonious labor relations is established based on the theory of human resources ecosystem, the principal component analysis and AHP (analytical hierarchy process) are used to evaluate harmonious labor relations. This study constructs a comprehensive index system, composed of 10 first grade evaluation indexes and 23 second grade evaluation indexes, therefore the weight of each individual index can be calculated.

Keywords Human resources ecosystem · Harmonious labor relations · Index system · AHP

1 Preface

Human resources ecosystem is the appearance, integration and application of ecological theory, it is an important development and innovation of today's ecological theory. As a matter of fact, human and natural ecosystems have a mutual tolerance and co-existence relationship. For example, ancient Chinese philosophy contains the thought of "harmony between the heaven and human", expounds the relationship

Y. Li (✉)
Business Administration School, Shenyang University, 110044 Shenyang, People's Republic of China
e-mail: liyulong339@163.com

Y. Song
Global Institute of Environment and Sustainable Developmnet at Yale, Yale University, New Haven, CT 06511, USA

X. Zhang
Business School, The University of New South Wales, Sydney 2052, Australia

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between man and nature, such as Dong Zhongshu (the scholars of Han dynasty). Since Webber and Commons proposed the concept of labor relationship in 1940s, great deals of profound and comprehensive research on labor relations have been carried and constructive research findings were obtained. But in recent years, with the development of Chinese economy, new type of labor relations problems are produced.

Since the Chinese Communist Party put forward "constructing harmonious community" in 2006, the issues of harmonious labor relations have been given great attention. Academic fields have launched the discussion of the harmonious labor relations, business community also carried out the "evaluation campaign of harmonious labor relations enterprise". Despite that fact, quantitative research of harmonious labor relations from human resources ecosystem perspective can not be seen too much, which is the core meaning of this study. This study dedicates to quantify an evaluation index system of harmonious labor relations under the perspective of human resources ecosystem.

2 Literature Review

A good literature review is able to consolidate foundation, it can help provide a direction for the in-depth research, and the following will make a literature review from the perspective of human resources ecosystem and harmonious labor relations.

Broadly speaking, human beings were under an identical ecosystem, with the gradual development of globalization, the concept of identical ecosystem is more deeply rooted in people's heart, human resources ecosystem can very good at summarizing of labor relations problems between country, industry and enterprise.

Carroll and Hannan [4] introduced the concept of ecological niche into enterprises' competition and cooperation for the first time. Baum and Singh [1] pointed out that the enterprise species can be considered as an aggregation of multiple enterprises in multidimensional niche space. Haddad [5] examined labor theory of ownership from an ecological perspective, and explores its role in western US property rights disputes.

Domestic scholars Ma and Wang [7] made main contribution of the concept of human resource ecosystem, they give a definition of ecological system from the perspective of social, economic and natural. Yan [11] argued that human resource ecosystem refers to a "material-energy-information system", which is built by various types of human resources and the surrounding natural and social environments. Song [6] from Yale university based on urban environmental crisis management to carry out long-term research on the human and the nature ecosystem structure and function, in the perspective of the interdisciplinary ecosystem.

At present, academic research of harmonious labor relations is less, many scholars pay attention to labor conflict. Beissenova et al. [2] observed growth of social conflicts, including labor conflicts, they find that in Kazakhstan there are no operating mechanisms for the solution of labor conflicts, technologies on settlement of labor disputes with participation of all parties of labor process. Blanco [3] aimed to focus on the main role of the companies and all the labor organizations in the productive system in the promotion of employability, and the responsibility they should assume as part of their social commitment for the welfare of their workers. Medina [8] described and analyzed the extrajudicial system for labor conflict resolution in Andalusia.

China Federation Trade Unions in 2006 put forward a standard of harmonious labor relations measuring method, such as strictly implements the system of labor contract; establishes the equal consultation and collective contract system; respects and maintains the cultural rights and interests of workers. Wang [10] built a quantitative evaluation system of harmonious labor relations, the system has four aspects, four aspects are income protection, labor environment, interests realization and skill development. Su [9] built a harmonious labor relations system based on the private enterprises human resource management concept and method innovation.

To sum up, although scholars have made some exploratory research for evaluation of harmonious labor relations, and have obtained the comparatively abundant research results, but as mentioned above, harmonious labor relations research based on the theory of human resources ecosystem cannot be seen. So this study try to build a harmonious labor relations evaluation index system from the perspective of human resources ecosystem, it will have a good theoretical significance.

3 Orientation and Principles on Constructing Ecological Evaluation Index System of Harmonious Labor Relations

Based on above literature, this paper give a definition of human resources ecosystem, it emphasizes the "organization-individual" ecosystem; it is a structural, functional and value-orientated organic system. The subjective construction of human resource ecosystem is deemed as "system momentum", which aims to optimize the integration of external and internal circumstances and their essential factors and standardizes the human resource administration by establishing communication channels, links and platform for internal and external circumstances.

From macroscopic perspective, culture, policy and social economy impacts significantly on harmonious relationship but in respective way.

Culture, as a fundamental factor, accounts for many current unharmonious labor relation issues. As a kind of social relations, labor relation is not only the economic relationship and contractual relationship, but also a kind of cultural relations. Generally speaking, the ecological evaluation index system should be built on cultural entity. Culture dimension theory proposed by Hofstede could be applied into ecological evaluation index system constructing (power distance, individualism, masculinity and uncertainty avoidance).

Regulation is the most solid factor affecting labor relationship, which could be set from government, industry and enterprise. Social economy is an important factor to stabilize the staff, including macro-economic environment, political environment, values, technical environment and natural environment. Apart from macro-economy, labor relationship is affected by staff in enterprise, namely individuals and leaders. Out of different backgrounds, individual impacts labor relationship in terms of intelligence, capability, personal experience, gender, age, term of office, job satisfaction, dedication and job expectation, etc. leaders factors have obvious influence on labor relationship too.

Meanwhile, in this paper, the design of indexes conforms to Herzberg's two-factor theory (the opposite of satisfaction is not dissatisfaction, is no satisfaction, the opposite of dissatisfaction is not satisfaction, is no dissatisfaction), so this fact will result in different factors in harmonious and inharmonious relationship, therefore, the indexes used to evaluate harmonious labor relationship is not necessarily effective in alerting labor disputes and conflicts.

All evaluation index system should conform to certain basic principles, the ones of this study follows.

Index system is comparable in time and space, indexes are intelligible, should being easily understood and applicable for governors and professions; Indexes in the evaluation system should be objective, specific, standardized. Meanwhile, indexes sensitively imply individual activity in economic environment and organization; Information in index system is accessible, clearly specified, easily computed and cost-effective. Comprehensive evaluation index system does not reflect current labor relationship, but also aims to indicate the perspective in labor relationship. Index system is supportive and oriented for decision-maker, reflects current labor relationship, social response and existing policy relevance. Index system should cover comprehensive labor relationships at all aspects, therefore, indexes should be integrated as much as possible.

4 The Preliminary Selection of Evaluation Index and Established of Index System

This paper is based on the above index guiding ideology and related design principles, reference the EPI index system framework and research methods of Yale and Columbia University to form scientific, direct evaluate index of harmonious labor relations. Based on the methods of literature and expert interview, put forward the preliminary index system (11 representative first level indexes and 27 typical secondary indexes).

Invite labor relations expert, three high-level managers from different industries, two high-level managers from social management, two university professor to participate in the symposium, requiring them giving variety evaluation factors of harmonious labor relations. Based on above, to further refine primary index system, at last,

Table 1 Harmonious labor relations of ecological evaluation index system

	Principle level	First level index	Second level index
A harmonious labor relations of ecological evaluation index system	B1 culture	C1 democratic participation	D1 organization information disclosure
			D2 individual advice adopted degrees
		C2 conflict management	D3 communication differences
			D4 collective bargaining
		C3 staff development	D5 development space
			D6 mutual aid with each other
	B2 regulation	C4 compensation and benefit	D7 organization pay level
			D8 organization welfare spending
		C5 training and promotion	D9 vocational training
			D10 promotion space
		C6 incentive and restriction	D11 get the material rewards level
			D12 disciplinary penalties
			D13 economy situation
	B3 social economy	C7 economy	D14 income distribution
			D15 post status
		C8 the social responsibility and security	D16 charity
			D17 social image
			D18 social insurance
	B4 individual factors	C9 organize individual	D19 security
			D20 feelings of love
			D21 loyalty
	B5 relationship between labor and leader	C10 relationship between labor and leader	D22 concern for work
			D23 individual’s care

identified primary index system as 10 first-level indicators, 23 secondary indexes, to compile the harmonious labor relations evaluation questionnaire, A total of 120 questionnaires (20 field distributing, 100 E-mail form) for state-owned enterprises and private enterprises, back to 96, recovery rate reached 80 %, remove 6 invalid questionnaire, received 90 valid questionnaires, using SPSS18.0 statistical software for statistical analysis, using principal component analysis, variance test is generally accepted. Analyze the same features of each factors, to name of each factor, finally formed a higher convergent validity of harmonious labor relations of ecological evaluation index system, specific indicators as shown in Table 1.

5 To Determine the Weights of Comprehensive Evaluation Index

After establishing the evaluation index system of harmonious labor relations, based on the analytic hierarchy process (AHP) to establish a model to determine the weight of each index. To determine the weights of indicators, Invite labor relations expert to participate in the symposium (three middle-level managers from different industries, two middle-level managers from social management, two university professor), by comparison, communication and analysis of everybody's opinion, Establish the comparison of importance value between two factors in the same level, to construct judgment matrix, 14 judgment matrixes are constructed. Matrix 1, for example, the 1/2 in the first row of the table represents the B1 is not slightly important than B2, the 5 in the first row of the table said B1 is more important than B3 (Table 2).

Based on 14 judgment matrixes, use YAAHP0.5.2 software for computing the largest eigenvalue lambda Max, the weight vector W and consistency ratio CR, on the basis of random consistency index RI values, calculate the consistency index value of the CI. All 14 judgment matrix pass the consistency check. Through the AHP method eventually form a complete evaluation index weight system of harmonious labor relations, are shown in Table 3 below.

Table 2 A: B1, B2, B3, the judgment matrix

A	B1	B2	B3
B1	1	1/2	5
B2	2	1	6
B3	1/5	1/6	1

Table 3 Harmonious labor relations of ecological evaluation index system

	Principle level	First level index	Second level index
A harmonious labor relations of ecological evaluation index system	B1 culture (0.22976)	C1 democratic participation (0.3089)	D1 organization information disclosure (0.4532)
			D2 individual advice adopted degrees (0.5468)
		C2 conflict management (0.2785)	D3 communication differences (0.6347)
			D4 collective bargaining (0.3653)
		C3 staff development (0.4126)	D5 development space (0.5677)
			D6 mutual aid with each other (0.4323)
	B2 regulation (0.3313)	C4 compensation and benefit (0.4221)	D7 organization pay level (0.7856)
			D8 organization welfare spending (0.2144)
		C5 training and promotion (0.2560)	D9 vocational training (0.1871)
			D10 promotion space (0.8129)
		C6 incentive and restriction (0.3219)	D11 get the material rewards level (0.7451)
			D12 disciplinary penalties (0.2549)
	B3 Social economy (0.1711)	C7 economy (0.0985)	D13 economy situation (0.2155)
			D14 income distribution (0.3017)
			D15 post status (0.4828)
		C8 the social responsibility and security (0.2180)	D16 charity (0.1136)
			D17 social image (0.4388)
			D18 social insurance (0.4476)

(continued)

Table 3 (continued)

	Principle level	First level index	Second level index
	B4 individual factors (0.0733)	C9 organize individual factors (0.4872)	D19 security (0.1970)
			D20 feelings of love (0.5019)
			D21 loyalty (0.3011)
	B5 relationship between labor and leader (0.1467)	C10 leadership factors (0.1963)	D22 concern for work (0.2618)
			D23 individual's care (0.7382)

6 Conclusion

This study proposed an evaluation index system based on harmonious labor relations under the perspective of human resources ecosystem, specific conclusions as following:

(1) New interpretation on the ecologic human resource system and harmonious labor relations are given; Human resource ecosystem is a structural, functional and value-orientated organic system, it is built on the mutuality symbiosis of external and internal circumstance in human resource administration, include culture factors, regulation and social economy factors, individual factors, leadership factors.
(2) Constructs a comprehensive index system, composed of 10 first grade evaluation indexes and 23 second grade evaluation indexes; AHP is used to calculate the weight of each individual index, it plays a significant role in improving and promoting harmonious labor relations.
(3) Empirical analysis on index weight turns out, regulation factors and culture factors are more significant compared with social economy factors, second grade evaluation indexes such as pay grade factor, material reward factor, and so on, display relatively high coefficient values, this finding means current labor issues are still riveted in the restriction of cultural regulation and social economy.

As a matter of fact, if an organization has a good cultural atmosphere, a good system and strong market cradle, it will get their own competitive advantage. Only building sound human resources ecosystem between "culture-regulation-social economy- individual-leadership", and continuously devoting to improving and attaching importance to the indexes in harmonious labor relations, high quality human resource management will flourish and economy and society will prosper.

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Does Pay Dispersion Associate with Organizational Performance?

Ping Liu, Yumeng Tian and David A. Keatley

Abstract This study aimed to investigate the mechanism of pay dispersion and organizational performance. Eighty-five enterprises across three different industries including Information Technology ($N = 34$), Electronics Manufacturing ($N = 26$), and Medical and Health ($N = 25$) participated this study, and the data was then analyzed through a series of hierarchical linear regression. The effect of pay dispersion on organizational performance was examined while the variables of organizational size and ownership status were controlled. The results indicated that (1) the effect of pay dispersion on sales margins was moderated by pay levels, and (2) the industry of Medical and Health was a significant moderator towards the relation between pay dispersion and organizational performance.

Keywords Pay dispersion · Pay strategy · Pay level · Organizational performance

1 Introduction

Pay dispersion has received amounts of attentions in the management researches. Lots of researchers have studied the effects of pay dispersion on both individuals' and organizational performance. But the outcomes of experiments have still remained inconsistencies [7]. Paradoxes have been existed in both theories and experiments outcomes.

P. Liu (✉) · Y. Tian
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: xiahxiah13@163.com

D.A. Keatley
School of Psychology and Speech Pathology, Curtin University,
Perth 6102, The Commonwealth of Australia

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Theories in organizational behavior claimed that unequal pay distribution would result in inharmonious and low individual performance [5]. But some of the experiment outcomes revealed that pay dispersion had a positive effect on both individual and organizational performance [2, 6, 11]. At the same time, there were also some experiments revealed that the relationship between pay dispersion and organizational performance was negative. In contrast, some researchers said that the effect of pay dispersion on organizational performance was mixed.

In the end of the 1980s, lots of people from rural area flooded into cities to make their lives, that is “the flood of migrate laborers”, but in recent years, the shortage of migrate labors has appeared, especially in the east of China, a lot of enterprises could not employ labors even by increasing pay levels. As for those labors worked in forefront of production, their characteristics result in few possibilities of changing jobs and the salary or working conditions in the enterprise are important to them. According to Maslow’s hierarchy of needs [15], labors worked in forefront of production have lower-order needs, that is, the amounts of pay affect them more than others. The study of pay dispersion focuses on workers in forefront of production has positive effects on labor market in the background of China. It has an important impact on management practices.

This study addressed the mechanism of pay dispersion and organizational performance, that is, under what conditions would pay dispersion affect organizational performance significantly.

The study will give the advice to enterprises employed labors from rural areas about adjusting pay structure contingently.

Both the organizational behavior theory and experimental researches had discussed a lot about the effects of pay structure on organizational performance.

According to equity theory [1], individuals would compare their inputs with outcomes, and they will compare them with others’ inputs and outcomes. The equity theory had been applied to many studies to investigate the mechanism of employees’ reactions to pay inequity [3, 12, 16, 19]. At the same time, because of the various outcomes in the domain of pay dispersion research, some researchers argued that to clarify in which conditions pay dispersion will significantly affect organizational outcomes would be more valuable [19]. Since then many researcher had been investigated the effects of pay dispersion on organizational performance under the conditions of pay basis [12, 16], pay level [22], pay system communication [13], the attribute of the job [21].

From the view of the equity theory [1], under the control of pay basis and the degree of collaboration, hierarchical pay structure would lead to employees’ perceptions of inequity and result in low organizational performance, if the enterprises adopted pay strategy which leading the market, it would influence the effects of pay inequity on organizational performance. Brown et al. [4] investigated the moderate effects on relationships between pay dispersion and return on assets, they conducted the research in hospitals, and the experimental outcomes revealed that when an hospital adopted a compressed pay dispersion and a pay strategy which lagging the market, the return of assets would be the highest, and when the hospital adopted a hierarchical pay dispersion under the condition of leading the market, organizational performance would be the highest.

As for those worked in forefront of productions, their work needed high collaboration, in this point of view, pay structure needed to be compressed to strength employees' perceptions of equity. When an enterprise adopt pay strategy which was leading the market, compressed pay structure would strength the perception of equity, but in the condition of adopting pay strategy which is lagging the market, a compressed pay structure would provide external inequity more than internal equity to employees, the enterprise needed a hierarchical pay structure to motivate employees. Though there had been few experimental outcomes supported this point of view so far.

Hypothesis 1 Under the control of pay basis and pay system communication, the interaction of pay strategy and pay dispersion will significantly affect the organizational performance. Under the condition of pay strategy which is leading the market, pay dispersion would have a negative association with organizational performance, under the condition of pay strategy which is lagging the market, pay dispersion would have a positive relation with organizational performance.

Hypothesis 2 Under the control of pay basis and pay system communication, the interaction of pay dispersion and industry will significantly associate with organizational performance.

2 Method

2.1 Data Sources

Data were collected from eighty-five enterprises from three industries in Cheng Du Hi-tech Industrial Development Zone. The data collection sessions were conducted by means of salary survey. Gupta et al. [10] argued that one of the reasons for inconsistent results between pay dispersion and organizational outcomes was the meaning of the "salary" various from different studies. Some used annual pay [3, 19, 20], some interpreted "salary" as direct cash [14, 18], total compensation [8], and wage increases [9] were also used as salary. Gupta et al. [10] claimed that researchers should clarify their definition of the salary so that the experimental results would be more reliable.

In the salary survey, the data were reported by human resource managers from different enterprises, they were asked to report the components of their annual pay in 2013 from two parts: basic wage and merit pay, at the same time, demographic information of employees such as (age, gender, seniority, education, skill) and organizational performance like sales margins were also required. The number of subjects in each enterprises depended on the size of themselves, micro, small and medium sized enterprises were required to report the salary of the whole workers worked in

Table 1 Participant information

Mean (SD)	Information technology	Electronics manufacturing	Medical and health
Organization size	2.50 (0.57)	2.19 (0.83)	2.72 (0.46)
Ownership status	1.64 (0.93)	1.67 (0.92)	1.04 (0.20)
Age	27.81 (43.61)	28.12 (6.26)	35.99 (8.04)
Gender	1.27 (0.44)	1.39 (0.49)	1.61 (0.49)
Seniority	5.80 (3.54)	4.96 (4.07)	10.46 (7.80)
Education	2.36 (0.72)	4.07 (0.70)	4.10 (0.93)
Skill	35.37 (0.86)	35.88 (0.45)	34.75 (1.38)

Note Seniority represents the length of time an individual worked in the enterprise

the forefront of production, as for large sized enterprises could only report 20 % of the whole workers. As a result, eighty-five enterprises from three industries in total and more than 14628 workers worked in the forefront of production (Information Technology: $N = 1613$; Electronics Manufacturing: $N = 11417$; Medical and Health: $N = 1598$) participated in this salary survey. The participants' information in each industry is illustrated in Table 1.

2.2 Measures

1. Demographic information
Human resource managers reported the age, gender, seniority, education and skill of their employees especially those worked in forefront of production, and size, ownership status of their enterprises. Organization size (1 = "large", 2 = "medium", 3 = "small", 4 = "micro") was measured from both turnover and the total number of staff. Ownership status represents the state of owning enterprise (1 = "domestic-funded enterprise", 2 = "enterprises with investment from Hong Kong, Macaw and Tai Wan", 3 = "foreign-funded enterprise"). As for gender, 1 represents "male", 2 represents "female". Education, 1 represents "bachelor", 2 represents "undergraduate", 3 stands for "institutions of higher education", 4 stands for "senior middle school", 5 stands for "junior high school". Skill refers to individuals' technical ability, 31 represents "senior technician", 32 represents "technician", 33 represents "senior skill", 34 stands for "mid-level skill", 35 stands for "primary skill", and 36 stands for "no certification".

2. Organizational performance
Organizational performance was measured by sales margins; sales margins will reflect the organizational performance effectively [23]. Sales margins were computed as the profit divided by turnover. It represents the profit ability of the enterprise.

3. Pay dispersion
Human resource managers were asked to report the annual pay of workers worked in forefront of production. The annual pay was computed as the sum of basic pay and merit pay. This study adopt coefficient of variation [19] to measure pay dispersion. Pay dispersion computed as the standard division divided by mean. Gupta et al. [10] argued that there were several reasons for the inconsistence existed in the study; one of them was the misuse of the measurement of pay dispersion. They claimed that if the independent variable was organizational performance then it was better to use coefficient of variation, because coefficient of variation took the whole pay into consider, employees' pay at some degree may consider as a kind of cost, it may affect financial performance. So when researchers adopt organizational performance especially financial performance as an independent variable, it was better to use coefficient of variation.

4. Pay strategy
Pay strategy and pay structure were regarded as two main aspects of compensation systems [4]. Brown et al. [4] used pay level to measure pay strategy. In general, pay strategy were always divided into three categories, leading the market, matching the market, and lagging the market [17]. Pay strategy in this study was computed by the same means of Brown et al. [4], that is the standardized annual pay, the higher represents the more leading the market, and the lower represented the more lagging the market. Pay strategy was measured by pay level.

5. Control variables
Many researchers argued that it was necessary to control variables of human resource capital, especially when applied equity theory to research, because the assumption of equity theory is equal inputs. But as Gupta et al. [10] argued that controlled human resource capital will also limit some important variance, as such, this study only controlled organizational variables.

2.3 Analysis

Hierarchical regression was carried out to investigate whether pay dispersion and pay strategy, pay dispersion and the types of industry could affect the organizational performance. For the first study, in the first model (step 1), organizational size and ownership status were included as independent variables, in the second model (step 2), pay dispersion and pay level were added to independent variables, in the third model (step 3), the interaction outcome of pay dispersion and pay level was added into independent variables. The interaction outcome was the product of the standardized value of both pay dispersion and pay level.

For the second study, in the first model (step 1), control variables such as organizational size and ownership status were added to independent variables, in the second model (step 2), pay dispersion and Information Technology and Electronics Manufacturing were included as independent variables, the effect of industries was conducted by computing two dummy-coded variables, type1 (0 = not Information Technology, 1 = Information Technology), type2 (0 = not Electronics Manufacturing, 1 = Electronics Manufacturing), and Medical and Health was chosen as a baseline group. In the third model (step 3), interaction terms of pay dispersion and industries were added as independent variables. The interaction terms were the products of dummy variables and standardized value of pay dispersion.

3 Results

3.1 Preliminary Analysis

Correlations between variables in this study are illustrated in Table 2. Results show that pay dispersion and pay strategy have significant correlation with sales margins, and ownership status has significant correlations with pay dispersion, pay strategy and industry. The findings indicate that ownership status has positive effects on pay dispersion and pay strategy; these reveal that foreign-funded enterprises prefer to adopt hierarchical pay structure and pay strategy leading the market. Pay dispersion positively correlated with pay strategy, this indicates that the enterprise prefer hierarchical pay dispersion are likely to adopt pay strategy leading the market. Pay dispersion and pay strategy both negatively correlated with sales margins, these reveal that hierarchical pay strategy yields low sales margins so does pay strategy leading the market.

3.2 Hierarchical Linear Regression

1. Study 1

In step 1 of the hierarchical linear regression, all the control variables are added as the independent variables, and there is no significant effect on sales margins. In

Table 2 Correlation matrix

Variable	Mean	SD	1	2	3	4	5
1. Organization size	2.41	0.76	–	–	–	–	–
2. Ownership status	1.48	0.83	−0.24*	–	–	–	–
3. Pay dispersion	0.26	0.18	−0.17	0.35*	–	–	–
4. Pay strategy	0.00	0.99	−0.05	0.32**	0.50**	–	–
5. Industry	1.89	0.83	0.18	−0.28**	−0.27*	0.00	–
6. Sales margins	−0.02	0.77	−0.04	−0.01	−0.32**	−0.36**	−0.22

*$p < 0.05$ at 2 tailed. **$p < 0.01$ at 2 tailed

Table 3 Results of regression analysis: effects of pay dispersion and pay strategy on sales margins

Variables	Step 1	Step 2	Step 3
Step 1: control			
Organization size	−0.05	−0.1	0.04
Ownership status	−0.02	0.15	0
Step 2: linear effects			
Pay dispersion	–	−0.25	0.02
Pay strategy	–	−0.27*	−0.13
Step 3: interaction			
Pay dispersion × pay strategy	–	–	−0.56**
Overall R^2	0	0.18	0.39
Changed in R^2	–	0.18**	0.21**

$^{*}p < 0.05$ at 2 tailed. $^{**}p < 0.01$ at 2 tailed

step 2, that is the test of linear effects, pay dispersion and pay strategy are included in the model as independent variables, and the results indicate that pay strategy has a significant effect on sales margins. In step 3, the interactions of pay dispersion and pay strategy is added to the model as an independent variable, and the results show that the interaction has a significant effect on sales margins. From step 2 to step 3 increases the variance explained by the model by 39 %. Table 3 displays the results of the regression models. Figure 1 illustrated the moderation effects of pay strategy on the relationship between pay dispersion and organizational performance.

Figure 1 shows that when pay strategy is leading the market, there is a significantly positive relationship between pay dispersion and sales margins, when pay strategy is lagging the market, pay dispersion is negatively related to sales margins and is statistically significant. Hypothesis 1 is supported.

2. Study 2
In the first step, organizational size and ownership status are added into the model as independent variables, there are no significant effects on sales margins. In the second step, pay dispersion and dummy variables are included in the model as independent variables; the results indicate that both of pay dispersion has negative effects on sales

Fig. 1 Study 1: interactions among pay dispersion and pay strategy

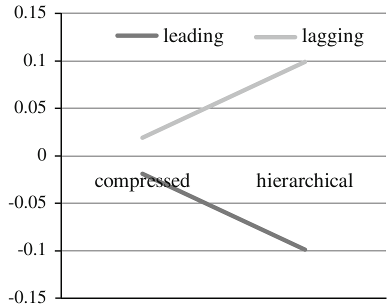

Table 4 Results of regression analysis: effects of pay dispersion and industry on sales margins

Variables	Step 1	Step 2	Step 3
Step 1: control			
Organization size	−0.046	−0.09	−0.02
Ownership status	−0.021	0.05	−0.03
Step 2: linear effects			
Pay dispersion	–	−0.46**	−1.32**
Information technology	–	0.38**	0.69**
Electronics manufacturing	–	0.26	0.56**
Step 3: interaction			
Pay dispersion × information technology	–	–	0.76**
Pay dispersion × electronics manufacturing	–	–	0.59**
Overall R^2	0	0.23	0.38
Changed in R^2	–	0.23**	0.15**

*$p < 0.05$ at 2 tailed. **$p < 0.01$ at 2 tailed

margins. In step 3, the interaction terms of pay dispersion and industry are added into the model as independent variables. The results show that interactions among pay dispersion and Information Technology have a significantly positive relation with sales margins, so do the interactions among pay dispersion and Electronic Manufacturing. The change in sales margins goes up as industry changes from Medical and Health to Information and Technology and sales margins increases more significantly in Electronics Manufacturing than it in Medical and Health. From step 2 to step 3 increases the variance explained by the model by 38 %. Table 4 displays the results of the regression. Hypothesis 2 is supported.

The regression results indicate a significant difference between the baseline group (Medical and Health) and the other two industries. The relations between pay dispersion and organizational performance among different industries are presented in Fig. 2.

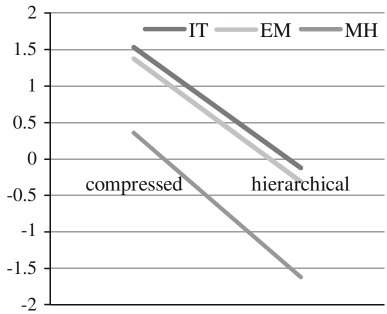

Fig. 2 Study 2: interactions among pay dispersion and industry

Figure 2 shows that enterprises in all three industries have negative relations between pay dispersion and sales margins.

4 Discussion

The experimental outcomes revealed that pay strategy and industry played an important role in the effect of pay dispersion on organizational performance. The strength of affecting organizational performance is larger in Information Technology than other industries.

The limitation of this research is the types of pay dispersion should be various, it only investigates the effects of horizontal pay dispersion, vertical pay dispersion should also be taken into consider, to display the whole picture of the pay dispersion.

For future research, data from various time points could reveal the effect of pay dispersion and organizational performance. And there should be more moderators to better reveal the mechanism of pay dispersion and organizational performance.

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An Exploratory Case Study of the Relationship Between Strategy and Brand Value Based on Innovation Choice

Liming Zhang, Rui Zhou and Jing Xu

Abstract The study of the relationship between strategy and brand value is a frontier issue. However, the research about how does competitive strategy enhance brand value is not enough. Thus, this paper introduces breakthrough innovation and incremental innovation creatively to construct a model among strategy, innovation and brand value. In order to verify the reliability of model, this paper select three representative cases. We find that the company implementing competitive strategy could enhance brand value; the company implementing cost leadership strategy could enhance brand value choosing incremental innovation; the company implementing differentiation strategy could enhance brand value choosing breakthrough innovation.

Keywords Cost leadership strategy · Differentiation strategy · Breakthrough innovation · Incremental innovation

1 Introduction

Brand is the strategic asset of a company [19]. With the Economic Globalization and environmental dynamics, the company must make suitable competitive strategy to require and maintain competitive advantages. Thus, the study of competitive strategy and brand value becomes a frontier issue. Reviewing the relevant papers, we find there is an argue on which competitive strategy can promote brand value. And some studies even found there is no positive correlation between competitive strategy and brand value [4]. These studies focus on comparison with influence of Port's competitive strategy, however the study on how does competitive strategy influence brand value is

L. Zhang (✉) · R. Zhou · J. Xu
Business School, Sichuan University, Chengdu 610064 , People's Republic of China
e-mail: zhangliming@vip.163.com

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not enough. Just analyzing the relationship between competitive strategy and brand value is not enough, and it is more important to explore the inner mechanism between competitive strategy and brand value.

Many studies find innovation could improve brand value. Thus, this paper constructs a new conceptual model based on innovation choice. Moreover, this paper analyzes how does competitive strategy choose innovation and the influence of innovation choice on brand value.

Competitive strategy always takes an important role in strategic management theory [9]. The main research about competitive strategy includes Porter [20], Mile and Snow [17] and Mintzberg [18]. This paper chooses Porter's competitive strategy, including three types: cost leadership strategy, differentiation strategy and focus strategy. In some extent, focus strategy is the utilizing of other two strategies [15]. Thus, this paper focuses on cost leadership and differentiation strategy. In Porter's theory, cost leadership strategy focuses on low cost to acquire and sustain competitive advantage; differentiation strategy focuses on special product or service, which acquires and sustains competitive advantage.

Innovation is a new function, which puts relevant factors and environment into production system [23]. In view of duality, many studies have researched a consensus innovation is divided into breakthrough innovation and incremental innovation [5]. Breakthrough innovation means putting new product and technology into market in first time [27], which requires enough capital and high technology [14]. Incremental innovation means incremental, low amplitude and sustainable innovation by importing technology [2]. Incremental innovation focuses on optimization of existing product or craft, but breakthrough innovation includes more new knowledge and technology. And breakthrough innovation requires more capital, technology and management [12].

Competitive brand is considered as important intangible asset and resource of competitive advantage [13]. Now the studies definite brand value mainly in two perspectives: customer perception and finance. In the view of customer perception, brand value is the effect and emotional value that customer feels; but in the point of finance, brand value is premium income [30]. For the convenience of researching, this paper chooses the brand value in view of customer cognition. Exploring inner mechanism between competitive strategy and brand value is important in theory, and it is helpful for companies to improve the ability of evaluating and implementing competitive strategy.

2 Theory and Model Construction

2.1 Effect of Competitive Strategy on Brand Value

The cost leadership strategy requires cost leadership advantage by controlling cost and rebuilding value chain, guaranteeing the quality and promoting brand value. But incremental strategy constructs brand by technology innovation. Thus, this paper thinks both competitive strategies can promote brand value. Zhang [31] found customer cognition is a process, in which they choose design, brand image, etc., and he has proved rational merge based on competitive strategy can take positive influence. Huang [11] found company should choose cost leadership strategy by promoting service and cost-effective product to construct brand. Fu [8] found company chooses differentiation strategy according to customer's requirement to construct competitive advantage [8]. Thus, this paper proposes and verifies the following hypothesis:

Hypothesis 1 Both low cost strategy and differentiation strategy are helpful to enhance the brand value.

2.2 Innovation Choice of Competitive Strategy

Both two strategies need innovation, but innovation choice is different. Cost leadership strategy can help company acquire competitive advantage by cost advantage [10]. Companies implementing cost leadership strategy would like to choose incremental innovation, and they innovate on the base of existing knowledge. These companies just focus on existing product and market, and they don't input resource to seek for new market. Because breakthrough innovation would eliminate experiment of the company, so this strategy little focuses on breakthrough innovation.

Company implementing differentiation strategy focuses on design and quality of the product [32]. In order to promote brand value, company tries to meet customer's need with powerful ability of R&G, unique product, and high-quality service.These enterprises pay more attention on technology innovation, and they are good at creating dynamic and uncertainty to rival. So they choose breakthrough innovation to enhance brand value, which could obtain and maintain competitive advantage. Thus, this paper proposes and verifies the following hypothesis:

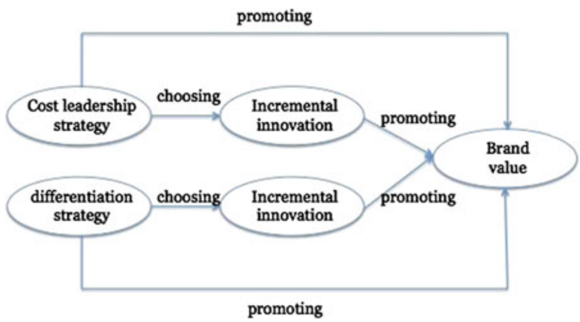
Hypothesis 2 Implementing low cost strategy is good for choosing incremental innovation.

Hypothesis 3 Implementing differentiation strategy is good for choosing breakthrough innovation.

2.3 The Influence of Innovation on Brand Value

Facing the complexity and uncertainty, innovation gets more important. Now, many studies have demonstrated the important role of innovation on brand value: both strategies can promote brand value. The brand based on technology innovation gets

Fig. 1 Relationship model



competitive advantage in market [16]. Qiao and Peng [22] found innovation is the core of brand value. The innovation includes product innovation, technological innovation, and marketing innovation, and they have proved the important role of innovation on brand value.

Bai [1] found a company acquires competitive advantage and brand value by culture innovation and management mechanism. Tian [24] found company enhances brand value by innovation strategy in form of following and imitating. Wang [25] distinguished innovation into leapfrog innovation and incremental innovation, and he pointed out incremental innovation helps to improve enterprise capability of independent innovation. Yang [28] found domestic automobile enterprises insist on independent innovation to integrate technical knowledge and experience into technical ability,which occupies the highest links of value chain. And the study suggested breakthrough innovation helped to enhance brand value. Thus, this paper proposes and verifies the following hypothesis:

Hypothesis 4 Incremental innovation could promote brand value.

Hypothesis 5 Breakthrough innovation could promote brand value.

Based on the analysis, we put forward a relationship model among competitive strategy, innovation choice, and brand value, as shown in Fig. 1.

3 Method

From the perspective of innovation choice, we study on the relationship between competitive strategy and brand value with multi case research method. Different types of research need different method [29]. When there is lack of theory or the existing studies are not enough, researchers should construct theory model from organization practice in case study method [26]. Although the competitive strategy and brand value are not new concept, but the study on how does competitive strategy promote brand value in the view of innovation choice is new. Thus, this paper selects case study is appropriate.

Table 1 Three cases

Name-founded time-nature	Status of company	Product structure
Wal-mart—1962 year—foreign company	Ranked first in American "fortune" magazine of the world's top 500 in 3 consecutive years, including 8500 stores, located in 15 countries around the world	Retail business
Chery—1997 year—state-controlled company	In 2013, total sales volume breaking through 4 millions, becoming the largest passenger export enterprises in China for 11 consecutive years	Passenger cars, commercial vehicles, trucks and buses
Vanon company—1987 year—private enterprise	Including more than 10 subsidiaries, starting bamboo industry in 2006, constructing new process in 2012, establishing BABO in 2014	Fabric, bamboo and intelligent

Source from the author's collecting

1. Case Choice
If condition permits, the case study can extract theory [7]. It is not necessary to meet sampling principle in case study, but it is necessary to select special and representative cases in case study [6]. The standard we choose cases are these: (1) For the universal manifestation of the model, the cases we selected include foreign enterprises and domestic enterprises; private enterprises and state-owned enterprises; manufacturing enterprises and service enterprises; (2) The selected enterprises all have a history more than ten years, which ensures us to obtain relevant data [3]; (3) we are convenient to get relevant data in these cases.

2. Company Profile
According to the standard we select cases, finally we selected three cases as shown in Table 1.

4 Case Analysis

1. Wal-Mart-Creating Top Retail Brand by Implementing Competitive Strategy
Since established in 1962, Wal-mart had created cover $14 billion in signal day. After years of development, Wal-mart has become the world's largest private employer and chain retailer, and it repeatedly topped World's Top 500. In 2012 it became the most value of retail brand as the result of implementing flexible competitive strategy.

Competitors around Wal-mart include native companies like Sears, Kamath, foreign companies like Carrefour, Aldi. Certainty, it also faced to new competition from new companies. Facing the situation, Wal-mart chosed differentiation strategy to avoid strong competitors, which laid the foundation for future development. With continuous development, Wal-mart tried to control cost by controlling logistics cost, establishing information processing system, and retaliating supply chain management. Thus, Wal-mart established the leading position in retail industry by cost leadership strategy.

As a case of this paper, Wal-mart is suitable in some extend. Because Wal-mart built its brand value by flexible competitive strategy,which can support this research. In fact, Wal-mart's success also came from its organization management, human resource management,etc. But this paper does not control these variable, and this effect the result of this paper.

2. Qhery-Promoting Brand Value by Incremental Innovation in Process of Cost Leadership Strategy
Since established in 1997, Chery had obtained customer's approval by incremental innovation in process of cost leadership strategy. There are four sub brands in Qhery: Chery, Ruiqi, Wei Lin and Dirks, which include passenger cars, commercial vehicles, and mini cars. Up to 2013, sales breaked through $4 million, and Qhery became the largest passenger vehicle export enterprises in China for 11 consecutive years.

Low cost strategy of Chery is reflected in three aspects: supply chain cost strategy, R&D cost strategy and labor cost strategy. In supply chain cost strategy, Chery did not initially establish vehicle production line, but it used automobile engine production line of Ford incrementally. Along with the success of the design, the engine became the core part of the vehicle. In choice of parts, Chery reduced cost by using domestic support system. In the process of R&G, Chery developed new models by imitating foreign products through the "Outsourcing—mergers—joint design" pattern. In labor cost strategy, Chery has created advantage of low cost in use of low labor costs in Anhui pronvince.

From the case of Qhery, this paper analyzes its cost advantage from supply chain, R&D, and labor cost. In fact, Qhery also implemented differentiation strategy in its development, but this paper does not analyze this strategy.

3. Vanon-Promoting Brand Value by Breakthrough Innovation In Process of Differentiation Strategy
Since established in 1987, Vanon focused on industrial investment, and it owns three business units, fabric, bamboo and intelligent robot. During the past twenty years, Vanon has established more than ten subsidiaries. Vanon always pays attention to technology, and it has filled many technology blank in domestic and foreign research. Vanon has become the world famous brand by breakthrough innovation in process of differentiation.

Focusing on the blank of new material applications in biomass of bamboo fiber, Vanon constructs the independent brand-BABO. There are four innovational pots. (1) Innovating in the process of product, new product keeps natural bamboo antibacterial and antimicrobial in it; (2) According to EU food standard, the new product has non sulfide and other toxic substances residues; (3) Vanon invents more important functional material; (4) Vanon realizes the full use of development and utilization of biomass. In the process of differentiation strategy, Vanon achieves rapid development by breakthrough innovation in process of differentiation strategy.

Although Vanon has four innovational pots in its new independent brand-BABO, it is still a new brand. Thus, whether BABO could acquire sustainable development is still a puzzle. Vanon has a long history of operating and managing, but that may not be transplanted to its sub brand.

As a study method, case study is suitable for new theory or practice question. Because the relationship between competitive strategy and brand value is new, especially in the view of innovation choice, so it is reasonable to select case study in this paper.

In order to improve the university of the model, this paper selects cases from different countries, industries, and ownership. The Wal- mart is foreign compay, Qhery and Vanon are both from China; Wal-mart is in retail industry, Qhery and Vanon are manufacturing industry; Qhery is state-controlled company, while the Vanon is the private enterprise. However, the representativeness and typicalness is still limited. At the same time, the effectiveness is limited for lack of relevant data.

5 Conclusion and Future Research Recommendation

1. Conclusion

In the perspective of innovation choice, this paper introduces the breakthrough and incremental innovation to study the relationship between competitive strategy and brand value. Constructing the concept model after theory reviewing, this paper chooses exploratory case analysis method to check the model. And we get some important conclusion.

(1) Both competitive strategies can promote brand value. Many studies have found competitive strategy is helpful to enhance brand value, and this paper also confirms that. In fierce market competition, company must implement suitable competitive strategy according to environment. Ether cost leadership strategy or differentiation strategy is better than no strategy.

(2) Different strategy, different innovation choice. Company implementing cost leadership strategy chooses incremental innovation, while company implementing differentiation strategy chooses breakthrough innovation. Different competitive strategies need difference in organization arrangement, controlling program and innovation system [21]. The analysis is consistent with hypothesis. Cost leadership strategy controls and rebuilds value chain, and it can obtain and maintain competitive advantage by incremental innovation. Differentiation strategy focuses on design and quality, and company obtains and maintains competitive advantage by breakthrough innovation.

(3) When competitive strategy effects on brand value, innovation takes an intermediary role. No matter which competitive strategy is chose, companies all should take innovation, and innovation becomes the link of competitive strategy with brand value. Innovation is the source of sustainable development, and it is the mainstream of enterprise management. Company can shorten the distance with leader, draw lessons from other enterprises, and enhance brand value in the process of implementing low cost strategy by incremental innovation. Company implementing differentiation

strategy chooses breakthrough innovation to establish barriers to imitate, and it can help enterprise to gain and maintain sustainable competitive advantage. Of course, the breakthrough innovation required high ability to deal with the risk prediction.

2. Future Research Recommendation
This paper extends the research of competitive strategy and brand value. In the perspective of innovation choice, this paper introduces breakthrough and incremental innovation to study the relationship between competitive strategy and brand value. Analyzing three classic cases, this paper gets some important conclusions, which enriches the research in relevant field. When analyzing cases and model constructing, this paper goes for scientific principles.

However, there are still some flaws: (1) we choose the method of exploratory case research method, and the cases we selected have particularity inevitably. In order to promote the reliability of the conclusion, we will get further research with empirical data in future research; (2) This paper only considers the factor of innovation choice, and its does not consider environment, enterprise life cycle and other factors. We will consider other factors in further study to research the relationship between competitive strategy and brand value in the view of innovation choice.

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A Research on Chinese Creative Industry Development Efficiency Based on Geography District

Ying Zhang, Yongzhong Yang and Lirong Zhong

Abstract Grounded on a large number of researches on the development efficiency of creative industry, the paper builds efficiency evaluation index system of regional creative industry development in China from the perspective of input and output. Itimplements the classic DEA modelłCCR and BCC models to evaluate the development efficiency of creative industry in 31 provinces, cities and autonomous regions in China, and thenit adopts the method of averaging to assessthe comprehensive efficiency (technical efficiency, TE), pure technical efficiency (PTE) and scale efficiency (SE) ofcreative industry development in China's seven regions. In addition, this paper accentuates the influence of the policy environment and investment on the efficiency of creative industrydevelopment, and finally puts forward some important relevant conclusions.

Keywords Creative industry · Development efficiency · Geography district · DEA model

1 Introduction

Under the background of economic globalization, creative industry is an emerging industry and one of the fastest growing industries in recent years, which regards creativity as its core. How to maintain its sustainable and healthy development has become one of the problems that governments all over the world should focus on. To keep creative industry developing stably and healthily, the first thing is to understand the developing level and the comprehensive competitiveness of local creative industry, and then to find the influencing factors promoting or hindering its development, which can make accessible solutions to improve the local creative industry development.While it can not only scientifically assess the efficiency of national or regional development of creative industry, but also find out the relevant influencing

Y. Zhang (✉) · Y. Yang · L. Zhong
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: 512651420@qq.com

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factors via establishing a rational and perfect evaluation system for the development efficiency of creative industries, and furthermore it can estimate the creative vitality and developing potential of the region. With reviewing the extant literatures on the creative index and creative industry development efficiency home and abroad, it builds a comprehensive regional creative industry development efficiency evaluation index system according to the characteristics of creative industry development in some regions, and then it uses the system to evaluate the efficiency of Chinese regional creative industry development. Finally, combined with the evaluation results, it draws some appropriate conclusions and recommendations for the development of creative industry.

2 Literature Review

Since Hawkins puts forward the concept of creative industries, foreign scholars have been doing many studies on all aspects of the creative industry to a certain depth and breadth. They achieve certain advantages in researches on the creative index, creative industries efficiency and creative industries practice. On creative development index and the efficiency of the creative industries development, Florida [1] presented the famous "3Ts" theory, which holds that the creative industry must have a combination of the three key elements: "Talent", "Technology" and "Tolerance", and establishes a creative index system for the first time, which is used to assess creative capacity of 50 states and major cities in the US. "3Ts" theory has been recognized and supported by the majority of scholars, producing a profound influence on the studies of creative index later. Therefore, creative index systems in many countries and regions have been established on the basis of this theory, as well as with the actual situation in the region. Then Florida and Tinagli [2] begined to cooperate to make a comparison on creative economic development elementsbetween14 European countries and USA and establish the European Creativity Index (ECI) and Global Creativity Index (GCI), which is used to estimate the creative index of 45 countries. British scholar Charles Landry takes personnel quality, will and leadership, urban space and facilities, network power relations as a base to divide the creative city development scale into 10 grades [3]. While Poland scholar Andrzei Klimczuk describeed general barriers to the development of creative industries in culturally diverse regions on the example of Podlaskie Voivodship from Poland. He argueed one of the key challenges of the region is diagnostic and programming work for the construction of a regional model of a creative industry [4].

The research on the development efficiency of creative industry in domestic is overall later than abroad. And the scholars in domestic mainly concentrate on city creative industry efficiency from the perspective of economics, analyzing the developing efficiency and level of creative industry from the angle of input-output. The main researches include: in 2005, Hong Kong builds a set of index system of creative industry–Hong Kong Creativity Index on the basis of "3Ts" theory and European Creativity Index [5]. The index includes creative achievement, organization and institutional capital, human capital, social capital and cultural capital, which is also called “5Cs”. Europe and Hong Kong Creativity Indexes have obvious geographic restrictions, while the Cultural and Creative Industry Research Center of Renmin University of China has established a set of culture index for domestic provinces and cities in order to better assess and evaluate the development efficiency of the creative industry in China [6]. The index is grounded on the improved culture industry review theory of the Asia Pacific region proposed in UNESCO Jodhpur forum. Culture industry review theory of the Asia Pacific regionCevaluate development of culture industry should consider from the cultural capital, infrastructure, policy environment, cultural output (products and services) three aspects. to build the framework, combining Porter’s diamond model and China’s national conditions to select the measurement variables. The index is constituted by three indicators: the first class indicator consists of industry productivity, industry influence and industry driving force. In addition, Tan et al. [7] put forward the seven factors of competitiveness of the city’s creative industries combined with organizational ecology theory, which explores that intelligence inputs, capital investment, basic environmental factors as the main factors by analyzing cross-section data from 20 cities nationwide. Lin et al. [8] presented the main factors affecting the creative industry development in the city based on the related theories and literatures, including institutional factors, talent reserve, city openness, city’s infrastructure, and conduct an empirical study on 43 cities in China, further divides the city’s creative team, and offers the corresponding development strategy for the creative industry.

Domestic and foreign scholars have obtained abundant the or eticalor practical achievements on efficiency evaluation of the creative industry development and creative development index, which provides valuable references for us. While the domestic researches on the development efficiency of creative industry mainly focus on how to build the reasonable evaluation systems, but ignore the empirical analysis. Simultaneously, researchers only emphasizes on a region-based monomers city in the rather few empirical analysis, but ignore the cooperative and competitive interaction relationship between city group and regional creative industry. Due to geographical proximity, provinces and cities in the same regions tend to have similar natural resources, cultural resources, and customs, etc., which areal ways important bases for cooperation and competition between these provinces and cities. Based on the characteristics, many major strategic development plans are developed, such as the famous South-to-North Water Diversion and West-East Gas Transmission. After reviewing the relevant literatures, it can easily explore that there are few articles researching on regional creative industry. Therefore, it attempts to build regional creative industry development effectiveness evaluation system in the paper, which takes seven geographical divisions (East China, South China, North China, Central China, Southwest China, Northwest China and Northeast China) as study objects, then assesses the development efficiency and competitiveness of creative industry in the seven areas and provides the corresponding suggestions.

3 Construction of Evaluation Index System of Creative Industry Development Efficiency

1. The Thought of the Construction of Evaluation Index System
The research is based on reviewing the a lot of literatures on creative industry development index and efficiency, considering the actual conditions of China and the accessibility, operability of specific indicators data, combining "3T" theory and the improved culture industry evaluation theory of the countries and regions in the Asia Pacific. Then it builds a reasonable evaluation index system to evaluate Chinese regional creative industry development efficiency and the comprehensive competence, in order to quantify the overall standard of scientific and standardized assessment of the regional development efficiency of creative industries and the overall competence.

2. Evaluation Index System Theory Based Framework
Florida mentions in his book The Rise of the Creative Class clearly, "Technology, talent and tolerance··· they are necessary to attract creative talent, encourage innovation and promote economic growth··· a real creative center must be with the three elements at the same time" [1]. Florida's "3T" theory focuses on investment and development environment of creative industries (culture atmosphere) to assess the developing potential and level of creative industry, without taking the output levels into account, so it can't effectively reflect input and output efficiency of a country or region's creative industry. UNESCO Jodhpur forum points out explicitly that "the development of cultural industry should be evaluated from the cultural assets (capital), infrastructure policy and cultural outputs (products and services)". Considering the above two theories, the paper will build China's regional creative industry development effectiveness evaluation system from three aspects, which are capital investment, the environment and policy support as well as the creative output. Creative capital input indicators are composed by cultural capital, human capital and technological capital reflecting the developing potential of creative industries. The output indicators are mainly economic and social benefits brought by the creative industries. While the environment and policy support index mainly refers to reflect the policy support, the degree of city (region) openness, particularly including: government policies, the degree of openness. See Fig. 1.

3. The Concrete Construction of the Evaluation Index System
The paper divides the evaluation index system into three levels: the first class indicators include capital input index, environment and policy indicators (indicators of environmental capital investment) and output index. The capital input index is divided into three categories, which are the cultural capital, human capital and technology capital. Environment and policy index consists of the government policy support and the degree of city openness of the two class city. And the output index is considered from two aspects, which are economic benefit and social benefit of creative industry. The specific indicators selected are as follows:

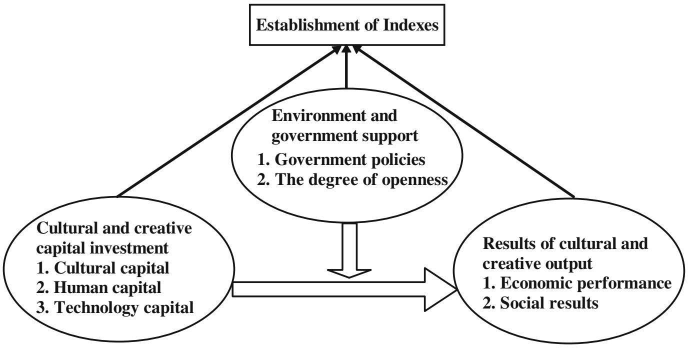

Fig. 1 Creative industry development efficiency evaluation index system

(1) Indexes of capital inputs
Cultural capital: The number of infrastructure for cultural activities. Cultural capital is the source of a country or a region for creative content. The richness of the cultural capital in a region plays an important influence on the creative industry development in this district. Many indicators can be used to assess cultural capital, while the common-used indicators are the number of state-level non-material cultural heritage, total number of infrastructure for cultural activities, public library collections and performing arts venues seats number, etc. The paper selects the total number of infrastructure for cultural activities as evaluation index of cultural capital just because compared with other indexes, it can be adjusted according to the change in a certain period. While other indicators such as the number of non-material cultural heritage cannot change much in the short term, and thus it is of less significance to research on them.

Human capital: The average number of students on campus per ten thousand populations. Creative talent is the subject to create and an inexhaustible source of ideas, so creative talent is the core factor of production inputs for creative industry. Creative talent and the level of human capital in an area are incarnated in the number of high-quality university students. Therefore, it is believed that the more the number of students on campus occupies in the total proportion of the local population, the higher quality of the region's stock of human capital, and the more prominent creative capability, the higher output efficiency of investment in human capital.

Science and technology capital: R&D internal expenditures occupying in a share of GDP. Mutual integration between science and culture, innovation and creativity is the main melody of creative industry development, which is a dual-engine to promote the healthy development of creative industry. The investment of cultural capital can reflect a region's creative basis and ability to some extent; while the technology capital investment can reflect the innovative ability in the area. R&D internal expenditures occupying in a share of GDP can intuitively reflect the extent to which the region's support for science and technology.

(2) Indexes of environmental inputs

Government support: Policies for creative industry. It is indispensable for any industry to get healthy development with the government support. The enterprises engaged in the creative industry are mostly small and medium-sized, even micro, whose anti-risk capability is rather weak that they need strong support and help from the state and local government. Therefore, the number of policies can reflect the local government's attention and support for the development of creative industry to a certain extent. So here we select "policies for creative industry" as the index of government support.

Degree of openness: Import and export trade as a share of GDP. Creative industry is the product of highly open economy, which is always appearing among the extensive outreach center cities [9]. Open cities contain with tolerate environment, where all kinds of culture collide and blend with each other to form a multicultural environment, which provides hotbed for creative industry's flourishing. Many empirical studies have proved that high degree of openness and tolerance of cities tend to be much easier to attract creative people gathering together, and then promote the development of creative industry. Many scholars have used "import and export trade as a share of GDP" as indicators to measure the degree of openness. Similarly, the paper also adopts it as the index of urban open degree. The higher the percentage is, the more urban openness will be.

(3) Indexes of outputs

Economic performance indicators: The number of patent license and the added value of the creative industries as a share of GDP.

(i) The number of patent license: Patent authorization possessed by a nation or a region is the external expression of creative knowledge and thinking, which is a form of high-valued intellectual property acquired by much inputting of human capital, cultural capital and other factors of production. This kind of intellectual property rights is protected by the related patent law and provides the base of core competence differentiated from the similar enterprises in the creative production for local creative enterprises, which represents to some extent that creative industry's output capability and the economic benefit in this region. Therefore, this paper holds that the more the quantity of authorization patent that a national or regional possesses, the more competitive advantages the creative products will obtain, which indicates that the production output effect with the input of human capital, culture capital and other creative industry factors may be better, and then the economic benefit of the creative enterprises may be greater.

(ii) The added value of the creative industries as a share of GDP: The added value of the creative industries reflects the development scale of creative industry, the size of which is the most direct expression of the economic benefits for creative industry. Therefore, the size of the creative industry is directly reflected in the level of economic benefits of creative industry. The proportion of added value in creative industry accounted for in GDP is bigger, the value creation and realization ability is stronger, and the development status of creative industry becomes better.

Social benefit indicator: Creative industry employment. Employment increase in creative industry has at least two aspects of social benefits: On the one hand, it can relieve the whole society's employment pressure when employment increase in creative industry, and it can improveresidents' income, which is conducive to social harmony and stability; On the other hand, with the increasing of the employment of creative industry, it can enhance innovation and creation atmosphere of the whole society, and promote the shift of industrial technology innovation and the mode of economic development, which will improve the overall efficiency of economic development. Therefore, it takes "creative industry employment" as the important evaluation indicator to measure the social benefits of creative industry.

4 Empirical Analysis

1. Data Sources
Specifically, taking the China's seven major geographical partitions as the research objects, this paper evaluates and measures the developing efficiency and competence of the creative industry in these seven areas, and further explores the regional creative industry developing characteristics and the related influencing factors. The data are collected through statistical yearbooks of the provinces and cities and the era of cultural and creative industry network (http://fy.iciba.com/). Considering the completeness and accessibility, all data in this study are selected in 2010. Classification of creative industry in this study mainly includes the following eight categories: class of film and television culture, advisory planning, design services, telecommunications, software, scientific research and education, performance, entertainment and technology trends.

2. The Method and the Model
The paper evaluates the developing efficiency in seven districts from the perspective of input-output, and therefore, it chooses a non-parameter statistical methodCData Envelopment Analysis (Referred to as the DEA), which is commonly used to evaluate the input-output effectiveness of the same kind of decision making units within multiple inputs and outputs. The commonly used DEA models are mainly CCR model and BCC model. Although the process of development in DEA is emerging a lot of new models, they are derived from the CCR and BCC models. BCC model and CCR model are very popular in scholars at home and abroad since they have produced, and widely used to evaluate the efficiency of different industries listing corporations, so we use the CCR model and BCC model of DEA method in our study. Specifically, DEA is mainly used to evaluate the efficiency of input-output, so we will take the indicators of environment and policy support as environmental capital, belonging to indexes of input. The evaluation system adjusted is as shown in Table 1.

Table 1 Creative industry evaluation index system

First class indicator	Second class indicators	Third class indicators
Inputs (X)	Cultural capital	Number of infrastructure for cultural activities (X_1)
	Human capital	The average number of students per thousand population of colleges and universities (X_2)
	Science and technology capital	R&D expenditures within a share of GDP (X_3)
	Environmental input	Policies for Creative industry (X_4)
		Import and export trade as a share of GDP (X_5)
Outputs (Y)	Economic performance targets	Patent license number (Y_1)
		The added value of the creative industries as a share of GDP (Y_2)
	Social benefit index	Creative industry employment (Y_3)

3. DEA Model Operation

Taking the accuracy and objectivity of results as well as the size of the sample into account, we will take 31 provinces (including municipalities and autonomous regions) as 31 decision making unit (DMU), and detailed empirical analysis will be divided into three steps. The first step is to calculate the traditional CCR model results, give overall efficiency values of all decision-making units, the optimal index weight coefficient and slack variable values, etc. The second step is to use BCC model to calculate the pure technical efficiency values of decision making units, in order to obtain the scale efficiency values of evaluation units. The last step is to calculate the technical efficiency, pure technical efficiency and scale efficiency of the seven districts (East China, South China, North China, Central China, Southwest China, Northwest China and Northeast China) in China by the method of averaging. All the results are calculated by DEAP2.1 software (Please see Table 2 and 3).

4. Result Analysis of DEA Models

(1) TE analysis of creative industry development level in seven areas of China

Technical efficiency, also named integrated efficiency, is the joint effect of pure technical efficiency and scale efficiency and mainly reflects the overall efficiency of the decision making unit DUM. In Table 2, without considering environment and policy factors, there are provinces and cities whose comprehensive efficiency is 1, including Beijing, Shanghai, Zhejiang, Hunan, Guangdong, Hainan and Yunnan, which implies that this is valid for DEA, namely the level of creative industry development in these areas is high and the competitiveness is strong. The average comprehensive efficiency of the other 31 is 0.695, the provinces and cities whose comprehensive efficiency is lower than the average value are 17 provinces including Shaanxi, Tianjin, Inner Mongolia, Liaoning, Heilongjiang, Anhui and others, which means that

Table 2 China's 31 provinces and cities of the creative industries technical efficiency, pure technical efficiency, scale efficiency in 2010

Within Environmental Input Factors						Without Environmental Input Factors			
Liaoning	6	0.599	0.629	0.953	irs	0.437	0.506	0.863	irs
Jilin	7	1.000	1.000	1.000	–	0.999	1.000	0.999	drs
Heilongjiang	8	0.439	0.613	0.717	irs	0.412	0.558	0.738	irs
Shanghai	9	1.000	1.000	1.000	–	1.000	1.000	1.000	-
Jiangsu	10	1.000	1.000	1.000	–	0.996	1.000	0.996	drs
Zhejiang	11	1.000	1.000	1.000	–	1.000	1.000	1.000	-
Anhui	12	0.803	0.831	0.966	irs	0.662	0.733	0.904	irs
Fujian	13	0.938	0.974	0.963	irs	0.937	0.968	0.968	irs
Jiangxi	14	0.484	0.670	0.722	irs	0.421	0.588	0.717	irs
Shandong	15	1.000	1.000	1.000	–	0.868	0.913	0.951	irs
Henan	16	1.000	1.000	1.000	–	0.515	0.783	0.657	irs
Hubei	17	1.000	1.000	1.000	–	0.717	0.746	0.962	irs
Hunan	18	1.000	1.000	1.000	–	1.000	1.000	1.000	-
Guangdong	19	1.000	1.000	1.000	–	1.000	1.000	1.000	-
Guangxi	20	0.542	0.899	0.604	irs	0.522	0.857	0.609	irs
Hainan	21	1.000	1.000	1.000	–	1.000	1.000	1.000	-
Chongqing	22	0.714	0.743	0.961	irs	0.562	0.631	0.891	irs
Szechwan	23	1.000	1.000	1.000	–	0.493	0.749	0.658	irs
Guizhou	24	0.695	1.000	0.695	irs	0.648	1.000	0.648	irs
Yunnan	25	1.000	1.000	1.000	–	1.000	1.000	1.000	-
Tibet	26	0.697	1.000	0.697	irs	0.583	1.000	0.583	irs
Shaanxi	27	0.833	0.841	0.990	drs	0.447	0.524	0.852	irs
Gansu	28	0.432	1.000	0.432	irs	0.296	0.624	0.474	irs
Qinghai	29	1.000	1.000	1.000	–	0.740	1.000	0.740	irs
Ningxia	30	0.896	1.000	0.896	irs	0.646	0.805	0.803	irs
Sinkiang	31	0.354	1.000	0.354	irs	0.136	0.880	0.154	irs
MEAN		0.828	0.935	0.884	0.695	0.848	0.808		

[a] TE = technical efficiency from CRS DEA; PTE = technical efficiency from VRS DEA; SE = scale efficiency; drs = decreasing returns to scale; irs = increasing returns to scale.

the creative industry development is low and the competitive power is weak in these 17 provinces without considering the environmental policy and other factors. While the development level of the rest of 7 provinces is in the middle. When taking the policy environment and other factors into account and using them as input variables (environmental input), then there are 15 provinces and autonomous regions of which the comprehensive efficiency is 1, including Beijing, Shanghai, Zhejiang, Hunan, Guangdong and others. Finally it leads to an increase of 8 provinces than not to consider the environment policy input, the comprehensive efficiency of the most close to 1 of the area is the East China and Southern China areas in Table 3 without consid-

Table 3 China's seven major areas of creative industry technical efficiency, pure technical efficiency and scale efficiency in 2010

Within Environmental Input Factors					Without Environmental Input Factors		
Area	DUM	TE	PIE	SE	TE	PIE	SE
North China	1	0.847	0.955	0.891	0.699	0.884	0.778
Northeast China	2	0.680	0.747	0.890	0.616	0.688	0.867
East China	3	0.890	0.921	0.950	0.841	0.886	0.934
Central China	4	1.000	1.000	1.000	0.744	0.843	0.873
South China	5	0.847	0.966	0.868	0.841	0.952	0.87
Southwest China	6	0.821	0.949	0.871	0.657	0.876	0.756
Northwest China	7	0.703	0.968	0.734	0.453	0.767	0.605

[a] Because here, PIE, TE and SE are calculated by an average of 31 provinces, so they don't satisfy the equation strictly, which is TE = PIE × SE.

ering the environmental inputs, which means that the development level of creative industry is the highest and the comprehensive competitiveness is the strongest with the non-environmental policy, the comprehensive efficiency is 1 in the central region of the country when considering environmental policy factor, i.e., the overall DEA is effective, we can draw a conclusion that the input of environmental policy into the development of creative industry in this region plays an important role.

(2) PTE analysis of creative industry development level in seven areas of China
Different from the overall efficiency value of DMU, the technical efficiency value of DMU indicates the technological output ability in the given input elements based on variable returns to scale. Table 2 is about the pure technical efficiency values of 31 provinces and autonomous regions in China without considering the environment and policy factors. It shows that besides the overall effective DEA of 7 provinces and cities such as Beijing, Shanghai, Zhejiang and others, the pure technical efficiency values are also 1 in 7 other provinces and autonomous regions such as Tianjin, Hebei, Jilin, Jiangsu, Guizhou, which are the overall non-effective DEA. And the pure technical efficiency values of DMU in the rest places such as Shanxi, Inner Mongolia, Liaoning are less than 1. Futhermore the valueof Liaoning is minimum of 0.506. This shows that compared with the other 14 places,the technological output ability of the creative industries is relatively low and need to be further improved in Shanxi, Inner Mongolia, Tibet and other 17 provinces and autonomous regions under the investment of fixed factors of production. And from Table 3, it can be seen that the highest pure technical efficiency value is 0.952 in Southern area within the seven areas in China which indicates that the technological output ability of this area is relatively high. The lowest pure technical efficiency value is in northeast area, only 0.688, far lower than the average value of pure technical efficiency of the seven areas which is 0.842. Thus we can draw a conclusion that the technological output ability in this place needs to be improved.

It can be drawn from Table 2 that on the whole the average net efficiency value of 31 provinces and autonomous regions in China reaches 0.935 under the consideration

of the environmental input conditions which indicates that the creative industry development is basically at the forefront of the pure technical efficient production. It is also verified that as the mainstay of creative industry in our country, the small and medium-sized enterprises' capability of technology innovation, integrated innovation and application is relatively strong. And the higher technical efficiency values are the main drive to support the overall higher efficiency of main cities in China. Besides, from Table 3, we find that the seven regions except the Northeast (0.747), pure technical efficiency values in other parts are all above 0.9 which once again proves that the technological output ability of creative industry is pretty strong.
(3) SE analysis of creative industry development level in seven areas of China
Note that investigation of changes in scale reward, when scale reward is invalid, the trend of decision-making unit scale reward turns to effective direction. The reason of scale reward increasing is that the insufficient inputs result in the poor overall resource using efficiency, so it need add inputs to improve the overall efficiency level at this time. The reason of scale reward decreasing is that redundant inputs lead to the poor resource using efficiency, so we should decrease these excess inputs to improve the overall efficiency level at this time. In terms of the overall level of China's creative industry, scale presents the obvious increasing trend, so we should seize the opportunity to add the investment, to further improve the efficiency of the whole.

5 Conclusion

This paper firstly determines 31 provinces, cities and autonomous regions as evaluation units for the development efficiency of creative industry, constructs a specific creative industry evaluation index system in the DEA model, and then based on the relevant data collection, it takes full use of the class models of DEA-the models of CCR and BBC to carry on empirical analysis, obtains the comprehensive efficiency (technical efficiency, TE), pure technical efficiency (PTE) and scale efficiency (SE) of the development efficiency of creative industries in China's seven major areas through the method of averaging. The evaluation result reflects the development situations of creative industry in the seven areas of China. The result shows: efficiency of basic creative industry development in our country presents cascade development from coastal to inland, but at the same time, the creative industry development of the inland is uneven and unbalanced.

In addition, this paper also focuses on the effect of the policy environment and investment on the efficiency of the creative industry development. Without considering environmental input, ranking of comprehensive efficiency from high to low in the seven regions, the order is East China, South China, Central China, North China, Southwest China, Northeast China and Northwest China. And pure technical efficiency from high to low order is followed by: South China, East China, North China, Southwest China and Central China, Northwest China. From these results, it can be easily found that: No matter from the point of comprehensive efficiency or pure technical efficiency, the districts where creative industry develops the best are East China and South China, while the worst areas are northwest and northeast China. And developing levels of Southwest, North and Central China are in the middle or upper level. But when considering environmental inputs, the ranking of comprehensive efficiency from high to low in the region is in the following order: Central China, East China, South China, North China, Southwest, Northwest and Northeast China.Andthe order of the technical efficiency from high to low is followed by: Central China, Northwest China, South China, North China, Southwest and East China, Northeast China. Based on the above conclusions, it should improve inputs in the structure and quality of the elements according to the situations of development of creative industry, and then improve the level of outputs, build up optimization ideas and the specific path for the regional differentiation in the future development of creative industry in China.

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Chinese New Generation Employees' Turnover Intentions: Effects of Person-Organization Fit, Core Self-evaluations and Perceived Opportunities

Xiaoye Qian, Yao Shi and Hao Zhou

Abstract This study examines the effects of person-organization fit to Chinese New Generation employees' turnover intentions. We hypothesize that for the New Generation workers, core self-evaluations mediated the P-O fit-turnover intention relationship and the perceived job opportunities moderated the core self-evaluations-turnover intentions relationship. Surveying 267 data from New Generation employees in a Chinese firm, we find that the New Generation employees reporting higher P-O fit show lower level of turnover intentions. This study also finds support for the mediating effect of core self-evaluations and the moderating effect of perceived opportunities.

Keywords New generation employee · Turnover intention · Person-organization fit · Core self-evaluations · Perceived opportunities

1 Introduction

The most recent cohort to enter workforce in China is named "the New Generation". In some literatures, they are also named "Generation Y", Nancy [13]. Compared with the earlier generational cohort, the New Generation employees born in 1980s and 1990s demonstrate identifiable features in the way they react to authority, their work-related values and what they will do to satisfy their values. On one hand, the New Generation are very creative, willing to learn and open to challenges [13]. These features lead to their high job performance. On the other hand, the New Generation generally have higher requirement for work environment, such as latest technology, regular feedback, fair reward and recognition system [12]. If they did not obtain what they expected from the employer, they are more inclined to leave the organization

X. Qian · H. Zhou (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zhouhao@scu.edu.cn

Y. Shi
Economics and Management School of Wuhan University, Wuhan 430072,
People's Republic of China

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[15]. Abundant studies report high turnover intentions of New Generation employees [12, 15, 18, 19]. In China, according to a recent survey conducted by Mercer, 55 % of the New Generation respondents reported that as long as other companies can provide higher pay or better opportunities, they will not hesitate to leave [19].

The compatibility between individual and origination has long been important in the organizational behavior studies [1, 4]. Nearly two decades of research consistently support that poor P-O fit necessarily leads to turnover [16]. However, there is little specific discussion regarding how P-O fit influence the New Generation's turnover intentions. In this study, we estimate the effect of person-organization fit as the predictor of New Generation employee's turnover intentions.

Existing literature on China's New Generation employees is relatively small. Among those studies, the effect of individual's personality on New Generation's work outcomes (such as employee's job performance and workplace creativities) has been proved [18, 19]. This study will discuss the mediating effect of personality in the relationship between person-organization fit and New Generation employees' turnover intentions. Unlike previous studies [18, 19], we will adopt core self-evaluations to measure the New Generation's personality, because core self-evaluations is a "better description of individual's personality" and "has stronger predictive power in explaining the variety of work outcomes" [8]. We will also discuss the moderating role of perceived job opportunities.

2 Hypotheses

2.1 Person-Organization Fit and Turnover Intentions

Person-organization fit refers to the degree of compatibility in values between individuals and organizations [11]. According to Kristof [1], the supplementary fit perspective defined person-organization fit as compatibility of people and organizations, which occurs when one party possesses characteristics similar to the other party. Employees being compatible with the organization will find themselves sharing the similar values, culture, goals and norms with others in the organization, hence are more easily to build trusts with others. Also, working in a high P-O fit environment, employees feel more comfortable, consequently report higher job satisfaction and lower turnover intentions. For the New Generation who have high requirement for work environment, a comfortable work climate is necessary to attract them [18].

The complementary fit perspective provides another explanation why employees are less willing to leave. According to Kristof [1], the complementary fit occurs when one party's characteristics "make whole" the other party or add to it what is missing. For the New Generation who have strong self-concept and high self-realization expectation, an organization that "make them whole" can provide resources to help them display their talent and achieve their goals, therefore can satisfy their needs of self-realization. On the contrary, working in an organization doesn't fit them well, employees' needs can hardly be satisfied, leading to strong intention to leave. The existing research did find that higher person-organization fit can significantly reduce employee's turnover intentions [17]. As such, a positive relationship between P-O fit and turnover intentions is predicted.

Hypothesis 1 Person-organization fit will be negatively related to the New Generation employees' turnover intentions.

2.2 The Mediating Role of Core Self-evaluations

Core self-evaluations is a higher-order construct consisting of our individual traits: self-esteem, neuroticism, self-efficacy, and locus of control [2], it refers to an individual's fundamental and enduring assessment of one's own worth and competence. Under the approach/avoidance framework [5], individuals with high approach temperaments such as high core self-evaluations are more sensitive to positive stimuli, and more likely to evaluate situations as favorable, hence are inclined to adopt positive ways to respond to outside stimuli. On the contrary, low core self-evaluations person is more sensitive to negative information. Suggested by the coping resource perspective [9], high level of core self-evaluations allow individuals to better cope with the negative information, such as to endure relative more negative feedbacks or to better tolerant the workplace stress, while lower core self-evaluations people have less coping resources to deal with setbacks occurred during work. Consequently, employees with low self-evaluations are more frequently unsatisfied with their jobs and have stronger intention to leave.

As aforementioned, an organization with higher P-O fit is an organization that can either share similar climate with or can provide complementary resources for the employees. Working in a compatible organization, the New Generation employees are more easily to accomplish job tasks and be recognized by their work group. Also, their opinions and innovation ideas are more likely to be adopted by an organization recognizing their worth and capabilities. Those success and positive feedbacks obtaining from work will enhance the employees' confidence of their own abilities, increase their self-esteem. Therefore, employees working in a high P-O fit organization exhibit higher core self-evaluations. According to the above discussion, core self-evaluations function as a mechanism through which the P-O fit help reduce employees' intent to leave. Thus, we predict the following moderation hypothesis:

Hypothesis 2 Core self-evaluations will mediate the relationship between person-organization fit and the New Generation employees' turnover intentions.

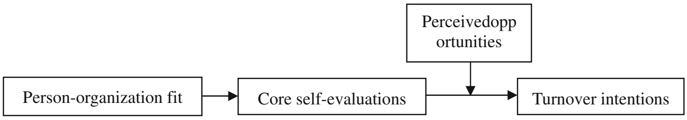

Fig. 1 Research model

2.3 The Moderating Role of Perceived Opportunities

Perceptive job opportunities were defined as the probability of finding a job similar to or better than the current job in the local external labor market for the employees. Perceived job opportunities is often considered as a contextual factor that influences the turnover rate or intention [14]. According to Festinger's cognitive dissonance theory [6], employees with low level of core self-evaluations have a high likelihood of confronting with setbacks from job, leading to cognitive conflicts between how the environment evaluates one's ability and how he values himself. Since the inconsistency of cognitions motivates a person to change his cognition, attitude, or behavior [6], employee will have high motivation to change from current environment to another in order to reconcile the cognition. However, if employee has the knowledge that it is not easy to find a similar or better job in the external labor market, he will turn to other ways to deal with the cognitive dissonance, for example, to try to gain new insight of himself, or forget the importance of those cognitions. In either way, the employees who perceived less job opportunities will have less intention to leave. Conversely, if the employees perceived many opportunities in external labor market, it is more likely for them to consider changing to a new organization to reconcile the cognition.Therefore, we put forward the following hypothesis:

Hypothesis 3 Perceived opportunities moderate the negative relationship between core self-evaluations and turnover intentions, such that the relationship is stronger for those perceived more job opportunities and is weaker for those perceived less job opportunities.

Figure 1 demonstrates the research model of this study.

3 Method

1. Participants and Procedures

We collected data from a state-owned manufacturing enterprise in southwestern China. In this firm, 91.5 % of the workers ($N = 319$) were born after 1980s. We gathered the information from the New Generation workers ($N = 292$) via a survey. Participants completed the self-report surveys anonymously during work time. 267 (84 %) usable questionnaires were returned. 82 % of the valid sample are male, and 71 % have received secondary education. Among the 292 new generation workers, 60 % were born after 1980s and 40 % after 1990s. Most of the participants have a tenure of 1–3 years (55 %), 16 % of the New Generation sample have job experience more than 3 years.

2. Measures

Core self-evaluations

A12-item scale developed by Judge et al. [7] was adopted in this research. It directly measures the four characteristics of positive feelings about self: self-esteem, generalized self-efficacy, emotional stability, and locus of control. A sample item is "Overall, I am satisfied with myself" ($\alpha = 0.84$). Responses were anchored on a five-point scale ranging from 1 = I don't agree at all to 5 = completely agree.

Person-organization fit

A three-item scale developed by Cable and Judge [3] was used to measure person-organization fit (e.g., "To what degree do you believe your skills and abilities 'match' those required by the job"; $\alpha = 0.80$). Responses were anchored on a five-point scale ranging from 1 = not at all to 5 = completely.

Turnover intentions

Turnover intentions was measured by means of a Chinese translation of the widely used five-point scale survey. The turnover intentions survey consists of four items. An example item is "I intend to leave this organization this year" ($\alpha = 0.95$).

Perceived opportunities

A four-item scale was used to measure how many job opportunities the employees perceived [14] (e.g., "I have many jobs to choose from besides this job"; $\alpha = 0.87$). Responses were anchored on a nine-point scale ranging from 1 = not at all to 9 = a lot.

In the models, we also control variables that may have impact on turnover intentions, including demographic variables such as employee's age, gender, marital status, race, and other background variables such as educational level, tenure, political status and Hukou status.

4 Results

1. Preliminary Analysis

The coefficient correlation matrix is displayed in Table 1 as well as the mean, standard deviation and internal consistency alpha values of the constructs. Coefficient alphas range from a high of 0.95 to a low of 0.80.

Table 1 reveals general support for the hypotheses. Person-organization fit is significantly negatively correlated with turnover intentions ($r = 0.388$, $p < 0.01$). The core self-evaluations has a significant negative correlation with turnover intentions ($r = 0.520$, $p < 0.01$), and a significant positive correlation with person-organization fit($r = 0.268$, $p < 0.01$). Perceived opportunities is significantly correlated with turnover intentions, person-organization fit and core self-evaluations at 0.01 level.

Table 1 Correlations, alpha, mean, and standard deviation

Variables	M	SD	1	2	3	4
1. Turnover intentions	2.515	1.191	(0.95)	–	–	–
2. Person-organization fit	3.083	0.948	−0.388*	(0.80)	–	–
3. Core self-evaluations	3.773	0.637	−0.520*	0.268*	(0.84)	–
4. Perceived opportunities	5.287	1.686	0.371*	−0.129*	−0.163*	(0.87)

Notes $^{*}p < 0.01$; Constructs' internal consistency alpha values are on the diagonal

2. Regression Analysis Results

Table 2 displays the regression results for each of our hypotheses. The dependent variable is turnover intentions. The estimates of column 2 (M2) support the Hypothesis 1. Overall, the P-O fit predicts the New Generation employees' turnover intentions ($R2 = 0.27$), the estimated coefficient of P-O fit is -0.428 ($p < 0.001$).

The four-step procedure for mediation [10] is used to prove the mediation relationship predicted in Hypothesis 2. In step 1, P-O fit needs to be related to turnover intentions. This requirement is supported by the results of Hypothesis 1 in M2. Step 2 requires P-O fit be related to core self-evaluations. The results in M6 reveal that P-O fit is significantly related to employee' score self-evaluations ($\beta = 0.158$, $p < 0.001$). Step 3 requires the core self-evaluations be related to turnover intentions. Suggested by estimates in M3, the core self-evaluations is significantly related to turnover intentions ($\beta = -0.903$, $p < 0.001$). Finally, step 4 requires that the significant relationship between P-O fit and turnover intentions will be deceased or eliminated when core self-evaluations is introduced into the same model. The M4 results demonstrate that after introducing the core self-evaluations, the coefficient of P-O fit on turnover intentions has decreased from -0.428 to -0.301. The above results suggest that the core self-evaluations partially mediated the effect of P-O fit on turnover intentions. A Sobel test confirms that the indirect effect is significant ($Z = -3.479$, $p < 0.001$). The calculated ratio of mediating effect of core self-evaluations on the total effect is 29.7 %.

The moderating effects of perceived opportunities on the relationship between core self-evaluations and turnover intentions are tested in M5. Perceived opportunities and the interaction terms of perceived opportunities and core self-evaluations are introduced in M5. Regression results reveal that perceived opportunities and core self-evaluations interacted negatively to predict turnover intentions ($\beta = -0.131$, $p < 0.001$). Figure 2 shows the form and nature of the significant interaction graphically, using a cut value of one standard deviation below and above the mean of perceived opportunities. Figure 2 shows that perceived opportunities strengthened the negative effects of core self-evaluations on turnover intentions. The relationship between core self-evaluations and turnover intentions is more negative when perceived opportunities is higher than lower.

Table 2 The results of hypotheses test

Dependent variables

Model	Turnover intentions (M1)	Turnover intentions (M2)	Turnover intentions (M3)	Turnover intentions (M4)	Turnover intentions (M5)	CSE (M6)
Age	0.007	0.028	0.026	0.038*	0.028	0.013
Gender	0.433*	0.253	0.308	0.196	0.302	−0.071
Marriage	−0.286	−0.363*	−0.335*	−0.384**	−0.269	−0.026
Firstjob	0.178	0.145	0.191	0.167	0.089	0.027
Tenure	0.087*	0.058	0.068	0.05	0.055	−0.01
Race	−0.32	−0.227	0.075	0.095	−0.105	0.402
Hukou	0.085	0.107	0.115	0.127	0.185	0.025
Education	–	–	–	–	–	–
Secondary	−0.001	−0.136	0.162	0.048	0.106	0.231
Tertiary	0.155	0.16	0.209	0.206	0.196	0.058
Department2	0.215	0.248	0.32	0.331	0.285	0.104
Department3	0.917**	0.709*	0.518*	0.416	0.419	−0.366*
P-O fit	–	−0.428***	–	−0.301***	–	0.158***
CSE	–	–	−0.903***	−0.801***	−0.795***	–
PO	–	–	–	–	0.185***	–
CSE_PO	–	–	–	–	−0.131**	–
Observations	267	267	267	267	267	267
R-squared	0.162	0.268	0.381	0.431	0.459	0.113

Notes Standard errors in parentheses $^{*}p < 0.05$, $^{***}p < 0.01$, $^{***}p < 0.001$; P-O fit refers to person-organization fit, CSE refers to core self-evaluations, PO refers to perceived opportunities

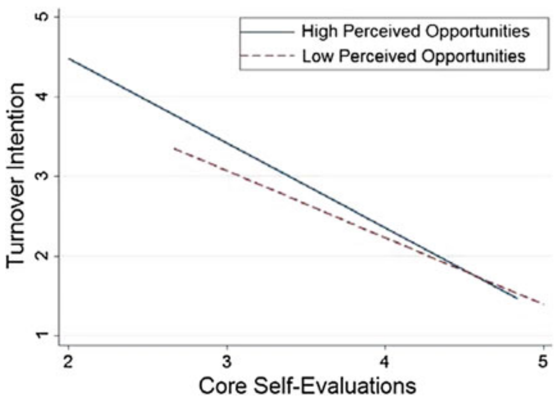

Fig. 2 The moderating role of perceived opportunities

5 Conclusion and Discussion

1. Summary of Findings
This study examines how and in what way the compatibility between individual and organization influences the New Generation employee's turnover intentions. Although the turnover intentions is a topic that has been widely discussed [14, 17] and recently been highlighted in the New Generation literature [12, 15, 18, 19], there are less studies discussing the role of interaction between individual and organization on the turnover intentions [17]. One reason P-O fit is not so well studied in the literature is that the earlier born working cohort (before 1980s) are more loyal and self-sacrificing employees, and more likely to spend long time in one same organization once they are recruited [12]. On the contrary, for the New Generation employees, the compatibility with the environment are more important in their decisions in choosing employers. Findings from this study will extend earlier studies on the influential factors of New Generation employee's turnover intentions.

This study finds that person-organization fit will significantly reduce the New Generation employee's intention to leave. It also provides evidence for the partial mediating role of core self-evaluations in the relationship between person-organization fit and turnover intentions. In addition, we introduce an external labor market factor, the perceived opportunities into the model, and prove that high perceived opportunities will strengthen the negative relationship between P-O fit and turnover intentions.

2. Practical Implication
This study provides evidence on how person-organization fit negatively affects New Generation employee's turnover intentions. In an organization where the New Generation employees feel less compatible, they accumulated less positive appraisal about their value and self-esteem. Employees with lower level of core self-evaluations have difficulty coping with negative information with positive method, and are more inclined to choose leave as a response. These findings suggest that in order to reduce the turnover intentions, organizations should screen job applicants in the first place. Those who match with organization's culture and values should be considered as candidates. Also, managers could put emphasis on improving person-organization fit through reconstructing the culture and norm of the organization, or through effective communication between employer and employees. Specifically, methods such as increasing job autonomy, providing positive feedbacks and fair reward system will help to promote New Generation employees' loyalty and reduce their turnover intentions.

Acknowledgments This research was supported by the National Natural Science Foundation of China (No. 71402108, 71472129, 71002047), the Humanities and Social Sciences Foundation of the Ministry of Education (No. 14YJC630103), and the Philosophy and Social Science Fund of Sichuan Province (No. SC14C017).

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Real-Time Scheduling Optimization of Hierarchical Medical Equipment Based on Simulation

Li Luo, Yong Luo, Chunrong Qin, Shijun Tang and Xian Chen

Abstract Considering the priority of patients and the hierarchies of the medical equipment, combing with CT scan instance, we use Special Customers First real-time scheduling rules, establish the current scheduling simulation model and the optimized scheduling simulation model of West China Hospital CT scan. We discover that after optimization the utilization rates between hierarchical equipments are more balanced, the utilization rate of high hierarchical equipment improved from 69.9 to 86.7 %, and the average waiting time of patients are greatly shortened.

Keywords Hierarchical medical examination · Real-time scheduling · Simulation

1 Introduction

Large medical inspection equipments such as CT, MRI, X-rays are important parts of medical resources. These equipments play crucial role in disease diagnosis and treatment. Its large capital investment, high operating costs, complex operation and technique increase the medical expenses. So in many countries, the purchase of such equipment are strict in control [3]. Under the contradiction between limited medical inspection equipment and increasing inspection demands, scheduling medical inspection equipment is particularly important. Especially in certain medical examination, there are different hierarchies of inspection equipment to check the corresponding patients, such as enhanced scan and plain scan in CT scan. High hierarchical equipment can be used to make low hierarchical examinations, but low

L. Luo · Y. Luo (✉) · S. Tang
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: luoyongcds@163.com

C. Qin
Chongqing University of Posts and Telecommunications, Chongqing 401520,
People's Republic of China

X. Chen
West China Hospital of Sichuan University, Chengdu 610064, People's Republic of China

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hierarchical equipment cannot be used to make high hierarchical examinations. Because the hierarchy of patients and the medical equipment are not the same, patients and equipments cannot be unified scheduled. In order to use medical resources evenly and efficiently, hospital managers pay more attention to how to dispatch hierarchical medical equipments. Researches about hierarchical medical equipment scheduling are mainly using analytical method and simulation.

Application of analytical method to hierarchical medical equipment scheduling include queuing theory and mathematical programming. Zhuang and Li [18] researched hierarchical inspection equipment allocation between three types of patient using Markov Decision Process. Schütz and Kolisch [11] using radiation as an example, studied multi-service priority appointment scheduling. When there are cancellations and no-shows, they established continuous time Markov decision model and solved with approximate dynamic programming. Patrick et al. [9] focued on examination scheduling with priority. By approximate dynamic programming model, they scheduled multi-service priority patients in advance on a single CT aiming to improve equipment utilization, reduce patients' waiting time and minimize costs. Kolisch and Sickinger [4] studied approximation algorithm of pre-scheduling on two CTs. Cheng et al. [1] built a MIP based scheduling model and solve it with CPLEX to get the optimization policy. Numeric example with real data from a large general hospital in West China are employed to do comparison between optimization policy and manual policy to prove the effectiveness of the model.

Given the complexity of hierarchical medical equipment scheduling, there are many studies using simulation, including the design of appointment rules, the influence of uncertain service time and process improvement. Granja et al. [2] presented a case study of a conventional radiology workflow analysis in a Portuguese healthcare provider. Ramakrishnan et al. [10] used simulation model to analyzed the efficiency of CT examination with new workflow. Patrick and Puterman [8] using simulation made appointment scheduling to patients' with multi-service priority on single CT. Sickinger and Kolisch [12] using simulation analyzed the scheduling results of Baily-Welch rule for outpatient on two CTs. Vermeulen et al. [13] using simulation studied dynamic capacity allocation and scheduling problem on two CTs. Li et al. [6] developed a general strategy that allows for automatically, prospectively, and objectively determining the optimal patient-specific CT simulation protocols based on radiation-therapy goals.

Researchs about medical examination scheduling, overseas has been in the forefront of the field, and continue to move forward. By contrast, they are not mature in domestic. And research problems mainly include the characteristics of medical examination department management, status and development. See related literatures Yao and Han [17], Li [7], Wu et al. [16], Wang et al. [15], Wang et al. [14].

Whether in domestic or abroad, the current literatures about medical examination scheduling mainly focus in the assignment under the same level of equipment between different types of patients. Researches on medical examination real-time scheduling of hierarchical equipment are few. In this paper, based on CT scan of West China Hospital, we use simulation to study real-time scheduling of hierarchical CT when there are enhanced scan and plain scan patients. We compare the current scheme and the optimized scheme, making high hierarchical equipment to meet the high hierarchical of inspections firstly, maximizing use of the equipments of different hierarchies. It has reference to hospital hierarchical resource scheduling.

2 Background and Parameters

2.1 Background

There are two mainly CT scan typesenhanced scan and plain scan. The complexity of the two types of scan is different, and therefore different types of scan corresponding to different hierarchies of equipment. Enhanced CT scan equipment can be used to make plain scan, but plain CT scan equipment cannot be used to make enhanced scan.

In this paper, we study the CT1 and CT2 in West China Hospital radiology department. The CT1 can only make plain scan. CT2 mainly make enhanced scan, at the same time, it also can make plain scan. In this study, CT2's hierarchies higher than CT1, and the hierarchies of enhanced scan patients higher than plain scan patients. In the process of inspection, CT2 only consider to check the plain scan patients while there were no enhanced scan patients in waiting queue. We adopt Special Customers First (SCF) real-time scheduling rules.

2.2 Basic Hypotheses

Hypothesis 1 Patients arrive at examination room according to the appointments their made.

Hypothesis 2 Ignoring other overtime, CT1 and CT2 serve patients from 7:30 am to 17:30 pm every day.

Hypothesis 3 We only consider the patients who complete CT examination at 7:30 am to 17:30 pm.

Hypothesis 4 The unit revenue of plain scan on CT1 is c_1. The unit revenue of plain scan on CT2 is c_2. The unit revenue of enhanced scan on CT2 is c_3. According to the real situation, the unit revenue of enhanced scan higher than plain scan, that is $c_3 > c_1$, and $c_1 = c_2$. According to SCF rules, CT2 mainly make enhanced scan. In order to limit plain scan patients unlimited occupying CT2, we assume $c_1 > c_2$. But in order to avoid the CT2 not serve plain scan patients, c_2 also shoulds not be too small. Therefore we assume that they meet this relationships: $c_3 > c_1 > c_2 > \frac{2}{3}c_1 > 0$.

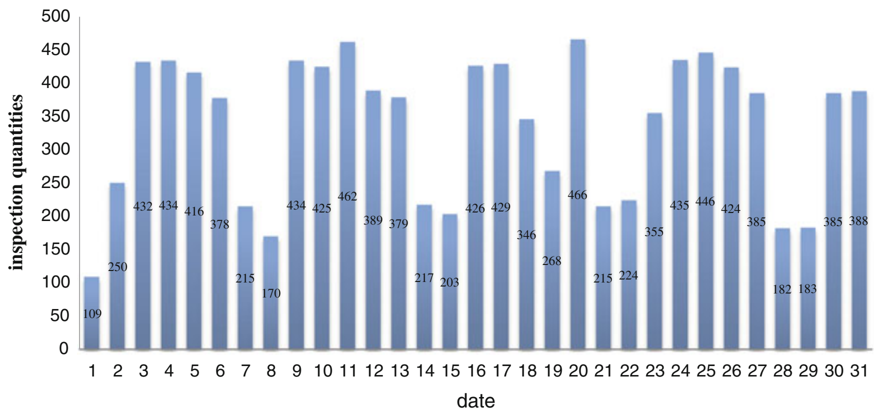

Fig. 1 CT examinations from 7:30 am to 17:30 pm in July 2012

2.3 Simulation Parameters

In this paper, simulation data from radiology information system (RIS) of West China Hospital. From the RIS we select 10470 effective records which inspection equipment are CT1 and CT2 and booking date is July 1 to 31, 2012, appointments at 7:30 am to 17:30 pm. Daily inspection quantities as shown in Fig. 1. According to the real situation, we eliminate the records on weekend then to get 8752 valid records.
(1) Arrival Rate
The arrival rates are different corresponds to the scan types and time intervals. Therefore, we analyze arrival rate on different time intervals for plain scan and enhanced scan respectively. It is generally believed that arrival rates of service system obey the Poisson distribution. We use SPSS 17.0 make single sample Kolmogorov Smirnov test to the collated data. The results obey Poisson distribution. And the corresponding distribution parameters are shown in Table 1.
(2) Inspection Time
Inspection time is the time interval from the patient arrive to the examination room to leave the examination room, that is the time patient occupying CT equipment and other medical resources. Although there has take the report time field in RIS system, but by verification, the accuracy has much to do with the habit of doctor, and take the report time is not the same as the end of examination time, therefore we artificial collected 790 records of 7 consecutive days. Due to the samples by manual observation, we use SPSS 17.0 to make explore analysis of the inspection time. The frequency histogram is shown in Fig. 2.

Further eliminating mistaken records, we use box figure analyze the discrete features. We get the inspection time of plain scan patients as shown in Table 2.

According to Table 2, we use triangular distribution Random. Triangular(1, 2, 4) (unit: minutes) to simulate the plain scan patient's service time. In the same way to

Table 1 Patients arrival rates distribution and parameters

Time intervals	Enhanced scan		Plain scan	
	Distribution	Parameters	Distribution	Parameters
7:30–8:30	Poisson	$\lambda = 32.45$	Poisson	$\lambda = 6.23$
8:30–9:30	Poisson	$\lambda = 30.05$	Poisson	$\lambda = 12.27$
9:30–10:30	Poisson	$\lambda = 20.55$	Poisson	$\lambda = 13.45$
10:30–11:30	Poisson	$\lambda = 22.95$	Poisson	$\lambda = 13.05$
11:30–12:30	Poisson	$\lambda = 24.00$	Poisson	$\lambda = 10.36$
12:30–13:00	Poisson	$\lambda = 21.91$	Poisson	$\lambda = 5.59$
13:30–14:30	Poisson	$\lambda = 24.59$	Poisson	$\lambda = 8.73$
14:30–15:30	Poisson	$\lambda = 54.73$	Poisson	$\lambda = 10.82$
15:30–16:30	Poisson	$\lambda = 33.00$	Poisson	$\lambda = 10.68$
16:30–17:30	Poisson	$\lambda = 25.82$	Poisson	$\lambda = 16.59$

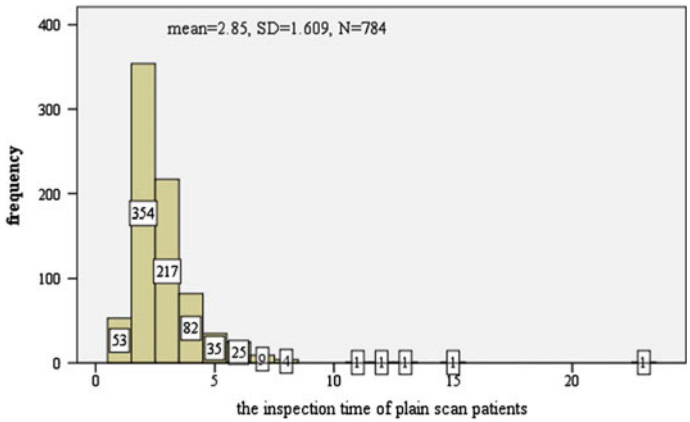

Fig. 2 The frequency histogram of plain scan patients

Table 2 The inspection time of plain scan patients

Inspection time (min)	Frequency	Percentage	Valid percent	Cumulative percentages
1	55	7.8	7.8	7.8
2	354	50.0	50.0	57.8
3	217	30.6	30.6	88.4
4	82	11.6	11.6	100
Summation	708	100.0	100	

analyze, we use triangular distribution Random. Triangular(2, 4, 6) (unit: min) to simulate the enhanced scan patient's service time.

(3) Run Times

In order to ensure the meaIn order to ensure the mean of the output indicators within the 95 % confidence interval, we need to calculate the minimum run times. The running times can be calculated according to the iteration method proposed by Law and Kelton [5]. The run times of this simulation model we set up are 200.

(4) Model Calendar

The model calendar of this simulation model we set up is 10 h, that is from 7:30 am to 17:30 pm every day.

3 The Simulation Results of the Current Scheme

The current scheme of West China Hospital's is that CT2 assist CT1 make plain scan at 7:30–8:00 everyday according to SCF rules. When the first batch of enhanced scan patients entering CT2 examination room, CT2 only make enhanced scan or serve ICU patients. Even if CT2 may be idle, it don't help to make plain scan. Follow the basic hypothesis, according to the data analysis results, we build the simulation model of current scheme with Simio, and run the model 200 times. The results are shown in Table 3.

From Table 3 we can get the following results:

(1) The arrival of plain scan patients are 290, among them served by CT1 are 244, the revenue take by CT1 are $244c_1$. The arrival of plain scan patients served by CT2 are 4, the revenue take by CT2 are $4c_2$. The total plain scan patients served are 248.
(2) The arrival of enhanced scan patients are 106, served by CT2 are 102, the revenue are $102c_3$.
(3) The total revenues take by both CT1 and CT2 are $244c_1 + 4c_2 + 102c_3$.
(4) The utilization rate of CT1 is 94.8 %, The utilization rate of CT2 is 69.9 %.
(5) The total waiting time of patients is 91.5 min.

Table 3 The simulation results of the current scheme

Patients type	Total arrival (person)	Serves (person)		Revenue (yuan)		Utilization (%)		Total waiting time (m)
		CT1	CT2	CT1	CT2	CT1	CT2	
Plain scan	290	244	4	$244c_1$	$4c_2$	94.8	69.9	97.3
Enhanced scan	106	–	102	–	$102c_3$	–	–	–

4 The Simulation Results of the Optimized Scheme

According to the current scheme, CT2 have not been utmost used, and the utilization rate of CT1 is much higher than CT2. In order to alleviate the pressure of the CT1 and also can improve the utilization rate of CT2, We proposed optimized scheme: as long as idle, CT2 can make plain scan. Follow the basic hypothesis, according to the data analysis results, we build the simulation model of optimized scheme with Simio, and run the model 200 times. the results are shown in Table 4.

From Table 4, we can get the following results

(1) The arrival of plain scan patients are 290, served by CT1 are 221 the revenue take by CT1 is $221c_1$. The arrival of plain scan patients served by CT2 are 48, revenue take by CT2 are $48c_2$. The total plain scan patients served are 269.
(2) The arrival of enhanced scan patients are 106, served by CT2 are 102, the revenue are $102c_3$.
(3) The total revenues take by both CT1 and CT2 are $221c_1 + 48c_2 + 102c_3$.
(4) The utilization rate of CT1 is 86.2 %. The utilization rate of CT2 is 86.7 %.
(5) The total waiting time of patients are 43.1 min.

Comparing the current scheme and the optimized scheme we can get the following conclusion:

(1) Due to the same arrival rate, the arrival of plain scan patients and the enhanced scan patients between two models are the same.
(2) After optimization, the plain scan patients served by CT1 are decreased from 244 to 221. And the plain scan patients served by CT2 are increased from 4 to 48. The total number of served plain scan patients increased 21.
(3) The enhanced scan patients served by CT2 remain the same.
(4) After optimized, revenue changes are $(221c_1 + 48c_2 + 102c_3) - (244c_1 + 4c_2 + 102c_3) = 44c_2 - 23c_1$. According to the basic assumptions Hypothesis 4, $44c_2 - 23c_1 > 442/3c_1 - 23c_1 = 19/3c_1$, So the total revenue increased.
(5) The utilization rate of CT1decreased from 94.8 to 86.2 %. And the utilization of CT2 increased from 69.9 to 86.7 %. The utilization of CT1 and CT2 are more balanced.
(6) The total waiting time of patients are decreased from 91.5 to 43.1 min.

Table 4 The simulation results after optimized

Patients type	Total arrival (number)	Serves (person)		Revenue (yuan)		Utilization (%)		Total waiting time (m)
		CT1	CT2	CT1	CT2	CT1	CT2	
Plain scan	290	221	48	$221c_1$	$48c_2$	86.2	86.7	43.1
Enhanced scan	106	–	102	–	$102c_3$	–	–	–

In conclusion, the revenue of optimized scheme higher than the current scheme. More important, the enhanced scan patients served by CT2 remain the same and plain scan patients increased 21. The utilization rate of CT1 decreased from 94.8 to 86.2 %, and the utilization of CT2 increased from 69.9 to 86.7 %, the utilization of CT1 and CT2 are more balanced. It means that the West China Hospital's CT examination scheme remains to be improved. If don't restrict the time interval of CT2 to serve plain scan patients, CT2 can get utmost used, the waiting time of patients shortened, the utilization of CT1 and CT2 more balanced and more patients can complete inspection the same day. Also from the simulation results, enhanced scan patients arrival a total of 106, at the end of examination, enhanced scan patients did not complete inspection. CT2 served plain scan patients, and the utilization rate of CT2 did not reach 100 %. It means that enhanced scan patients make an appointment near off hours. We can see from Table 1, the arrival rate of enhanced patients at time interval 16:30–17:30 is $\lambda = 16.59$. There is the same problem on CT1. From Table 3 we can see CT1 can serve 244 plain scan patients at least, but it only serve 221 plain scan patients. CT1 and CT2 work together, there are still 21 plain patients did not finish inspection in normal working hours. And the utilization rate of CT1 and CT2 did not reach 100 %. It means that the appointment of plain scan patients should be improved. So we suggest to adjust appointment appropriately, as far as possible make appointment before 16:30.

5 Conclusion

In this paper, we build the simulation models of the current scheme and the optimized scheme with Simio. We find if the time interval of CT2 serve plain scan patients is unlimited, CT2 can get better used, the waiting time of patients shortened, the utilization of CT1 and CT2 are more balanced and more patients can finish inspections the same day. This simulation results is helpful to hospital management decisions, they can according to the results weigh whether it is necessary to limit the time interval of CT2 serving plain scan patients.

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Empirical Analysis of the Relationship Between Brand Marketing Strategies and Marketing Performance of Agricultural Science and Technology Enterprises

Wensheng Li, Yu Ding, Daijun Deng, Wangwei Jiang and Zhenggang Liu

Abstract The theoretical relationship model of brand marketing strategies and marketing performance of agricultural science and technology enterprises is constructed and research hypothesis is proposed with theoretical research method. It is proved that four brand marketing Strategies combinations of agricultural science and technology enterprises have positive effect on marketing performance. That helps enterprises to select suitable brand marketing strategy and enhance strategy application by strategy combinations with different dimensions so as to promote the marketing performance.

Keywords Agricultural science and technology enterprises · Brand marketing strategy · Marketing performance · Empirical analysis

1 Introduction

Nowadays, China's food safety problems are very severe. As the pacemaker of agribusiness, agricultural science and technology enterprises should make use of resource capability and brand marketing strategy to improve the safe as well as reliable recognition of products so as to promote marketing performance. However, there is limited research on influencing way and mechanism of brand marketing strategy on marketing performance. Thus, specific and effective theory guidance to marketing strategy of agricultural science and technology enterprises is in scarcity.

W. Li · W. Jiang · Z. Liu
School of Forestry and Horticulture, Xinjiang Agricultural University,
Urumqi 830052, People's Republic of China

Y. Ding (✉)
School of Economy and Trade, Xinjiang Agricultural University,
Urumqi 830052, People's Republic of China
e-mail: 396670030@qq.com

D. Deng
Xinjiang Institute of Light Industry Technology, Urumqi 830052, People's Republic of China

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Research on relationship between finance performance and marketing resources has attracted attention in academic circle [12]. Currently, the relationship between marketing especially for brand and remaining competitive advantages of enterprises has been explained by theoretical models and empirical researches [8]. As incorporeal capital, brand has significant effect on performance of enterprises. That is widely accepted [2, 7]. Relevant brand strategies including brand combination, managing incorporeal brand combination capital from strategic decision level have been carried out in many corporate champions [1]. As little research on effect of brand marketing strategies especially for combination strategy on performance of enterprises is done [11, 13], further empirical study [3, 5, 9]. In China, documents about brand marketing strategies are in scarcity, not specific and lack of empirical analysis as well as further study on influencing mechanism of brand marketing strategies on performance of enterprises.

In a word, brand has great effect on acquiring and remaining competitive advantages. However, there exist kinds of brand marketing ways and influencing effect of brand on performance changes with changing of marketing environments. So it is necessary for enterprises to choose appropriate brand marketing strategies according to market environments. What is the exact influencing mechanism of brand on performance? In what way does brand marketing strategy combination affect marketing performance from different dimensions? That is of great theoretical value and guidance to enterprises in choosing brand marketing strategy combination and promoting brand image strategy application form different dimensions of strategy combination in order to enhance performance of enterprises.

2 Definition and Study Status of Agricultural Science and Technology Enterprises

On the basis of study on agricultural science and technology enterprises, it is defined as enterprises relating with agriculture, making use of hi-technology, integrating research, management and service and applying modern management system. As study shown, basic enterprises of agriculture, forestry, livestock farming and fishery as well as downstream enterprises serving agriculture, forestry, livestock farming and fishery are all included in agricultural science and technology enterprises. In this paper, companies and corporate champions of agriculture, forestry, livestock farming and fishery that listed in Shenzhen-Shanghai stock market are chosen as samples for study. The existing study on agricultural science and technology enterprises mainly focuses on technology innovation, social responsibilities, performance evaluation and development. Thus, documents about brand are scare, providing research space for the study.

3 The Enlightenment of Brand Marketing Theory for Choice of Brand Marketing Strategy

Brand marketing theory consists of brand image theory, brand location theory, brand extension theory, brand capital theory and brand relations theory according to study by Shen Pengyi and Hu Zhengmin in 2008 [10].

According to brand image theory, marketing should not only emphasize on products or service but also relevant image of products and service including customer experience, customer perceived value, symbolic meaning as well as mutual expectation realm of enterprises and consumers. By brand image strategy, agricultural science and technology enterprises could create better brand memory to guide purchasing behavior of consumers and further enhance brand loyalty of consumers to enterprises. That is of great strategic significance in long term and important to new product release and continual improvement of performance. So it is believed brand image strategy is one of marketing strategies for agricultural science and technology enterprises.

Brand location theory marketing strategies involving differentiation and diversification are based on competition among enterprises, consumers and competitors. With location strategy, agricultural science and technology enterprises could avoid homogeneous competition, meet different requirements of consumers and expand space for different and diversified development. As brand location strategy is of vital importance to development, it is believed brand location strategy is one of marketing strategies for agricultural science and technology enterprises.

As brand extension theory says, the existing well-known brand could be used to provide advantages for new product marketing. However, risk exists in brand extension. Bad market performance of extension may affect image and base of well-known brands. Correspondingly, good performance is helpful for new product promotion, reducing marketing cost and strengthening brand position in consumers. It is believed brand extension strategy is one of marketing strategies for agricultural science and technology enterprises.

As brand capital theory says, incorporeal capital is formed and reflected by capital market performance with brand marketing. That may exert unconsciously guidance to consumers and affect integral value formation of enterprises. It is not common for agricultural science and technology enterprises to improve value by means of brand marketing. At least, it is not shown in samples of the study. We don't deny the guidance of brand capital to enterprises. According to brand capital theory, effect of brand capital strategy on enterprises is not embodied in positive guidance to development and is not of realistic universality. So we think brand capital strategy in not suitable for development and operation of enterprises and should not be taken into consideration in brand marketing strategy combination.

Brand relations strategy is mainly dealing with the relationship between brand and brand, consumer and brand, product and brand, marketing and brand, other stakeholders and brand, etc. That means as a result of systematization, brand forms networking structures together with products, marketers and consumers and mutually affects [4]. That brand relations is a good way for enterprises to deal with relationship between stakeholders. By affecting value perception and satisfaction of customers, brand relations strategy finally affect after-purchase behavior of customers [15]. It is believed brand relations strategy is one of marketing strategies for agricultural science and technology enterprises.

As mentioned above, we hold the idea that brand strategy combination including brand image strategy, brand location strategy, brand extension strategy and brand relations strategy are suitable for agricultural science and technology enterprises. The above four brand strategies could promote brand marketing from different angles.

4 Meaning and Evaluation of Marketing Performance

1. Meaning of marketing performance
Marketing performance is defined from the following angles: result angle (Bermar -din and Kane), behavior angle (Campbell and Murphy) and comprehensive angle of result and behavior (Brumbrach) in existing documents.

In this paper, we emphasize on the effect of market strategy on market performance. Namely, we studied on market performance of enterprises. We think marketing performance refers to operating result and efficiency of strategic marketing. That means result of a series of work done by functional departments in order to achieve strategic marketing aims.

2. Evaluation of marketing performance
Traditionally, marketing performance is mainly evaluated by finance index and sales measurement index [6, 14].

Many adjustment factors including market occupation, service quality, customers' satisfaction and customers' loyalty existing in marketing productivity lead to randomness of marketing input process to output process. Some scholars think "overall-performance" should be considered in evaluating market performance.

Strategic marketing further promotes change from simple evaluation to multi-dimensional evaluation in marketing performance evaluation. Typical research are done by following scholars: Kumar [9] et al.

Key performance indexes and balance accounting card are applied in marketing performance evaluation by many scholars. While some suggest marketing performance classification for overall evaluation of performance on the basis of mentioned two ways.

Considering research conditions and requirements of research angle, we mainly evaluated the effect of marketing performance on brand cognition such as cognition of consumers and marketing innovation. With balance accounting card, key performance indexes and marketing performance classification, customers along with studying, innovation and market performance are involved in performance evaluation. Based on that, customers' cognition, marketing innovation, market performance and study capability are chosen as evaluation factors of marketing performance.

5 Theoretical Model of Relationship Between Marketing Performance and Marketing Strategy of Agricultural Science and Technology Enterprises

On the basis of theoretical research and documents, we think brand image strategy directly affect the image of products and service in consumers' mind. By influencing consumers' cognition to products and service, brand image strategy has important effect on brand marketing especially for cognition of customers.

With brand location strategy, agricultural science and technology enterprises could segment market for products and service by targeting at different customers. That is helpful for enterprises to provide better service, meet requirements of special customers and improve customers' cognition so as to promote sales of products and service.

Brand extension strategy make customers purchase new products and service by influencing customers with well-known brands. With extension strategy, economic recognition way for enterprises and customers, convenience for new products and service promotion as well as quality and credit guarantee for new products and service is gained if information symmetry does not exist. That means extension strategy could greatly consumers' cognition to brands and improves marketing efficiency from enterprises and customers.

Brand relation strategy affects marketing by establishing relationship between brands and relevant main bodies. Marketing efficiency could be improved with reasonable match of brands and products. Main bodies are diversified including consumers, products, brands and marketers. If relationship between brands and main bodies be well dealt with, marketing efficiency of enterprises will be greatly improved. So, the following hypotheses are proposed:

Hypothesis 1. Brand image strategy has positive effect on marketing performance.

Hypothesis 2. Brand location strategy has positive effect on marketing performance.

Hypothesis 3. Brand extension strategy has positive effect on marketing performance.

Hypothesis 4. Brand relations strategy has positive effect on marketing performance.

Index systems are involved in developing model on the basis of theory and features of study are as follows:

Brand Image Strategy: According to the connotation and function of brand image strategy, the paper argues that function image, experiencing image and symbol image are included in measuring brand image strategy.

Brand Location Strategy: According to the connotation and function of brand location strategy, the paper argues that objective market division, product differentiation and price difference should be taken into consideration in brand location strategy measuring.

Brand Extension Strategy: According to the connotation and function of brand extension strategy, the paper argues that brand popularity, product diversification and product correlation should be taken into consideration in brand extension strategy measuring.

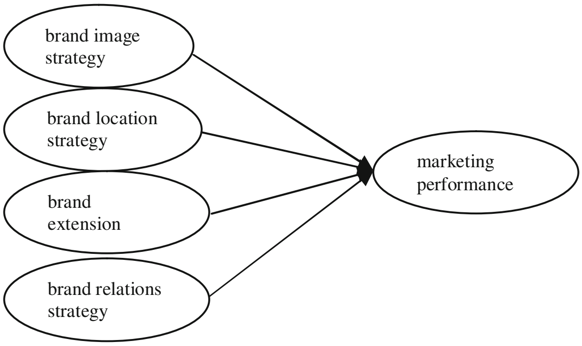

Fig. 1 Theoretical model of relationship of agricultural science and technology enterprises' brand marketing strategy and marketing performance

Brand Relations Strategy: According to the connotation of brand relations strategy, the paper argues that relation between brand and consumers, the relation between brand and products, the relation between brand and brand, the relation between brand and stakeholders should be taken into consideration in brand relations strategy measuring.

The influencing mechanism of four strategy combination on marketing performance is analyzed in this paper. Theoretical model of marketing performance and brand marketing strategy is constructed on the basis of above analysis (Fig. 1). Four dimensions including brand image strategy, brand location strategy, brand extension strategy and brand relations strategy are involved in marketing strategy while only one dimension for marketing performance.

6 Large Sample Analysis

1. Design of questionnaire
Theoretical dimensions of measuring variables are deducted or concluded with literature research. The following variables including brand image strategy, brand location strategy, brand extension strategy, brand relations strategy and marketing performance are measured in model. The measuring scale is made on the basis of existing scales and actual situation of the study.
2. Pretest of primary questionnaire
Two professors and five masters engaged in strategy and marketing management have been invited to modify the description of specific measuring items to enhance validity of questionnaire after the primary design is finished. Pretest is done among twenty relevant people only to test items of questionnaire without special choice of sample type. And correction is done on the basis of problems raised by testers to improve the validity of questionnaire. The questionnaire is in accordance with requirements of large sample study with the above two corrections.

3. Granting and taking-back of questionnaire

With agricultural science and technology enterprises as study subject, 296 people from 37 enterprises in northwest, middle and southwest area of Xinjiang province are chosen for investigation, with 8 people from different departments including strategy planning, production and marketing departments of every enterprise. The effective recovery is 87.2 % with 296 questionnaires delivered, 277 returned, 19 invalid and 258 valid.

4. Descriptive statistics of large samples

In survey, 194 male employees' accounts 75.2 % of the overall, which is in accordance with characteristic of agricultural science and technology enterprises. People aged below 35 accounts 79.1 %, which complies with young trend of enterprises. Considering education background, bachelors and masters occupy 80.2 %, which meets requirement of study for knowledge level. The even distribution of enterprise scale means development level is reasonable and samples are representative. Considering position type, marketing accounts nearly half and consists relevant subject of marketing; people from middle-level and strategic planning account 37.6 % and consist with investigation plan as set. And data of position constitution is reasonable. Considering features of industries, food industry accounts for 43 %. That is relative with marketing of study as marketing of food industry is representative. The result of descriptive statistic of large samples shows investigation data is consistent with sample requirement of the study (Table 1).

5. Correlation analysis of variables

As Table 2 shown, the correlation coefficient of main variables is significant on the level of $p < 0.01$. That indicates the correlation of variables is better and needs further analysis.

6. Factor and reliability and validity analysis

SPSS 17.0 is used for exploratory factor analysis and results are: KMO is 0.873, Bartlett hemisphere inspection is significant on the level of $p < 0.001$. That indicates data is suitable for factor analysis. 33 measurement items (including 12 items of 3 variables that has important effect on brand marketing) are analyzed into 8 principal component factors, which suggests high quality of questionnaire design and sample data that consists with hypothesis of the study.

Confirmatory factor analysis is done with AMOS7.0 to test reliability and validity of exploratory factor analysis. The results are shown in Table 2.

As exploratory factor and confirmatory factor analysis shown, the questionnaire is of good validity with factors loading of concepts are bigger than 0.5. The result of reliability analysis shows cronbach α of each concept is greater than 0.7, which means the questionnaire is reliable (Table 3).

7. Path analysis

The theoretical model of marketing performance and brand marketing strategy of agricultural science and technology enterprises is studied by path analysis with AMOS 7.0 and results are shown in Fig. 2.

Fitting indexes of Fig. 2, χ^2 is 213.076, df is 108, $\chi^2/$ df is 1.973. RMSEA is 0.062, GFI is 0.913 and CFI is 0.931. That suggests fitting indexes are in conformity with requirements of structure equation model. The path coefficient of brand image

Table 1 Sample's descriptive statistics ($N = 258$)

Variable	Category	Number	Percentage (%)
Sex	Male	194	75.2
	Female	64	24.8
Age	Not more than 25	64	24.8
	26–35 years old	166	64.3
	36–45 years old	26	10.1
	More than 46 years old	2	0.8
Education background	Associate degree	48	18.6
	Bachelor	122	47.3
	Master	85	32.9
	Doctor	3	1.2
Scale of enterprise	Less than 100	44	17.1
	101–300	76	29.5
	301–500	53	20.5
	Over 500	85	32.9
Position type	Marketing	112	43.4
	Middle cadres	71	27.5
	Strategic planning	26	10.1
	Production	39	15.1
	Others	10	3.9
Industry characteristic	Food	111	43
	Cultivation	58	22.5
	Forage	41	15.9
	Seed	16	6.2
	others	32	12.4

Table 2 Correlation analysis of main variables

	1	2	3	4	5
Brand image strategy	1				
Brand location strategy	0.346**	1			
Brand extension strategy	0.296**	0.304**	1		
Brand relations strategy	0.360**	0.293**	0.208**	1	
Marketing performance	0.547**	0.481**	0.418**	0.282**	1
Mean	5.14	5.31	4.9	5.01	5.04
Variance	0.65	0.62	0.74	0.7	0.65

Note **indicates significant on the $p < 0.01$'s level

strategy and marketing performance is 0.23 and is more remarkable when $p < 0.01$ proving Hypothesis 1. The path coefficient of brand location strategy and marketing performance is 0.23 and is more remarkable when $p < 0.05$ proving Hypothesis 2.

Table 3 Correlation analysis of main variables

Measurement item	Factor loading	Alpha
Brand image strategy		
Emphasize on function image	0.83	0.824
Emphasize on experiencing image	0.79	
Emphasize on symbol image	0.73	
Brand location strategy		
Emphasize on objective market division	0.67	0.763
Emphasize on product differentiation	0.84	
Emphasize on price difference	0.66	
Brand extension strategy		
Better brand popularity	0.71	0.719
Products in diversification	0.78	
Higher correlation among the products	0.55	
Brand relations strategy		
Better dealing with relation between brand and consumers	0.83	0.774
Better dealing with relation between brand and products	0.7	
Better dealing with relation between brand and brand	0.59	
Better dealing with relation between brand and stakeholders	0.6	
Marketing performance		
Better brand cognation	0.72	0.813
Innovative marketing activities	0.64	
Better market performance of products and service	0.72	
Better learning capability of marketing	0.82	

Note Loading coefficient of factors are remarkable on level of $p < 0.001$

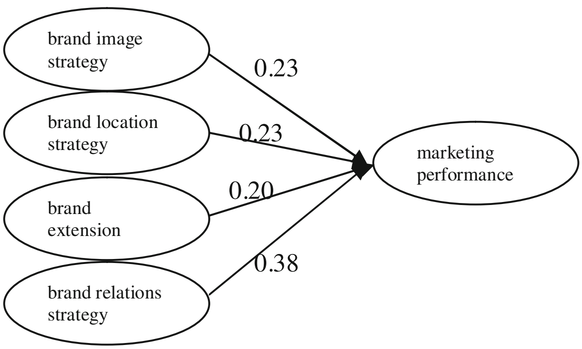

Fig. 2 Path analysis on theoretical model of marketing performance and agricultural science and technology enterprises

The path coefficient of extension strategy and marketing performance is 0.20 and is more remarkable when $p < 0.01$ proving Hypothesis 3. The path coefficient of relations strategy and marketing performance is 0.38 and is more remarkable when $p < 0.001$ proving Hypothesis 4.

7 Conclusion

Theoretical model of relationship between marketing performance and agricultural science and technology enterprises is constructed and four hypotheses are proposed in this paper. Four hypotheses are proved by large samples with questionnaires, thus proving the theoretical model.

The conclusions are:

Brand image strategy has positive effect on marketing performance; Brand location strategy has positive effect on marketing performance; Brand extension strategy has positive effect on marketing performance; Brand relations strategy has positive effect on marketing performance.

It is proved brand marketing strategy has positive effect on marketing performance. So marketing performance of agricultural science and technology enterprises will be improved with proper marketing strategy. According to the model, performance could be improved by enhancing application of image strategy from function image, experiencing image and symbol image. Performance could be improved by enhancing application of location strategy from objective market division, product differentiation and price difference. And it could be improved by enhancing application of extension strategy from brand popularity, product diversification and product correlation. It is also could be improved by enhancing application of relations strategy from relation between brand and consumers, the relation between brand and products, the relation between brand and brand, the relation between brand and stakeholders.

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Research on Local Government Balanced Policy Effect on the Citizens' Satisfaction of Public Service in China

Liming Suo and Zhufeng Zhang

Abstract Under the background of the Chinese urban-rural dualistic system is developing, the gap of enjoying basic public services between urban and rural residents is being enlarged. Whether citizens' perception of the disequilibrium affects their satisfaction with public services delivery in a certain extent or not is worth exploring. The paper puts forward hypotheses: perception of disequilibrium has significant effects on citizens' satisfaction with public services; Urban and rural balanced development policies of the provincial level government have less significant effects on the municipal governments. This paper collects the research data of 2010–2011 citizens' satisfaction with basic public services in 38 cities in China, as stated in the Public Service Blue Book. Moreover, the number of local governments' policies concern urban and rural balanced development of 30 cities from the strategic documents, notices, decisions, meetings and government affairs dynamic are stated. Moreover, citizens' satisfaction with public services is chosen as the dependent variable, unbalanced perception as the independent variable and sense of fairness as the intermediate variable to build a model. Furthermore, an analysis of their relationship with Pearson relationship is made and an estimation of simple linear regression equation to verify the above hypotheses is conducted. Finally, a conclusion is attained.

Keywords Local government · Policy · Balance · Public service · Satisfaction

1 Introduction

Fairness has become a primary factor that is influencing social harmony of China. Meanwhile, facilitating equalization of basic public services is an acting point to improve people's livelihood and promote social equality. Under the background

L. Suo · Z. Zhang (✉)
School of Political Science and Public Administration,
University of Electronic Science and Technology of China,
Chengdu 611731, People's Republic of China
e-mail: redzhang88@126.com

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where China's city-countryside dualization system is developing, the gap between residents in urban area and those in rural areas is being widened with regard to enjoyment of basic public services, such as compulsory education and public health. Therefore, whether citizens' perception of such disequilibrium has to certain extent influenced their satisfaction with public services or not is something worth discussing.

This paper has constructed a theoretical model of unbalance perception and public service satisfaction and pointed out that there's highly positive correlation between balancing urban and rural areas of local governments relevant policies and citizen's satisfaction with public services, and municipalities with more degree of correlation than common cities. Moreover, provincial policy's influence for citizen's satisfaction with public services is less than city policies. It is favorable for local governments to formulate relevant policies of public service more scientifically, especially for municipal levels of governments.

The full text is structured as follows: firstly, to review related studies of China and abroad about supply of public services, equalization and satisfaction. In the next section, put forward the hypothesis of this paper that the unbalance perception has influence for citizen's satisfaction with public services; Following, elaborated independent variables, dependent variables and substitution variables of this paper. Eventually, to carry out the verification for the model by the analysis of descriptiveness and correlation.

2 Review of Related Studies

1. Public Service Delivery

The New Public Management emerged in the 1980s, and with it, research on public service supply is increasing. Since the Second World Wartwo main approaches have dominated the service delivery terrain–public sector delivery model and private sector delivery model. By the mid-1990s, many governments leading to a mixed model approach to service delivery. Frank et al. [14] examined the adoption of the mixed model in the Canadian municipalities of Hamilton and Ottawa, they found the model is better in enhancing the five variables when compared to solely public or private services delivery. Malesky et al. [13] found that recentralization significantly improved public service delivery in areas important to central policy-makers, especially in transportation, healthcare, and communications. Nava et al. [1] conducted a field experiment on incentives for public service delivery, they illustrated that extrinsic rewards can improve the performance of agents engaged in public service delivery, and that non-financial rewards can be effective in settings where the power of financial incentives is limited. Clayton et al. [5] highlighted how emotions are at the heart of the experiences of those delivering services in the North East of England or private services delivery.

2. Equalization of Public Services

Bai [3] put forward that difficulty primarily confronted in the process of studying equalization of public services is how to define "public service". Since Wagher proposed the concept of basic public service, Leon Duguit has interpreted basic public service from perspective of social public laws while Samuelson et al. from perspective of public goods. Another issue that needs to be defined is the definition and measurement of equalization. Hay [6] had defined equalization in distribution of public services in foreign countries from 8 critical concepts, such as procedural fairness, justice, formal equality, substantive equality, right and need.

With respect to studies of equalization of public services, some achievements have been made. In content level, Jiang and Wu [9] proposed that domestic studies are primarily on connotation of equalization of public services, how to measure and evaluate, status quo of equalization of public services in China and existent problems, and theoretical approaches and mechanism for achieving equalization of public services. On the other hand, foreign studies on equalization of public services focus on different intra-city groups, classes, neighborhood and communities. Yu et al. [19] developed a scientific and effective evaluation index system for equalization of basic public health services. Basically, these studies can be reduced to problems put forward by Lasswell [10], that is, "who gets what?", "when to get?" and "how to get?" Since public services are varying in social function and different social services are influenced by external environment in different ways, the different degrees of mastering public services by institutions that provide the services will directly influence evenness of their distribution. Therefore, the definition of public service categories is also a key point in foreign studies on equalization of public services. Among them, Baer is a representative. Baer [2] had pointed out that definition of urban public service should cover purposes of the services, service suppliers as well as ways to provide services. Besides that, Smith [16] and Hero [7] had studied equalization of public services from perspective of supplying subjects.

3. Satisfaction with Public Services

Satisfaction with public services is an extension and improved application of customer satisfaction in the field of public services. In nature, it is evaluation of quality and performance of public services. As with quality of public services of local governments, it can be evaluated with citizen satisfaction. Meanwhile, CSI concluded by quality research center of business school of University of Michigan is so far an evaluation model that has been widely applied in various fields all over the world. With the carrying out of "New Public Administration" and "Government Reinvention" movements in western countries, customer satisfaction and its representative model have been universally applied by government departments. Most studies on satisfaction with basic public services in China have referred to results of researches on customer satisfaction in foreign countries. For example, Zhu [20] had verified theories for evaluating public satisfaction with basic public services and the evaluation model (PSCI). Liu et al. [11] had applied structural equation modeling to design an index model for evaluating satisfaction with basic public services as well as common basic public service satisfaction indexes for administrative service centers.

3 Research Hypothesis

1. Relationship between Disequilibrium and Fairness

Behavioral economics created by Matthew [15] had proved the decisive significance of fairness to people's behaviors and psychological needs. Since the nature of equalization of public service is fairness and equality of social welfares, it is conducive to equitable distribution. According to some scholars, Wang [18] had stressed the efficiency while overlooking fairness in the process of striving hard to construct economy; consequently, gaps between urban and rural areas, between industries and between areas have been widened as the original pattern of interests had been broken. In other words, the issue of fairness has widened the gaps. When stated with quantitative language, fairness is negatively related to disequilibrium between urban and rural areas.

2. Relationship between Sense of Fairness and Satisfaction with Public Services

This paper is primarily on equilibrium between urban and rural areas and its relationship with satisfaction with public services. It focuses on perception of fairness between urban and rural areas. Due to regional differences in distance, citizens in a region are most likely to make a horizontal comparison with people who are closest to them in distance, which will generate perception of fairness.

Currently, scholars have made a lot of studies on factors that are influencing citizens' satisfaction with public services. For example, Lu [12] had studied rural people's satisfaction with public services by taking Changsha, Zhuzhou and Xiangtan as cases; he has verified that perception of fairness has positive influence on rural people's satisfaction with public services through analyzing elements that are influencing rural people's satisfaction with public services. Moreover, Chen [4] had studied urban and rural citizens' satisfaction with basic public services by taking Changzhou city as an example; besides that, she has concluded that rural residents of Changzhou city have felt the general gap between urban and rural areas. Those research results have proved that perception of fairness is influencing people's satisfaction with public services.

3. Putting Forward of Hypothesis

Through above theoretical researches, this paper has put forward a hypothesis. The idea that perception of disequilibrium is affecting citizens' satisfaction with public services is valid theoretically.

4 Research Design

1. Data and Dependent Variable

(1) Data

Data collection was undertaken using two methods:analysis of primary documents and review of revelent academic sources. The two groups of data both came from second-hand data.

(2) Dependent variable

In July of 2011, research group of research office of economic and social construction of institute of Marxism of Chinese Academy of Social Sciences published Blue Book of Public Service, Hou et al. [8] had established an evaluation index system for China's basic public services. In total, this system is consisting of 9 first-class indicators, 35 second-class indicators and 77 third-class indicators. Moreover, 38 cities (include the 4 municipalities directly under the central government, 22 provinces, capital cities of 5 autonomous regions, 4 special economic zones and 5 municipalities with independent planning status) in China and 9 fields (public transport, public security, housing security, basic education, social security and employment, health care, municipal environment, culture and sports, and public service) are selected for attaining data. The evaluation system includes two aspects: first, the objective index system for evaluating basic public services of local governments; second, the subjective index system for evaluating basic public services of local governments, that is, satisfaction with basic public services which is also the dependent variable of this paper.

2. Independent Variable

(1) Disequilibrium perception

Disequilibrium perception is perception of the disequilibrium state with regard to public services. Therefore, the research has to be made from perspective of disequilibrium state, including the disequilibrium with regard to experience of providing public services and ability of public management. In other words: from dimension of time, disequilibrium in the process of providing public services is presented as disequilibrium experience in the process of providing public services; from dimension of nature, it is in nature disequilibrium with regard to behavior of providing public services or a kind of typical path dependence. Suo [17] put forward that the disequilibrium in outputs and outcomes of public services is disequilibrium between the urban and rural areas with regard to public management ability in the process of trying to achieve balanced development in public services. Moreover, the disequilibrium in output and outcome is presented as disequilibrium in public management ability. Fundamentally, it is disequilibrium in quantity of public services and chance to provide public services.

(2) Substitute variable-total policy score

Since disequilibrium perception is a subjective concept and disequilibrium involves various fields and aspects, it is difficult to collect data on disequilibrium perception. Considering that, author of this paper has tried to replace with a group of objective data that are featured with quantifiability and high operability. Finally, policy is found as a substitute variable.

Hypothesis 1. relevant policies issued by the government for developing public services in urban and rural areas are effectively executed by governments of all levels and relevant departments.

The author's behavior of regarding objective government policies as a substitute variable is based upon a hypothesis, that is: relevant policies issued by the government for developing public services in urban and rural areas are effectively executed by governments of all levels and relevant departments.

Hypothesis 2. relevant policies issued by the government for developing public services in urban and rural areas and executive outcomes of relevant departments can be perceived by residents in urban and rural areas.

From the argument of disequilibrium perception in the third chapter, we can see that the disequilibrium among governments in experience and public management ability in the process of providing public services can be perceived by citizens. Here, the policies issued by the government belong to experience category of public service provision; meanwhile, the execution by governments of all levels and relevant departments belongs to category of public management ability. Hence, it is safe to assume that relevant policies issued by the governments for developing public services in urban and rural areas and executive outcomes of governments of all levels and relevant departments can be perceived by residents in urban and rural areas.

5 Data Analysis and Result

First of all, this paper has divided policies in various cities for evenly developing public services into three categories according to original data of those policies as well as their degrees of authority and importance: the first category includes relevant policy and strategic and general documents issued by provincial (municipal) governments, government offices and so on; the second category includes relevant notifications and announcements issued by provincial (municipal) governments, government offices and departments directly under their control and relevant meetings; the third category includes trends and news reports related to local governments. According to provincial and municipal policies with different degrees of intensity, this paper has attached with three scores (3, 2 and 1) and set provincial and municipal weights for 26 cities that are not directly under the central government (Fig. 1).

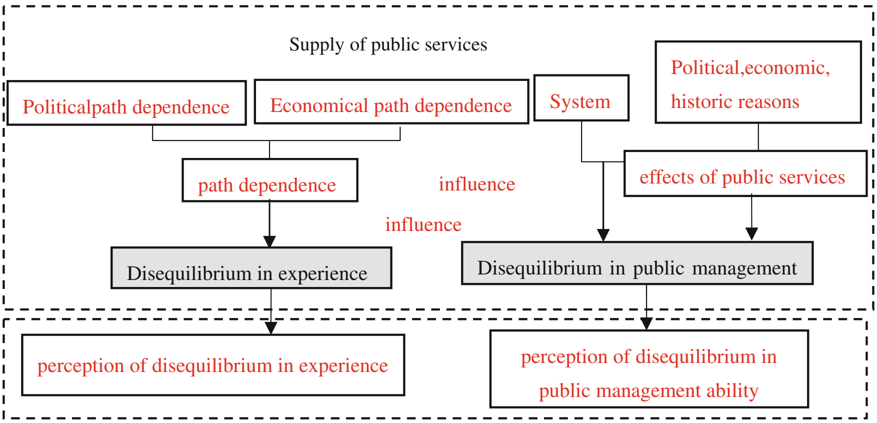

Fig. 1 Two types of disequilibrium states and processes of perceiving them

5.1 Descriptive Analysis

Description of the two groups of variables is shown in Table 1.

The minimum value of satisfaction among the 26 cities is 50.26, the maximum value is 57.55, the range is 7.29 and the values are quite concentrated; the mean value is 54.38, the standard error is 0.38, and the degree of dispersion is low. The minimum value among total policy scores among the 26 cities is 18.6, the maximum value is 52, the range is 33.4, and the values are relatively dispersed. The mean value is 37.12, the standard error is 1.49 and the degree of dispersion is high.

Since only municipal relevant policies are involved for the 4 municipalities directly under the central government, this paper has separately considered the four municipalities directly under the central government. Description of the two groups of variables of the municipalities directly under the central government is shown in Table 2.

The minimum value of satisfaction of the four municipalities directly under the central government is 50.87, the maximum value is 57.27, the range is 6.4, the values are relatively concentrated and the range is smaller than that of the 26 cities. The mean value is 54.47, the standard error is 1.44 and the mean value is higher than that of the 26 cities, which means urban and rural residents' satisfaction with public services in the four municipalities directly under the central government is a little higher than average level of other cities. The minimum value of total policy scores of the 4 municipalities is 42, the maximum value is 55, the range is 13, the values are comparatively concentrated and the range is obviously lower than that of other cities. The mean value is 48.75, the standard error is 3.12 and the degree of dispersion is high, which means the total policy score for evenly developing public services in urban and rural areas in the four municipalities is significantly higher than that of other cities.

5.2 Correlation Analysis

After that, SPSS is used to normalize satisfaction degrees and total policy scores to attain two groups of data (Z satisfaction and Z policy).

First of all, a scatter diagram is made with two groups of data of the 26 cities by regarding Z policy as the abscissa and Z satisfaction as the ordinate, as shown in Fig. 2. Observe positions of all elements in the diagram to identify the strongly and positively related linear relationship between the two groups of variables.

The distribution of all points is like a line with a slope bigger than 0. Hereby, it is speculated in this paper that total policy score of a city is linearly dependent on citizens' satisfaction with public services. When the two variables are linearly related, Pearson product-moment correlation coefficient can be used for making a correlation analysis. Pearson product-moment correlation coefficients of the two groups of variables of the 26 cities are shown in Table 2 as following.

Table 1 Description table of satisfaction and total policy scores of 26 cities from 2010 to 2011

Descriptives								
	N	Range	Minimum value	Maximum value	Mean value		SE[a]	Variance
	Stat[b]	Stat[b]	Stat[b]	Stat[b]	Stat[b]	SE[a]	Stat[b]	Stat[b]
Satisfaction	26	7.29	50.26	57.55	54.38	0.38	1.92	3.7
Total policy scores	26	33.4	18.6	52	37.12	1.49	7.62	58.12
Valid N (list state)	26							

[a] Standard error
[b] Statistics

Table 2 Description table of satisfaction and total policy scores of the 4 municipalities directly under the central government from 2010 to 2011

Descriptives									
	N	Range	Minimum value	Maximum value	Sum	Mean value		SE[a]	Variance
	Stat[b]	Stat[b]	Stat[b]	Stat[b]	Stat[b]	Stat[b]	SE[a]	Stat[b]	Stat[b]
Satisfaction	4	6.40	50.87	57.27	217.87	54.47	1.44	2.89	8.36
Total policy scores	4	13.00	42.00	55.00	195.00	48.75	3.12	6.24	38.92
Valid N (list state)	4								

[a]Standard error
[b]Statistics

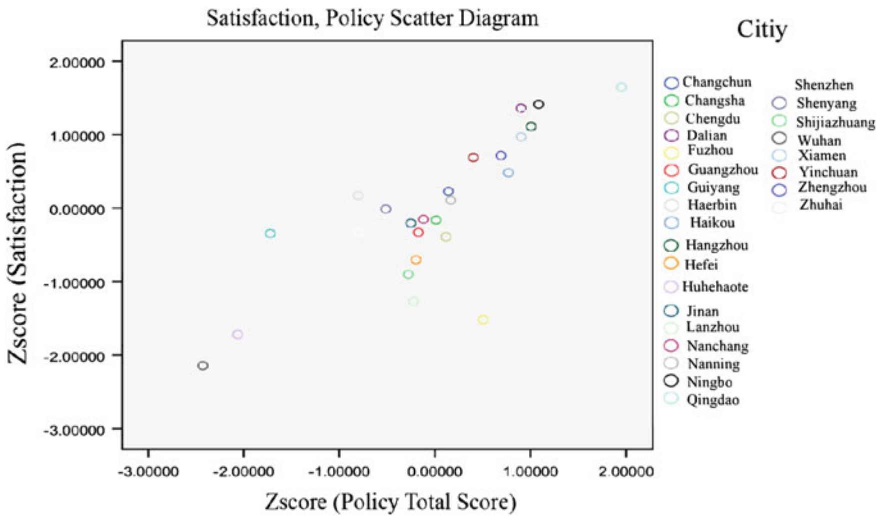

Fig. 2 Scatter diagram of satisfaction and policies of the 26 cities from 2010 to 2011

The above table has presented the correlation between the satisfaction (independent variable) and total policy score (dependent variable). From that, we can identify significant correlation between satisfaction and total policy score. The Pearson product-moment correlation coefficient between satisfaction and total policy score of the 26 cities reaches as high as 0.792: ($0.7 < r < 1$), that is, the two are highly positive related to each other (Table 3).

Similarly, 4 groups of data of the 4 municipalities directly under the central government are applied for making a Pearson correlation analysis of satisfaction and total policy score, as shown in Table 4.

Table 3 Pearson correlation analysis table of satisfaction and policy data of the 26 cities from 2010 to 2011

		Z score (satisfaction)	Z score (total policy score)
Zscore (satisfaction)	Pearson correlation	1	0.792**
	Correlation bilateral		0.000
	N	26	26
Zscore (total policy score)	Pearson correlation	0.792**	1
	Significance bilateral	0.000	
	N	26	26

**Significant correlation above 0.01 level. (bilateral)

Table 4 Pearson correction analysis table of satisfaction and policy data of the 4 municipalities directly under the central government from 2010 to 2011

		Z score (satisfaction)	Z score (total policy score)
Zscore (satisfaction)	Pearson correlation	1	0.984**
	Correlation bilateral		0.016
	N	4	4
Zscore (total policy score)	Pearson correlation	0.984**	1
	Significance bilateral	0.016	
	N	4	4

**Significant correlation above 0.05 level (bilateral)

This group of variables of the 4 municipalities directly under the central government are significantly correlated and their Pearson correlation coefficient is as high as 0.984. Their correlation is significantly higher than that of the 26 cities.

Result one: the total score of relevant policies issued by local governments for achieving balanced development between urban and rural areas is highly and positively related to citizens' satisfaction with public services; moreover, degrees of correlation among common cities are more significant than those among the municipalities directly under the central government.

5.3 *Regression Analysis*

(1) Regression analysis of relevant policies and satisfaction

After the correlation analysis is made, this paper assumes the satisfaction and total policy score meet the linear regression model considering features of the data. Assume the model as:

$$Yi = \beta_1 + \beta_2 X_i + \mu_i \quad i = 1, 2, \cdots, n. \tag{1}$$

The modified coefficient of determination of satisfaction model and total policy score of the 26 cities is 0.612 and the Durbin-Watson value is 1.136. The D.W. test signifies that first-order autocorrelation is absent in the residual term.

Therefore, the unary linear regression equation should be: satisfaction $= 49.96 + 0.2 \times$ total policy score. Its standardized regression equation is: satisfaction $= 0.792 \times$ total policy score.

Similarly, the two groups of variables (the satisfaction and policy score of the municipalities directly under the central government) also meet features of the unary linear regression equation and they are highly and positively related to each other. When measuring the dependent variable and independent variable with SPSS, we can see that the modified coefficient of determination of the model is 0.952 and the

Durbin-Watson value is 2.821. The D.W. test signifies that first-order autocorrelation is absent in the residual term.

Therefore, the satisfaction-policy score-unary linear regression equation of the 4 municipalities directly under the central government is:

Satisfaction = 32.271 + 0.455× total policy score.

Its standardized regression equation is: Satisfaction = 0.984 × total policy score.

Compared with that of the unary linear regression equation of the 26 cities, the constant term decreases by 17.689. It means the satisfaction of the 26 cities is more stable and differences among the cities are relatively small. The model coefficient of the 26 cities is 0.2, the model coefficient of the 4 municipalities directly under the central government is 0.455 and β_1 of the 4 municipalities has a higher degree of determination.

Result two: the coefficient and constant term of the regression equation between total score of relevant policies issued by local governments for achieving balanced development between urban and rural areas and citizens' satisfaction with public services are positive numbers which are positively related to each other. Moreover, the degree of determination of total policy score of the municipalities directly under the central government to satisfaction is higher compared with coefficients of common cities. Furthermore, common cities are lower and more stable with regard to degree of satisfaction.

(2) Regression analysis of provincial and municipal policies and satisfaction

To further point out the relationship between provincial and municipal policies and satisfaction, the author has made a stepwise regression analysis of involved provincial policies and municipal secondary policies to demonstrate whether any cause-result relationship is existent between the variables or not. Assume the provincial policy score as X_1 and the municipal policy score as X_2. Assume the model as:

$$Yi = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \mu_i \quad i = 1, 2, \cdots, n. \tag{2}$$

Use SPSS regression analysis to attain a primary analysis table shown as Table 5.

From above table, we can see the modified coefficient of determination of Eq. (2) is 0.616 and its fitting degree is the highest; the Durbin-Watson value is 1.23. The D.W. test signifies that first-order autocorrelation is absent in the residual term.

From Table 6, we can see that municipal policy score is included into the Eq. (1) as an independent variable and provincial and municipal policies are included into Eq. (2) as two independent variables.

According to the outputs of the regression coefficient table, all regression coefficients have passed the test. From coefficients of partial correlation, we can see that coefficients of Eq. (2) are higher and have more significant influence on dependent variables compared with on independent variables of Eq. (1). Among them, the coefficient of municipal policies reaches as high as 0.79 and that of provincial policies is close to 0.7; meanwhile, municipal policies have more significant influence on dependent variable compared with provincial policies.

Table 5 Analysis table of satisfaction and provincial and municipal policy model of the 26 cities from 2010 to 2011

Model	R	R square	Adjusted R square	Standard estimated error	Statistics of changes					Durbin-Watson
					Changes of R square	Changes of F	df1	df2	Changes of Sig. F	
1	0.573[a]	0.329	0.301	1.609	0.329	11.75	1	24	0.002	
2	0.804[b]	0.646	0.616	1.193	0.318	20.67	1	23	0	1.23

[a]Predictive variable: (constant), municipal policies
[b]Predictive variable: (constant), municipal policies, provincial policies
[c]Dependent variable: satisfaction

Table 6 Regression coefficients of satisfaction and provincial and municipal policies of the 26 cities from 2010 to 2011

Model	Non-standardized coefficients		Standard coefficients	t	Sig.	95.0 % Confidence interval of B	
	B	Standard errors	Beta			Lower limit	Upper limit
1 (Constant values)	51.6	0.87		59.17	0	49.794	53.396
Municipal policies	0.078	0.02	0.57	3.428	0.002	0.031	0.124
2 (Constant values)	46.28	1.33		34.66	0	43.522	49.046
Municipal policies	0.12	0.019	0.87	6.2	0	0.078	0.157
Provincial policies	0.1	0.022	0.64	4.546	0	0.054	0.145
Model	Correlation			Statistics of collinearity			
	Zero order	Deviation	Portion	Tolerance	VIF		
1 (Constant values) Municipal policies	0.573	0.573	0.573	1.000	1.00		
2 (Constant values) Municipal policies	0.573	0.79	0.77	0.787	1.27		
Provincial policies	0.235	0.69	0.56	0.787	1.27		

[a]Dependent variable: satisfaction

Therefore, the multiple linear regression equation should be:

Satisfaction $= 46.284 + 0.1 \times$ provincial policy score $+ 0.12 \times$ municipal policy score

Its standardized regression equation is:

Satisfaction $= 0.64 \times$ provincial policy score $+ 0.87 \times$ municipal policy score

Result three: compared with relevant municipal policies issued by local governments for achieving balanced development between urban and rural areas, relevant provincial policies issued by local governments for achieving balanced development between urban and rural areas have less influence on citizens' satisfaction with public services.

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Study on Institutional Investors' Shareholding, Free Cash Flow and Dividend of Listed Corporations

Yong Liang and Shengdao Gan

Abstract Dividend is an important manifestation of investors' return on investment. The company dividends reflect the company's profitability and operating conditions in a certain degree, and it also reflects the company's social responsibility. In recent years, the government has continued to strengthen the supervision of dividend policy of listed Corporations, and dividend situation has gradually improved. However, mandatory dividend policy still has its own shortcomings. Through the analysis on the institutional investors' shareholdings, the free cash flow and the dividends of the A-Shares listed Corporations of the Shanghai Stock Exchange and Shenzhen Stock Exchange, it show that there is a positive correlation between the shareholdings of institutional investors and the dividends of listed corporations, we may find free cash flow is the basis for the dividends. Soit is important to play the institutional investors positive role in corporate governance, and supervise the listed Corporations to effective use of free cash flow under the ownership structure, and actively implement the dividend policy, and the effective protection of shareholders' interests.

Keywords Institutional investors · Free cash flow · Bonus · The interests of shareholders · 'Semi mandatory' policy

1 The Summary and Analysis of Dividend Policies of Listed Corporations in China

Dividends of listed corporations are one of essential methods for investors to achieve reasonable return on investment. Sustainable and stable dividends objectively reflect the listed Corporation's profitability, reflecting the company's social responsibility

Y. Liang (✉) · S. Gan
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: yunsongl@163.com

Y. Liang
Planning and Finance Department, Sichuan Normal University, Chengdu 610066, People's Republic of China

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and the ability to maintain the interests of the investors. It is advantageous to achieve the enhancement of corporate finance and investment attractions, and to create a good social environment for the company at the same time. What's more, dividends will affect the long-term investment philosophy in the entire capital market and the orderly development of financing and investment environment in the capital market.

For a long time, because of the slow development of capital market, many listed corporations pay fewer dividends or no dividends to the shareholders. Because of the agency problem coupled with information asymmetry and other factors, the state-owned major shareholders have failed to play a role of supervisory in the operation of companies. Shi [12] pointed out that China's listed Corporations, paying great attention to financing and little attention to dividends, have led to the higher risk and less profit of Chinese investors. China's dividend is mainly characterized as that the dividend is only distributed among a few industries. The dividends account for a very low percentage of the profit and the dividend rate is too low, leading to the increasing contradictions between the listed Corporations and investors, who has a strong demand for the dividends.

In order to guide and regulate the cash dividends of the listed Corporation, "semi mandatory dividend" supervision mode has become increasingly outstanding in China. Since 2001, many regulatory policies and measures have been made to direct the dividend distribution of listed corporations. According to some relevant data statistics, there were 856 listed companies using cash dividend in 2008, occupying the 52 % of listed companies. The dividend cash 342.3 billion yuan, occupying the 36.65 % of the total net profit. In 2012, there were 1774 cash dividend listed companies, occupying the 68 % of all the listed companies, which increased by 1.1 times compared with 2008. The dividend cash 678.4 billion yuan, occupying the 34.7 % of the total net profit, increased by 98.19 % compared with 2008.

2 Literature Review

Lintner [9] started to make researches on the dividend distribution behavior of listed corporations in 1956, and later on the related theories which analyses the intrinsic value of dividend distribution activities in a listed corporation from different perspectives came into being gradually. The advancement of the dividend irrelevance theory of Modiglian and Moiller [11], the theory of dividend signaling of Bhatta-chary [3], the theory of dividend agency of Easterbrookzai [5], and the Catering Theory of Dividends of Baker and Wurgler [2], have given fully theoretical support for the dividend distribution activities. Kim et al. [8] found that there is a significantly positive correlation between intuitional investors and dividends. Huo [1] studied the problem that how the indictional investors influence on the cash dividends policy from cash tendency and cash level. She found out that indictional investors was no significant correlation.

Institutional investors prefer the firms which can share out dividends, a higher level of distributed dividends in the firms will lead to the higher ratio of institutional investors' shareholdings. Allen [7] thought that due to the influence of the prudent principle and the tax advantages related to dividend, the institutional investors prefer dividend distribution, and the ratio of Institutional holdings will increase with the distributed dividends on each share. Grinstein and Michaely [6] found that cash dividend would affects the percentage of institutional investors' share-holding, and the firms which pay cash dividends tend to those firms which can pay less cash dividend, meanwhile, the proportion of institutional investors' share-holding makes no difference upon the dividend policy of listed companies.

Of course, different institutional investors, including securities company, social security funds, insurance fund, QFII and so on, they affect the dividend distribution of listed corporations in different ways for their the heterogeneity. Dong [4] demonstrated that different types of institutional investors have somewhat different views on the distribution of cash dividends.

3 Research and Assumptions

3.1 Data's Sources and Samples' Selection

Data in this paper is chosen from Shanghai and Shenzhen A-share companies from 2009 to 2012. In order to avoid the influence of outliers, we didn't bring into consideration all sorts of ST companies, listed corporations in financial and insurance industries, and companies own negative or abnormal ROE. Therefore, we got 1961 samples, among which 473 samples are from the year of 2009, 595 samples from 2010, 475 samples from 2011 and 418 samples from 2012. Resources are from China Tai'an (CMSAR) and Shanghai composite databases and some annual reports, and we use Excel and SPSS 18.0 to analyze data.

3.2 Variables Settings

1. The selection of the dependent variable

This paper chooses companies' dividends as the dependent variable. It assumes that whether a listed company shares out dividends (DIT) represents the trend of the listed companies' dividends distribution and per dividend's share (DIV) represents the ratio of listed companies' dividends distribution. The purpose of this paper is intended to analyze the influence of institutional shareholdings upon the distribution of dividend. We use all samples of every year to examine the influence of institutional shareholdings upon the tendency of dividends distribution in a listed corporation and when we examine the factors which influence the ratio of dividends distribution, we eliminate samples which did not share out dividends every year, and as a result, we finally got 1304 samples.

Table 1 The schedule of variables

	Name		Variable symbols
The dependent variables	The tendency of dividend	DIT = 1 dividend	DIT
		DIT = 0 no dividend	
	The ratio of dividends	Dividends of per common share	DIV
Explanatory variables	Institutional investors	The ratio of institutional shareholdings	-Inst
	Cash flow	Free cash flow	FCF
Control variables	Growth opportunities	Tobin-Q	Tobin-Q
	Financial leverage	The ratio of liabilities to assets	Lev
	Profitability	The return on net equity	Roe
	Company size	Natural logarithm of total assets	Size
	Characteristics of equity	The ratio of the largest shareholder	Top1
	Factors of industry	Ind	$I = 1, 2, 3, \cdots$ [a]

[a]Means various industries, based on manufacturing, if it belongs to which, we use 1, and if not, we use 0

2. Explanatory variable

This paper mainly involves two variables: institutional shareholdings and FCF (free cash flow). Institutional shareholdings will be used to analyze its influence upon the distribution of dividends and the ratio of dividends in profits as a whole in a listed corporation, while FCF is left after being deducted the required cash to make sure t positive future expected NPV, moreover, it is also the main source of companies' dividends (Table 1).

3. The selection of control variables
4. Research and assumptions

According to the theory of Agency costs of Free Cash Flow, the related practices of Li [10], this paper makes the following assumptions:

- There is a positive correlation between institutional investors and the tendency of Dividend, and institutional investors seek dividends on shares.
- The higher the institutional investor' shareholdings is, the higher is the ratio of dividends of a firm.
- Free cash flow is positively correlated with the distribution of dividends in a company. The larger the Free cash flow is, the more dividends per share be distributed to investors in a listed corporation.

5. Model analysis

- *The model of Dividend distribution tendency*

This paper adopts Logistic's Regreesion approach to test how the proportion of institutional investors' shareholdings affects the distribution of dividends in listed corporations. Assumed that the probability of $IFD = 1$ is P, then the probability of $IFD = 0$ is $1 - P$. After the Logit transform, we can get Logistic regression Eq. (1) to test hypothesis 1:

$$LN\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1\text{Inst} + \beta_2\text{Fcf} + \beta_3\text{Tobin} - Q + \beta_4\text{Lev} + \beta_5\text{Size} + \beta_6\text{Roe} + \beta_7\text{Top}_1 + \sum\text{Industry} + \varepsilon. \quad (1)$$

- *The model of testing the ratio of dividends distribution*

This paper selects the dividends of per common share as the dependent variable, takes INSTOWN as the explanatory variable, adopts the corresponding control variables, and using the multi-factor linear regression model to test how the shareholding structure affects the intensity of dividends in the meanwhile.

$$\text{DIV} = \beta_0 + \beta_1\text{Inst} + \beta_2\text{Tobin} - Q + \beta_3\text{Lev} + \beta_4\text{Size} + \beta_5\text{Roe} + \varepsilon. \quad (2)$$

- *The effect of free cash flow on the ratio of shared-out dividends*

This paper selects the dividends of per common share as the dependent variable, takes free cash flow as the explanatory variable, adopts the corresponding control variables, and uses the multi-factor linear regression model to test how free cash flow affects the intensity of dividends.

$$\text{DIV} = \beta_0 + \beta_1\text{Fcf} + \beta_2\text{Tobin} - Q + \beta_3\text{Lev} + \beta_4\text{Size} + \beta_5\text{Roe} + \sum\text{Industry} + \varepsilon. \quad (3)$$

4 Research and Assumptions

1. Descriptive Statistical Analysis

Using the software SPSS 18.0 to make descriptive statistical analysis on these samples, we found that the average ratio of institutional shareholdings was 19.02, the average shareholding ratio of largest shareholder was 37.6346, which means the proportion of institutional shareholdings in the firms is higher and higher. And the average of free cash flow is 0.05709, the maximum 0.6984, which means that the free cash flow is relatively low. The ratio of liabilities to assets is 52.0798, which means the debt levels is high.

2. T-Test and Analysis of Samples

Taking into account that the sample corporations are different, we use the independent-sample T test for these sample firms to test if there were any significant differences in the proportion of institutional investors' shareholdings in the

Table 2 The descriptive statistics of variables in the sample

	N	Minimum	Maximum	Average	Standard deviation
Institutional shareholdings	1961	0.0200	90.5605	19.0184	18.1446
Free cash flow	1961	0.00004	0.6984	0.05709	0.05654
Tobin-q	1961	0.000375	50.2988	0.6269	2.7532
The ratio of liabilities to assets	1961	1.080	95.5400	52.0798	19.0151
The return on net equity	1961	0.0100	448.5200	13.6552	16.6764
The shareholding of largest shareholder	1961	4.488	110.1300	37.6346	15.8878
Company size	1961	18.1812	28.2820	22.14651	1.34244
Effective N list status	1961				

Table 3 Independent T-test

	Distribution tendency	N	Average	Standard deviation	SE Mean	T	Sig.
Instown	1	1347	20.86	18.6504	0.50816	6.739	0.000
	0	614	14.97	16.2805	0.65703		
Free sash flow	1	1347	0.0580	0.05579	0.0015	1.054	0.292
	0	614	0.05509	0.05818	0.0023		
Tobin-q	1	1347	0.5968	2.8409	0.0774	−0.718	0.473
	0	614	0.6930	2.5515	0.1030		
The ratio of liabilities to assets	1	1347	49.9909	18.8932	0.5148	−7.301	0.000
	0	614	56.6625	18.4847	0.7460		
The return on net equity	1	1347	14.9211	10.0672	0.2743	5.009	0.000
	0	614	10.8783	25.6011	1.0332		
Company size	1	1347	22.4060	1.3386	0.03647	0.354	0.024
	0	614	21.5772	1.16406	0.04698		

case of dividends distribution and no dividends distribution. After the test, we found that in different dividend paying groups, there was a significant difference in the proportion of institutional investors' shareholdings, the ratio of liabilities to assets, the return on net equity and the company size when Sig. values is less than 0.05, while there was not obvious difference no matter how much Tobin-Q was (Tables 2, 3).

3. The Results and Analysis of the Regression Model

By establishing a logistic regression model based on the sample corporations, we test whether the holdings of institutional investors have an effect on the distribution of or not. The result reflects that holdings of institutional investors is positively related to the dividend sharing-out tendency of the firms, and when the proportion of institutional investors' shareholdings is less than 0.05, it significantly correlated with the distribution of dividends. The result confirms hypothesis 1, and also illustrates that the holdings of institutional investors have an effect on the policy of dividends

Table 4 The results of Logistic regression model (1)

	B	S.E	Wals	Df	Exp (B)
Institutional investor shareholdings	0.011	0.003	10.301	1	1.011
Free cash flow	0.333	0.986	0.114	1	1.395
Tobin-Q	−0.028	0.019	2.070	1	0.973
The ratio of liabilities to assets	−0.044	0.004	151.766	1	0.957
The return on net equity	0.020	0.006	9.848	1	1.020
The ratio of the largest shareholder	0.010	0.004	6.717	1	1.010
Company size	0.823	0.061	183.299	1	2.276
Industry characteristics	−0.012	0.112	0.012	1	0.988
Constant	−15.715	1.223	165.035	1	0.000

Table 5 The result of Linear regression model (2)

	Non-standardized coefficient		Standardized coefficient	T	Sig.	Collinearity statistic	
	B	Standard error	trial version			Tolerance	VIF
Constant	−0.897	0.131		−6.857	0.000		
Institutional shareholdings	0.001	0.000	0.043	1.583	0.114	0.968	1.034
The ratio of liabilities to assets	−0.004	0.000	−0.298	−9.846	0.000	0.763	1.311
Company size	0.057	0.006	0.275	9.027	0.000	0.753	1.328
Tobin-q	0.005	0.003	0.049	1.846	0.065	0.995	1.005

distribution, and they played a positive role of shareholder activists. Dividend distribution tendency was negatively correlated with the ratio of liabilities to assets, Tobin-Q and industry characteristics. The difference is l significant, but surprisingly, the size of firms has an obvious effect on the distribution of dividends, when it is less than 0.05, it is significantly correlated (Table 4).

Table 5 shows that there was a positive correlation between institutional investors shareholdings and the ratio of dividends,but it isn't obvious. In Eqs. (2) and (3), there is a significant correlation between the ratio of liabilities to assets, company

Table 6 The result of Linear regression model (3)

	Non-standardized coefficient		Standardized coefficient	T	Sig.	Collinearity statistic	
	B	Standard error	trial version			Tolerance	VIF
(Constant)	−0.928	0.124		−7.452	0.000		
Fcf	0.280	0.127	0 .056	2.198	0.028	0.940	1.064
Lev	−0.004	0.000	−0.243	−8.582	0.000	0.746	1.340
Roe	0.010	0.001	0.341	13.078	0.000	0.881	1.135
Size	0.049	0.006	0.237	8.328	0.000	0.742	1.348
Tobin-q	−0.003	0.003	−0.028	−1.131	0.258	0.948	1.055
Ind	0.049	0.014	0.089	3.490	0.000	0.924	1.083

size and the ratio of dividends. The former is negatively correlated while the latter is positively correlated. In the test for multi-collinearity, the VIF of every variable is less than 2, which means that there does not exist multi-collinearity among explanatory variables.

According to Table 6, we can see that there was a positive correlation between free cash flow and the ratio of dividends. When it is less than 0.05, there is a significant correlation between free cash flow and the ratio of dividends, which is more significant than the effect of holdings of institutional investors on the dividends distribution of a listed corporation.

5 The Effective Measures to Promote the Dividends Distribution of Listed Corporations

(1) Adhering to the Principle of "the Mandatory Dividend Distribution Policy along with the Encouragement of Dividend Distribution"

The distribution of dividends is one of the important forms to reflect the return on investment of a listed company, and it also relies on the company operation status and development strategic positioning. Under the current background, the Chinese capital market is still yet to be developed, the limited financing channels and the big financing risk must affect the decision of dividend distribution in a listed company Although in recent years, the dividend policy in China gives priority to mandatory dividend distribution, here is certain rigidity about the distribution of dividends. Therefore, the dividend distribution is often regarded as a task by the listed company, which they have to finish, or it will lose investors or violate the relevant regulation cannot improve the financing environment of the listed company radically, and it will make investors have not enough confidence to wait for gains without pains or wait for the regular or irregular dividends of listed companies.

Therefore, we should not only adhere to the mandatory share out bonus, but also they should cultivate the ability to guide the dividends distribution. our country should make greater efforts to develop those mature, well-run companies, especially the monopolistic listed company should share out bonus actively to build a model. And from the normative perspective, our country should guide the well-run companies to share out bonus so as to stabilize the order of capital market.

(2) Cultivating the Environment for the Distribution of Dividends, and Creating a Good Financing Environment for the Listed Company

Dividends and financing are two closely related markets. On the one hand, the distribution of dividends in a company protects the interest of the investors. On the other hand, it can also lay the foundation for the company financing. According to the Signaling theory, dividend reflects the profitability of listed companies and can attract the investors who prefer the dividend distribution to buy shares of the company, and then the company can expand the scope of financing. According to the Catering theory of dividend, when the market investors prefer to protect their interests in the form of distributed dividends, the company's management should make more choices to share out bonus to attract investors, which can form a long-term share out bonus expectations for the investors, reduce the behaviors that investors are voting with their feet, and change from the "short-term speculation" to "long-term value investment". In these ways both sides can achieve a win-win situation, and then they can improve the financing environment of the company.

(3) Developing the Shareholder Activism of Institutional Investors, and Supervising the Distribution of Listed Corporations

In recent years, the ranks of institutional investors grew up gradually, and they became the major power of their companies' shareholding. Institutional investors rely on their professional talent team, professional financial strength, and the capabilities in information gathering and powerful analysis, playing an active role in corporate governance. Therefore, we should constantly improve the policy of corporate governance in which institutional investors participate, and provide a strong backing for their participation in companies' dividend distribution decisions. Meanwhile, we should further standardize the investment market for institutional investors, strengthen the supervision of the industry, and overcome short-term investment behaviors and herd behaviors of institutional investors. We should respect and make full use of the shareholders' difference of institutional investors, let the social security funds and insurance funds play a long-term supervisory role, and guide securities investment funds and other institutional investors whose shareholding duration is short. In one word,we should work together to supervise and monitor the distribution of dividends in listed companies.

(4) Considering and Studying the Substitute Advantages of Preferred Stocks so as to Meet the Needs for the Dividends Distribution of Companies and Investors

It is well known that the most outstanding characteristic of the dividends distribution of preferred stocks is to ensure the shareholders who hold preferred stocks to get the dividend. so, minority shareholders can be given priority over the rights of ordinary shareholders to distribute company's current property and income. As for a company, the share capital is constantly expanding, and majority ownership remains unaffected, which untie the company's policy of dividends distribution to some extent. So both of them can get benefits. However, it is an urgent task for us to consider how to improve the policies, such as the issuance settings, issuance terms, issuance methods, issuance size, and conditions for making profits and so on of preference shares as soon as possible. Of course, it will take a long time to implement such polices about the issuance of preference shares, and it will be a long process for the management of the company and shareholders to accept such policies. However, it is a new idea of solving the problem of dividends distribution, which is worth to try and explore.

6 Conclusion

In conclusion, the institutional investors shareholdings is positively related to the dividend distribution policy of the firms. But the connection between the proportion of institutional investors' shareholdings and the ratio of dividends is weak, which means that institutional investors' ability to supervise the dividends distribution of a listed company is limited. The analysis also shows that there was a significantly positive correlation between free cash flow and the ratio of dividends, so the supervision of free cash flow is a key factor for the institutional investors to safeguard their own interests and protect the interests of smaller shareholders.

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The Contribution Ratio of Electricity Industry to Economic Development in Yunnan Province

Lili Tan and Chongguang Jiang

Abstract As one of the five pillar industries in Yunnan Province, the electricity industry promotes the local economic development directly and indirectly. This empirical study focuses on that to what degree the electricity industry make such promotion. Based on a database containing 12 indicators of electricity industry and 13 indicators of the local economy, from 2002 to 2011, we study the contribution ratio of electricity industry to the local economic development in Yunnan Province with the co-integration analysis, and get some positive and interesting results.

Keywords Supplier selection · Uncertain variable · Uncertain programming · Genetic algorithm

1 Introduction

Electricity industry is one of the five pillar industries in Yunnan Province, southwest China. The development of the electricity industry promotes the local economic development directly and indirectly [3, 4]. However, to what degree the electricity industry make such promotion? The paper want to give a feedback to this question. Our empirical study based on a database containing 12 indicators of electricity industry and 13 indicators of the local economy of Yunnan Province, from 2002 to 2011.

The 12 indicators of electricity industry are Total Electricity Consumption, Secondary Industry Electricity Consumption, Tertiary Industry Electricity Consumption, Generated Electricity, Urban Household Electricity Consumption, Rural Household Electricity Consumption, Nonmetallic Mineral Product Industry Electricity

L. Tan (✉)
School of Public Administration, Yunnan University,
Kunming 650091, People's Republic of China
e-mail: tanlilichn@foxmail.com

C. Jiang
Fudian Bank, No.41 of Tuo East Road, Kunming 650033, People's Republic of China

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Consumption, Ferrous Metal Product Industry Electricity Consumption, Nonferrous Metal Product Industry Electricity Consumption, Heating Industry Electricity Consumption, Oil and Coke Industry Electricity Consumption, Chemical Raw Materials and Chemical Products Industry Electricity Consumption [5, 7].

The 13 indicators of the local economy are GDP, Secondary Industry Added Value, Tertiary Industry Added Value, Fixed Assets Investment, Mineral Industry Added Value, Nonmetallic Mineral Product Industry Added Value, Ferrous Metal Product Industry Added Value, Per Capita Disposable Income, Per Capita Net Income, Nonferrous Metal Product Industry Added Value, Heating Industry Added Value, Oil and Coke Industry Added Value, Chemical Raw Materials and Chemical Products Industry Added Value [6, 8].

2 Quantitative Analysis on the Contribution Ratio of Electricity Industry

With the help of the co-integration analysis, we quantitatively study the contribution ratio of electricity industry to the local economic development in Yunnan Province, and get some positive and interesting results [1].
1. The Contribution Ratio of the Development of the Electricity Industry to the Economic Growth

We analyze the relationship between GDP and the total electricity consumption in Yunnan Province from 2002 to 2011. We find that as a pillar industry, the development of electricity industry has a significant promoting effect on the GDP growth, and the contribution ratio is as shown in Table 1.

The table above shows a long-term and stable relationship between $\log(GDP)$ and $\log(YD)$:

$$\log(GDP) = 9.83 + 0.961\log(YD). \tag{1}$$

Table 1 The contribution ratio of electricity consumption to GDP

Variable	Coefficient	Std. error	t	Prob
C	9383478	0.876052	7.929887	0.0001
LOG(YD)	0.959766	0.098219	20.68796	0.0000
R-squared	0.937584	F-statistic		180.8576
Adjusted R-squared	0.923832	Prob (F-statistic)		0.000001

Dependent variable: LOG (GDP); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note $\log(GDP)$, $\log(YD)$ are both integrated of order 1, and there exists a co-integration relationship

This means that the GDP grows 0.96 % with every 1 % increase of electricity consumption. The reverse version of this relationship is close to the so called "electricity elasticity coefficient". According to our analysis, the electricity elasticity coefficient is 1.048, which is within a reasonable range of the historic electricity elasticity coefficient of Yunnan Province [2] (Tables 2, 3, 4, 5, 6 and 7).

1. *The Contribution Ratio of the Growth of Industrial Electricity Consumption to the Growth of the Second and Tertiary Industry*

We analyze the relationship between the added values of the second and tertiary industry and the electricity consumptions of the two industries from 2002 to 2011. We find that the industry electricity consumption has a significant promoting effect on the development of the second and tertiary industry, and the contribution ratios are:

The table above shows a long-term and stable relationship between log(DECY) and log(DECYYD).

$$\log(\mathrm{DECY}) = 9.21 + 1.101\log(\mathrm{DECYYD}). \tag{2}$$

Table 2 The contribution ratio of the electricity consumption of the second industry to the growth of the second industry

Variable	Coefficient	Std. error	t	Prob
C	9.205218	0.253618	36.29563	0.0000
LOG(DECYYD)	1.101071	0.040341	29.77271	0.0000
R-squared	0.991056	F-statistic		886.4142
Adjusted R-squared	0.989938	Prob (F-statistic)		0.000000

Dependent variable: LOG(DECY) Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(DECY), log(DECYYD) are both integrated of order 1, and there exists a co-integration relationship

Table 3 The contribution ratio of the electricity consumption of the second industry to the growth of the second industry

Variable	Coefficient	Std. error	t	Prob
C	12.19358	0.655328	18.60684	0.0000
LOG(DSCYYD)	1.93532	0.174150	6.876424	0.0001
R-squared	0.855296	F-statistic		47.28521
Adjusted R-squared	0.837208	Prob (F-statistic)		0.000128

Dependent variable: LOG(DSCY); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(DSCY), log(DSCYYD) are both integrated of order 1, and there exists a co-integration relationship

Table 4 The contribution ratio of electricity generation to the total investment in fixed assets

Variable	Coefficient	Std. error	t	Prob
C	6.806195	0.218703	31.12079	0.0000
LOG(FD)	1.123542	0.032619	46.70657	0.0000
R-squared	0.996346	F-statistic		2181.503
Adjusted R-squared	0.995889	Prob (F-statistic)		0.000000

Dependent variable: LOG(TZ); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note $\log(TZ)$, $\log(FD)$ are both integrated of order 1, and there exists a co-integration relationship

Table 5 The contribution ratio of total electricity consumption to the added value of mining industry

Variable	Coefficient	Std. error	t	Prob
C	3.919997	0.916321	4.277975	0.0027
LOG(YD)	1.221354	0.141814	12.13812	0.0000
R-squared	0.948498	F-statistic		147.3339
Adjusted R-squared	0.942060	Prob (F-statistic)		0.000002

Dependent variable: LOG(KC); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note $\log(TZ)$, $\log(FD)$ are both integrated of order 1, and there exists a co-integration relationship

Table 6 The contribution ratio of total electricity consumption to the added value of mining industry

Variable	Coefficient	Std. error	t	Prob
C	5.023580	0.852945	5.889685	0.0004
LOG(YD)	1.127571	0.132006	9.147868	0.0000
R-squared	0.912743	F-statistic		83.68348
Adjusted R-squared	0.901836	Prob (F-statistic)		0.000016

Dependent variable: LOG(FJS); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note $\log(KC)$, $\log(YD)$ are both integrated of order 1, and there exists a co-integration relationship

This means that the added value of the second industry grows 1.1 % with every 1 % increase of the industrial electricity consumption.

The table above shows a long-term and stable relationship between log(DSCY) and log(DSCYYD).

$$log(\text{DSCY}) = 12.91 + 1.09 log(\text{DSCYYD}). \tag{3}$$

This means that the added value of the tertiary industry grows 1.09 % with every 1 % increase of the electricity consumption.

2. *The Contribution Ratio of the Electricity Industry to the Total Investment in Fixed Assets*

Table 7 The contribution ratio of the total electricity consumption to the added value of the ferrous metal product industry

Variable	Coefficient	Std. error	t	Prob
C	4.224245	1.290994	3.272088	0.0113
LOG(YD)	1.20660	0.199800	7.110407	0.0001
R-squared	0.863383	F-statistic		50.55789
Adjusted R-squared	0.846306	Prob (F-statistic)		0.000101

Dependent variable LOG(HJS); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note $\log(HJS)$, $\log(YD)$ are both integrated of order 1, and there exists a co-integration relationship

We analyze the relationship between the total investment in fixed assets and the electricity generation from 2002 to 2011. We find that the electricity generation has a significant promoting effect on the total investment in fixed assets, and the contribution ratio is: The table above shows a long-term and stable relationship between $\log(TZ)$ and $\log(FD)$:

$$\log(TZ) = 6.81 + 1.12\log(FD). \tag{4}$$

This means that the total investment in fixed assets grows 1.12 % with every 1 % increase of the electricity generation.

3. *The Contribution Ratio of the Electricity Industry to the Growth of Major Pillar Industries and the High Energy-Consuming Industries*

We analyze the relationship between the added values of the mining industry, the non-mental mineral product industry and the ferrous metal product industry and the electricity consumption from 2002 to 2011. We find that the growth of the electricity consumption has a significant promoting effect on the added values of mining industry, the non-mental mineral product industry and the ferrous metal product industry. The contribution ratios are:

The table above shows a long-term and stable relationship between $\log(KC)$ and $\log(YD)$:

$$\log(KC) = 3.92 + 1.22\log(YD). \tag{5}$$

This means the added value of mining industry increases 1.22 % with every 1 % increase of the electricity consumption.

The table above shows a long-term and stable relationship between $\log(FJS)$ and $\log(YD)$:

$$\log(FJS) = 5.02 + 1.13\log(YD). \tag{6}$$

This means the added value of the non-mental mineral product industry increases 1.13 % with every 1 % increase of the electricity consumption.

The table above shows a long-term and stable relationship between $\log(HJS)$ and $\log(YD)$:

$$\log(HJS) = 4.22 + 1.02\log(YD). \tag{7}$$

This means the added value of the ferrous metal product industry increases 1.02 % with every 1 % increase of the electricity consumption.

4. *The Contribution Ratio of the Income Increase of Urban and Rural Residents to the Growth of Electricity Consumption*

We analyze the relationship between the income of the urban and rural residents and the household electricity consumption from 2002 to 2011. We find that both the increase of the urban per capita disposable income and the rural per capita net income promote the growth of the electricity requirement in urban and rural areas, and the contribution ratios are:

Table 8 shows a long-term and stable relationship between log(CZYD) and log(CZKZP):

$$\log(\text{CZYD}) = -7.81 + 1.30\log(\text{CZKZP}). \tag{8}$$

This means the urban household electricity consumption increases 1.3 % with every 1 % increase of the urban per capita disposable income increases 1 %. If we take year 2011 as the base year, the urban per capita disposable income is 18576 RMB and the urban population is 1.704 million. Then the relationship above means the annual household electricity consumption increases 4.38 KWH when the urban per capita disposable income increases 100 RMB.

Table 9 shows a long-term and stable relationship between log(NMYD) and log(NMRJ):

$$\log(\text{NMYD}) = -7.07 + 1.25\log(\text{NMRJ}). \tag{9}$$

This means the rural household electricity consumption increases 1.25 % with every 1 % increase of the rural per capita net income increases 1 %. If we also take

Table 8 The contribution ratio of the urban income to the urban electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−7.811281	1.030799	−7.577887	0.0001
LOG(CZKZP)	1.289073	0.110539	11.66174	0.0000
R-squared	0.944443	F-statistic		135.9962
Adjusted R-squared	0.937498	Prob (F-statistic)		0.000003

Dependent variable: LOG(CZYD); Method: least squares

Sample (adjusted): 2002 2011; Included observations: 10 after adjustments

Note log(CZYD), log(CZKZP) are both integrated of order 1, and there exists a co-integration relationship

Table 9 The contribution ratio of the rural income to the rural electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−7.069953	0.751074	−9.413119	0.0000
LOG(NMRJ)	1.248874	0.095619	13.06097	0.0000
R-squared	0.955204	F-statistic		170.5889
Adjusted R-squared	0.949605	Prob (F-statistic)		0.000001

Dependent variable: LOG(NMYD); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(NMYD), log(NMRJ) are both integrated of order 1, and there exists a co-integration relationship

year 2011 as the base year, the rural per capita net income is 4722 RMB and the rural population is 2.927 million. Then the relationship above means the annual household electricity consumption increases 2.45 KWH when the per capita rural net income increase 100 RMB (Tables 10 and 11).

5. *The Contribution Ratio of Growth of the High Energy-Consuming Industries to the Growth of the Electricity Consumption*

We analyze the relationship between the added value of the high energy-consuming industries and industrial electricity consumptions from 2002 and 2011. We find that the increase of the added values of the high energy-consuming industries significantly promote the growth of the industrial electricity requirement, and the contribution ratios are:

The table above shows a long-term and stable relationship between log(FJSYD) and $\log(FJS)$:

$$\log(\text{FJSYD}) = -3.58 + 0.589 \log(FJS). \tag{10}$$

This means that the industrial electricity consumption increased 0.589 % with every 1 % growth of the added value of the non-mental mineral product industry. If

Table 10 The contribution ratio of the added value of the non-mental mineral product industry to the industrial electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−3.576217	0.584616	−6.117209	0.0003
LOG(FJS)	0.589456	0.045599	12.92707	0.0000
R-squared	0.954314	F-statistic		167.1092
Adjusted R-squared	0.948604	Prob (F-statistic)		0.000001

Dependent variable: LOG(FJSYD); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(FJSYD), $\log(FJS)$ are both integrated of order 1, and there exists a co-integration relationship

Table 11 The contribution ratio of the added value of the ferrous metal product industry to the industrial electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−5.492993	0.880178	−6.240775	0.0002
LOG(HJS)	0.724446	0.065686	11.02900	0.0000
R-squared	0.938290			121.6388
Adjusted R-squared	0.930576	Prob (F-statistic)		0.000004

Dependent variable: LOG(HJSYD); Method: least squares

Sample (adjusted): 2002 2011; Included observations: 10 after adjustments

Note log(HJSYD), $\log(HJS)$ are both integrated of order 1, and there exists a co-integration relationship

we take year 2011 as the base year, the relationship above means the annual electricity consumption increases 5550 KWH when the added value of the non-mental mineral product industry increases 10 thousand RMB.

The table above shows a long-term and stable relationship between log(HJSYD) and $\log(HJS)$:

$$\log(\mathrm{HJSYD}) = -5.49 + 0.724 \log(HJS). \tag{11}$$

This means that the industrial electricity consumption increases 0.724 % with every 1 % growth of the added value of the added value of the ferrous metal product industry. If we take year 2011 as the base year, the relationship above means the annual electricity consumption increases 5802 KWH when the added value of the ferrous metal product industry increases 10 thousand RMB.

Table 12 shows is a long-term and stable relationship between log(YSJSYD) and log(YSJS):

$$\log(\mathrm{YSJSYD}) = -5.42 + 0.735 \log(\mathrm{YSJS}). \tag{12}$$

This means that the industrial electricity consumption increases 0.735 % with every 1 % growth of the added value of the non-ferrous metal product industry. If we take year 2011 as the base year, the relationship above means the annual electricity consumption increases 6902 KWH when the added value of the non-ferrous metal product industry increases 10 thousand RMB (Tables 13, 14 and 15).

The table above shows a long-term and stable relationship between log(DLRLYD) and log(DLRL):

$$\log(\mathrm{DLRLYD}) = -13.2 + 0.926 \log(\mathrm{DLRL}). \tag{13}$$

This means that the industrial electricity consumption increases 0.926 % with every 1 % growth of the added value of the production and supply industry of electricity and heat. If we take year 2011 as the base year, the relationship above means

Table 12 The contribution ratio of the added value of the non-ferrous metal product industry to the industrial electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−5.415429	0.765019	−7.078816	0.0001
LOG(YSJS)	0.734646	0.054944	13.37082	0.0000
R-squared	0.957169	F-statistic		178.7789
Adjusted R-squared	0.951815	Prob (F-statistic)		0.000001

Dependent variable: LOG(YSJSYD); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(YSJSYD), $\log(YSJS)$ are both integrated of order 1, and there exists a co-integration relationship

Table 13 The contribution ratio of the added value of the production and supply industry of electricity and heat to the industrial electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−13.19093	2.638383	−4.999625	0.0011
LOG(DLRL)	0.925639	0.185008	6.516679	0.0002
R-squared	0.841481	F-statistic		42.46711
Adjusted R-squared	0.821666	Prob(F-statistic)		0.000185

Dependent variable: LOG(DLRLYD); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(DLRLYD), log(DLRL) are both integrated of order 1, and there exists a co-integration relationship

Table 14 The contribution ratio of the added value of the oil processing industry and nuclear fuel processing industry to the industrial electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−3.958436	1.566964	−2.526181	0.0355
LOG(SY)	0.587571	0.131540	3.387353	0.0095
R-squared	0.589199	F-statistic		11.47416
Adjusted R-squared	0.537849	Prob (F-statistic)		0.009537

Dependent variable: LOG(SYYD); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(SYYD), $\log(SY)$ are both integrated of order 1, and there exists a co-integration relationship

the annual electricity consumption increases 3452 KWH when the added value of the production and supply industry of electricity and heat increases 10 thousand RMB.

The table above shows is a long-term and stable relationship between log(SYYS) and $\log(SY)$:

$$\log(\mathrm{SYYS}) = -3.96 + 0.588\log(SY). \tag{14}$$

Table 15 The contribution of the added value of raw chemical material and chemical products manufacturing industry to the industrial electricity consumption

Variable	Coefficient	Std. error	t	Prob
C	−0.161815	0.319863	−0.505889	0.6266
LOG(HXYL)	0.356478	0.023546	15.13988	0.0000
R-squared	0.966275	F-statistic		229.2159
Adjusted R-squared	0.962060	Prob (F-statistic)		0.000000

Dependent variable: LOG(HXYLYD); Method: least squares
Sample (adjusted): 2002 2011; Included observations: 10 after adjustments
Note log(HXYLYD), log(HXYL) are both integrated of order 1, and there exists a co-integration relationship

This means that the industrial electricity consumption increases 0.926 % with every 1 % growth of the added value of the oil processing industry and nuclear fuel processing industry. If we take year 2011 as the base year, the relationship above means the annual electricity consumption increases 1402 KWH when the added value of the oil processing industry and nuclear fuel processing industry increases 10 thousand RMB.

The table above shows a long-term and stable relationship between log(HXYLYD) and log(HXYL):

$$\log(\mathrm{HXYLYD}) = -0.16 + 0.356 \log(\mathrm{HXYL}). \tag{15}$$

This means that the industrial electricity consumption increases 0.356 % with every 1 % growth of the added value of the oil processing industry and nuclear fuel processing industry. If we take year 2011 as the base year, the relationship above means the annual electricity consumption increases 2744 KWH when the added value of raw chemical material and chemical products manufacturing industry increases 10 thousand RMB.

3 Conclusion

In Yunnan Province, southwest China, the electricity industry is a pillar industry, and promotes the growth of the local economy and development of other important local industries. With the co-integration analysis, we find that: The local GDP grows 0.96 % with every 1 % increase of electricity consumption; The added value of the second industry grows 1.1 % with every 1 % increase of the electricity consumption; The added value of the tertiary industry grows 1.09 % with every 1 % increase of the electricity consumption; The total investment in fixed assets grows 1.12 % with every 1 % increase of the electricity generation; The added value of mining industry increases 1.22 % with every 1 % increase of the electricity consumption; The added value of the non-mental mineral product industry increases 1.13 % with every 1 % increase of the electricity consumption; The added value of the ferrous metal product industry increases 1.02 % with every 1 % increase of the electricity consumption. Meanwhile, the development of the local economy and industries also promote the consumption of the electricity and certainly the development of the electricity industry. Taking the 2011 as a base year, we find that: The annual household electricity consumption increases 4.38 KWH when the urban per capita disposable income increase 100 RMB; The annual household electricity consumption increases 2.45 KWH when the per capita rural net income increase 100 RMB; The annual electricity consumption increases 5550 KWH when the added value of the non-mental mineral product industry increases 10 thousand RMB; The annual electricity consumption increases 5802 KWH when the added value of the ferrous metal product industry increases 10 thousand RMB; The annual electricity consumption increases 6902 KWH when the added value of the non-ferrous metal product industry increases 10 thousand RMB; The annual electricity consumption increases 3452 KWH when the added value of the production and supply industry of electricity and heat increases 10 thousand RMB; The annual electricity consumption increases 1402 KWH when the added value of the oil processing industry and nuclear fuel processing industry increases 10 thousand RMB; The annual electricity consumption increases 2744 KWH when the added value of raw chemical material and chemical products manufacturing industry increases 10 thousand RMB.

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A Research of Implementation Effect Measurement on Low-Carbon Economic Policy in the Urbanization Processes: A Case Study of Wenjiang District, Chengdu City

Yunqiang Liu and Fang Wang

Abstract Although the low-carbon economy is a relatively new concept, a large amount of effective work has been done and a great number of supporting policies and measures have been established in WenJiang district, stimulating the low-carbon economy development. Based on the existing data of WenJiang district, the essay simulates the policies needed to be further changed in that area via optimization techniques, mathematical models, etc., so as to comprehensively analyze and evaluate the outcomes in detail.

Keywords Low-carbon economic · Evaluating indicator · Policy simulation · Cge model

1 Introduction

Although the low-carbon economy is a new concept, it is closely related to the notion of energy conservation and emissions reduction, recycling economy, and so forth. In the recent years of economic and social development, the whole society have begun to pay attention to energy conservation and emissions reduction as well as resource recycling, which are directly related to sustainable development.

There were many researchers making progresses in low-carbon economy. They can be broadly broken down into two key areas. One was about factors evaluation research, especially the carbon emission, and the other was evaluation system research. Mazzarino [5] applied comparative static approach and monetary estimates to find the transport sector significantly contributing to energy consumption and carbon dioxide emissions. The Data Envelopment Analysis (DEA) was applied to research the relationships between economic growth, and, carbon dioxide emission [6]. Ugur et al. [7] used VAR model including energy consumption, carbon

Y. Liu · F. Wang (✉)
Management College, Sichuan Agricultural University,
Chengdu 611130, People's Republic of China
e-mail: wangfangscnd@sicau.edu.cn

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emissions, economic growth and granger causality to investigates the effect of energy consumption and output on carbon emissions in the United States. Koji et al. [4] developed a method formulating long-term scenarios towards a low-carbon economy at local level. Cheng et al. [1] used fuzzy goal programming based on grew and inputłoutput theory to simulate three kinds of emissions strength and economic impact under different carbon tax scheme. Jyoti et al. [3] evaluated the present carbon emissions situation in Indian through IO and SAM.

Low-carbon economic security system is a significant supporting platform for realizing the structure adjustment, industrial optimization, and technological innovation of low-carbon energy.

2 Model Building

CGE model, the full name for Computable General Equilibrium model, originated and developed from Walras's abstract General Equilibrium Theory in western economics, is a mathematical model of real economy [2]. After decades of development, CGE model has become a very normative model. As a powerful tool for policy analysis, CGE model has been increasingly used and has become a formal branch of applied economics.

2.1 Basic Structure

The basic idea of CGE model is to simulate the cyclical process of production-income- demand in macro economic operation, where assumptions satisfying the behavior subjects include: producers, within certain production technology, attempt to maximize profits by minimizing the cost; consumers, under the conditions of limited income, seek to maximize their consumer utility through selecting consumer products according to their preference; merchants, within a certain level of output, endeavor to maximize revenue both at home and around the world through price conducting mechanism; and in terms of the supply and demand of elements, optimal resource endowment allocation will be achieved in the process of production. The behavioral optimization hypotheses above are demonstrated, in the CGE model, by the four types of equation modules, which are the production optimization module, the consumer demand module, the trade module, as well as the equilibrium and macro closure module, respectively. In addition to the above four modules, the income distribution module and the price forming module are included in this model, describing the operation of the macro economy.

1. Production Optimization Module

The model assumes that a commodity is allowed to be made by multiple producers, which reflects that it can be produced with different production technology and the technology of all departments has the feature of constant returns to scale. The production demonstrated in the model uses the multilayer nested CES function to describe the different alternatives among the production elements. On the first level, output is eventually decided by the combination of synthetic intermediate input and the synthetic added value. On the second level, using Leontieff function synthetic intermediate input is described as the demand for intermediate products of each department; and the synthetic added value is further decomposed into synthetic labor input and synthetic capital. On the third layer, the synthetic capital is broken into various capital requirements. On the fourth layer, by using CES function the synthetic energy is divided into fossil energy synthesis and electrical energy. On the fifth layer, fossil energy synthesis is further decomposed into coal, oil, and natural gas by CES. The extent of the substitution among various production elements depends on their substitution flexibility and the base year share during the process of production. The pollution emissions caused by production are based on the pollution discharge rates of all departments.

2. Income Distribution Module

The national income generated from production and trade is allocated to three principal institutions: enterprises, residents and the government. Income distribution includes initial income distribution and income redistribution. During the primary distribution of national income, all kinds of production factor holders obtain income in line with the contribution they offered in the process of production, namely laborers earn income from work, capital owners receive capital income, and the government levies an indirect tax on producers' production behavior. In the process of income redistribution, various income is readjusted and reallocated among residents, enterprises, and the government: after paying enterprise income tax, capital income (the total capital returns of all departments) becomes receipts of the enterprise, a portion of which is allocated to residents, while the rest of which becomes savings and investment of the enterprise for expanded reproduction in future; the body of residents' income is derived from the factor payments, that is, labor and capital income; in addition, the residents also obtain transfer payments and subsidies from the government. The capital and enterprise income is allocated to residents in a fixed share. The government's revenue includes direct tax of enterprises, inhabitant income tax, import tariffs, and all kinds of indirect taxes. Meanwhile, subsidies are considered as negative revenue of the government.

3. Consumer Demand Module

The demand principally includes residents consumption demand, government consumption demand, investment demand, and intermediate demand. Residents demand function is expressed as ELES, which is derived from the Stone-Geary utility function under the constraints of a certain income budget and the minimum consumption of commodities for residents. The model assumes that the residents' marginal saving tends not to change along with the change of residents' income, and it is considered and saved as a fixed share of disposable income. Other final demands, such as government regular expenditure, investment, and variable inventory demand, etc. are described by LES, that is, LES is derived from the Cobb-Douglas utility function under the condition of a fixed share of total expenditure and under the constraint of certain commodity prices, in terms of their demand for a wide variety of commodities.

Armington assumption is adopted in this model to describe the incomplete substitute relation between different import commodities and regional products, which is determined according to the cost-minimized principle and under a certain relative price, in terms of the demand for import commodities and domestic products among the demand of various consumer goods.

4. Regional Trade Module

As a part of a country, apart from the import and export trade of general goods, the regional trade includes the trade with other regions of the country. To distinguish two different approaches between domestic trade and international trade of a region, the nested CET function of regular elastic transformation is utilized in the model to describe the substitute relation of tradable goods sales in different regional markets, and the nested CES function is used to describe the final consumption composition relationship of different regional commodities in the area examined. The commodities purchased from each region become goods sold in that specific area, and vice versa. Armington assumption is used in the model to describe the incomplete substitute relation between import commodities and domestic products, and CES function is utilized to describe the optimal selection between synthetic purchased commodities and regional products in line with the principle of minimizing cost of final consumption. Furthermore, through CES function synthetic purchased commodities are divided into the demand for commodities purchased from home and abroad. According to the income maximization principle, products produced by firms are allocated to both international and domestic market by using the CET function. Small country assumption is adopted in this model, namely the fluctuation of commodity price in the international market is not influenced by Chinese imports and exports, and the price remains constant. Foreign demand for Chinese exports is described by demand curve of constant elasticity, that is, it can be represented as an exponential function about the ratio of international commodity prices and the F.O.B. prices of goods exported from China.

5. Equilibrium Close Module

Equilibrium module includes supply and demand equilibrium of all kinds of factor markets and commodity markets. It also includes various labor supply equilibrium, capital market supply equilibrium, and domestic and international market demand-supply equilibrium. The supply and demand of various labor is balanced in the model through exogenesis of labor average wage and endogeny of labor demand quantity, while that of capital is balanced in the capital factor market through endogenous capital returns. The model assumes that labor flows fully among departments and that capital is relatively fixed among internal departments in the short-run. The commodities in both domestic and international markets are balanced through the relative price of endogenous goods. Macro closure in the module is reflected by three principal macro identity relations, namely (1) saving-investment balance; (2) balance of government revenues and expenditures; (3) trade balance, including the balance of both domestic trade and current account of international trade. Saving drive from "Neoclassical closed principle" is adopted in the model to balance saving-investment; endogeny of government saving surplus is utilized to balance government revenues and expenditures; endogenous domestic trade surplus and foreign exchange reserve are used to balance domestic and international trade. In the model gross export calculated by border price (including export taxes and subsidies) plus net foreign transfer and foreign capital inflow equals gross import calculated by world (border) price. Exchange rate of the model converts world price to domestic price. One of the two variables, exchange rate and foreign exchange saving (trade surplus or deficit), is exogenously fixed, and foreign account balance is realized through the relative prices of tradables and non-tradables, that is, the actual exchange rate will change.

6. Pricing Mechanism

All prices in the model are relative prices. Aside from relation among each other through a variety of nested CES or CET functions, the prices fluctuate under the influence of various taxes or subsidies. Factors triggering price fluctuation include production value-added taxes, production taxes, production subsidies, import and export tariffs, and export rebates levied by the custom, and exchange rates.

The six modules above constitute a complete CGE model, and through comparative static analysis, it can simulate the influence on the economic system via the change of exogenous variables.

2.2 Variable Parameter

The name and meaning of all variables and parameters as well as the determination of principal parameters in the model are listed in this section. It is noticeable that the price variables in CGE model refer to the relative prices, and their value is not equal to the prices of commodities produced in real life; quantitative variables in this model are variables converted from relative price variables, and their quantity is not equal to the number of commodities produced in real life. The variation of price variables and quantitative variables in CGE model can reflect the variation of price and quantity of commodities produced in real life. The markers and explanation of the variables and parameters are shown in Table 1. Table 2 lists all variables.

Table 1 The variables and parameter markers in the model

Markers	Meaning	Details
i, j	Production sector	Departments merged in this model
e	Energy sector	Coal mining and processing industry, oil and gas exploration industry, power generation and supply industry
ne	Non-energy sector	Other sectors except e
nele	Fossil energy sector	Coal mining and processing industry, oil and gas exploration industry
p	Contaminant	CO_2, SO_2, etc.

Table 2 Parameters in the production model

Parameters	Parameters meaning
α_j^{nd}	CES share parameter of non-energy intermediate input synthesis demand in j sector
α_j^{kel}	CES share parameter of capital-energy-labor synthesis demand in j sector
α_j^{p}	Substitution elasticity between capital-energy-labor synthesis and non-energy intermediate input synthesis in j sector
α_{ne}^{j}	Direct consumption coefficient of non-energy sector in j sector
α_j^{1}	CES share parameter of labor demand in j sector
α_j^{ke}	CES share parameter of capital- energy synthesis demand in j sector
σ_j^{kel}	Substitution elasticity between capital-energy synthesis and labor in j sector
α_j^{k}	CES share parameter of capital demand in j sector
α_j^{e}	CES share parameter of energy synthesis demand in j sector
σ_j^{ke}	Substitution elasticity between capital and energy synthesis in j sector
$\alpha_j^{\mathrm{nelec}}$	CES share parameter of fossil energy synthesis demand in j sector
α_j^{elec}	CES share parameter of electrical energy synthesis demand in j sector
σ_j^{e}	Substitution elasticity between electrical energy synthesis and fossil energy synthesis in j sector
α_j^{nele}	CES share parameter of various fossil energy demand in j sector

2.3 Equation System

In this section each equation and its economic meaning in the specific model of each module is demonstrated, based on which specific recycling economic policies can be adjusted partially during simulation.

1. Production Equation

The model assumes that in each production sector exists a competitive enterprise, producing a product. The nested 5 layer CES function is used to describe production behavior, and the output level of each sector is decided by market equilibrium through the input of six factors, namely capital, labor, coal, oil, natural gas, and power. In all departments, technology presents the feature of constant return to scale.

Equations (1) and (2) reflect the nest of the first layer departmental production, representing demand for synthesis of non-energy intermediate input and capital-energy-labor, respectively.

$$nd_j = \alpha_j^{nd} \left(\frac{px_j}{pnd_j} \right)^{\sigma_j^p} xp_j, \tag{1}$$

$$kel_j = \alpha_j^{kel} \left(\frac{px_j}{pkel_j} \right)^{\sigma_j^p} xp_j. \tag{2}$$

Equations (3)–(5) reflect the nest of the second layer.

$$xap_{ne,j} = \alpha_{ne,j} nd_j, \tag{3}$$

$$l_j^d = \alpha_j^l (\lambda_j^l)^{\sigma_j^{kel}-1} \left(\frac{pkel_j}{\phi_j^l w} \right)^{\sigma_j^{kel}} kel_j, \tag{4}$$

$$ke_j = \alpha_j^l \left(\frac{pkel_j}{pke_j} \right)^{\sigma_j^{kel}} kel_j. \tag{5}$$

Among them, Eq. (3) reflects non-energy intermediate input calculated via Leontief function, which is equal to the fixed proportion of synthesis of non-energy intermediate input. Equations (4) and (5) respectively indicate demand for labor and capital-energy synthesis after decomposing demand for capital-energy-labor synthesis via CES function, among which the labor demand function includes efficiency factors, which indicate the fluctuation of labor utilization efficiency, and wage adjustment coefficient revealing wage differences among departments.

Equations (6) and (7) demonstrate the nest of the third layer, which respectively indicate demand for capital and energy synthesis after decomposing demand for capital-energy synthesis via CES function. Among them, capital demand function contains efficiency factors indicating the fluctuation of capital utilization efficiency and capital price adjustment coefficient revealing capital price differences among departments.

$$k_j^d = \alpha_j^k (\lambda_j^k)^{\sigma_j^{ke}-1} \left(\frac{pke_j}{\phi_j^k r} \right)^{\sigma_j^{ke}} ke_j, \tag{6}$$

$$e_j = \alpha_j^e \left(\frac{pke_j}{pe_j} \right)^{\sigma_j^{ke}} ke_j \tag{7}$$

Equations (8) and (9) exhibit the nest of the forth layer, respectively suggesting demand for fossil energy synthesis and electrical energy after decomposing demand for energy synthesis by CES function.

$$\mathrm{nelec}_j = \alpha_j^{\mathrm{nelec}} \left(\frac{pe_j}{\mathrm{pnelec}_j} \right)^{\sigma_j^e} e_j, \tag{8}$$

$$\mathrm{elec}_j = \alpha_j^{\mathrm{elec}} \left(\frac{pe_j}{\mathrm{pelec}_j} \right)^{\sigma_j^e} e_j \tag{9}$$

Equation (10) reflects the fifth layer nested, showing demand for coal, oil, and natural gas after decomposing demand for fossil energy synthesis with CES function. Efficiency factors indicate the fluctuation of fossil energy utility efficiency in departments.

$$xap_{\text{nele},j} = \alpha_j^{\text{nele}} (\lambda_j^{\text{nele}})^{\sigma_j^{\text{nele}}-1} \left(\frac{pnelec_j}{pa_{\text{nele}}}\right)^{\sigma_j^{\text{nele}}} \text{nelec}_j \tag{10}$$

2. Income Equation

Equations (11)–(14) describe income formation,

$$yh = \sum_j \phi_j^l w \cdot l_j^d + \beta \times ye(1 - te), \tag{11}$$

$$yd = (1 - th)yh + \text{pindex} \times \overline{\text{trgh}}, \tag{12}$$

$$ye = \sum_j \phi_j^k r \times k_j^d, \tag{13}$$

$$yg = \sum_j tp_j xp_j px_j + th \times yh + te \times ye + \sum_j tm_j xm_j pm_j - \sum_j tex_j es_j pex_j. \tag{14}$$

Among them, the Eq. (11) indicates residents' income, equal to the sum of labor remuneration and enterprise's profit distribution; Eq. (12) shows residents' disposable income, equal to the gross income minus income tax for the government, and then plus the government's transfer payment for residents; Eq. (13) illustrates enterprise income, equal to the capital return; Eq. (14) reavels the government revenue, equal to the sum of production tax, inhabitant income tax, enterprise income tax, import tariffs and export rebate which is negative income.

3 Data Processing

Comprehensive and detailed economic data is the foundation of effective policy analysis as well as the precondition of modeling.

1. Data Base

Wenjiang district basic data in 2013, which are principally from sources such as statistical yearbooks, are utilized in this report. Because some data are not detailed, and even missing, sources, for instance, Sichuan input-output tables and Chengdu statistical yearbooks in 2013, are fitted and data from each yearbook are calculated according to a certain proportion and coefficient. In this report, all sectors in Wenjiang are grouped into 6 major ones: (1) agriculture; (2) industry; (3) construction; (4) transportation post and telecommunication; (5) business and catering services; (6) non-material production sector.

2. Parameter Calibration

Parameter calibration in CGE model refers to the determination of relevant parameters, and there are generally two parameter estimation approaches. One is to utilize an econometric approach, namely to conduct regression analysis and to estimate parameters via econometric methods based on many years' historical statistics of a economic sector; while the other is calibration approach, in which a parameter is determined by using benchmark balanced data sets and satisfying equilibrium conditions in the CGE model.

The reliability of data estimated via an econometric approach is high; nevertheless, data collection is difficult since many years' time-series data are needed. Although data collection of calibration approach is relatively easy considering its only need for data of a benchmark year, its reliability is low due to the high dependence on benchmark data. Given their merits and demerits, both approaches are combined. Some parameters are determined via an econometric approach; some are determined by estimating relevant data of Sichuan 2013 input-output tables via a calibration method; and some are determined by consulting existing research achievements.

4 Policy Analysis

The principal objective of this model report is to evaluate the effect, benefit, and potency of existing policies implemented, which are related to low carbon economy development at Wenjiang. Policy effect evaluation at Wenjiang is to evaluate the extent to which energy conservation and emission reduction are promoted as a result of policies implemented, namely to analyze whether the expected energy-conserving target is achieved through the comparison between actual outcomes of government policies and ideal results. Policy benefit evaluation is to assess the relationship and identify the ratio between policy effect and policy input. Policy effectiveness evaluation in the report is to assess comprehensively the impact of low carbon agricultural subsidy policy in the entire social system, including the analyses of positive and negative, short-run and long-run, as well as direct and indirect effects of the policy.

The impact of the report on low carbon agricultural subsidy policy evaluation at Wenjiang is to provide support for effective implementation and adjustment of the policy. During policy evaluation, sound reasons for low carbon policy adjustment at Wenjiang are provided through comprehensive analyses of the outcomes in this area as well as accurate and appropriate assessment of the policy; and through policy evaluation residents' recognition of this issue is unified and obstacles of policy implementation are eliminated, thereby implementing the right policies effectively.

1. Status Quo of Policy

'Three Rural Issues' have been attached considerable importance, and the key points in serving these issues have been highlighted in Wenjiang, where the people show a strong sense of responsibility and urgency. Since 2008, people in charge of agricultural and rural work at this district have been steadily strengthening agricultural infrastructure construction, facilitating reform pilots on balancing urban and rural areas comprehensively and vigorously, actively promoting the steady development of agriculture and continuous increase in rural income, effectively resolving the rural dwellers' livelihood issues, steadily speeding up the building of a new socialist countryside and the development of modern suburban agriculture, as well as greatly enhancing the rural public service. They have been exerting great effort in strengthening agricultural policy guarantee, including grain subsidies, policy-oriented agricultural insurance, grain for green, household appliances down to the countryside pilots, etc.; they have been steadily promoting agricultural industrialization, rural infrastructure construction and service; In terms of significant projects, for instance, key agricultural project construction and construction of a new countryside, it should be ensured that the leaders are present, measures are implemented, clear and reasonable objectives are set, and responsibilities are shouldered, thereby forming a working pattern where things are taken care of by specific individuals, who have a clear responsibility, which should be taken in a certain period of time.

2. Scene Design

Fiscal expenditure of Wenjiang in 2013 amounted to 541,870,000 RMB, of which the spending on agriculture, forestry, and irrigation works was 60,850,000 RMB, 67.95 % higher than that in 2012, which was 36,230,000 RMB. According to the agricultural policies at various levels , namely national, provincial, municipal, and district level, 'Three Rural Issues' will be highlighted increasingly, and in terms of expenditure on agricultural subsidy, an upward trend will be shown. Therefore, the scenes are set as follows: scene 1, expenditure on agricultural subsidy increases 20 % of base value in 2007; scene 2, spending on agricultural subsidy increases 30 % of base value in 2007; expenditure on agricultural subsidy increases 40 % of base value in 2013.

3. Outcome Analysis

Adjusting the data above, scenario simulation of the impacts on relevant national economic sectors has been conducted via CGE models of six sectors after implementing agricultural subsidy policies. 5 evaluation indices, that is, actual GDP, rural residents' income, urban residents' income, government savings, and government subsidies, are selected, and the index changes under different agricultural subsidies situation (compared with the baseline scenario) are demonstrated in Table 3. With the increase of agricultural subsidies, rural residents' income ascends significantly and their consumption grows as well. The beneficiaries of subsidies increased are agricultural laborers. Due to the increase of agricultural subsidies, the government savings falls slightly, and meanwhile the government public expenditure goes up. Additionally, it has certain influence on the actual GDP.

Table 3 Change rate of macroeconomic indices

	Scene 1	Scene 2	Scene 3
Actual GDP	0.21	0.34	0.45
Urban residents' income	0.51	0.76	0.92
Rural residents' income	3.52	6.86	8.22
Government savings	−0.06	−0.29	−0.53
Government subsidies	1.43	2.68	3.47

4. Model Conclusion

Beginning with policy simulation, this study puts forward and analyzes a general CGE model framework. In terms of agricultural subsidy policy in Wenjiang, the impact of the subsidy policy variables' changes on the national economy is simulated via CGE model and data calculation. System operation and simulation outcomes indicate that simulation system prototype can achieve its preliminary purpose expected and can visually reflect the effects of policy variables on economic indices, thereby providing support for decision makers.

5. Policy Suggestions

Agricultural subsidy is an indispensable section of the "Three Rural Issues" policies, and the current agricultural subsidies principally include direct subsidies to grain producers, subsidies for growing superior crop varieties, and direct and general subsidies for purchasing agricultural supplies. Practice has proved that these preferential policies for the farmers play a role in promoting grain production and in increasing farmers' income. Nevertheless, there are still some demerits of the current subsidy policies, for instance, insufficient and diversified funds, small scopes, and irrational structures, which reducing the incentive effect. Therefore, feasible measures should be taken to enhance the agricultural subsidy policies.

(1) Increase subsidies, adjust the structure. The increase in agricultural subsidies should be continued annually and the structure of subsidies should be optimized within local financial capabilities. A regularly-based and temporarily-supplemented system should be constructed. In terms of temporary subsidies, the foreign experience of counter-cyclical payments should be drawn on, and the severe and relatively significant external supply shortage of agricultural products should be underlined and addressed. The experience should be adopted carefully for the sake of avoiding excessiveness. To maintain the stability and continuity, regular subsidies should be related to the rise of agricultural production costs and prices level. Highlighting regular subsidies is to provide stable expectation for market participants, thereby promoting production of grain and other major agricultural products and enhancing the capacity of the agricultural sustainable development.

(2) Perfect subsidy approaches, enhance efficiency, and strengthen supervision. Direct subsidies distribution should be perfected, and agricultural allowance management should be strengthened. Through transforming "indirectness" into "directness" and "complicity" into "simplicity", the organization is integrated, procedures are simplified , and allowance is distributed directly and fairly, thereby cutting the work cost of subsidy implementation. It is suggested that the significant sectors, for instance, finance and agriculture, adhere to the open, transparent principle and further establish and perfect the notice system of agricultural subsidy distribution. Before subsidy distribution financial departments in towns should reveal to the public not only the scope and approaches but also the items, amount, as well as deposit time. By issuing notices or clear cards, farmers are informed timely, which facilitates mutual supervision and enhances transparency.

(3) Develop the advantage of agricultural production scale, and consider appropriately the interests of farmers with small arable land. From the perspective of development, it is inevitable that agriculture will be transformed into a large-scale

and modern sector. The guidance of agricultural subsidies policy should comply with this change. Large grain growers should be supported and encouraged regarding agricultural subsidy policies. Allowances should be distributed to them in line with their actual land area which reaches a certain scale, and to farmers utilizing advanced production technology as well. Given constructing a "harmonious society", it is suggested that the interests of farmers with small arable land, the impoverished, in particular, be considered appropriately, and that co-operation be encouraged among small farmers through a relatively higher subsidy rate.

(4) Agricultural subsidies lean towards popularizing advanced technology. The government should support the innovation of agricultural high-tech through a variety of approaches, for instance, setting up risk funds for agricultural hi-tech industry and guiding the financial sector or enterprises' agricultural high-tech investment via interest subsidies; establishing agricultural high-tech information network to provide information consulting service; funding private enterprises and professional farmers to establish model base of new technology; supporting agricultural technological enterprises through equity investment; increasing direct research funds for leading enterprises, and so forth.

(5) Expand the scope of the subsidies. Based on the original itemized subsidies, the government should constantly establish and perfect subsidies systems such as creating agricultural insurance subsidy, ecological and environmental subsidy, and educational subsidy, and so forth. As a weak and low benefit sector, there are huge natural and unnatural risks of agricultural production in China. Therefore, to promote the rapid and sound development of agricultural insurance the system of agricultural insurance subsidies should be established promptly. Agricultural environment protection subsidy is beneficial to protecting and enhancing farming structure, augmenting arable land production efficiency, and boosting the competitiveness of agricultural products. Education can effectively break the vicious cycle of poverty, improving the laborers' capability of obtaining higher income.

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Multi-Stage Dynamic Game Model of Financing: On Reputation of Post-disaster Reconstruction Project

Qilin Cao, Maomin Wu, Yun Chen and Anhua Yang

Abstract Reconstruction fund is essential to post-disaster reconstruction of private firms. Based on the present studies, by using multi-stage dynamic game model of financing, this paper calculated the optimal effort level of management fund institution with taking reputation into account. It helps to resolve the moral hazard problem of fund managers and provides theory guide for raising of post-disaster reconstruction fund.

Keywords Financing · Reputation · Game model · Post-disaster reconstruction fund

1 Introduction

On April the 20th, 2013, Lu Mountain of Yaancity was struck by earthquake, which is just as serious as the one in Wenchuan town. The earthquake caught unbalance of ecosystem, social system and economic system in Lu Mountain and brought serious damage to national economy and people. The affected population is about 1520 thousand; the affected area is as much as $12,500\,\text{km}^2$ and over 99 % houses in Longmen town were destroyed.

Economic recovery is important for the full recovery of disaster area. Private firm is an important part of national economy; its recovery can determine the future economic development in some degree and should be paid more attention. Post-disaster reconstruction is a complex project and need a great deal of money in terms of economy, society as well as nature. Such a huge demand of money can't be raised easily. So comes the problem: how to raise the money. Unlike the traditional "transfusion" model, this paper puts forward the hybrid fund financing model. Hybrid fund consists of government funding, donating and venture capital (VC), among which VC is the most important and the content of this paper.

Q. Cao (✉) · M. Wu · Y. Chen · A. Yang
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: qlcao@scu.edu.cn

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Based on the present studies, this paper offers the hypothesis of fund supervising entity raising money from VC for reconstruction and studies multi-stage dynamic financing problem by using multi-stage dynamic game model of financing on the ground of reputation.

VC does not provide fund directly to the affected private firms, but by intermediary, namely the reconstruction fund management institution (FMI: built by government in advance). This leads to principal-agent relation between VC and FMI. In our study, FMI plays the role of VC and their mainly job is to raise money. These money flows only to the post-disaster reconstruction project of private firms. We mainly study the principal-agent problem between VC and FMI. VC choose post-disaster reconstruction project for not only the potential high return but also to make contribution to post-disaster recovery. To making full use of their professional management ability, FMI try hard to maximize their own profit when meeting the demand of investors. FMI has a lot to do if they want to manage the fund well. If there is no way to measure their work and job cost, then FMI may seek private profit because of interest of inconsistency and information asymmetry. What's worse, moral hazard may follow. Considering the reputation effect, FMI might begin to think about reputation effects on VC and themselves. They may also work hard to improve reputation and lower moral hazard level.

Generally speaking, VC is risk neutral and pretty sensitive to risk. Before investing, investors would always strictly assess FMI's performance, ability, and reputation by collecting information. FMI's performance and reputation have great influence on recovery of private firms. Post-disaster recovery is supported by government and has several other particular characteristics. Investors may not think too much about this, but moral hazard indeed exists. The Red Cross Scandal is an example.

FMI's reputation and ability can be seen during work. This means that they can improve reputation by hard working. To successfully raise the subsequent fund, FMI should consider about reputation effects during all the process except the last stage. Only by doing this can they maximize the total utility. Based on the above, we analyze multi-stage dynamic financing problem by using multi-stage dynamic game model of financing on the ground of reputation.

2 Literature Review

2.1 Abroad Literature

There is little abroad literature, but papers about reputation effects on fund manager start early and there is a lot empirical studies in both micro aspect and macro aspect. Macro studies mainly focus on market efficiency problem. Kennes and Schiff [10] held that reputation is a reflection of the past deal. Opportunistic behavior can impair reputation in later days. Klein and Leffler [11] thought that reputation can help to maintain the performance of contract. Micro studies seek to find the working system and influence factors based only. Fombrun [2] defined reputation as a kind of cognitive function and sense description. Abroad experts'analysis about reputation builds the foundation of further study.

Abroad studies show that great reputation means a lot to manager and it is a kind of invisible inspiration. By building the agent-reputation model, Holmstrom [5] found that FMI managers work hard under the reputation system. Fama [1] held that incentive problem was exaggerated in the literature about principal-agent problem. What Fama cared about is agent market's rules on agents' behavior. He thought that manager's market value depends on their past performance and they should be responsible for what they do. For this reason, managers would still work hard even without explicit incentive; and they can improve reputation and salary in the market. Gompers's analysis [3] found, in the aspect of VC, that VC investors can get not only implicit incentive, but also explicit incentive that comes from profit.

Smith's [18] and Scherler's [15] empirical study found that private equity fund managers build great reputation to attract more investors. Norton [13], Gompers and Lerner [4], Janney and Folta [7] held that fund is positively related with their reputation in mature market. Thus we take the amount of fund as proxy variable of manager reputation. Abroad experts' papers about reputation influence on managers built the foundation of this paper and provided basis for the variables we chose.

2.2 Domestic Literature

Domestic literature about post-disaster reconstruction fund of multi-stage dynamic game model of financing is not so much. Yu [14] held that reconstruction fund should be led by fiscal resources and based on the public finance provided by government; whereas, development fund should be raised worldwide by various of mechanisms. By analyzing the related data about Wenchuan earthquake, Yuan [21] found that reconstruction project face a funding gap of 1300 billion in the early stage. This example proved that government financial support is not enough for reconstruction project. External fund must flow into the market. Du [20] put forward to build our own catastrophe risk management system and assurance system by combining government with market. Besides, we should also better catastrophe risk sharing system and strengthen our bearing capacity. The above studies built the theory foundation for VC to flow into post-disaster reconstruction fund.

Some domestic experts study reputation influence on fund managers. Jin [22] held that effort level of stages with reputation influence is strictly higher than those without. The longer the stage is, the bigger incentive on managers from reputation and the harder they work. Wang [6] found that limited partnership contract can be an effective incentive for managers and an exit way to external investors. Wang et al. [8] found that efficiency lost from performance incentive system grow with the decrease of information transparency in stock market and increase of invest duration. Wang and Peng [17] found that factors affect mangers reputation are growth rate of net value, dividends of the first quarter, fund liquidity and scale, investor structure and manager's honesty. Chen [12] held that managers would work harder in whichever situation for there is no hitch-hike. For the existence of prisoner's dilemma, contracts signed with two investors would not be chosen in reality, whereas, joint venture made managers with high salary work less hard.

Investors hope to invest for more times and correct excessive investment in the aspect of game. VC would lost its information advantage for this. An [16] found that with the increase of asset and predict value of venture companies, equity financing can lead to stock dilution of management and the dilution ratio would increase. Thus, financing times of venture companies should be controlled if the fund is enough. Hu [9] found that operating system in credit market of imperfect information make it more difficult for small and medium sized companies to finance. By promoting signal transmission, reputation effect restraint and building of credit mechanism, information asymmetry problem can be relieved effectively and game environment of small and medium sized companies can be bettered. Under repeated game condition, reputation becomes a kind of implicit incentive for contracts and cooperation become equilibrium. Wang [19] found that there are two Nash equilibrium in game between banks and companies, which means that the two sides of the game have different decision to maximize their own benefit. If banks press the debt is up to whether the bank has loan and if companies pay the money back on time.

3 Model Design and Computing

1. Hypothesis Condition of Basic Game Behavior

(1) VC investors are all external fund providers and can provide fund by buying bonds, stocks and loan.
(2) Whichever way is used to provide fund, it is individual reasonable behavior. So the profit should be shared among the whole society, investors can turn to other project otherwise.
(3) For the existence of FMI, reconstruction fund project make agreement with the local government. The government has considered about its own benefit and has no effects on the profit sharing system between company and other investors. Because post-disaster reconstruction of private firms is led by government, and government's call can help to promote financing. During this game, government is an external party and we would not think about its benefit.
(4) The game players are mainly FMI and external VC. Based on the project condition and information collected, this game can be converted to a signal game. In terms of post-disaster reconstruction of private firms, profit has two different values: either greater than or equal to zero or negative ($\pi \geq 0, \pi < 0$). Post-disaster reconstruction project may lose money because of its own particular characteristics. The project would carry on even though it loses money because it is not caused by disaster. Post-disaster reconstruction project would stop in no case. In this condition, VC seems like a kind of charity. But is the lost is caused by

second disaster, the project would stop. We set the possibility of second disaster happening as β.

(5) The total external fund needed is set as I (total fund demand minus government fund, donation, etc.). Profit of VC's project is set as u (profit of FMI is $1-u$). Opportunity cost of VC is w.

2. Description of Game Theory

Profit is generally certain when reconstruction project is expected to begin. Taking all the risks into account, if total profit is and FMI promise to distribute $u[0, 1]$ to potential investors, these investors would decide whether to invest based on u (Different from other project, reconstruction project is possible to lose money, set the possibility as β and it is uncertain. But if the project indeed lose money, the consequence is serious. So investor would consider both u and the possibility of second disaster. Concerning the contingency of disaster and public welfare of reconstruction project, we take the possibility of second disaster as rare event and β is set small.). If investors investor to other project other than reconstruction project, the opportunity cost is w and profit of FMI is 0. Opportunity cost of FMI that invests to reconstruction project is v. Profit of investors would be $\pi \times u$ if they make investment decision based on the signal FMI provide. Profit of FMI would be $\pi \times (1-u)$.

3. Analysis of Game Behavior

In the game theory of this paper, FMI give signal in a continuity interval $u[0, 1]$ (considering the public welfare of reconstruction project, data rang of u is narrow). Investors can only choose between accept the signal or not. When investors get the signal that profit rate is u, investor would accept u if and only if. For FMI, if profit is π, it would distribute u to investors only if $\pi > \pi \times u$.

4. Computing and Analysis of Multi-Stage Dynamic Game Model of Financing

To make the problem simple, we would not take disaster into account. Assume that FMI invest for only two stages. Investors decide the volume of investment based on other ways other than reputation in the first stage; and effort and operating ability of the first stage in the second stage. Assume that VC investors and FMI are all rational economic man and investors make decisions independently. FMI can carry on the second stage only if the first stage is finished. We set $I_t(t=0,1)$ as the initial volume of investment, $\pi_t(t=1,2)$ is profit of the two stages and $e_t(t=1,2)$ is FMI managers' effort level of each stage.

Output function of each stage is as follows:

$$\pi_t = bT_{t-1} + ce_t + d\theta + \xi_t, \quad t = 1, 2.$$

In the function, $b, c, d > 0$ and they are all constant. θ is operation $E\theta > 0$ is a certain number. $\mathrm{var}(\theta) = \sigma_\theta^2$; $\xi_t(t=1,2)$ is exogenous environment variables.

$$\begin{aligned} E\xi_t &= 0, \mathrm{var}(\xi_t) = \sigma_\xi^2, \quad \mathrm{cov}(\xi_1, \xi_2) = 0, \\ E\pi_t &= bI_{t-1} + ce_t + dE\theta, \quad t = 1, 2, \\ \mathrm{var}\pi_t &= d^2\sigma_\theta^2 + \sigma_\xi^2. \end{aligned}$$

Reputation of FMI is symbolized by operating performance. Past performance is measured by profit u of reconstruction project to profit of other project ratio. It is as follows:

$$f = u\pi_t / wI_{t-1}, \quad t = 1, 2.$$

In the function, f is reputation coefficient of FMI, u is profit ratio of investors, w is opportunity cost of investors.

General investors would decide the volume of investment of next stage based on the reputation coefficient of FMI. Assume that the above two are positively related. $T_t = f I_{t-1}, t = 1, 2 \cdots$.

Profit structure of FMI

Assume that FMI managers are cautious about post-disaster reconstruction project and coefficient of risk aversion is $\rho(\rho > 0)$. Profit structure of FMI would be as follows:

Regular fee of the operating the fund is $\phi I_{\mathrm{t}-1}, t = 1, 2$ and profit is $(1-u)\pi_t$, $t = 1, 2$. Given discount rate of the second stage profit is and cost of FMI is increasing function of effort level. The function if as: $c(e_t) = me_t^2, m > 0, c(e_t) > 0$. m is constant total utility function of the two stages of FMI is: $U = \phi I_0 + (1-u)\,\pi_1 - C(e_1) + \delta[\phi I_1 + (1-u)\pi_2 - c(e_2)]$.

Expected revenue of FMI is:

$$\begin{aligned} EU &= \phi I_0 + (1-u)E\pi_1 - me_1^2 - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma_\xi^2) \\ &\quad + \delta[\phi I_1 + 1\mathrm{-u}E\pi_2\mathrm{-me}_2^2 - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma_\xi^2)]. \end{aligned}$$

It is the same as follows:

$$\begin{aligned} EU &= (1+\delta f)(\varphi + b - bu)I_0 + (1-u)c(e_1 + \delta e_2) + (1-u)dE\theta(1+\delta) \\ &\quad - m({e_1}^2 + \delta {e_2}^2) - 0.5\rho(1-u)(1+\delta)(d^2{\sigma_\theta}^2 + {\sigma_\zeta}^2). \end{aligned}$$

For FMI, concerning the financing of the second stage, it must take the influence of reputation of the first stage on the second stage into account. The total expected profit is maximized if effort level of the first stage should be e_1.

$$\begin{aligned} \frac{\max}{EU} EU &= (1+\delta f)(\phi + b - bu)I_0 + (1-u)c(e_1 + \delta e_2) + (1-u)dE\theta(1+\delta) \\ &\quad - m(e_1^2 + \delta e_2^2) - 0.5\rho(1-u)(1+\delta)(d^2\sigma_\theta^2 + \sigma_\xi^2). \end{aligned} \tag{1}$$

In the second stage, influence of reputation on subsequent financing is not our concern and utility of the second stage is maximized if effort level is e_2.

$$\begin{aligned} \frac{\max}{\theta_2} EU_2 &= \phi f I_0 + (1-u)bf I_0 + (1-u)ce_2 + (1-u)dE\theta - me_2^2 \\ &\quad - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma^2). \end{aligned} \tag{2}$$

Generally speaking, VC investor would agree to invest in the second stage if reputation coefficient of the first stage f_1 is more than 1. That is to say certain profit of reconstruction project should be higher than opportunity cost of other project, opportunity cost is too high otherwise and the project would be abandoned. For the public welfare of post-disaster reconstruction project, $f_1 \geq 1$, $f_1 = u\pi_1/wI_0 \geq 1$. It is the same as follows:

$$e_1 \geq \frac{wI_0}{uc} - \frac{dE\theta}{c}.$$

Assume that the minimum profit of FMI that invest to other project is v_1 and v_2. Investors would choose post-disaster reconstruction project other than others only if:

$$\begin{aligned} EU &= (1+\delta f)(\phi + b - bu)I_0 + (1-u)c(e_1+\delta e_2) + (1-u)dE\theta(1+\delta) \\ &\quad - m(e_1^2 + \delta e_2^2) - 0.5\rho(1-u)(1+\delta)(d^2\sigma_\theta^2 + \sigma_\xi^2) \geq v_1 + \delta v_2, \\ EU_2 &= \phi f I_0 + 1\text{–u}bf I_0 + (1-u)ce_2 + (1-u)dE\theta - me_2^2 \\ &\quad - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma_\xi^2) \geq v_2. \end{aligned}$$

Two stage dynamic game model of financing of FMI is as follows:

$$\begin{aligned} \frac{\max}{EU} EU &= (1+\delta f)(\phi + b - bu)I_0 + (1-u)c(e_1+\delta e_2) + (1-u)dE\theta(1+\delta) \\ &\quad - m(e_1^2 + \delta e_2^2) - 0.5\rho(1-u)(1+\delta)(d^2\sigma_\theta^2 + \sigma_\xi^2) \\ s.t.\ \frac{\max}{e_2} EU_2 &= \phi f I_0 + (1-u)bf I_0 + 1\text{–uc}e_2 + (1-u)dE\theta - me_2^2 \\ &\quad - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma_\xi^2). \\ EU &= (1+\delta f)(\phi + b - bu)I_0 + (1-u)c(e_1+\delta e_2) + (1-u)dE\theta(1+\delta) \\ &\quad - m(e_1^2 + \delta e_2^2) - 0.5\rho(1-u)(1+\delta)(d^2\sigma_\theta^2 + \sigma_\xi^2) \geq v_1 + \delta v_2, \\ EU_2 &= \phi f I_0 + (1-u)bf I_0 + (1-u)ce_2 + (1-u)dE\theta - me_2^2 \\ &\quad - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma_\xi^2) \geq v_2, \\ e_1 &\geq \frac{wI_0}{uc} - \frac{dE\theta}{c}. \end{aligned}$$

In the second stage, reputation of FMI managers is not our concern. To make the problem simple, we compute the first-order derivative for the profit function of FMI managers in the second stage.

$$\frac{\partial EU_2}{\partial e_2} = (1-u)c - 2me_2, \text{ set } \frac{\partial EU_2}{\partial e_2} = 0,$$

we get $e_2^* = (1\text{–}uc)/2m$.

We can see that the optimal effort level e_2^* of FMI managers in the second stage is positively related with profit ratio $1-u$ and output effort coefficient c, and negatively related with effort cost coefficient m. The bigger $1-u$, the bigger c and e_2^* is. While the bigger m, the smaller e_2^*.

Put $f_1 = u\pi_1/wI_0$ into Eq. (1),

$$\frac{\max}{EU} EU = \frac{u\delta(\phi + b - bu)(ce_1 + bI_0 + dE\theta)}{w} + (\phi + b - bu)I_0 + (1-u)c(e_1 + \delta e_2^*) \\ + (1-u)dE\theta(1+\delta) - m(e_1^2 + \delta e_2^2) - 0.5\rho(1-u)(1+\delta)(d^2\sigma_\theta^2 + \sigma_\xi^2).$$

Partial derivative of e_1 is as follows:

$$\frac{\partial EU}{\partial e_1} = \frac{u\delta(\phi + b - bu)c}{w} + (1-u)c - 2me_1.$$

Set the value of the above function as 0,

$$e_1^* = \frac{u\delta(\phi + b - bu)c}{2mw} + \frac{(1-u)c}{2m} > \frac{(1-u)c}{2m} = e_2^*\zeta. \tag{3}$$

We can see that the optimal effort level of FMI managers in the first stage is higher than that in the second stage, and:

$$\frac{\partial e_1^*}{\partial c} > 0, \frac{\partial e_1^*}{\partial b} > 0, \frac{\partial e_1^*}{\partial (1-u)} < 0, \frac{\partial e_1^*}{\partial \delta} > 0, \frac{\partial e_1^*}{\partial m} < 0, \frac{\partial e_1^*}{\partial w} < 0.$$

We can wee that the optimal effort level e_1^* is positively related with output effort coefficient c, output investment coefficient b. profit ratio $1-u$ and discount rate δ; and negatively related with opportunity cost w of investors and effort cost coefficient m.

Combining function (2) and (3), we get that FMI can attract more investors on the condition that FMI managers' operating ability meets the following function:

$$E\theta \geq \frac{wI_0}{du} - \frac{u\delta c^2(\phi + b - bu)}{dmw} - \frac{(1-u)c^2}{2md}.$$

It is clearly that investors would invest to the second stage if operating ability meet the above condition, investors would reject to invest otherwise.

Above all, the optimal effort level of FMI is:

$$e_1^* = \frac{u\delta(\phi + b - bu)c}{2mw} + \frac{(1-u)c}{2m}, e_2^* = (1-u)c/2m.$$

The constraint condition is as follows:

$$\begin{aligned}
EU &= (1+\delta f)(\phi + b - bu)I_0 + (1-u)c(e_1 + \delta e_2) + (1-u)dE\theta(1+\delta) \\
&\quad - m(e_1^2 + \delta e_2^2) - 0.5\rho(1-u)(1+\delta)(d^2\sigma_\theta^2 + \sigma_\xi^2) \geq v_1 + \delta v_2, \\
EU_2 &= \phi f I_0 + (1-u)bfI_0 + (1-u)ce_2 + (1-u)dE\theta - me_2^2 \\
&\quad - 0.5\rho(1-u)(d^2\sigma_\theta^2 + \sigma_\xi^2) \geq v_2, \\
E\theta &\geq \frac{wI_0}{du} - \frac{u\delta c^2(\phi + b - bu)}{dmw} - \frac{(1-u)c^2}{2md}.
\end{aligned}$$

If the first two conditions is not met, FMI would exit in advance because its effort and operating ability is not paid well. If the third condition is not met, investors enthusiasm would be damaged. The above result is get without considering the possibility of second disaster; otherwise the optimal effort level would be as follows:

$$e_t{}^* = \begin{cases} e_1{}^*(1-\beta), & t = 1 \\ e_2{}^*(1-\beta), & t = 2. \end{cases}$$

The smaller β, the higher effort level. Decrease of β is related with anti-disaster behavior and measure of strengthening aseismic ability.

4 Conclusion

In the financing model of FMI, two parties are involved. Whether post-disaster reconstruction project can successfully raise money depend on two aspects. The first, opportunity cost of investors, which can affect profit ratio u. the higher w, the higher u is. This means that profit ratio has great influence on fund raising of reconstruction project. The second, to assure the reality of u, FMI should expose more information.

To encourage investors and FMI join actively in the investing, the government should strengthen moral culture education and anti the ideology of maximizing personal profit. The government and news media can praise and award investors and FMI to make compensation for their potential lost.

This paper can be perfected by taking more stages into account. Post-disaster reconstruction project need a long period of time and a great deal of money. More potential investors should involve in this process. In the further complex stage, profit ratio need to be reset.

Seen from the model, output profit of private firms is the final determinant of profit of investors and FMI. Operating performance of private firms can subjectively reflect the effort level of FMI. The principal-agent relation between private firms and FMI is a multi-stage financing problem, so we have more subsequent studies to do.

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Part VII
Industrial Engineering

Methods and Tools for the Operational Reliability Optimisation of Large-Scale Industrial Wind Turbines

Raúl Ruiz de la Hermosa González-Carrato, Fausto Pedro García Márquez, Karyotakis Alexander and Mayorkinos Papaelias

Abstract Wind turbines (WT) maintenance management is in continuous development to improve the reliability, availability, maintainability and safety (RAMS) of WTs, and to achieve time and cost reductions. The optimisation of the operation reliability involves the supervisory control and data acquisition to guarantee correct levels of RAMS. A fault detection and diagnosis methodology is proposed for large-scale industrial WTs. The method applies the wavelet and Fourier analysis to vibration signals. A number of turbines (up to 3) of the same type will be instrumented in the same wind farm. The data collected from the individual turbines will be fused and analysed together in order to determine the overall reliability of this particular wind farm and wind turbine type. It is expected that data fusion will allow a significant improvement in overall reliability since the value of the information gained from the various condition monitoring systems will be enhanced. Effort will also focus on the successful application of dependable embedded computer systems for the reliable implementation of wind turbine condition monitoring and control technologies.

Keywords Wind turbines · Maintenance management · Vibration · Fast Fourier transform · Wavelet

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R. Ruiz de la Hermosa González-Carrato (✉)
Colegio Universitario de Estudios Financieros, Serrano Anguita 8, 28009 Madrid, Spain
e-mail: raulruiz@cunef.edu

F.P. García Márquez
Ingenium Research Group, ETSII, Avda. Camilo JoséCela S/N, 13071 Ciudad Real, Spain

K. Alexander
Terna Energy, 85 Mesogeion Ave., 11526 Athens, Greece

M. Papaelias
School of Metallurgy and Materials, University of Birmingham, Birmingham, UK

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1 Introduction

1. Summary

The renewable energy industry is in a constant improvement in order to cover the current demands. Companies are competing to take advantage of any evolving opportunity presented. Nowadays one of those remarkable competitive advantages focuses on maintenance management and some terms such as operating and maintenance costs, availability, reliability, safety, lifetime, etc. emerge.

Wind turbines (WT) are one of the fastest growing sources of renewable energy production [14]. The number of WTs and their complexity has increased in recent years, making difficult to maintain the level of reliability, and resulting in increased maintenance costs due to the occurrence of non-monitored failures [26, 28]. There are case studies that present specific faults and consequent maintenance activities on WTs but they depend on the model considered, the geographic and environmental changes that occur in different wind farms, etc.

Techniques such as condition monitoring (CM) are employed to detect and identify these failures/faults at earlier stages, maximising the productivity performance, minimising possible downtimes of the WT, and increasing the reliability, availability, maintainability and safety (RAMS) levels [15].

CM is implemented from basic operations of the equipment to study [14]. The system provides the "condition", the state of a characteristic parameter that represents the health of the component(s) being monitored. Reliable data acquisition can be achieved with the optimal type and placement of sensors as well as employing the appropriate number of them. Conditioning also reduces the susceptibility to interferences during the features transport. Data processing, sorting and manipulation according to the objectives pursued, are usually performed by a digital signal processor. Then it can be shown via a screen display, stored or transmitted to another system.

As part of some fault detection and diagnosis (FDD) approaches, features are extracted via CM. FDD is based on different methods employed to obtain the information needed from these features [13]. For example, the most used technique for CM in WTs is vibration, while the most studied components are mechanical components such as gearboxes, blades or bearings.

FDD relies on the number and type of sensors used and the processing and simplification methods employed to extract the information from the signals. Once information is obtained, an electronic measuring system provides the suitable data to an observer or other technical control systems. Therefore the three main block functions in a measurement system are data acquisition, data processing and data distribution. The information about the variables measured is turned into an electrical signal. The main advantages offered by these FDD systems are:

(1) The prediction, reduction and elimination of downtimes;
(2) The reduction of energy, maintenance and operating costs;
(3) The use of monitoring alert notifications.

2. Objectives

A number of turbines (up to 3) of the same type will be instrumented in the same wind farm. The data collected from the individual turbines will be fused and analysed together in order to determine the overall reliability of this particular wind farm and wind turbine type. It is expected that data fusion will allow a significant improvement in overall reliability since the value of the information gained from the various condition monitoring systems will be enhanced. Effort will also focus on the successful application of dependable embedded computer systems for the reliable implementation of wind turbine condition monitoring and control technologies.

2 Bearing Failures

Bearings are mechanical devices that reduce the friction between a shaft and other rolling parts of a set, providing a continuous displacement. They can be found in several rotating machines.

Bearings failures are mostly focused on improper maintenance policies. It is assumed that only 10 % of the bearings complete their life cycle. These failures are caused by a deficient lubrication in 30 % of the cases, by a poor assembly or installation in 40 % of the cases, including misalignments; and focused on overloads, manufacturing defects or other sources in the remaining cases (20 %).

If machines are properly aligned and balanced, if they operate at resonant frequencies or if they are properly lubricated, the life cycle of a device can be higher. A defective bearing will vibrate at non-multiple rotational speed frequencies. This will be the first warning of an emerging failure.

3 Vibration (Fast Fourier Transform)

3.1 Introduction

The Fast Fourier Transform (FFT) of a function $f(x)$ is defined as [6]:

$$\int_{-\infty}^{\infty} f(x)e^{-i2\pi xs}dx. \tag{1}$$

This integral, which is a function of s, may be written as $F(s)$. Equation (2) is obtained transforming $F(s)$ by the same formula, where $F(s)$ is the Fourier transform of $f(x)$:

$$\int_{-\infty}^{\infty} f(s)e^{-i2\pi \omega s}ds. \tag{2}$$

The use of the FFT is extended for analysis in the frequency domain, allowing a spectral representation and a detail analysis [24]. It is helpful when periodic patterns are studied [2]. Vibration analysis also provides information about a particular reason of the fault origin and/or its severity [19].

3.2 Fast Fourier Transform Applications

Due to the entailment to vibration, the FFT is introduced into processes where there are rolling elements such as engines or generators [16]. Although this is the main connection, FFT can be used for other types of analysis or failure detection.

(1) Wind Turbines

The wide variety of existing WTs makes also diverse the inclusion of novel techniques that ensure their correct operation. The FFT is one of the most frequent analytical methods used for this purpose.

Within the WT engines, the main efforts are focused on bearings to detect the occurrence of failures in early stages [17]. Diagnoses from generators can find incipient faults on drive trains. The main advantage is that the signal to be analysed is easily detectable. Some authors suggest the use of techniques such as FFT for the analysis [5]. While in contrast, it must be taken into account the considerations of the method since the operation is predominately non steady due the stochastic performance of the wind speed [3].

The study of the storage capacity, the demand response and the ensemble of generators is considered from a power spectrum and FFT [4]. Swartz et al. [29] introduced it on WT structures to check the status of the tower from its vibration. The monitoring is done using wireless communication systems. Therefore although the area of study is ground-breaking, it can be observed that the technique is commonly used.

(2) Other Applications

As aforementioned, the analysis of vibration signals is the most exploited technique for CM of rolling machines. However, sometimes the diagnoses are constrained and additional features are needed to obtain accurate results. As a consequence, the FFT is typically supported by other types of signals, e.g. acoustic signals, even when it is well known that sound has inferences to be considered [20, 21].

On the other hand, there are other research fields where the FFT still achieves the set objectives despite its less novel character and limitations, e.g. the engines, employed as early diagnosis in diesel engines ensures reliable operation over its lifetime. Fault detection in the crankshaft through the FFT has proved to be enough effective for this purpose [9]. The effect of misalignment is studied to determine the nature and extent of this phenomenon by FFT [25]. The analysis of the acoustic radiation emitted from axisymmetric bodies is carried out using FFT [30]. Noise tracking methods for non-invasive study of defective structures from acoustic signals also introduces the technique [27]. Depending on the material, there are properties that directly affect the durability and safety of these structures and the consolidation of the FFT for the study of ultrasonic suits with precision [8].

3.3 Results Employing FFTs

Frequencies appear in the 20–60 kHz range in a first damage phase. The higher frequencies correspond to the natural frequencies. When damage becomes bigger, they tend to cause a bearing resonance. This resonance appears as a bell at the natural frequency. In a third stage, failure modes can be seen and harmonic peaks are generated as the result of the bearing impacts. Vibration levels increase and therefore more harmonics and sidebands will appear in a fourth stage. In most severe stages, the amplitude of the natural rotational frequency (1X) and their corresponding harmonics increases. These features can be attributed to the emergence of gaps due to the failure. Finally, the natural frequency tends to be lessened, leading to noise accumulations.

Based on the above, three sources of failure can be considered in this case study. Each type is supported by a graphical representation of the signals taken at different dates and loads (Table 1). Sensors collect axial, radial and non-radial signals. It must be taken into account that the main failure mode does not always have a unique nature, so frequency spectrum can overlap characteristics coming from different sources, e.g., in the case of the gaps, they can be the consequence of failures in the bearings.

(1) Rolling Element Bearing Wear

The first case is a summary of the aforementioned. Failures associated with rolling element bearings follow a classic pattern, beginning with a high-frequency “ringing” of the bearing. As the failure progresses, the spectrum will change in a characteristic way. There will be peaks at non-synchronous frequencies, typically with harmonics, and often with sidebands around the 1X or the cage frequency (Fig. 1).

(2) Cocked Bearing

This misalignment generates a considerable axial vibration. Peaks will often be observed at 1X, 2X as well as 3X (see Fig. 2). The presence of peaks at 2X and 3X would indicate a cocked bearing condition. The strong axial vibration is often confused with misalignment, and with imbalance in an overhung pump or fan.

(3) Journal Bearing Clearance

The spectrum shows very similar characteristics to rotating loosenesss. There are strong harmonics. In most cases, the vertical axis of vibration will have higher levels than the horizontal. In more severe cases, half-order and even one-third order harmonics will be present in the spectrum (Fig. 3).

Table 1 Measurements

Date	11/04/2014	11/04/2014	13/04/2014	19/04/2014	26/04/2014	27/04/2014
Load	44 %	100 %	50 %	7 %	51 %	26 %

Fig. 1 Fast Fourier transform (100 % load)

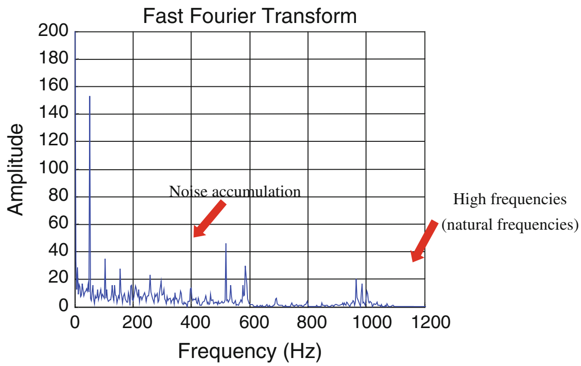


Fig. 2 Fast Fourier transform (100 % load)

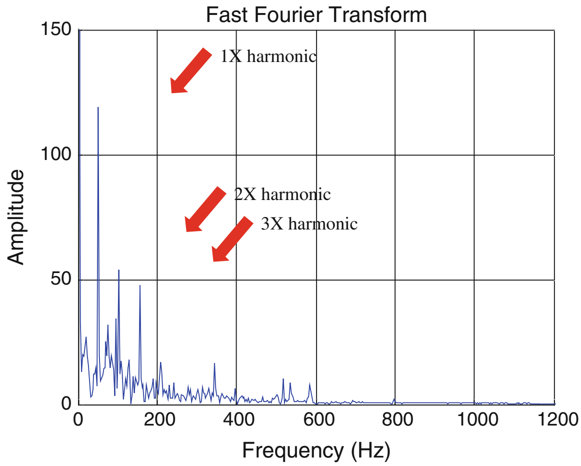
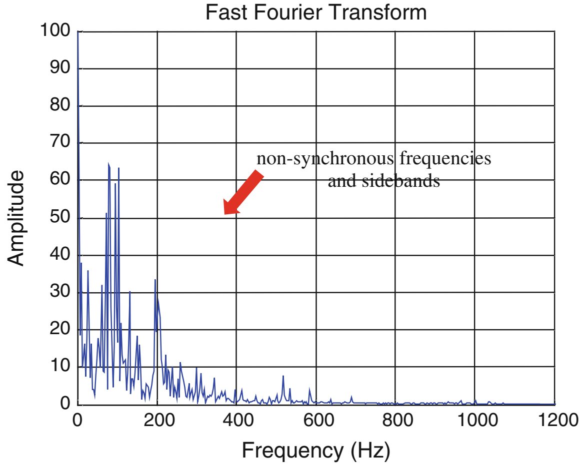


Fig. 3 Fast Fourier transform (51 % load)



4 Vibration (Wavelet Transform)

4.1 Introduction

The wavelet transform is a method of analysis that identifies local characteristics of a signal in the time and frequency domain, e.g. with the use of a series of decomposition coefficients at different frequency bands [12]. Its use is recommended for large time intervals where great accuracy is required at low frequencies and vice versa, e.g. small regions where precision details are required at higher frequencies [11]. The wavelet transform is also a useful method to characterize and identify signals with spectral features, unusual temporary files and other properties related to non-standing waves.

Some authors define it as an improved alternative to the FFT or the Short-Time Fourier Transform since none of them are able to obtain good results in the time domain [18, 22]. The signal processing from the time domain to the frequency domain by these methods usually implies loss of information, making difficult to determine the appearance of specific frequencies [23].

Wavelet transforms are commonly categorized as continuous wavelet transforms (CWT), discrete wavelet transforms (DWT) or wavelet packet transforms (PWT). The difference between them is that the CWT provides more detailed information while the DWT is efficient with fewer parameters [10]. The PWT is an extension of the DWT with a larger number of filtering levels.

The wavelet transform is an alternative representation of a signal. It usually represents the characteristics of the original signal in the time or space domain. It decomposes the original signal into several components at different frequency bands. These levels are a linear combination of all the frequency components of the original signal and their sum results in the original signal. In addition, one of the features of the signal is the energy. In the time domain, the energy is defined as the integral of its square over time.

$$E_f = \int_{-\infty}^{\infty} |f(t)|^2 \, dt. \tag{3}$$

For a Fourier signal representation, the energy can be characterized from the Parseval's theorem, providing an energy relationship. This energy distribution across the frequency domain is the so called spectrogram and is used to estimate the power spectrum of a signal. When this differential is integrated over all frequencies, the energy of the signal is Eq. (4):

$$E_f = \frac{1}{2\pi} \int_{-\infty}^{\infty} |F(\omega)|^2 d\omega. \tag{4}$$

The concept of energy can also be defined for the wavelet transform. The main difference is that a scale-translation differential element will be required to obtain the energy in both domains. The energy is:

$$E_f = \frac{1}{C_g} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left| W_g f(a, b) \right|^2 \frac{dadb}{a^2}, \tag{5}$$

where C_g is an admissibility constant used to normalize the energy when required. The mother wavelet-energy dependence will be always relevant: there will not be a unique energy distribution for a particular signal.

Before continuing, it must be noted that the case study base their results in the energy. The first phase of this research focuses on the selection of accurate frequencies. It is important to choose a significant frequency range to use the wavelet transform as in the case of the Fourier transform. The right selection of the levels of decomposition will provide better findings in the signal processing and analysis. Signals are decomposed in different levels employing the Daubechies wavelet family. The approximated decomposition is called a_n, where n is the highest level of decomposition. It is considered the low frequency component while d_1 is the high frequency component.

Signals are divided therefore into low frequency approximations (A) and high frequency details (D), where the sum of A and D is always equal to the original signal. The division is done using low pass and high pass filters (Fig. 4) [7]. In order to reduce the computational and mathematical costs due to the data duplication, a subsampling is usually implemented, containing the half of the collected information from A and D without losing information. In the case of the multilevel filters, they repeat the filtering process with the output signals from the previous level. This leads to the so called wavelet decomposition trees (Fig. 5) [1]. Additional information is

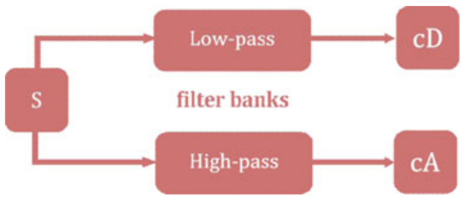


Fig. 4 Decomposition diagram

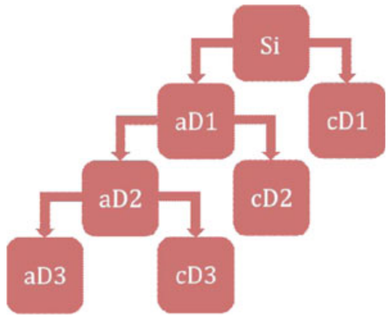


Fig. 5 Wavelet decompositions tree

obtained filtering at each level. However more decompositions levels do not always mean accurate results.

4.2 Results Employing Wavelet Transform

Tables 2, 3 and 4 demonstrate the effectiveness of decomposing the signal at adequate levels (it will be divided into 12 levels in this case study). When 4 levels were initially chosen (Table 2), the most representative information was linked to the natural frequency, giving less importance to any contribution of mechanical nature. The later choice of 12 levels indicated that there were low frequencies peaks associated to the bearings and significant percentages appeared. Any “low frequency” citation is related to the rotational frequency of the generator and must be the starting point of the study.

Discussed frequencies are around the rotational speed (1X) and its multiples. Therefore, a prefiltering is deemed necessary. However, to select appropriate decomposition levels is relevant again, since more decompositions means more accurate information for a specific frequency (Tables 3 and 4).

Table 2 4 levels energy decomposition

Device	Load (%)	Date	a (%)	d4 (%)	d3 (%)	d2 (%)	d1 (%)	Energy
Generator	44	11-abr	19.55[b]	65.30[a]	13.80[b]	1.26	0.09	111800[c]
Drive	100	11-abr	19.67[b]	65.01[a]	14.01[b]	1.23	0.09	50860[c]
End	50	13-abr	17.84[b]	64.93[a]	15.58[b]	1.54	0.11	17900[c]
Axial	7	19-abr	14.65[b]	64.85[a]	18.37[b]	1.98	0.15	7170[c]
	51	26-abr	17.68[b]	66.67[a]	14.35[b]	1.22	0.08	44470[c]
	26	27-abr	17.85[b]	66.16[a]	14.62[b]	1.28	0.09	39230[c]
Generator	44	11-abr	1.82	7.10	66.03[a]	22.84[b]	2.21	49500[c]
Drive	100	11-abr	2.47	5.30	66.04[a]	23.87[b]	2.31	40350[c]
End	50	13-abr	1.66	6.00	65.40[a]	24.61[b]	2.34	28520[c]
Radial	7	19-abr	1.99	6.54	66.79[a]	22.54[b]	2.14	18830[c]
	51	26-abr	1.42	2.45	65.58[a]	27.81[b]	2.74	41320[c]
	26	27-abr	1.21	2.91	66.08[a]	27.11[b]	2.68	53100[c]
Generator	44	11-abr	2.14	5.64	60.79[a]	28.57[b]	2.87	4151[c]
Non	100	11-abr	6.78	11.83	55.54[a]	23.45[b]	2.41	1580[c]
Drive	50	13-abr	6.30	11.40	54.89[a]	24.81[b]	2.59	1395[c]
End	7	19-abr	3.78	23.53	55.06[a]	16.05[b]	1.58	1837[c]
Radial	51	26-abr	2.02	7.41	58.86[a]	28.80[b]	2.91	5449[c]
	26	27-abr	1.99	4.83	60.53[a]	29.63[b]	3.03	6911[c]

[a]High level of energy
[b]Medium level of energy
[c]Low level of energy

Table 3 12 levels energy decomposition

Device	Load (%)	Date	a (%)	d12 (%)	d11 (%)	d10 (%)	d9 (%)	d8 (%)	d7 (%)
Generator	44	11-abr	13.21[b]	0.99	0.50	0.60	0.89	1.01	1.53
Drive	100	11-abr	13.29[b]	0.99	0.82	0.40	1.26	2.16	1.37
End	50	13-abr	27.93[b]	0.47	0.19	0.11	1.30	2.29	1.06
Axial	7	19-abr	32.93[b]	1.16	0.67	0.82	1.27	1.78	1.24
	51	26-abr	14.66[b]	0.84	0.34	0.72	0.93	1.47	2.05
	26	27-abr	21.00[b]	1.25	0.67	0.94	1.95	3.17	1.78
Generator	44	11-abr	28.50[a]	5.29	2.35	1.85	2.88	10.39[b]	14.51[b]
Drive	100	11-abr	70.27[a]	0.84	0.51	1.24	0.65	3.98[b]	3.91[b]
End	50	13-abr	77.17[a]	1.75	1.54	0.85	0.70	4.40[b]	5.43[b]
Radial	7	19-abr	59.49[a]	5.70	1.90	0.86	0.64	5.76[b]	6.70[b]
	51	26-abr	52.32[a]	2.36	1.86	1.20	1.55	11.47[b]	9.96[b]
	26	27-abr	72.08[a]	1.40	0.41	1.02	0.95	6.81[b]	6.15[b]
Generator	44	11-abr	31.04[a]	6.17	0.71	1.07	5.55	14.27[b]	7.04
Non	100	11-abr	71.94[a]	0.51	0.86	0.62	3.16	4.47[b]	2.70
Drive	50	13-abr	74.23[a]	1.61	0.82	0.51	0.98	8.27[b]	3.72
End	7	19-abr	63.53[a]	5.27	1.52	1.48	2.41	13.06[b]	6.74
Radial	51	26-abr	52.72[a]	3.60	0.86	1.21	2.76	6.23[b]	5.29
	26	27-abr	72.51[a]	0.94	0.84	0.47	1.83	7.38[b]	4.36

[a]High level of energy
[b]Medium level of energy

Table 4 4 levels energy decomposition (cont.)

Device	Load (%)	Date	d6 (%)	d5 (%)	d4 (%)	d3 (%)	d2 (%)	d1 (%)	Energy
Generator	44	11-abr	9.27[a]	35.52[b]	31.09[b]	4.98	0.39	0.03	372.20[c]
Drive	100	11-abr	5.86[a]	40.47[b]	29.24[b]	3.83	0.30	0.02	233.70[c]
End	50	13-abr	9.68[a]	37.00[b]	17.26[b]	2.50	0.19	0.01	120.90[c]
Axial	7	19-abr	12.80[a]	37.05[b]	9.02[b]	1.17	0.09	0.01	116.20[c]
	51	26-abr	6.98[a]	41.43[b]	26.35[b]	3.89	0.30	0.02	190.90[c]
	26	27-abr	7.62[a]	27.73[b]	28.68[b]	4.80	0.38	0.03	118.40[c]
Generator	44	11-abr	7.37	19.85[a]	6.11	0.82	0.07	0.00	16.62[c]
Drive	100	11-abr	4.16	11.11[a]	3.00	0.31	0.02	0.00	46.64[c]
End	50	13-abr	2.75	3.24[a]	1.84	0.30	0.02	0.00	38.82[c]
Radial	7	19-abr	6.84	9.48[a]	2.35	0.26	0.02	0.00	33.18[c]
	51	26-abr	6.62	9.33[a]	2.96	0.33	0.03	0.00	30.32[c]
	26	27-abr	4.84	4.60[a]	1.51	0.21	0.02	0.00	37.33[c]
Generator	44	11-abr	5.64	22.83[a]	5.17	0.47	0.03	0.00	31.80[c]
Non	100	11-abr	2.58	10.28[a]	2.62	0.24	0.02	0.00	67.24[c]
Drive	50	13-abr	1.81	6.35[a]	1.54	0.14	0.01	0.00	65.37[c]
End	7	19-abr	2.42	2.93[a]	0.58	0.06	0.00	0.00	48.61[c]
Radial	51	26-abr	3.90	18.49[a]	4.53	0.40	0.03	0.00	46.56[c]
	26	27-abr	2.05	7.60[a]	1.84	0.17	0.01	0.00	63.88[c]

[a]High level of energy
[b]Medium level of energy
[c]Low level of energy

Vibration is collected by sensors placed in three different points of the generator: drive end axial, drive end radial and non-drive end radial. Knowing the location of the defective bearings in the generator, it can be considered that the non-drive end radial signal is closer to the fault free operation since it is the farthest point from the bearing. Failures will modify the original vibration signal.

Another interesting observation one can make on this study is that each signal has been picked at different load and in several dates. The performance of the wind turbine depends on the wind conditions so different behaviors for different workloads should be expected. This information is presented with an example in Fig. 6, which shows that despite the above-described; load changes do not modify significantly the behavior of the signals, but they will depend on their location as expected. In general terms, a pattern where the approximate signal and intermediate decompositions from d_5 to d_8 are highlighted, is repeated.

If the study is further specified on the differences for the three signals taken at the same time interval, then Figs. 7, 8 and 9 must be referenced. Their graphics

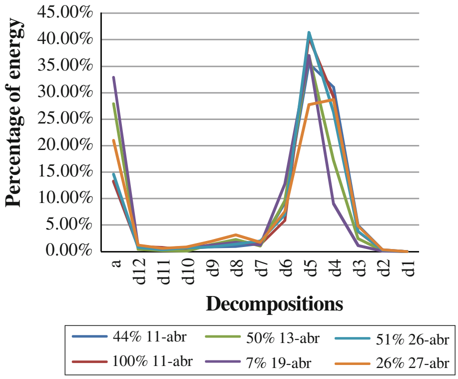


Fig. 6 Generator drive end axial (performance per decomposition in time)

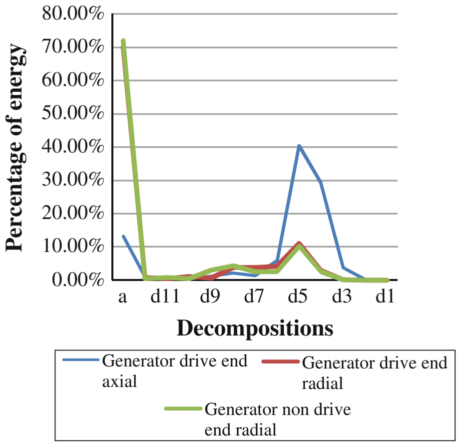


Fig. 7 100 % load (11th April)

Fig. 8 50 % load (13th April)

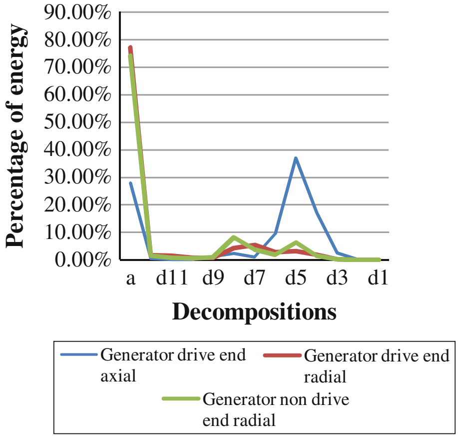
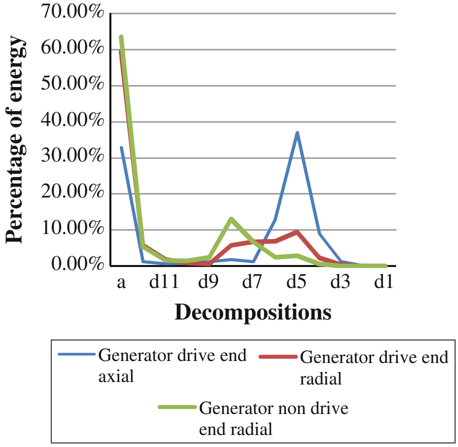


Fig. 9 7 % load (19th April)



provide information on possible operation anomalies for the generator in relation to the bearings.

Sensors that collect information next to the bearings have a different performance between them (drive end radial and axial). The radial components (drive end radial and non-drive end radial) have a similar behavior, even with differences, despite their different location regarding to the bearing. If this last comment is considered for possible failures, one of the aforementioned features needs to be reviewed: the load.

Figures from Figs. 7, 8 and 9 are examples that evidence the influence of the load, especially when the set loads are below the 50 % of the total. For these cases, the percentage of energy is distributed along different frequencies (from d_8 to d_4) when the sensor is close to the bearing, while specific peaks are observed at the so-called free fault conditions.

This could be an expected situation since in the case of damaged bearings, it was mentioned previously that noise is produced throughout the whole spectrum as the result of gaps for advanced stages of deterioration, emphasizing that these gaps become evident when the system load is lower. It is the authors' opinion that this is due to high load attenuating this effect.

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An Empirical Study on the Technological Development Trend of China's Strategic Emerging Industries

Xue Yang, Xin Gu and Yuandi Wang

Abstract In 2010, China's State Council promulgated the 'Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries' and pointed out that 'in 2015, strategic emerging industries should account for the proportion of China's gross domestic product (GDP) of around 8 %'. This study investigates the technological development trend of these emerging industries from 1995–2012, by using fuzzy comprehensive evaluation. The empirical analysis shows an overall upward development trend of China's seven strategic emerging industries. However, the technological development trend as well as technological input-output ratio appear distinct among different industries. Energy conservation and environmental protection industry, new generation of information technology industry, biotechnology industry, and advanced equipment manufacturing industry will become pillar industries of our national economy in the future.

Keywords Technological development trend · Strategic emerging industries · Fuzzy comprehensive evaluation · Entropy method

1 Introduction

As the competition around energy, talent, technology and standards is getting tougher worldwide, many countries have introduced relevant industrial policies, hoping to seize opportunities in the new round of technological and economic development, in order to achieve their long-term sustainable development. In September 2010, China's State Council promulgated the 'Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries' (hereinafter refers to as the

X. Yang (✉) · X. Gu · Y. Wang
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: cathyscu@sina.com

X. Gu · Y. Wang
Innovation and Entrepreneurship Research Institute, Sichuan University,
Chengdu 610064, People's Republic of China

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J. Xu et al. (eds.), *Proceedings of the Ninth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 362, DOI 10.1007/978-3-662-47241-5_100

'DECISION') and explicitly proposed to 'accelerate the development of strategic emerging industries'. In other words, the government would 'focus on strengthening the knowledge-and technology-intensive industries with less consumption of materials, having growth potential and comprehensive benefits, based on significant technological breakthroughs and development demands'. These industries will play a major leading role in overall economic and social situation with long-term development. The DECISION confirmed that there were 7 strategic emerging industries in China, which are energy conservation and environmental protection industry, new generation of information technology industry, biotechnology industry, advanced equipment manufacturing industry, new energy sources industry, new materials industry and new energy vehicles industry. This paper use statistical data from National Bureau of Statistics of the People's Republic of China to understand the technological development trend of China's seven strategic emerging industries with the help of empirical research. We anticipate that the results and suggestions will contribute to China's industrial policy formulation and implementation.

2 Theoretical Background

'Strategic emerging industry' is a concept formally proposed by Chinese government. This industrial classification system is similar to the 'new industry' in developed countries.

The foreign scholars did related research to evaluate these industries' technological innovation. Liao [1] evaluated international research and development (R&D) investment results of multinational corporations in Singapore's electronics and IT industry. The result shows that consistence with customer demands, achievement of time-based competitiveness, training of R&D manpower and development of conducive innovation environments are fundamental to the success of international R&D projects. Staniskis et al. [2] analyzed the Cleaner Production (CP)/pollution prevention concept application in Lithuanian companies by using technical, environmental, economic and financial information. Marin et al. [3] applied Sutton's 'bounds approach' to the chemical industry and predict that the lower bound on market concentration, the higher and faster growth of product concentration in markets with high R&D intensities. Jayanthi et al. [4] presented a conceptual framework to classify and identify the determinants related to technological and organizational variables in realizing the potential of innovations. They apply data envelopment analysis (DEA) model-based approach to conduct analysis of the potential of innovations in the U.S. photovoltaic and related manufacturing industry system. Liu et al. [5] presented a model for evaluation of technological innovation capability mutation in high-tech industries by introducing the catastrophe progression method. Shiue et al. [6] established a Markov Scenario analysis (MASA) model that integrates the concept of vision, linking analysis planning, Markov chain, and SA with state of constancy, disappearance, change and uncertainty in electric vehicle industry. Aydin et al. [7]

used the Supply Chain Operation Reference (SCOR) model and Analytical Hierarchy Process (AHP) to evaluate the performance attributed by retailers.

In China, strategic emerging industries had developed rapidly from 2008 to 2010. The added value of strategic emerging industries had reached 2.6 trillion yuan in 2010 which accounted for 6.36 % of China's GDP and increased by 0.54 % than that in 2008 [8]. Many scholars have done research on the evaluation indexes for the development of strategic emerging industries.

Zhang et al. [9] built an evaluation index system and the corresponding evaluation model for biomedical industry which belongs to strategic emerging industries according to grey system by using policy-oriented, economic efficiency, innovation and development potential as indicators. He et al. [10] constructed four characteristics of strategic emerging industries including overarching, leading, association and dynamic nature. They take Hunan Province as an example to evaluate by making use of Weaver-Thomas model. Yang et al. [11] proposed the new energy industry developing capability index system and build comprehensive evaluation model of industrial developing capability based on neural network. Huang et al. [12] selected ratio of R&D personnel, R&D investment intensity and patent applications per 100 R&D personnel to describe the technical characteristics and make specific evaluation standards of strategic emerging industries. Zhu et al. [13] proposed a grey relational evaluation model and evaluate the innovation competency in the Yanliang Aviation Industry Park. Xiong et al. [14] built corresponding indicator system and comprehensive evaluation model of the regional strategic emerging industry on the basis of AHP and principal component analysis (PCA). Yu et al. [15] used professionals input, technology and science funds input, technical achievements and economic output to measure the efficiency of technological and scientific resource allocation in strategic emerging industries. They also do empirical analysis by DEA method. Li et al. [16] evaluated the marine high-tech industry's technological capability using Delphi Method and Fuzzy Comprehensive Evaluation Method. The result shows that the evaluation model has scientific feasibility and is useful for the development of marine high-tech industry and national economy. Wang et al. [17] used Mahalanobis Distance to improve the traditional technique for order preference by similarity to ideal solution (TOPSIS) and evaluate the competitiveness of Chinese high-tech industry using data from 2011.

To sum up, from the above literature review, it can be seen that the current research on China's strategic emerging industries or new industries overseas are mostly done qualitatively from certain industry or year. Although the overall situation of strategic emerging industries in China has been evaluated in some studies, the empirical analysis on technological development trend of seven strategic emerging industries is still a gap. Based on existing research, this paper will use fuzzy comprehensive evaluation to investigate the technological development trend of emerging industries from 1995–2012.

3 Data and Methodology

Till now, there hasn't been any specific statistical yearbook of strategic emerging industries in China. Therefore, the data used in this paper comes from publications such as *China Statistical Yearbook*, *China Statistical Yearbook on Science and Technology* and *China Statistical Yearbook on High-technology Industry* published by National Bureau of Statistics of the People's Republic of China from 1996 to 2013. These industrial data is collected and classified to seven strategic emerging industries according to the contents and statistical standards of strategic emerging industries tested and verified by Zhou et al. [18].

3.1 The Indicators

In existing research, the evaluation indicators of strategic emerging industries are generally divided into two main factors, which are input factors and output factors.
1. Input Factors

The input factors include human resources input and capital input. On one hand, the input of scientific and technical personnel, particularly R&D staff, is the foundation of strategic emerging industries' development and guarantees for sustainable technological innovation. Human resources input is also considered to be the main force to determine industrial innovation capability and technological progress. On the other hand, as the driving force of industrial development, once capital input appears lack of investment or raising difficulties, technological innovation in strategic emerging industries will hit a bottleneck and form practical barriers in technological innovation. Furthermore, among capital input, the investment on new products development and technical renovation often directly affect the efficiency of industrial innovation. Therefore, they are also commonly used as indicators to measure industrial input.

In this paper, Full-time Equivalent of R&D Personnel (man-years), Internal Expenditure on R&D (10,000 yuan), Expenditure on New Products Development (10,000 yuan), Expenditure for Technical Renovation (10,000 yuan) are used as technical input indicators to evaluate technological development trend of China's strategic emerging industries.
2. Output Factors

The output factors include achievements in scientific research and financial performance.

Firstly, the number of patent applications is often used to measure the output of a company or industry which represents the level of scientific or technical innovation. Secondly, the financial performance of an industry is also an important factor in output indicators. According to evaluation standard of Chinese government, the proportion of gross industrial product to GDP is often used to measure the contribution of strategic emerging industries to national economy. Thirdly, output value and sales revenue of new products reflect industrial market acceptance and ultimate benefit of industrial technological innovation. Meanwhile, sales value of exports provides product standards of technological innovation to strategic emerging industries as well as offers driving force for industrial technological innovation. Finally, profits is often used to measure sustainable development potential of an industry.

In this paper, Number of Patent Applications (piece), Output of New Products (10,000 yuan), Sales Revenue of New Products (10,000 yuan), Sales Value of Exports (100 million yuan) are used as technical output indicators, Profits (100 million yuan) and Proportion of Gross Industrial Product to GDP (%) are used as economic benefit to evaluate technological development trend of China's strategic emerging industries.

3.2 The Model

Fuzzy comprehensive evaluation and entropy method are used in this paper to do empirical research.

1. Fuzzy Comprehensive Evaluation

In 1965, professor Zadeh, an American automatic control expert, proposed a concept of 'Fuzzy Sets' to express the uncertainty of objects. Based on this theory, Fuzzy Synthetic Evaluation Model is widely used by fuzzy mathematics to do quantitative evaluation with a variety of restraint factors. This model can better solve the problems which are vague, uncertainty and difficult to quantify.

The fuzzy comprehensive evaluation matrix is:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} \\ r_{21} & r_{22} & \cdots & r_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} \end{bmatrix}, \tag{1}$$

where r_{ij} represents the figure of indicator j belonging to selected object i. R is a $m \times n$ matrix. In this paper, the data of seven strategic emerging industries from 1995 to 2012 is collected as original sample with 10 indicators. Therefore, in this paper, m is 18 and n is 10.

According to Fuzzy Synthetic Evaluation Model, in this paper, $V = \{v_1, v_2, \ldots, v_{18}\}$ is assessment set of strategic emerging industries in past 18 years. $U = \{u_1, u_2, \ldots, u_{10}\}$ is assessment set of 10 evaluation indicators. Among these indicators, $U_1 = \{u_1, u_2, u_3, u_4\}$ is technical input indicators, $U_2 = \{u_5, u_6, u_7, u_8\}$ is technical output indicators, $U_3 = \{u_9, u_{10}\}$ is economic benefit. Here, (U, V, R) makes up a fuzzy comprehensive evaluation model.

2. Entropy Method

'Entropy' originally belongs to the thermodynamic concept. It was first introduced by Shannon to information theory and has been widely used. Entropy method is a method of objective empowerment, which calculates entropy weight by using information entropy according to the degree of variation of each index, and then gets more objective index weights based on the correction.

On the basic principles of information theory, information measures the degree of order in certain system while entropy measures the degree of disorder. If a system might be in a variety of different status, the probability of each state's appearance is $p_i (i = 1, 2, \ldots, m)$, the entropy will achieve maximum when the probability of each state appears the same, namely:

$$e_{\max} = \ln m. \tag{2}$$

Now that the original evaluation matrix $R = (r_{ij})_{m\times n}$ has m objects to be evaluated and n evaluation indicators. To certain indicator r_j, it has information entropy:

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}, \text{ where } p_{ij} = r_{ij} \Big/ \sum_{i=1}^{m} r_{ij}, k = 1/\ln m. \tag{3}$$

A smaller entropy index e_j indicates higher variation degree of this index and more information it provide. It illustrates that this index has greater effect on comprehensive evaluation and should has greater weight, vice versa. Hence, the entropy weight w_j of indicator j is:

$$\mathrm{w}_j = (1 - e_j) \Big/ \sum_{i=1}^{n} (1 - e_j). \tag{4}$$

4 Results and Analysis

According to the latest data released by Chinese government, China's strategic emerging industries accounted for about 4 % of GDP in 2010. Figure 1 shows the distribution of these seven strategic emerging industries.

As shown in Fig. 1, among seven strategic emerging industries, new generation of information technology industry had the highest percentage around 2.5 %. The proportion of advanced equipment manufacturing industry, biotechnology industry,

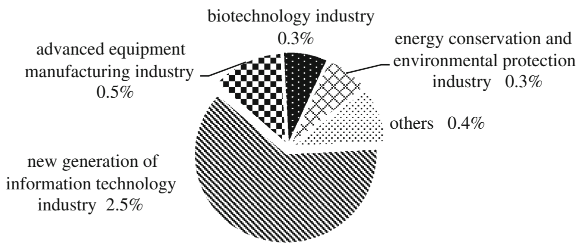

Fig. 1 The proportion of China's strategic emerging industries in GDP, 2010

energy conservation and environmental protection industry were about 0.5, 0.3 and 0.3 % in turn. The rest 3 industries accounted for approximately 0.4 %.

In order to further study the technological development trend of China's strategic emerging industries, we made data processing in MATLAB with formulas Eqs. (2)–(4). Tables 1 and 2 illustrate the weight of indicators in China's seven strategic emerging industries.

In Table 1, 10 indicators are Full-time Equivalent of R&D Personnel (u_1), Internal Expenditure on R&D (u_2), Expenditure on New Products Development (u_3), Expenditure for Technical Renovation (u_4), Number of Patent Applications (u_5), Output of New Products (u_6), Sales Revenue of New Products (u_7), Sales Value of Exports (u_8), Profits (u_9), Proportion of Gross Industrial Product to GDP (u_{10}). These indictors are classified to 3 assessment sets, which are technical input (U_1), technical output (U_2) and economic benefit (U_3). The weight of the sets is listed in Table 2.

Based on fuzzy comprehensive evaluation and entropy method, we calculated technological development trend evaluation single factor matrix of China's strategic emerging industries by using matrix processing function in MATLAB. Ultimately, we can get the score of each industry in past 18 years on the basis of single factor matrix multiplied by weight of indicators and sets though the method of weighted mean.

The overall technological development trend of China's strategic emerging industries from 1995 to 2012 are presented separately in Fig. 2.

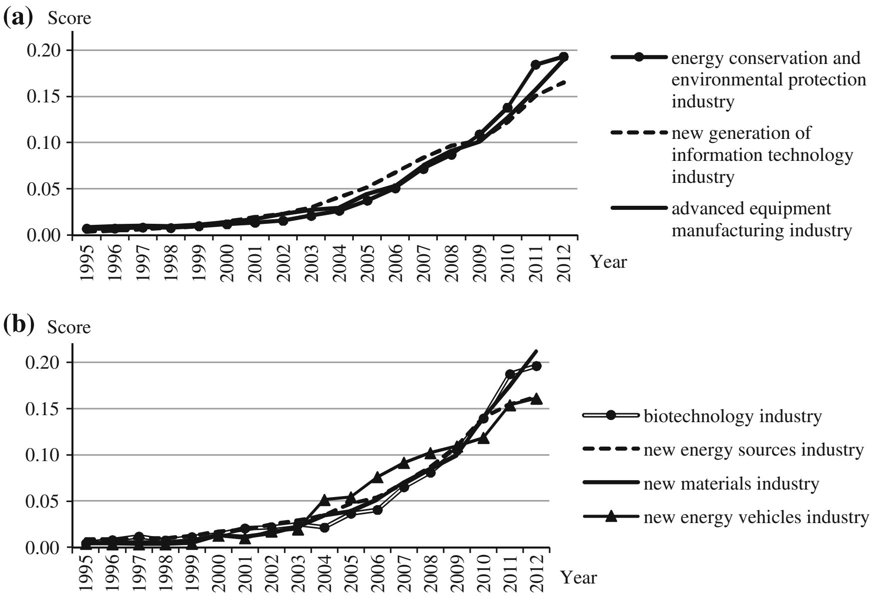

Fig. 2 The overall technological development trend of China's strategic emerging industries, 1995–2012. **a** The technological development trend in three strategic emerging industries. **b** The technological development trend in other four strategic emerging industries

Table 1 Weight of 10 indicators used in fuzzy comprehensive evaluation

Industries	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}
Energy conservation and environmental protection industry	0.0442	0.1245	0.1222	0.071	0.1596	0.1184	0.1185	0.0846	0.1371	0.0199
New generation of information technology industry	0.0814	0.117	0.1335	0.0146	0.1803	0.1144	0.1208	0.1267	0.0822	0.0292
Biotechnology industry	0.0551	0.1257	0.1343	0.0549	0.1113	0.123	0.1451	0.1154	0.1162	0.0191
Advanced equipment manufacturing industry	0.0066	0.1464	0.144	0.0346	0.2102	0.0852	0.0892	0.1151	0.1668	0.0018
New energy sources industry	0.0696	0.1386	0.1504	0.0192	0.1534	0.1267	0.131	0.0599	0.1475	0.0036
New materials industry	0.0852	0.1258	0.1301	0.023	0.1966	0.1026	0.1072	0.1016	0.1037	0.0243
New energy vehicles industry	0.0889	0.1127	0.1199	0.0563	0.1546	0.0967	0.0989	0.0914	0.1457	0.0349

Table 2 Weight of 3 assessment sets used in fuzzy comprehensive evaluation

Industries	$U_1 = \{u_1, u_2, u_3, u_4\}$				$U_2 = \{u_5, u_6, u_7, u_8\}$				$U_3 = \{u_9, u_{10}\}$	
Energy conservation and environmental protection industry	0.1221	0.3441	0.3377	0.1961	0.3317	0.2461	0.2464	0.1758	0.8731	0.1269
New generation of information technology industry	0.2350	0.3376	0.3853	0.0421	0.3327	0.2110	0.2227	0.2337	0.7378	0.2622
Biotechnology industry	0.1489	0.3397	0.3631	0.1483	0.2249	0.2485	0.2934	0.2332	0.8590	0.1410
Advanced equipment manufacturing industry	0.0200	0.4415	0.4342	0.1044	0.4207	0.1704	0.1785	0.2303	0.9891	0.0109
New energysources industry	0.1843	0.3670	0.3980	0.0508	0.3257	0.2690	0.2781	0.1272	0.9763	0.0237
New materials industry	0.2341	0.3454	0.3573	0.0632	0.3871	0.2020	0.2110	0.1999	0.8099	0.1901
New energy vehicles industry	0.2353	0.2982	0.3174	0.1491	0.3501	0.2190	0.2240	0.2069	0.8069	0.1931

Figure 2 reveals a steady upward trend in the overall technological development of China's seven strategic emerging industries from 1995 to 2012. Starting from 2003, this trend began to accelerate and finally reached the highest in all industries in 2012. However, the technological development trend in different industries varies slightly. Among seven industries, the new materials industry was still growing robustly in 2012, followed by advanced equipment manufacturing industry. Meanwhile, the growth rate of other 5 industries began to slow down in 2011. In 2012, relative to new materials industry (0.2119), energy conservation and environmental protection industry (0.1930), biotechnology industry (0.1962) and advanced equipment manufacturing industry (0.1898), the technological performance of new generation of information technology industry (0.1650), new energy sources industry (0.1620) and new energy vehicles industry (0.1610) appear weaker.

When we calculate input-output ratio by using scores of technical input and output assessment sets, the technological development trend of China's strategic emerging industries from 1995 to 2012 is described separately in Fig. 3. The overall upward development trend of seven industries is quite obvious despite the ups and downs. However, the fluctuations in seven industries are significantly different.

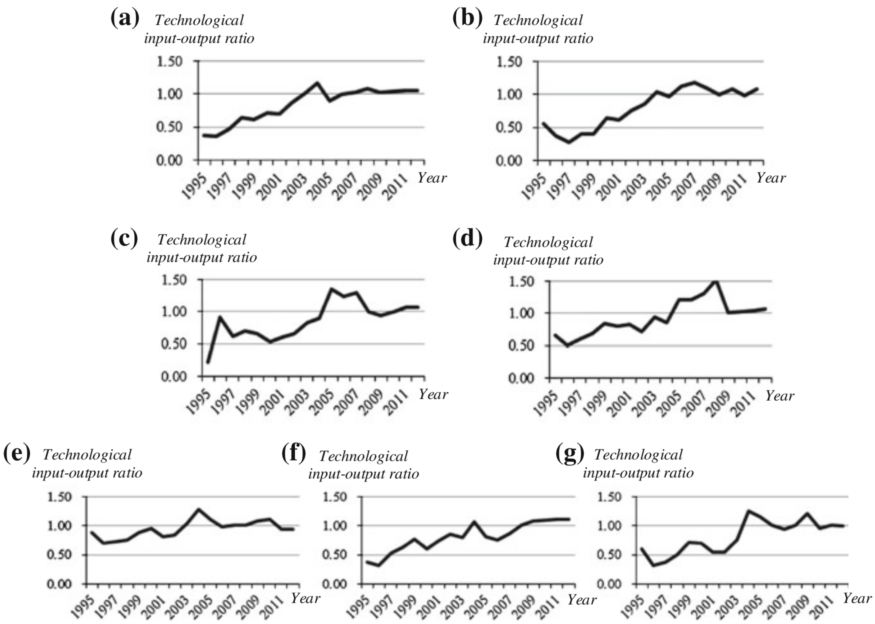

Fig. 3 The technological input-output ratio development trend of China's strategic emerging industries, 1995–2012. **a** Energy conservation and environmental protection industry. **b** New generation of information technology industry. **c** Biotechnology industry. **d** Advanced equpment manufacturing industry. **e** New energy sources industry. **f** New materials industry. **g** New energy vehicles industry

In 1995, China's seven strategic emerging industries' technical input-output efficiency were relatively low (less than 1). Among these industries, new generation of information technology industry, advanced equipment manufacturing industry, new energy sources industry and new energy vehicles industry had better technical foundation, with technical input-output ratios greater than 0.5. However, after 18 years, only in new generation of information technology industry and advanced equipment manufacturing industry, the technical output exceeded input (output/input $>$ 1) with the peak appeared during 2006–2008. In 2012, the technical input-output ratios in new energy sources industry and new energy vehicles industry were still slightly less than 1. Although they outstripped 1 just a little in a small number of years from 2003 to 2011. Meanwhile, the technical foundations of energy conservation and environmental protection industry, biotechnology industry and new materials industry were weak in 1995 with technical input-output ratios less than 0.5. But at the end of 2012, these ratios were all greater than 1. This trend indicates that the technological development of these 3 industries are better than others. Especially in energy conservation and environmental protection industry and biotechnology industry, the technical input-output ratios have being exceeded 1 and maintained an up trend since 2004.

5 Conclusions

In certain country or region, strategic emerging industries are leading industries to achieve sustained economic growth in the future. These industries have decisive, action-oriented effect on economic development and industrial structure transformation. Because of their broad market prospects and ability to guide scientific and technological progress, strategic emerging industries are close related to the country's economic lifeline and industrial safety. In 2010, China's State Council promulgated the DECISION and enhanced the development of strategic emerging industries to national level. Under this background, we investigated the technological development trend of these emerging industries from 1995–2012, by using fuzzy comprehensive evaluation together with entropy method. The empirical analysis demonstrates an overall upward development trend of China's seven strategic emerging industries. However, the technological development trend as well as technological input-output ratio appear distinct among different industries. On the one hand, new generation of information technology industry as well as advanced equipment manufacturing industry start to accelerate development earlier than others, and remain strong momentum of development due to their better technical foundation. On the other hand, energy conservation and environmental protection industry together with biotechnology industry set rapid pace of technological development. From the above analysis, we can safely come to the conclusion that among China's seven strategic emerging industries, energy conservation and environmental protection industry, new generation of information technology industry, biotechnology industry, and advanced equipment manufacturing industry will become pillar industries of our national economy in the future and China's industrial policy should focus more on these four industries. Based on this study, we believe that additional consideration such as data updated, indicators enriched and methods improved in future research will further enhance a collective understanding of the technological development trend of China's strategic emerging industries.

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The Impact of Internal Control Quality in Engineering Projects On the Corporate Value: An Empirical Study in Construction Industry

Yunchen Wang and Xuan Yu

Abstract Based on the "Application Guidance for Enterprise Internal Control: Engineering Project", this paper takes the listed companies in construction industry as research samples. It has unscrambled the development rules of internal control quality in construction enterprises from two aspects: self-evaluation & verification, and goal achievement, and has further analyzed the impact of the internal control quality on the corporate value. The study finds that: (1) The internal control quality of the companies concerned has been improving from 2008 to 2012, especially after 2010; (2) the internal control quality of engineering projects has a significant positive correlation with companies' sustainability and their current market value. This study would provide support to and serve as references for future efforts to strengthen the establishment of internal control quality and to upgrade the corporate value.

Keywords Internal control quality · Corporate value · Construction industry

1 Introduction

In recent years, construction industry, as one of the pillar industries of national economy, has been developed rapidly and extensively by relying on the proactive fiscal policies and the continuously expanded scale of investment in fixed assets. According to the statistics, the average annual growth rate of construction industry's total output value was more than 15 % in last three years. By 2012, the total output value had been more than 13 trillion yuan, and its year-on-year growth

Y. Wang
School of Economics and Management, Sichuan Agricultural University, Chengdu 611130, People's Republic of China

X. Yu (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: yuxuan_0917@aliyun.com

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was 16.2 %. However, along with the adjustment of economic structure and the intensified market competition, the construction enterprises will encounter more and more risks. Especially for those taking the construction of engineering projects as their main business, the risks encountered in the construction process will directly affect the enterprises' sustainable development level and current market value. Generally speaking, lots of reasons lead to the "high-risk area" of economic crimes and corruption [17]. The reasons include the enormous resources invested on the engineering projects, the occupation of large funds, the long construction period, too many links involved and the various complicated interests relationship. According to the "First Financial Daily" on October 29, 2010, China Railway Construction (601186, SH) was reported to suffer from a huge loss of 4.153 billion yuan in the engineering project of Saudi Arabia. This is the result of the problems in its internal control, like bidding, the procurement of engineering equipment, the project management and so on. Therefore, in order to effectively protect the investors' interests and strengthen the risk management capability in the construction of engineering projects, the Ministry of Finance and other four ministries and commissions formulated 18 pieces of "Application Guidance for Enterprise Internal Control" about engineering projects on April 26, 2010. It was after the promulgation of "Basic Norms of Enterprise Internal Control". Thereafter, our country has established a set of standard system in enterprises' internal control. That system is in consistency with the principal aspects of COSO's internal control framework which is internationally accepted.

Seen from its development history, internal control was generated from the continuous occurrence of enterprise financial frauds and failures. Besides, as Li Weian and Dai Wentao pointed out [5], with the occurrence and development of such periodic events, internal control, up to now, has been internalized in each process and link inside the enterprises and related to all kinds of personnel, so as to control the enterprises' overall risk . Meanwhile, in order to protect the investors' interests more effectively, USA Congress passed "Sarbanes-Oxley Act" in 2002. This bill emphasizes specially on the full and effective responsibility for companies' management layer to establish and maintain internal control system and corresponding control program. It even stipulates that the companies' CEO and CFO must make a vow for the authenticity of their financial report. Zhou and Zhang [23] stated that it also strictly makes an unprecedented provision on how to establish, implement and evaluate the internal control of a listed corporation. In 2010, our country promulgated "Application Guidance for Enterprise Internal Control–Engineering Projects" which subdivided the main risk points in the business process of engineering projects and established some effective control measures for the key links. This can assist the construction enterprises on engineering projects to take more specific implementation of internal control. It also contributes to the government departments' supervision and inspection for enterprises' implementation of internal control standard system, and enables the investors to make a reasonable evaluation on enterprises' internal control quality. Thereby, with the establishment and propulsion of enterprises' internal control system, how exactly is the level of internal control quality in these listed corporations, engineering-projects-oriented, in construction industry? Could their internal control quality achieve some obvious improvement after 2010? Whether the upgrade of that quality would significantly promote the corporate value? All these questions are worth our careful consideration and research.

2 Literature Review

Compared with that in other industries, the operating management of engineering projects in construction industry has some distinctive characteristics. This is due to its main duty in the construction of various engineering projects. In general, the whole process of engineering projects mainly includes five stages: project approval, design, bidding, construction and the final acceptance of completed project. Each stage can be subdivided into a number of links. Some potential risks exist probably in every stage. Specifically speaking, the potential control risks in the whole process of enterprises' project construction are as follows: (1) Risks in project approval. (2) Risks in project design. (3) Risks in project bidding. (4) Risks in engineering construction. (5) Risks in the final acceptance of completed project. In fact, in the activities of these engineering projects, the major risks exist in the business process and management layer's opportunism. Faced with the two kinds of risks, internal control should include correspondingly two aspects: firstly, how to achieve management control of lower staff at the business processes level; secondly, how to realize the balance of senior managers at the corporations' governance layer.

Parveen and Nandkumar [13] put forward that the enterprises' internal control is an institutional arrangement to achieve efficient allocation of resources. In order to comprehensively strengthen risk control of projects, improve the project quality, and promote corporate value, Chinese government has formulated a series of management measures. Particularly, in 2010 our country released "Application Guidance for Enterprise Internal Control–Engineering Projects". It has further enhanced the monitoring of whole process of engineering construction projects, and has established the management system for the projects' development and improvement. It has also clarified the job responsibilities and authority of related institutions and positions. Liu [11] suggested that the working procedures and control measures have been standardized in each stage, such as project approval, tendering, construction cost, construction and the final check and acceptance. Compared with the previous "Basic Norms of Enterprise Internal Control", the supporting guidance released after 2010 is more specific and operational: (1) In view of risk control in the process of project business. First of all, enterprises should organize some professional persons to anonymously assess the projects' scientific nature according to the development strategies, and to make decisions according to the authority. Some major projects must be submitted to the board of directors and other similar institutions for collective deliberation, and any person cannot make unauthorized decisions. Secondly, enterprises should select the satisfied units via open tender, and should also regulate the procedures of bid opening, evaluation and calibration of project tender. It is necessary for them to strengthen the management of construction cost and clarify the compilation techniques and basis of the cost in the whole process from a concept to a detailed case. Thirdly, in the process of engineering construction, strict tracking supervision is essential in whole process in accordance with the budget and supervision system. If there is any change, timely report and approval need to be made according to the authority. Finally, it is about the compilation of the completed projects' final accounts and audit and the establishment of their post-evaluation system, so as to evaluate the projects' actual performance from expectation and clarify their lifelong accountability system. (2) In regard to the governance risk control exposed from the engineering project management. The construction enterprises would finally form effective conclusions about internal control for the plan of operational control and the implementation of supervision and verification, which can not only provide additional useful information for decision-making [3], and also form a powerful reputation restriction to the corporations. It will facilitate the corporations to recognize their defects in internal control [6], and make rapid analysis of reasons and timely report to the board of directors and other similar institutions. Therefore, internal control would be arranged under both external and internal supervision. This enables the stakeholders to have more objective evaluation on the performance of management layer's entrusted economic responsibility, and then helps them make relevant decisions on dismissal, reward and punishment for management layer. Ultimately, all of these could effectively restrain the opportunism of management layer and protect the corporate value. As a result, this paper proposes the first hypothesis: compared with that prior to 2010, the internal control quality of listed corporations in construction industry has been significantly improved since 2010.

Since 2008, our country has gradually established a system of internal control in enterprises. Especially the release of "Application Guidance for Enterprise Internal Control" and other series of supporting guidance have made the construction and implementation of enterprises' internal control much more targeted and effective. Via the reasonable layout of organization structure, the appropriate agreement of authorities between functional departments, the rational distribution of staffing and the sound division of work procedures, the enterprises would internally form an effective balance mechanism among right, duty and interests. For example, there is separation containment, like "the separation of decision-making, execution and supervision", "government regulation separated from management", "regular rotation", and cooperation containment, like "collective decision-making", "joint deliberation and agreement" [7]. These contribute to the constraint and prevention of various risks, including the risks of nominal governance structure, the inefficient operation of internal organization and the failure of enterprises' operation and strategy. Thus, it will greatly drive the enterprises' sustainable development and current market value.

Furthermore, according to the signal transmission theory, the disclosure of internal control information will not only act on the company itself, and also pass on the information about specific implementation of company's internal control to the capital market [20], which will affect the information users' decision-making in the capital market. The market's response to the disclosure of internal control information will ultimately be reflected in the variation of corporate value. Studies have shown that internal control quality displays a significant and positive effect on corporate value

[5, 9]. Specifically, corporate value is the discounted value of the future cash flow, mainly depending on the company's future cash flow and the discount rate. If the internal control quality of the company is not high enough (such as the problems of internal control defects or poor achievement of goals, etc.), the disclosure of internal control information would convey to market the signal of company's high market risks and other special risks [1], and other signals, like the insufficient capacity of enterprise sustainable development. Thus, the investors would realize that they have been bearing a higher risk, and accordingly require higher risk compensation, thus leading to a lower discounted rate of future cash flow followed with reduced corporate value.

However, the quality improvement of enterprises' internal control is helpful to alleviate and prevent uncertainty the enterprises will face in the future. Then it will contribute to the prominent enhancement of corporate value [10, 22]. Studies have demonstrated that high quality of internal control could restrain major risks in the business process and management layer's opportunism existing in business activities such as R&D. Thereby, more corporate value would be achieved [19].

Based on the above analysis, this paper puts forward the second hypothesis: internal control quality of listed corporations in construction industry could significantly promote the corporate value.

3 Research Methods

1. Sample Selection and Data Resource

Considering the construction and execution situation of internal control, this paper selected 147 listed transportation companies in the main board of A-share from 2008 to 2012, deleting ST and PT companies as well as those without key variables. Furthermore, the data reflecting enterprise internal control quality come from DIBO; Our country listed company internal control index is from internal control and total risk management solution provider-Shen Zhen DIBO Enterprise risk management technology Co., Ltd. The rest data are all from CSMAR data base.

The measurement of corporate value. Corporate value is reflected in the enterprise sustainable development rate and its current market value. The latter includes the market value of equity capital and debt capital: the value of equity capital in listed companies can be calculated by shares, while that of debt capital by the closing amount. Enterprises' sustainable development rate originates from the researches by Higgins [4] and Van Horne [18].

In 1997, Higgins put forward the viewpoint of enterprise sustainable growth and initiated the research on it. Based on that, in 1988, Van Horne developed the enterprise sustainable model and regarded that SGR was decided by net profit margin on sales, asset turnover ratio, equity multiplier and preserve return rate. Such formula totally reflects the enterprise financial movement and business situation, manifesting the enterprises' best ascending ability under the constraint of internal and external environment. So, we have chosen this formula as measurement for the capacity of enterprise sustainable development.

Van Horne's sustainable growth model is as follows: SGR = (net profit margin on sales $\times$ asset turnover ratio $\times$ equity multiplier $\times$ retained earning rate)/(1 $-$ net profit margin on sales $\times$ equity multiplier $\times$ asset turnover ratio $\times$ retained earning rate)

The measurement of internal control quality. This paper holds that internal control quality can be divided into:

(1) Internal control quality based on the level of self-evaluation & verification. According to the requirements in "Evaluation Guidance for Enterprise Internal Control", the enterprises' board of directors or similar decision-making institutions should make a comprehensive evaluation and self assessment report on the effectiveness of enterprises' control internal design and operation. The corporations valuing the implementation of internal control will further integrate the audit verification of internal control, which is a powerful signal to the market of management layer's confidence in high performance of internal control [8]. Hereby, the self assessment of internal control and its audit verification release the quality information about the performance of enterprise internal control and reflect the actions taken during the performance [21]. Therefore, that the enterprise evaluation of internal control is more complete indicates that the enterprise management will emphasize more on internal control and that internal control quality will be better refined. Accordingly, we set the internal control quality as proxy variable, i.e. when one company discloses both the self-assessment report and the standard audit report of internal control, it implies that this enterprise internal control quality is the best, and the evaluation score is 2; if only disclosing the self-assessment report, the quality evaluation of enterprise internal control is 1; if with neither report, it is 0.

(2) Internal control quality based on the level of goal achievement. The higher level of effectiveness of enterprise internal control demonstrates the better internal control quality. According to the interpretation on the "Evaluation Guidance for Enterprise Internal Control" by the Accounting Department of the Ministry of Finance, the effectiveness of internal control refers to how much can the internal control system control the objects. It can be seen that the effectiveness can be measured by internal control strategy, business, reports, legal compliance and asset security [14]. "DIBOlisted company internal control index" released by Shen Zhen DIBO Enterprise risk management technology Co., Ltd. covers five aspects: strategy implementation (market share and risk coefficient), business return (return on invested capital and net profit margin), the integrity and authenticity of disclosed information (audit opinion and financial restatement), the legitimacy of business (illegal operation and lawsuits), and asset security (maintenance and appreciation of assets value), and it will replenish and rectify the great defects in internal control. In fact, this index reflects the main part of enterprise internal control objects and is also the specific manifestation of effective execution of internal control. So we chose this index as the measurement of internal control quality.

2. Model

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 \mathrm{Dual}_{it} + \beta_3 \mathrm{Indrat}_{it} + \beta_4 \mathrm{Zhsha}_{it} + \beta_5 Lev_{it} + \beta_6 Roa_{it} + \beta_7 \mathrm{Grow}_{it} + \sum \mathrm{Year}_{it} + \varepsilon_{it}. \quad (1)$$

In this model, the variables to be explained (Y) are current market value ($Q1/Q2$) and sustainable growth rate (SGR), while the variable to be researched (X) is internal control (ICEAD/IC). Besides, in the reference to the previous papers [2, 12, 15, 16], we also control the factors that reflect company's finance and governance. To be specific, they include: Dual, Indrat, Zhsha, Lev, Roa, Grow and Year. The specific definitions of variables can be found in Table 1, while the descriptive statistics of main variables are given in Table 2.

Table 1 Definitions of main variables

	Symbols	Variables' definitions
Dependent variables	$Q1$	RMB ordinary shares × current value of today's closing price + domestic listed foreign share B × current value of today's closing price × current exchange rate + (the total number of shares − RMB ordinary shares − domestic listed foreign share B) × final value of stockholder's total equity/current final value of paid-in capital + current final value of total liabilities
	$Q2$	The total number of shares domestic listed foreign share B) × current value of today's closing price of share A + domestic listed foreign share B × current value of today's closing price × current exchange rate + current final value of total liabilities
	SGR	(Net profit margin on sales × asset turnover ratio ×equity multiplier × retained earning rate)/(1-net profit margin on sales × equity multiplier × asset turnover ratio × retained earning rate)
Independent variables	ICEAD	If disclosing both self-assessment report and standard audit report of internal control, the score is 2; if only disclosing the self-assessment report of internal control, it is 1; if with neither report, it is 0
	IC	Reflected by the effectiveness of IC, standardized via the "DIBO · listed company internal control index" divided by 100
Control variables	Dual	1 represents the combination of general manager and chairman of the board; 0stands the opposite
	Indrat	The number of independent directors/the total number of the board of directors
	Zhsha	The shareholding ratio of the first and second largest shareholders
	Lev	Debt-to-assets ratio
	Roa	Net profit/[(the total asset ending balance + the total asset opening balance)/2]
	Grow	(Current year's operating income − last year's operating income)/last year's operating income

4 Analysis and Results

4.1 Descriptive Statistics

This paper has evaluated the internal control quality of construction enterprises from two levels: self-evaluation & verification (ICEAD) and goal achievement (IC). From the internal control quality based on the level of self-evaluation & verification (ICEAD), the descriptive statistics showed that the average level (Mean) of internal control quality of construction industry is 0.7347. The standard deviation (SD) is 0.8466, and the maximum value (Max) is 2. These indicate that there are great differences in the level of internal control quality of individual construction industry. From the internal control quality based on the level of goal achievement (IC), the average level (Mean) of internal control quality of listed corporations in construction industry is 6.7652. The standard deviation (SD) is 1.5251, and the maximum value (Max) is 9.7559. Compared with the full mark 10, it suggests that the internal control quality of listed corporations in construction industry is generally at the passing level. In addition, we have calculated the variance inflation factors (VIF) of each main variable, all of which are less than 2, manifesting that the model does not possess the feature of serious multicollinearity.

Seen from Table 2, taking 2010 as a division point, we have analyzed the differences in the enterprise internal control quality. On April 26, 2010, the Ministry of Finance and other four ministries and commissions jointly issued 18 pieces of "Application Guidance for Enterprise Internal Control", such as the "Application Guidance for Enterprise Internal Control No. 11–Engineering Projects", which was a critical approach to effectively enhance enterprise internal control quality. Based on this, from Table 3 we can find that: Compared with the numbers prior to 2010 (Year ≤ 2010), both mean (Mean: $1.2258 > 0.3765$) and median (Median: $1.5000 > 0$) of the internal control quality from the level of self-evaluation & verification (ICEAD) have been increased since then; Similarly, both mean (Mean: $6.8548 > 6.6999$) and

Table 2 Analysis of difference in enterprise internal control quality: based on the comparison between the quality before and after 2010

Variable	Year	N	Mean	SD	Median	Min	Max
ICEAD	$\leq$ 2010	85	0.3765	0.6358	0.0000	0.0000	2.0000
	$>$ 2010	62	1.2258	0.8574	1.5000	0.0000	2.0000
IC	$\leq$ 2010	85	6.6999	1.6684	6.7932	0.0000	9.7180
	$>$2010	62	6.8548	1.3113	6.8687	0.1675	9.7559
ICED	$\leq$ 2010	85	0.0471	0.2130	0.0000	0.0000	1.0000
	$>$2010	62	0.3710	0.4870	0.0000	0.0000	1.0000
ICRE	$\leq$ 2010	4	0.5000	0.5774	0.5000	0.0000	1.0000
	$>$ 2010	23	0.9565	0.2085	1.0000	0.0000	1.0000

median (Median: 6.8687 > 6.7932) of the internal control quality from the level of goal achievement (IC) have also been upraised after 2010 (Year > 2010). Further study has found that, compared with those before 2010 (Year ≤ 2010), the sample enterprises have disclosed much more internal control deficiencies (ICED). In other words, the ICED mean (0.3710) after 2010 is larger than that (0.0471) before 2010 (Year ≤ 2010). Besides, 95.65 % of the sample enterprises have taken internal control rectification measures (ICRE) after recognizing their internal control deficiencies since 2010 (Year > 2010), while, those having taken the same action before 2010 (Year ≤ 2010) only account for 50 %.

Seen from Table 3, in order to further point out the changes of internal control quality (ICEAD/IC) before and after the implementation of system, this paper has tested the differences between the quality before and after 2010: the mean (1.2258) of internal control quality (ICEAD) after 2010 (Year1112 = 1) is significantly higher than that (0.3765) before 2010 (Year1112 = 0). The result from Wilcoxon rank sum test is similar to that from mean T test. On the other hand, the mean (6.8548) of internal control quality (IC) after 2010 (Year1112 = 1) is larger than that (6.6999) before 2010 (Year1112 = 0). However, the gap between the two means of IC is not significant via the mean T test and Wilcoxon rank sum test. This may be related to the different index measurement of internal control quality (IC), thus allowing the weakened difference before and after the implementation of system. Nonetheless, from the view of overall trend, the internal control quality of listed corporations in construction industry has been upgrading since 2010. In summary, compared with that prior to 2010, the enterprises' internal control quality has been refined after the release of "Application Guidance for Enterprise Internal Control No.11-Engineering Projects" in 2010. Therefore, the first hypothesis has been verified.

Table 3 Test for the difference in enterprise internal control quality: based on the comparison between the quality before and after 2010

	ICEAD				IC		
	Mean	Median	N		Mean	Median	N
Year1112 = 0	0.3765	0.0000	85	Year1112 = 0	6.6999	6.7932	85
Year1112 =1	1.2258	1.5000	62	Year1112 = 1	6.8548	6.8687	62
Mean T Test	−6.8987***			Mean T Test	−0.6068		
Wilcoxon rank	−5.8920***			Wilcoxon rank	−0.8080		
Sum test				Sum test			

Notes (1) T value said T statistic after a Robust standard error correction; (2) ***, **, * respectively 1, 5 and 10 % significance level

Table 4 Test for the function of internal control quality on corporate value: based on the comparison of different evaluation methods

Variable	Total sample					
	$Q1$	$Q2$	SGR	$Q1$	$Q2$	SGR
	Regression1	Regression2	Regression3	Regression4	Regression5	Regression6
The dependent variable: corporate value						
ICEAD	0.3908***	0.3784***	0.0121***			
IC				0.7330***	0.7248***	0.0070**
Dual	−0.2877	−0.2329	0.0229*	−0.1565	−0.1033	0.0242*
Indrat	9.9213***	9.8079***	0.0554	5.7365***	5.6625***	0.0226
Zhsha	0.0048***	0.0046***	0.0001***	0.0036***	0.0034***	0.0001***
Lev	−0.3234***	−0.3591***	−0.0589***	0.4746***	0.4300***	−0.0513***
Roa	5.7125	6.8037	2.1221***	−9.7447**	−8.4707**	1.9629***
Grow	0.1453	0.1801	0.0109	−0.0970	−0.0589	0.0079
Cons	18.5821***	18.6858***	0.0285*	14.9915***	15.1360***	−0.0069
R^2	0.4884	0.4884	0.6336	0.7151	0.7103	0.6316
F	31.18***	31.99***	15.76***	63.85***	57.70***	13.31***

Note ***, **, * denote the significant levels of 1, 5 and 10 % respectively.

4.2 *Regression Analysis*

In Table 4, we have first estimated model (1) and analyzed the impact of internal control quality, evaluated by different methods, on corporate value. In the regression of 1–3, no matter what the dependent variable is $Q1$, $Q2$ or SGR, the regression coefficients of the internal control quality from the level of self-evaluation & verification (ICEAD) are significantly positive (all the significance levels are $P < 0.01$); in the regression of 4–6, no matter what the dependent variable is, $Q1$, $Q2$ or SGR, the regression coefficients of the internal control quality from the level of goal achievement (IC) are all significantly positive (the significance levels are $P < 0.01$, $P < 0.01$ and $P < 0.05$ respectively). The above results demonstrate that, whether from the level of self-evaluation & verification or goal achievement, the internal control quality of listed corporations in construction industry has a significant and positive correlation with the enterprises' sustainable development level and market value. Therefore, the second hypothesis has been verified.

5 Robust Tests

We have done the following robust tests: firstly, considering that the effectiveness may be reflected on the companies in next batch, we adjusted the model (1) to test the influence of L_IC in the companies in next batch on enterprise value.

The results remain the same. Secondly, considering the potential negative influence of the extreme value in variables and the limitation of samples, this paper has 0.5 % of Winsorize on each variable and has redone multiple regression analysis. The results still stay the same. Thirdly, as for the internal control quality based on the level of self-evaluation & verification, we adopt a new measurement. If it is measured only according to the disclosure of internal control's self assessment report or not, or only based on that of its standard auditing report or not, by repeating the test for hypotheses 1 and 2 as is stated above, the main conclusions remain unchanged.

6 Conclusions and Discussion

It is highly likely to trigger lots of risks, such as "bean curd residue" project, in the process of advancing the engineering projects. Hence, the investors and government supervision departments pay particular attention to the risk control problems of construction industry. In 2010, in order to effectively protect the investors' interests, Chinese government purposefully released "Application Guidance for Enterprise Internal Control-Engineering Projects" based on the promulgation of "Basic Norms of Enterprise Internal Control" in 2008. It is aimed at strengthening the risk management of engineering projects comprehensively and promoting the corporate value. Based on this background, this paper has researched the quality change of internal control in the listed corporations of construction industry and its impact on the corporate value. The study found that: (1) the internal control quality of listed companies in construction industry has been improved continuously from 2008 to 2012. Especially since 2010, the magnitude of improvement has been much more distinct than before. (2) The internal control quality of engineering projects has a significant and positive correlation with enterprises' sustainable development rate and current market value.

This study enlightens us that: (1) The supervision layer should integrate the special situation of industry and enterprises, timely subdivide and generate some distinctive application guidance for enterprise internal control, and urge relevant enterprises to guide certain enterprise to guard against risks, thus effectively upgrading corporate value; (2) The managers in construction enterprises need to recognize that high internal control quality can effectively restrain the enterprise risks and enhance the enterprises' sustainable development and the level of market value. Thereby, they must attach much importance, in thought and action, to the construction of enterprise internal control and try to avoid the phenomena of being short-sighted in the construction or having "two pieces of skins" in the execution, but to truly upraise enterprise internal control quality; (3) It is necessary to intensify the guidance for enterprises' disclosure of self assessment and verification report on the internal control validity so as to promote internal control quality. It also requires the refining of internal control effectiveness for the realization of goals. To sum up, this study is the first to probe into the evolution and function of internal control quality of listed corporations in construction industry by combining the implementation background of Chinese internal control system and industrial characteristics in its application. The findings have provided direct evidential support for the practical application of "Application Guidance for Enterprise Internal Control–Engineering Projects" and theoretical guidance for these listed corporations in construction industry to enhance their construction of internal control system and to upraise their corporate value.

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How to Measure Industrial Relations Climate in Chinese Context

Jiayun Deng, Derwin King-Chung Chan, Sophie Xin Yang and Kim M. Caudwell

Abstract The employees' perception of the industrial relations climate is essential to promote the development of enterprise, maintain social stability and human being's psychological well-being. With the development of China's economy, the complexities exist in the Chinese market may lead to some potential issues toward the industrial relations. Therefore, the need to understand the nature of the industrial relations in the Chinese market is crucial to the various stakeholders. The present study aimed to develop a psychometric scale measuring the Chinese industrial relations through three consecutive studies. The research was conducted from one hundred twenty-two enterprises across four different industries including manufacturing, software services, pharmacy and serving, with 3259 employees. The developed scale contains five psychological factors including interactiveness, motivation, harmony, careness and fairness, and the results supported the sound psychometric properties of the Industrial Relations Climate Scale.

Keywords Industrial relations · Organization climate · Industrial relations climate

1 Introduction

Industrial relations climate is a concept that indicates what the staff's perception of organization's industrial relations is. So we need to know what is industrial relations. Besides for the huge difference between China and western country in concept of industrial relations, it is basis to classify what industrial relations is in China.

Industry relations is the relationship between owner of labor and holders of capital in corporation. The essence of it is combing of labor and means of production in order to produce. In western country, there are three objects which are employee, employer

J. Deng · S.X. Yang (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: Sophie2717@hotmail.com

D.K.-C. Chan · K.M. Caudwell
Curtin University, Perth 6102, The Commonwealth of Australia

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and union in industry relations. But in China, for the special nature of unions, it is necessary to exclude union in considering the labor relations. Chinese labor relations include only two parts these are labor and employer.

Since industrial relations climate was developed, there are a number of researches about it and many scholars put out their understanding of it. Table 1 shows the different definition of industrial relations climate according to some researchers. In China, industrial relations describes the relationship between employee and employer. Union, as we know, is not such important in Chinese context. Therefore we applied Dastmalchian's [1] definition, on account of its excluding the influence of union and it is more in line with China's situation.

According to present study, Blyton et al. [5, 6, 10] applied organization climate to industrial relations, and develop a complete industrial relations climate concept and test it [1]. The concept of industrial relations climate is based on organization climate theory. Reichers and Schneider [11] proposed that organization climate is members' common sense of the formal or informal organization policies, operations, procedures and other aspects. Industrial relations is one of the most important relationship in enterprises, it offers another potential fruitful area for the application of

Table 1 Researcher and definition of industrial relations climate in past study

Researchers	Definition
Nicholson [2]	The status of labor getting along with employer, such as friction, angle, conflict and poor communication between labor and employer or employees seek benefits with intense way
Gordon et al. [3]	The developing trend of relationship between unions and management
Katz et al. [4]	Quality of industrial relations in the organization
Dastmalchian et al. [5]	The characteristics that affects the relationship between employees and managers in the workplace
Blyton et al. [6]	It reflects organization's members' perception to the practice of union—management relations
Dastmalchian et al. [1]	Organization members' perception to enterprise's industrial relations practice
Lee [7]	Employees perceive the degree of cooperation and shared interests of management
Kersley et al. [8]	Members perceived organizational climate characteristics, and the design of norms, attitudes and behaviors among employees, unions and management
Pyman [9]	Describe the relationship between the state and the quality of the manager-on union organization

the climate concept [6]. As a result, it is suggested that a firm's industrial relations activities generate a characteristic atmosphere in the organization. This characteristic atmosphere, as perceived by the organizational members, is what we regard as the industrial relations climate [1].

After reviewing existing organization climate, Campbell [12] found that there are four factors in all studies, and put forward the four core dimension of organizational climate: (1) individual autonomy, which is the degree of employee retention decisions; (2) job structure, that means the organization set clear goals and working procedure for employees; (3) reward, which represents there are reasonable reward, promotion and training for employees in organization; (4) understanding, warmth and support, that's the degree of organization's caring for employees and colleagues' caring about others.

Taking the concept of organizational climate, Dastmalchian [6] outlined six dimensions of industrial relations climate, which are cooperation, trust, mutual regard, joint participation, apathy and hostility. In Dastmalchian's [1] empirical research about industrial relations climate, he confirmed five factors relating to industrial climate: harmony, openness, hostility, apathy and promptness. Later, Dastmalchian [13] took a further study and pointed out six dimensions: union-management cooperation, trust and fairness, mutual regard, joint participation, communication and union support. Taking union into account, the factors pointed out in studies above can't explain Chinese industrial relations issues. Besides there are many differences among all scholars about how to measure industrial relations climate and few researches about measuring industrial climate in Chinese context. Therefore this paper will present a study about how to measure industrial relations climate in China.

2 Study 1

The objective of Study 1 includes: (a) to generate a item pool gathered from previous theory and research, and (b) to examine the content validity of the items via expert panels.

1. Participants

The expert sample comprised 12 participants: 4 scholars, 4 human resource management practitioners and 4 labor inspectors.

Four academic experts who come from Chengdu University of Technology, Southwestern University of Finance and Economics, University of Macau and Sichuan University have doctoral degree either in Management or Economics Education. 4 human resource management practitioners have 3–5 years' human resource management work experience. Labor inspectors have 5–10 years' labor dispute handling experience. All experts' age ranged from 29 to 45. Among them, there were 5 males and 7 females.

2. Procedures

From a review of literature on industrial relations climate, quality of industrial climate and harmonious labor relations, we sort out 55 items. For developing a science and rigorous labor relations climate scale, and ensuring the validity and reliability of the scale, based on the literature study, we draw up an initial manager interview outline and one for staff. Then, after five discussion meetings and five times modification, the testing interview outline was composed. Guiding with testing interview outline, we interview 6 MBA students of Sichuan University Business School. Table 2 shows the information of them.

According to criticism proposed by the interviewers, the researchers conducted a modification of interview outline further, and formed the formal interview outline. Then, we took a semi-interview in 11 enterprises in High-tech District in Chengdu. And we interview 59 staff, including 30 managers and 29 employees. After transcoding interview record, we took independent triangular coding method for encoding. According to coding material, we figured out 108 items. Combing interview and literature, removing some items these can not be measured from psychological perspective , we keep 33 items, these 33 items formed the initial scale. To assess the content validity of the proposed items [14], the initial scale was sent to 12 experts who include scholars, human resource management practitioners and labor inspectors. The experts were then required to examine each item independently. Each item was asked whether it is, "representative" (Does it represent industrial relations climate?, "clear" (Is it easily understood?), and "specific" (Is it focused enough and not too general or ambiguous?). Experts present their opinion in terms of, "Yes", "No", or "Unsure". At last, they were asked to make any feedback or comments about modifying scale, and list suggestions for alterations [15]. Then the data was analyzed as following steps [15]: an item was retained if it was considered relevant, representative, clear and specific by at least 9 experts. For some item that only 7 experts think it was relevant, representative, clear and specific, it was modified until meet the requirements. Finally, we keep 25 items which formed pilot scale.

3. Results and Discussions

The findings from literature search and interviews with employees ($N = 29$) and managers ($N = 30$) who were top managers ($N = 10$), middle managers ($N = 12$)

Table 2 Descriptive information of pre-interview participants

Interviewee	Gender	Age	Ownership	WE[a]	Post	EoM[b]
1	Female	20–30	Institutions	4	Examiner	Employee
2	Female	–	Private enterprise	3	Sales manager	Manager
3	Female	–	Private enterprise	1	Clerk	Manager
4	Female	–	–	5	Sales man	Employee
5	Male	30	State-owned enterprises	10	Project designer	Employee
6	Male	–	Private enterprise	4	Designer	Manager

[a]Work experience (years)
[b]Employee or manager

and senior managers ($N = 8$) contributed to the generation of an item pool (55 items) that was conducted with clear and specific definition of the industrial relations. After transcoding interview record, we obtained 108 items from interview and 56 items from literature. After 3 meetings to discuss which item should be kept, we merger 31 items that appeared in both literature and interview and removed some items that can not be measured by psychological scale, we finally figured out 33 items that were highly related to industrial climate subjectively. The content validity of these items was assessed by experts in the field ($N = 12$). A number of items were eliminated (7 items) because they were lacking clarity, specificity, and representation. Among the remaining 25 items, there is a small number of items (5 items) needed consideration. And on the other hand, based upon the experts' suggestions, minor modifications were made for 6 items. As a result, the analytical process generated 25 items for industrial relations climate scale.

Based on organization climate theory, present study about industrial relations climate and our qualitative research in terms of interview, we figured out five factors which should involve in Chinese industrial relation climate scale, that is interactiveness, motivation, harmony, careness and fairness. In our research interactiveness is related to openness and communication in Dastmalchian's [1, 13] two study. It reflects the effect of the communication between organization and employees and degree of the openness of organization to employees. Motivation factor came from interview with employees and managers in our study, which means the motivation degree of material conditions and personal development opportunities to staff provided by organization. It's the most special one in Chinese industrial relations climate. Harmony means the extent of mutual aid, mutual trust and mutual understanding between employers and employees [1]. Fairness represents the degree that organization offers a fair and reasonable reward, promotion and training for all employees. Careness means the degree of organization's concerning for staff and colleagues caring among them [12].

3 Study 2

The objective of study 2 was to examine the reliability of the items derived from study 1. In study 2, 25 items were addressed to measure industrial climate and were administered to employees to examine the reliability of the items contained in the scale.

1. Participants

The employees ($N = 98$) who were working in private enterprise, state-owned enterprises and joint venture came from High-tech Zone in Sichuan province in China and comprised 39 males and 58 females. The average length of service is 4.32 years. Their education range from elementary to master.

2. Procedures

According to the principle of convenience sampling, scholars sent the pilot questionnaire to Labor Department's staff of High-tech Zone in Sichuan province, and

the questionnaire was sent to some companies within their jurisdictions by the Labor Department's staff. Then inspectors retrieved the questionnaires filled by employees and delivered them to scholars. So questionnaire recovery was assured. 110 questionnaires were handed out, the effective recovery is 98, and the recovery rate is 89 %. Besides, the employees who participated in pilot study were asked to indicate their thoughts about how to improve the questionnaire. Because 7-Point Likert scale has better reliability, construct validity, and discriminant validity than 2-, 3-, and 4-point scale. Therefore the response scale ranged from 1 = strongly disagree to 7 = strongly agree. Then we used SSPS 19.0 to examine the reliability of the items.
3. Data Analysis

We used SPSS 19.0 to examine internal reliability of the scale. Cronbach Index [16] was used to assess the internal reliability of the scale. Cronbach value more than 0.80 indicates good reliability.

Table 3 Reliability of pilot scale

Scale	Cronbach's alpha
Interactiveness	0.86
Motivation	0.91
Harmony	0.87
Careness	0.95
Fairness	0.51
Industrial relations climate	0.89

Table 4 Cronbach's Alpha if item deleted in pilot study

Item	Corrected item-total correlation	Cronbach's alpha if item deleted	Item	Corrected item-total correlation	Cronbach's alpha if item deleted
IRC1	0.67	0.88	IRC14	0.646	0.88
IRC2	0.623	0.88	IRC15	0.659	0.88
IRC3	0.582	0.881	IRC16	0.644	0.882
IRC4	0.64	0.88	IRC17	0.707	0.88
IRC5	0.494	0.883	IRC18	0.676	0.881
IRC6	0.539	0.882	IRC19	0.688	0.881
IRC7	0.646	0.88	IRC20	0.676	0.881
IRC8	0.643	0.88	IRC21	0.693	0.88
IRC9	0.606	0.881	IRC22	0.766	0.879
IRC10	0.661	0.88	IRC23	0.649	0.881
IRC11	0.547	0.883	IRC24	0.674	0.881
IRC12	0.647	0.881	IRC25	0.364	0.952
IRC13	0.563	0.882			

4. Results and Discussions

As Table 3 shows, the Cronbach's Alpha of interactiveness sub-scale, motivation sub-scale, harmony sub-scale and careness sub-scale are more than 0.80, which indicates that interactiveness sub-scale, motivation sub-scale, harmony sub-scale and careness sub-scale have a good reliability. For faireness sub-scale, we found that if item 25 was deleted, the Cronbach's Alpha would rise to 0.93, and if one of the others was deleted, the Cronbach's Alpha would drop down. As a result we removed item 25, the Cronbach's Alpha of whole scale rose to 0.95 (see Table 4). Finally we figured out 24 items to measure industrial relations climate.

4 Study 3

1. Participants

In study 3, there were 3159 (age = 16–65, M = 30, SD = 7.20) participants of 122 companies from High-tech Zone in Sichuan province. The companies were distributed in four sectors which were manufacturing, software services industry, pharmaceutical industry and service industry. 1924 participants belong to manufacturing, 205 of them came from software services industry, 730 of them were in pharmaceutical industry, and the others were from service industry. Among them, 1657 were male and 1429 were female. Participants focused on the following posts: technology, administration, sales and operation. And the average work experience is 4.3 years. Their education covers elementary, junior high, high school, undergraduate, master and doctoral. 42.7 % of them joined union and 55.8 % didn't do that.

2. Procedures

Study 3 was divided into three phases. Because it is the first time to do industrial relations climate research in over 100 enterprises, there is no experience for taking large-scale research. So in phase 1, scholars committed to exploring a method for large-scale research. From July 2 to July 7, scholars selected Shiyang, Xiaojiahe and Zhonghe Street which is near to town to conduct research first. After that, researchers explored a way that is "one researcher plus one labor inspector". Firstly, the inspectors called human resource manager, told them what is the research and the purpose of it, and got permission to entry their company to do the research. Then the scholar went to objective enterprise with an inspector whose role is leading researcher to company. After going in company, the scholar hand questionnaires to manager. The manager organized staff to complete questionnaires. During the time participants filled in the questionnaire, the researcher helped them to complete it, which guarantees the efficiency and quality of the research. The employees in objective firm take about one hour to fill in questionnaires. After they completed it all, researchers gave their appreciation for managers' coordinating and left with completed questionnaire. In phase 2, the main task is entering Hezuo Street which includes 74 research companies to carry out research. It was taken from July 8 to July 15. Phase 3 was taken place in July 17–August 1. During this period, researchers sorted questionnaires in order to acquire missing information of some participants and increase research enterprises to ensure the number of integral questionnaire. All data is collected anonymously. Thus authenticity of the data can be guaranteed. Then the data was analyzed using EQS. 6.1.

3. Data Analysis

To assess the adequacy of the model's confirmatory factor analysis (CFA) [17], we used EQS. 6.1 to examine it. We use indexes, like comparative fit index (CFI) [18], non-normed fit index (NNFI) [19], standardized root-mean-square of the residuals (SRMR) [20], and root-meansquare error of approximation (RMSEA) [20] and its 90 % confidence intervals (90 % CI), to assess model's fit. The CFI and NNFI values greater than .90 were considered acceptable for a good fit model [18]. SRMR and RMSEA values equal to or less than .08 indicated adequate model fit [20]. In addition, the lower bound value for 90 % CI of the RMSEA close to zero, and its upper bound less than .06 suggested a good fit to the model [21].

4. Results and Discussions

For the sample in study 3, the 24-item five factors model measuring industrial relations climate displayed an acceptable fit to the data: $CFI = 0.94$; $NNFI = 0.93$; $SRMR = 0.044$; $RMSEA = 0.06$ ($90\,\%\ CI = 0.058 - 0.063$). The factor loadings and error terms of items is shown in Table 5. Factor loadings of any items are more than 0.40 [22]. According to the result of confirmatory factor analysis, the industrial relations climate scale we developed turn out to be a good one, which could measure industrial relations climate appropriately.

Table 5 Standardized factor loadings, and error terms from the confirmatory factor analysis of the industrial relations climate scale in study 3

Item	Factor loadings	Error terms	Item	Factor loadings	Error terms
IRC1	0.75	0.67	IRC13	0.8	0.59
IRC2	0.78	0.62	IRC14	0.82	0.58
IRC3	0.78	0.63	IRC15	0.8	0.61
IRC4	0.71	0.71	IRC16	0.8	0.61
IRC5	0.72	0.7	IRC17	0.82	0.57
IRC6	0.86	0.52	IRC18	0.9	0.43
IRC7	0.86	0.52	IRC19	0.92	0.4
IRC8	0.85	0.52	IRC20	0.91	0.43
IRC9	0.75	0.67	IRC21	0.86	0.51
IRC10	0.8	0.61	IRC22	0.9	0.45
IRC11	0.66	0.75	IRC23	0.87	0.49
IRC12	0.77	0.64	IRC24	0.8	0.6

5 Discussion

Confined available conditions, the sample of this research all come from High-tech Zone in Sichuan Province. In the future, it is necessary to expand the sample to other provinces and other countries whose culture and industrial relations are similar to China. On the other hand, based on existing industrial relations climate scale, it is meaningful to compare industrial relations climate from cross-cultural perspective.

In this study, main research question is developing a scale about industrial relations climate, the relationships between industrial relations climate and other organizational variables were not investigated. As a contextual variable, industrial relations climate will have a influence on organizational outcome variables. Investigating the relationship between them will be a important research direction.

Dyadic and longitudinal research designs may be employed to examine the processes involved in industrial relations climate exchanges and also their links with other variables.

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Eco-Friendly Car Policy: Targeted and Spillover Effects

Chenxi Li, Xueming Luo, Yiping Song and Chee Wei Phang

Abstract To bolster the automobile industry while stemming environmental side-effects, governments worldwide have developed various institutional policies. In this study, we examine the effectiveness of an institutional policy-Tax-reduction for Low-emission Vehicles Policy-implemented in China automobile market. We find that the institutional policy has positive targeted effect on small-engine cars and negative spillover effect on big-engine cars. We also find the positive targeted effect was driven by sales in smaller cities, while the negative spillover effect was attributed to sales in larger metropolitan cities and occurred mostly for non-indigenous car brands.

Keywords Institutional policy · Automobile market · Targeted effect · Spillover effect

1 Introduction

Developments in the automobile industry can be either a boon or a bane. On one hand, they can spur economic growth and fuel employment (Miravete and Moral [14]). On the other hand, they can produce environmental pollution from greenhouse gas emissions [9]. This double-edged sword may be particularly sharp in developing countries such as China and India. In China, vehicular emission pollution is the main source of dust-haze (Vehicle Pollution Prevention Annual Report 2013 [16]).

Thus, to bolster the automobile industry while stemming environmental side-effects, governments worldwide have developed various institutional policies. For instance, in 2009 the U.S. implemented the “cash for clunkers” program, formally known as the Cars Allowance Rebate System. The program offered a rebate of

C. Li · Y. Song (✉) · C.W. Phang
School of Management, Fudan University, Shanghai 200433, People’s Republic of China
e-mail: ypsong@fudan.edu.cn

X. Luo
Fox School of Business, Temple University, Philadelphia 19122, USA

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3,500–4,500 USD for each old and low fuel-efficient vehicle that consumers traded in for a newer, more fuel-efficient one [10]. While intended to reduce pollution and stimulate sales of more fuel-efficient cars, the policy garnered doubts about its effectiveness. Mian and Sufi [13] found that purchases stimulated by the policy were offset by a dip in auto sales further down the road, and Knittel [10] found the program to be too costly for tax payers. Thus, for institutional economies to effectively achieve intended goals is a challenge.

To overcome this challenge, the present study evaluates the impact of an alternative institutional policy launched in China. The Chinese automobile industry plays a critical role in the global economy as the world's largest automobile producer and consumption market. However, the pollution caused in China by automobiles is enormous. To help curb this pollution, in 2009 China launched the Tax-reduction for Low-emission Vehicles (TLV) policy, which reduced the purchase tax for cars with small engines for two years, from 2009 through 2010 (In China, three categories of automobile taxes, including the consumption tax, the value-added tax and the purchase tax, are charged by the government. Among these three taxes, the purchase tax is the only tax paid by consumers directly, while the consumption tax and value-added tax will be paid by manufacturers and retailers respectively. TLV reduced the purchase tax of small-engine cars (1.6 liter and below) from 10 to 5 % in 2009. The policy continued implementing in 2010 with a little revision, the reduced tax rate changed to 7.5 %, from January to December 2010. After the two-year TLV policy period, the purchase tax rate for small-engine cars turned back to 10 % in 2011. The purchase tax for big-engine (>1.6-liter) cars is 10 % all the time.). The implementation of TLV was intended to bloom the market of small-engine cars, of which the market share dramatically decreased from 2004 to 2007. The proposal of TLV policy was passed on January 14th, 2009 and implemented on January 20th, 2009.

TLV differed from "cash for clunkers" in two key ways: first, in the "cash for clunkers" program the federal government provided a direct incentive via monetary subsidy (up to 4,500 USD) for every qualified replacement of old vehicles, implying a high pay-out for the policy-maker. As Tyrell and Dernbach [20] noting, the hard reality about programs that depend on direct public subsidies (such as "cash for clunkers") is that they are difficult to support over time. In contrast, the TLV operated by allowing consumers to pay a lower tax to the government if they purchased a small-engine car (i.e., 1.6-liter and below). Thus, a large initial fund allocation was not required for this program, which also means that it may be more financially feasible for developing countries. Second, TLV represented policy measures that attempted to influence consumers' choice and decision, i.e., on whether to buy a smaller-engine car to enjoy a tax reduction. This implies that all consumers who intended to buy a new car would be affected by the policy. In contrast, Busse et al. [3] proposed taht the "cash for clunkers" was only eligible for those who owned an old car that met the program criteria. Thus, in the context of a developing country in China, where most new car purchases are made by first-time buyers, TLV policy may have a larger impact.

Our identification hinges on the changes in car sales before, during, and after the TLV policy. In terms of environmental aspects, we assess the change in sales of more environmental-friendly cars with small-engines ($\leq$1.6-liter) vis-à-vis less environmental-friendly cars with big-engine ($>$1.6-liter). Our analyses reveal that the TLV produced three key results: (1) the policy indeed boosted sales of small-engine cars (a positive direct effect or targeted effect); interestingly, it also simultaneously dampened sales of big-engine cars (a negative spill-over effect or untargeted surprising effect). (2) Deeper analyses document that the positive direct effect of the TLV policy was driven by sales in smaller rural cities with slower economic and infrastructural developments. (3) The negative spillover effect of the TLV policy was attributed to sales in larger metropolitan cities with faster economic and infrastructural developments. The dip in sales occurred mostly for non-indigenous car brands, while indigenous car brands experienced increased sales.

Recently, research made by Parry et al. [19] has addressed how car policies may curb pollution or "automobile externalities". Varieties of car policies have been considered to limit automobile ownership, reduce automobile use, and promote more eco-friendly vehicles. Policies limiting ownership involve bidding and lottery mechanisms implemented in China [5, 8] (In the former (bidding-based mechanism), consumers who intend to purchase a car need to bid for a car license; in the latter (lottery-based mechanism), non-transferrable car licenses are allocated through random draws among registered participants.). Policies that reduce automobile use involve raising fuel taxes [2, 18] and prescribing the use of odd- or even-numbered car plates on the road in some cities such as Beijing [4]. Policies changing automobile use patterns involve charging higher toll fees during times and places when road systems are congested (to encourage people to travel during off-peak hours or via less congested areas). Such measures may reduce vehicular emissions because they help minimize trip durations and decrease speed variations (Daniel and Bekka [6]). Though effective to varying extents, these policies often achieve their environmental purposes at the expense of the automobile industry's development, i.e., by discouraging car purchases due to the high costs of purchase or usage. Some policies that promote eco-friendly vehicles specifically target automobile makers or consumers'cars. Examples include imposing requirements to meet vehicle manufacturing standards such as the Corporate Average Fuel Economy (CAFE) program in the U.S. and the system for controlling emissions of new vehicles in the E.U. Policies that target consumers include the "cash for clunkers" program to address environmental problems and stimulate the automobile industry [13] (As stated by the U.S. Secretary of Transportation Ray LaHood on July 27, 2009, "with this program, we are giving the auto industry a shot in the arm, and struggling consumers can get rid of their gas-guzzlers and buy a more reliable, fuel-efficient vehicle. This is good news for our economy, the environment, and consumers' pocketbooks".).

A series of studies have been conducted to assess the effectiveness of such programs with respect to either automobile manufacturers or consumers, with mixed results. For instance, such programs have been credited with "halo" sales of another quarter million cars (Maritz Research 2010 [12]). In addition, an NHTSA's (National Highway Traffic Safety Administration). Report to Congress indicated that

49 % of the cars sold under such a program were manufactured locally, thus creating over 60,000 jobs in automobile manufacturing and sales and related industries [20]. However, a more recent study by Mian and Sufi [13] suggests programs simply shift purchases forward. Fewer autos were bought in the ten months after the U.S. program expired in counties with a higher number of clunkers, thereby offsetting most of the initial purchases made. They also found no evidence of the program's effect on employment in cities with higher exposure to the program. A study by Miravete and Moral [14] on a comparable cash for clunkers program in Spain reached similar conclusions-that these programs may simply accelerate intentions to change cars. With respect to the program's intended environmental effects, most studies have provided affirmative evaluations. For instance, the NHTSA's Report to Congress estimated that the program will lead to a reduction of greenhouse gas emissions by 9 million metric tons over 25 years. Also by replacing older vehicles with new ones, the program may reduce the emissions of other criteria pollutants. Yet, prior research made by Knittel [10] and Li et al. [11] pointed out that the costs of attaining these environmental benefits could be staggeringly high.

We contribute to the literature by showing that an institutional car policy may be effective in several ways. At its fundamental level, the policy could indeed orient consumer purchases toward small-engine cars as intended, while at the same inhibit the purchases of big-engine cars not targeted. In addition, Muller et al. [15] pointed that automobile, which belongs to transportation or manufacturing industry, is indeed a large source of air pollution; our empirical evidence demonstrates the institutional policy could effectively reduce the air pollution by decreasing the purchase of large-engine cars in large metropolitan, which are the area with the most critical environment problems; on the other side, it could simultaneously increase the sales of small-engine cars in middles size and small size cities, where the environmental problem is gradually concerned, so as to pursue a long-term environmental improvement. Our results also show that environmental policies could garner local economic benefits by limiting the sales of big-engine cars of non-indigenous brands, while stimulating sales of indigenous car brands. In 2006, Djankov et al. [7] claim that the role of political institutions in fostering or restricting entrepreneurship is very vital. Our study expand their study by improving the effectiveness of institutional policy, that TLV policy helped indigenous car brands, especially for local entrepreneurs, who usually play a crucial role in the success of country's economic growth and innovation, fend off competition.

The rest of the paper is organized as follows. Section briefly overviews the automobile industry in China prior to the implementation of TLV. Section reports the data and empirical results. Finally, Section discusses the study's contributions and concludes with implications of the results.

2 Background

The automobile industry in China has undergone rapid developments since the 1978 reform and opening up policy. In 1980, the number of motor vehicles in China was only 1.8 million, but within 10 years the number grew to 5.1 million with an annual growth rate of 11.1 %. The period from 1990 to 1999 witnessed a relatively stable growth of motor vehicles in the country, with the number reaching 14.5 million in 1999 (a 10.2 % annual growth rate). More rapid growth subsequently followed from 2000 to 2009, with an annual growth rate of 14.5 %; by 2009, the number of motor vehicles in China had reached 62.1 million. As a developing country, the automobile industry has played a key role in China's economic development, contributing to 28.6 % of the nation's total GDP (based on reported statistics from 1978 to 2006) while also significantly supporting the developments of a wide range of other industrial segments, e.g., steel, manufacturing and service.

China has been actively cultivating the automobile industry during the past 30 years. In the early days, Chinese state-owned automobile manufacturers primarily focused on producing large commercial trucks, and only a limited number of passenger cars [1]. Starting from the early 1980s, joint venture partnerships with major global automobile manufacturers were approved to develop China's domestic production capabilities through technology and knowledge transfer. The 1994 implementation of the Automobile Industry Policy took a significant step in this direction. The policy allowed large global manufacturers to operate in China under a joint venture with their ownership restricted to no more than half. Major local participants in these joint ventures included Beijing-based First Automobile Works (FAW), the Shanghai Automotive Industry Corporation (SAIC), and Hubei-based Dongfeng Motors, which collectively were the so-called "big three". Riding on the strong economic growth in China at the start of the 2000s, automobile production picked up significantly, with new state-owned and private manufacturers (e.g., Geely, Chery, and BYD) entering the market. In 2004 the Automobile Industry Policy was updated with a greater emphasis on domestic research and development, as a key objective was to develop a few famous indigenous brands and globally competitive automobile groups (top 500) by Baker and Hyvonen [1]. Yet, given the extremely competitive automobile market in China, indigenous brands occupy only a small percentage of the market [17]

It is important to recognize that due to the wide disparity in the economic development across the country, China constitutes a multi-tiered socio-economic landscape. First-tier metro cities are the most developed with the best infrastructures and typically host larger populations, e.g., Beijing and Shanghai. In contrast, lower-tiered rural cities lag in infrastructural development, and have smaller populations with lower average income levels. Traditionally the sales of private cars had been concentrated in higher-tiered cities, but this trend is changing as economic growth now drives personal income. According to a Nielsen report (2013) [16], more car purchases are increasingly coming from lower-tiered cities, with 56 % of potential buyers first-time ones. Coupled with the estimation that the penetration rate of the auto market is only 5 % in China overall, there is still much potential for theautomobile market.

Concomitantly, the negative implications of automobile development such as environmental pollution has also become increasingly striking. In 2009, vehicular emissions such as nitrogen oxide and hydrocarbon accounted for over 25 % of national total emissions in China. In large cities such as Beijing, Shanghai, and Guangzhou, vehicular emissions have become a major source of air pollution [21]. It has also been noted that car emissions are the leading contributor of summer problems in Beijing [22]. Against this backdrop, the TLV policy was initiated and evaluated in terms of its effectiveness.

3 Empirical Analyses

3.1 Data

Our dataset contains the entire record of passenger car registrations in China. To study the impact of TLV, we focus on the registration records from July 2008 through June 2011, covering the policy implementation period and six months prior and six months after the policy implementation. During this three-year observation window, 24,574,631 cars were purchased and registered in China. The registration records contain the following information: time of purchase (month), brand, car model, engine type, the city in which the car was purchased and car buyer's demographic data. There are 67283 missing values of demographic variables (age and gender) in our data, which is about 1.13 % of total 59,623,20 observations. We replace them by mean values of car buyer's age/gender proportion in specific month group, city-tier group and price-tier group respectively. We also collected a number of variables as controls from the China Statistical Yearbook, including GDP, average amount of savings, unemployment rate, and population. These variables have been considered in other studies investigating car policy stimuli [13, 14], given that they may influence consumer decisions to purchase cars vis-à-vis the cost of car usage.

Table 1 presents the summary statistics of our dependent variables. Apart from the statistics of total car sales during the study period, we split the records into the sales of big-engine cars ($>$1.6-liter) and small-engine cars ($\leq$1.6-liter), and separated the statistics into three time periods (before, during, and after the policy period), and by different city tiers.

Comparisons of monthly average sales six months prior to, during, and six months after the policy (TLV) show significant differences in terms of the sales of all cars, big-engine cars, and small-engine cars (see Table 1): sales were significantly higher during the policy implementation period, with a 124 % increase in sales of small-engine cars, and only a 52.3 % increase for big-engine cars. Comparing with the increase of total car sales (91.2 %) from pre-policy period to policy period, it's reasonable to state that the sales of small-engine cars increased much more dramatically than those of big-engine cars in general. These provide initial model-free evidence for the impact of the TLV on car sales.

Table 1 Panel A: summary statistics of car sales during the study period

(Thousand)	Pre-policy		Policy		Post-policy		
	Mean	SE	Mean	SE	Mean	SE	P-Value
Monthly sales of automobiles	380.79	12.36	728.75	41	799.98	79.32	<0.0001
Monthly sales of automobiles with Emission $\leq$1.6 L	204.97	8.36	406.9	30.4	493.21	45.85	<0.0001
Monthly sales of automobiles with Emission >1.6 L	175.81	6.11	267.85	12.02	306.77	33.93	<0.0001

Table 2 Panel B: summary statistics on car data

	Mean	SD	MIN	5 %	95 %	Max
Policy	0.667	0.471	0	0	1	1
Post	0.167	0.373	0	0	1	1
Time	18.5	10.39	1	2	35	36
Consumption Rate	0.944	0.229	0	0	1	1
Scrapped	0.528	0.499	0	0	1	1
Truck	0.611	0.487	0	0	1	1
GDP	15.39	12.17	0.395	1.654	42.43	53.21
Saving	10.20	8.329	0.185	1.058	31.41	40.41
Unemployment Rate	3.668	0.498	1.37	2.6	4.27	4.57
Population	5.228	2.785	0.292	0.633	10.13	10.50
Price (ten thousand)	14.85	13.22	3.58	4.48	39.66	96.2

Besides, Table 2 presents the summary of car related variables of our study.

3.2 Empirical Analyses

We first examine the change in car sales with the following regression model:

$$\text{Sales}_{ijt} = \alpha_0 + \alpha_1 \text{Policy}_t + \alpha_2 \text{Post}_t + \Delta \text{ControlVars}_{it} + \Omega i + \varepsilon_{ijt}, \tag{1}$$

where i indicates the city, j indicates the car type, and t indicates the month. The dependent variable, Sales_{ijt}, is the natural logarithm of sales volume. As the data cover three periods, i.e., pre-policy, during-policy, and post-policy, we use two dummies, Policy_t and Post_t, to identify the periods respectively. Policy_t is equal to 1 if month t is during the implementation of the TLV policy and 0 if otherwise. Post_t is equal to 1 if month t is after the implementation of the TLV policy, and 0 if otherwise. Thus, when both Policy_t and Post_t are 0, month t should be before the policy implementation. As previously mentioned, we also control the macro-economic impacts, including time trend, regional GDP (100 billion in RMB), regional savings per household (1000 in RMB), unemployment rate (%), and regional population (10 million), as well as other policies which were being implemented during the observation period of our dataset. Time trend is an important control because it helps rule out alternative explanation of consumers' ability to purchase cars in rural lower-tier cities over time, beyond the income effects controlled for by other covariates. We separated the analyses into the total car sales, the sales of big-engine cars, and the sales of small-engine cars, and estimated the three models contemporarily by Seemingly Unrelated Regression (SUR) method. Table 3 presents the results.

As the results show, the TLV policy had a positive effect on total car sales in general. However, when we refine the analysis by car types, we see that the policy indeed has a positive effect on the sales of small-engine cars (direct effects as intended by the policy). Interestingly, this policy also has a negative effect on the sales of big-engine cars (a negative spill-over effect). These effects are robust to controlling for the trends of growing car sales in China (denoted by the time trend variable), other policies that were implemented during the study period (both of them, denoted by Scrappage and Trucks), and other variables that may influence car sales: regional GDP, regional savings per household, unemployment rate, and regional population.

The positive targeted effect is straightforward: the TLV policy decreased price of small-engine cars and raised sales consequently. And about the negative spillover effect, it might be caused by the substitution effect, especially for big-engine cars

Table 3 Detecting the effects of TLV

Dependent variable	Total car sales	Sales of small-engine cars	Sales of big-engine cars
Policy	0.0183*** (0.002)	0.0216*** (0.002)	−0.0037* (0.001)
Post	−0.1194*** (0.003)	−0.0811*** (0.003)	−0.0582*** (0.002)
Time	0.0102*** (0.000)	0.0077*** (0.000)	0.0035*** (0.000)
Consumption Tax	−0.0196*** (0.002)	−0.0096*** (0.002)	−0.0116*** (0.001)
Scrapped	−0.0034[a] (0.002)	−0.0078*** (0.002)	0.0001 (0.001)
Truck	−0.0124*** (0.002)	−0.0069*** (0.002)	−0.0084*** (0.002)
Macro covariates	Yes	Yes	Yes
Observations	5962320	5962320	5962320
R-square	0.029	0.017	0.014

Note Consumption tax indicates a change in the rate of consumption tax (in September 2008). Scrappage indicates a car scrappage policy (from June 2009 to December 2010); Trucks indicates a policy to promote light trucks and vans in villages (from March 2009 to December 2010)

[a]$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

with emission closer to 1.6 L, which is the cut point. Our additional study on more emission groups also provides an additional support to this explanation.

To gain deeper insights into these effects of the TLV policy, we segment the data analyses by city tiers in China (see the Appendix). As previously mentioned, China has different city-tiers with considerable variation in terms of development levels. First-tier cities consist of sixteen mega cities, including Beijing, Shanghai, and main provincial capital cities (e.g., Hangzhou, Nanjing, and Chengdu). These cities possess rich resources of economy, education, nature and have a relatively developed economy. The 154 cities in the second-tier are usually the capital cities of small provinces (e.g., Taiyuan, Fuzhou, and Guiyang) or important cities in medium-level provinces (e.g., Datong, Dalian, and Erdos). Most of the second-tier cities have their own pillar industries. Beyond the second-tier, China has cities that do not have well-developed economies. 194 cities belong to such third-tier in our dataset. To ensure the robustness of our study, we also checked the result of first-tier cities without Beijing and Shanghai, where have additional limitation for car plate application. Table 4 presents the regression analysis across the three city-tiers.

The results show that the intended positive effect of the TLV on the sales of small-engine cars actually occurred in the lower-tier cities (tiers 2 and 3), but not in the first-tier cities. In contrast, the negative spillover effect of the policy on the sales of big-engine cars occurred in higher-tier cities (tier 1), but not in the 2nd and 3rd tier cities at the bottom-end. As such, the direct, targeted positive main effects of promoting smaller engine cars are driven by sales in lower-tier cities, whereas the indirect, untargeted negative spill-over effects of limiting larger engine cars are driven by sales in higher-tier cities.

A possible explanation for the existence of positive targeted effect on smaller cities only is that citizens of smaller cities usually have a lower income and are more price-sensitive. By and large, the public transportation in smaller cities is comparatively inconvenient. Therefore, a lower price stimulates the sales of small-engine cars in smaller cities. In contrast, citizens of mega cities are of less price-sensitivity, which means the policy would not increase their willingness to buy small-engine cars to a great extent. And the public transportation in larger cities is more convenient, so citizens of larger cities might change the means of transportation to subway, bus and some other kinds of public transportation.

We next assess the policy effects across car brands. As show in Table 5, we find that the policy stimulated the sales of small-engine cars of both indigenous and non-indigenous brands but only reduced the sales of large-engine cars of non-indigenous brands. As such, this TLV policy actually favors the growth of indigenous car brands vis-à-vis non-indigenous counterparts, an interesting spillover effect not intended by the policy. The occurrence of negative spillover effect on non-indigenous brands is possibly caused by the fact that prices of non-indigenous brand automobiles are generally higher than indigenous brands. Consumers preferring to buy cars with non-indigenous brands might be influenced more by the TLV policy, and the substitution effect thereby occurs more on non-indigenous brands.

Table 4 The effects of TLV across city tiers

	1st city tier	1st city tier[a]	2nd city tier	3rd city tier
Panel A: sales of small-engine cars ≤ 1.6 liter				
Policy	−0.0085 (0.015)	−0.0103 (0.016)	0.0282*** (0.003)	0.0244*** (0.002)
Post	−0.2619*** (0.024)	−0.2231*** (0.025)	−0.1083*** (0.005)	−0.0330*** (0.003)
Time	0.0210*** (0.001)	0.0203*** (0.001)	0.0107*** (0.000)	0.0056*** (0.000)
Consumption Rate	−0.0340* (0.015)	−0.0328* (0.016)	−0.0153*** (0.003)	−0.0072*** (0.002)
Scrapped	−0.0210 (0.013)	−0.0142 (0.014)	−0.0115*** (0.003)	−0.0066*** (0.002)
Truck	−0.0171 (0.016)	−0.0179 (0.017)	−0.0113*** (0.003)	−0.0061** (0.002)
Macro covariates	Yes	Yes	Yes	Yes
Observations	262080	229320	2522520	3177720
R-squared	0.012	0.012	0.013	0.014
Panel B Sales of big-engine cars > 1.6 liter				
Policy	−0.0479*** (0.014)	−0.0392** (0.015)	0.0012 (0.003)	0.0021 (0.001)
Post	−0.1415*** (0.022)	−0.1098*** (0.023)	−0.0720*** (0.004)	−0.0289*** (0.002)
Time	0.0098*** (0.001)	0.0098*** (0.001)	0.0052*** (0.000)	0.0030*** (0.000)
Consumption rate	−0.0126 (0.014)	−0.0081 (0.015)	−0.0179*** (0.003)	−0.0103*** (0.001)
Scrapped	0.0087 (0.013)	0.0117 (0.013)	−0.0006 (0.002)	−0.0026* (0.001)
Truck	−0.0152 (0.015)	−0.0211 (0.015)	−0.0122*** (0.003)	−0.0081*** (0.001)
Macro covariates	Yes	Yes	Yes	Yes
Observations	262080	229320	2522520	3177720
R-squared	0.008	0.007	0.009	0.010

[a]Without Beijing and Shanghai

Table 5 The effects of TLV on indigenous brands and non-indigenous Brands

	Indigenous brands	Non-indigenous brands
Panel A: sales of small-engine cars $\leq$ *1.6 liter*		
Policy	0.0134*** (0.002)	0.0325*** (0.003)
Post	−0.0633*** (0.003)	−0.1029*** (0.005)
Time	0.0075*** (0.000)	0.0080*** (0.000)
Consumption rate	−0.0024 (0.002)	−0.0186*** (0.003)
Scrapped	0.0007 (0.002)	−0.0184*** (0.003)
Truck	−0.0032 (0.002)	−0.0116*** (0.003)
Macro covariates	Yes	Yes
Observations	3313128	2649192
R-squared	0.015	0.020
Panel B: sales of big-engine cars > 1.6 liter		
Policy	−0.0002 (0.001)	−0.0072* (0.003)
Post	−0.0174*** (0.002)	−0.1085*** (0.004)
Time	0.0010*** (0.000)	0.0067*** (0.000)
Consumption rate	0.0020 (0.001)	−0.0285*** (0.003)
Scrapped	0.0053*** (0.001)	−0.0063* (0.002)
Truck	−0.0035* (0.001)	−0.0146*** (0.003)
Macro covariates	Yes	Yes
Observations	3313128	2649192
R-squared	0.006	0.025

4 Concluding Remarks

The automobile industry may buttress a country's economic development, but may also threaten the environment. We demonstrate that a policy measure designed to influence consumer purchase of more environmental-friendly cars with a tax-cut incentive could furnish both environmental and economical benefits. Environmentally, such a policy could encourage ownership of low-emission, small-engine cars and discourage ownership of high-emission, big-engine cars. Economically, the policy could favor the growth of indigenous brands, which is desired in a developing country such as China that hopes to cultivate its own brands to decrease dependence on non-indigenous companies.

Leveraging the uniquely huge and diverse markets of China, we also show that the policy is beneficial for encouraging purchases of small-engine cars in lower-tier cities, which range from fairly well developed to poorly developed areas. Furthermore, such a policy acted more to discourage the purchases of big-engine cars in higher-tier, mega cities, where air pollution due to vehicular emissions is particularly severe (For instance, Beijing has become one of the cities with the most severe vehicular emission pollution. In Shanghai, although the amount of cars is only 1/12 of that in

Tokyo, the air pollutants due to vehicular emissions are about equal to that of the latter. In Guangzhou, vehicular emissions constitute 22 % of the pollution sources (the largest component), whereas the percentage even reaches 70 % in Shenzhen.).

The heterogeneous results across the different city-tiers highlights a caveat of the TLV policy - it turned out to be ineffective in inducing the purchases of small-engine cars in first-tier mega cities in China to pursue a long-term environmental improvement. While this does not negate the value of the policy given that it did reduce large-emission big-engine cars in the first-tier cities, it does mean that prudent policy-makers ought to ponder alternative policy designs if their objective is to promote a fleet of more environmentally-friendly cars in their forerunner cities.

This study is limited because it does not use any environment index to directly measure the impact of TLV on air pollution. However, environment is a long term goal, which is hard to quantify in couple of years, especially by focusing on only several years of data and limited influential factors. Based on the main finding of our paper, it's reasonable to claim that the TLV policy will consequently reduce environmental pollution, to some extent, as it limits car sales of big engine and lifts up sales of small engine in the same time period.

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Investigation into Logistics Outsourcing Supplier Selection for Automobile Manufacturers

Jiliang Liu

Abstract Automobile manufacturers generally pursue an automotive logistics outsourcing strategy on account of fierce competition across the automotive industry. Focusing on automakers' selection of automotive logistics outsourcing suppliers, this paper analyzes the characteristics of the logistics demand of an automaker by establishing a performance index system for an automotive logistics supplier as well as an evaluation model for the same supplier based on fuzzy AHP. A case study is also conducted as a beneficial reference for the automaker to select an appropriate logistics service provider.

Keywords Supplier selection · Logistics outsourcing · Automotive manufacturing · Index system · Multistage fuzzy comprehensive evaluation approach

1 Introduction

In recent years, China has witnessed very fast development of the automotive industry. As indicated by the statistics released by China Association of Automobile Manufacturers, automobile ownership in China had totaled 137 million by the end of 2013; In 2013, the accumulative production came to 22.1168 million with year-on-year growth of 14.76 %, while the sales is 21.9841 million with year-on-year growth of 13.87 %; and the growth rate of production and sales rose by 10.2 and 9.6 % respectively on a year-on-year basis.

However, the competition in the automotive industry is also increasingly fierce. A lot of Sino-foreign joint-venture brands, represented by Shanghai GM, and such Chinese brands as Chery and BYD are stepping up efforts in technological revolution and launching of new generations. In the background of fierce competition, automakers have been focusing more efforts to research and development

J. Liu (✉)
College of Preparatory Education, Southwest University for Nationalities, Chengdu 610041, People's Republic of China
e-mail: fenzz39@163.com

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and manufacturing while outsourcing automotive logistics service. Automotive logistics concerns logistics service with regard to raw material, auto parts, finished vehicles, aftermarket accessories and other links on the automotive supply chain, therefore functioning as a significant bridge on the same chain. As a strategic decision-making step of the automakers, automotive logistics outsourcing has occupied an important place in the industry chain. The selection of an appropriate logistics outsourcing service provider plays a particularly important role in securing unblocked value stream for the automotive industry and upgrading overall competitiveness for the automakers. For an automaker, such selection must take account of the function and utility of the logistics service provider in terms of the entire automotive chain while making the logistics service supply chain as cost-efficient as possible. Therefore, an investigation into the selection of automotive logistics service providers is of very high realistic significance.

The investigation into logistics supplier selection comprises primarily the evaluation index system research and the evaluation model research. Xiang et al. [1] derived such supplier selection indices as quality system, corporate performance, production capacity and corporate environment. Xu et al. [2] succeeded in designing five first-stage supplier indices, i.e. corporate qualities, management innovation capability, financial quality, R&D capability and development prospect. In all of the above researches, both the domestic and foreign scholars were of the same opinion that quality, delivery period and price constituted the most important indices for supplier selection. With the birth of the green supply chain management theory, Noci [3] advanced a green supplier evaluation system based on environmental quality factors in order for performance evaluation for suppliers' environmental protection efforts. Wang et al. [4] established a green supplier selection index system based on basic corporate qualities, environmental protection capability, innovation capability, cooperation capability and service capability.

There are many supplier evaluation models and they are featured primarily by the combination of quality evaluation and quantity evaluation. Huang et al. [5] adopted analytic hierarchy process (AHP) for multi-objective decision making (MODA) to establish a supplier selection model. Li et al. [6] proposed an approach to military product supplier selection based on a fuzzy AHP. Arpan [7] suggested that an integrated fuzzy AHP should be used to perform a discriminant analysis of group decision making (GDM) and fuzzy goal programming (FGP) as group decision support (GDS) for supplier selection. Wang et al. [8] combined rough set theory (RST) and AHP to introduce a new method to research into the selection of logistics service providers. Lin et al. [9] introduced a fuzzy evaluation model based on the combination of the TOPSIS method and AHP. The cost method is also a generally adopted supplier evaluation method. Cheng et al. [10] discussed how to use the EOQ model to select from multiple suppliers. Colin [11] took one step further in demonstrating the advantage of the EOQ model and quantity discount in reconciling the interests of the supplier with those of the purchaser. Multi-objective programming (MOP) can coordinate the conflicts during supplier selection. Xia et al. [12] established a multi-objective mixed integer programming (MOMIP) model targeting such objectives as supplier numbers and order quantity between suppliers. Birsen et al. [13] established a

MOP-based supplier selection model targeting such objectives as quality, cost and delivery reliability. In empirical system evaluation, input indices are not always independent of output indices; rather, there is a complicated correlation of influence and feedback. In Ref. [14], an AHP-DEA supplier selection model was established. Khoo et al. [15] suggested using an intelligent software agent for supplier selection. Cook et al. [16] suggested using a case analysis system for making purchasing decisions, in which the mass information accumulated over time can be employed to train system capability and select the proper supplier. Albino et al. [17] proposed a decision support system (DSS) based on the artificial neural network (ANN). Durson et al. [18] proposed a fuzzy-QFD supplier selection approach.

The author of this article proposed a selection model for automotive logistics outsourcing service providers which was based on the multistage fuzzy comprehensive evaluation approach. The index system of the automaker's logistics outsourcing service provider was studied to establish a multi-index evaluation model as a reference for automotive logistics outsourcing in practice.

2 Automaker Profile and Characteristics of Logistics Demand

In the paper, a giant state-owned Chinese automaker is assumed which diversifies widely into R&D, manufacturing and sale of automobiles. It is the holder of several independently-developed car brands and has a joint-venture with a certain foreign automaker. In terms of production and sales, the automaker leads on top of most other domestic counterparts. In 2013, the company produced 2.11 million automobiles and sold 2.12 million, respectively up by 21.1 and 20.7 % on a year-on-year basis and exceeding the national average indices.

However, the company's current logistics service deliverability is anticipated to fall short of its future logistics service demand, a fact evidenced by an insufficiency of its own transportation capability. In this regard, the main problem is that it doesn't have enough trailers and ro-ro ships to cater to the demand. Besides, the company doesn't have its own railway wagons. As a result of land requisition obstacles and backward layout of warehousing-dedicated land, there is a shortage of warehouses, prompting the spiraling cost of logistics. At present, the company is planning to outsource its automotive logistics, i.e. finished vehicle transportation and supply chain management for raw material and auto parts, to a third-party logistics service provider. According to the car manufacturer's strategic objectives, in cooperation with automobile manufacturers logistics companies have an important role in the supply chain, logistics companies have truckload, parts distribution expertise, and the ability to respond quickly to market, while to meet the growing business needs of automotive logistics.

3 Evaluation Index System for the Logistics Outsourcing Supplier

Evaluation index system selection is the key to successful evaluation; also, it's the crux of the problem. The establishment of an evaluation system is based primarily on the automaker's demand for logistics performance. Based on the foregoing discussion of logistics service demand, the author provided the following diagram of outsourcing supplier demand:

As shown in Table 1, the paper tried to establish an evaluation index system for logistics outsourcing supplier selection based on logistics demand characteristics, corporate development goal and four indices: financial performance, transportation performance, warehousing performance and customer performance.

Table 1 Logistics outsourcing supplier evaluation index system

First level index	Second level index	Description
Financial performance	Financing capability profitability solvency	Financial performance reflects the supplier is operating status. Financing capability reflects development potential. Profitability and solvency reflect operation performance and sustainable profitability
Transportation performance	Transportation cost control punctuality incident handling	The main service of the third-party logistics service provider represents fundamental performance. Cost control and punctuality reflect the quality of transportation management
Warehousing performance	Warehousing cost control inventory availability inventory damage control	Warehousing is an important link in the logistics chain. Cost control and damaged goods percentage reflect management quality. Availability reflects service quality
Customer performance	Customer satisfaction complaint response and handling response to market	Customer performance is the ultimate goal of service. Customer satisfaction is the most direct representation of customer performance. Complaint response and handling reflects the supplier's handling of market response

4 Multistage Fuzzy Comprehensive Evaluation of the Automotive Logistics Outsourcing Supplier

In the following paragraphs, the author adopted the multistage fuzzy comprehensive evaluation approach to establish the logistics outsourcing supplier evaluation model and conduct an evaluation of a certain potential logistics service provider. In fact, supplier selection may be based on cost analysis, AHP, data envelopment analysis (DEA), or grey relational analysis (GRA). However, there were a series of problems: the complexity of evaluation factors, the hierarchy of the evaluation object, the fuzziness of the evaluation standard, the fuzziness or uncertainty of evaluation influencing factors, and the difficulty with quantification of qualitative indices. The introduction of multistage fuzzy comprehensive evaluation, which combined qualitative analysis and quantitative analysis, not only considered the complexity and hierarchy of the evaluation object, but also the fuzziness of the evaluation indices; furthermore, the evaluator's knowledge and experience were incorporated in multistage fuzzy evaluation to fit in with the practical situation and make a more reliable evaluation (Fig. 1).

1. Set of evaluation factors.

The determination of the domains of discourse for the supplier evaluation factors must consider the automaker's logistics demand. Based on the demand analysis and evaluation in the foregoing paragraphs, a set (U) of supplier evaluation factors was created: $U = \{$financial performance, transportation performance, warehousing performance, customer performance$\}$.

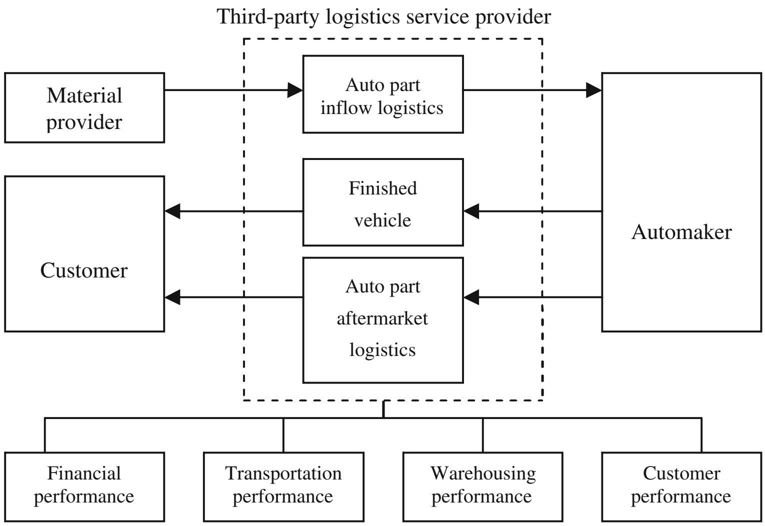

Fig. 1 Analysis of the demand for the logistics outsourcing supplier

2. Comments grade domain.

The set of the domains of discourse was expressed with V. According to the automaker's evaluation requirements, a four-stage set of the domains of discourse was created. $V = \{\text{very good, good, passable, bad}\}$.

3. The weights were determined for the factors in the first-stage indices and second-stage indices.

First of all, questionnaires were handed out to academics and senior executives of the automaker's logistics branch. 20 effective questionnaires were handed in. The data were sorted out as indicated in Tables 2, 3, 4, 5 and 6. Then, the random consistency ratio was worked out for the evaluation matrix (see Table 7).

Finally, judgment matrices were derived directly from Tables 2, 3, 4, 5 and 6. The eigenvectors corresponding to the maximum eigenvalues of the various judg-

Table 2 The academics' scores for first-stage indices

	Financial performance	Transportation performance	Warehousing performance	Customer performance
Financial performance	1	1/7	1/3	1/5
Transportation performance	7	1	5	3
Warehousing performance	3	1/5	1	1/3
Customer performance	5	1/2	3	1

Table 3 The academics' scores for second-stage indices in terms of logistics capability

	Financing capability	Profitability	Solvency
Financing capability	1	2	3
Profitability	1/2	1	3
Solvency	1/3	1/3	1

Table 4 The academics' scores for second-stage indices in terms of service quality

	Transportation cost control	Punctuality	Incident handling
Transportation cost control	1	2	1/5
Punctuality	1/2	1	1/5
Incident handling	5	5	1

Table 5 The academics' scores for second-stage indices in terms of pricing

	Warehousing cost control	Inventory availability	Inventory damage control
Warehousing cost control	1	1/9	1/5
Inventory availability	9	1	4
Inventory damage control	5	1/4	1

Table 6 The academics' scores for second-stage indices in terms of development potential

	Customer satisfaction	Complaint response and handling	Response to market
Customer satisfaction	1	3	5
Complaint response and handling	1/3	1	3
Response to market	1/5	1/3	1

Table 7 Random consistency ratio

	First stage index	Financial performance	Transportation performance	Warehousing performance	Customer performance
Random consistency ratio	0.075	0.046	0.046	0.061	0.033

ment matrixes were the weights of the variously-staged indices. The eigenvalues and eigenvectors could be worked out very easily with the Matlab built-in command ($[V, D] = eig(A)$). They could also be worked out using the so-called approximation algorithm (summation method or rooting method). The investigation showed that the error among the results of these algorithms didn't exceed 1 % and met the evaluation precision requirements. In Table 8, the rooting method was used to derive the results.

4. Single factor evaluation and establishment of fuzzy evaluation matrix (R).

The degree of membership of V was defined by proceeding from a factor. The first step was a statistical analysis through questionnaires aimed to obtain the supplier's scores of the indices (see Table 9).

The second step was to normalize each first-stage index based on Formula before calculation. The fuzzy evaluation matrices for second-stage indices (i.e. financial performance) were listed as follows:

$$R_1 = \begin{Bmatrix} 0.7 & 0.3 & 0 & 0 \\ 0.8 & 0.1 & 0.1 & 0 \\ 0.1 & 0.7 & 0.1 & 0.1 \end{Bmatrix}, R_2 = \begin{Bmatrix} 0.6 & 0.2 & 0.2 & 0 \\ 0.2 & 0.1 & 0.6 & 0.1 \\ 0.4 & 0.5 & 0 & 0.1 \end{Bmatrix},$$

$$R_3 = \begin{Bmatrix} 0 & 0.7 & 0.2 & 0 \\ 0.1 & 0.5 & 0.4 & 0 \\ 0.4 & 0.4 & 0.1 & 0.1 \end{Bmatrix}, R_4 = \begin{Bmatrix} 0.4 & 0.5 & 0.1 & 0 \\ 0.3 & 0.5 & 0.2 & 0 \\ 0.2 & 0.3 & 0.2 & 0.3 \end{Bmatrix}.$$

Finally, the single-factor fuzzy evaluation formula ($B_i = w_i \times R_i$) was worked out based on w_i (see the following):

$$B_1 = (0.6494, 0.2893, 0.0472, 0.0140), B_2 = (0.2944, 0.1642, 0.4592, 0.0822),$$
$$B_3 = (0.1633, 0.4889, 0.3186, 0.0291), B_4 = (0.3532, 0.4791, 0.0726, 0.0951).$$

Table 8 The weights of the variously staged indices

First-stage index	Weight of first-stage index	Second-stage index	Weight of second-stage index
Financial performance (W_1)	0.0535	Financing capability (W_{11})	0.5278
		Profitability (W_{12})	0.3325
		Solvency (W_{13})	0.1396
Transportation performance (W_2)	0.5484	Transportation cost control((W_{21}))	0.1779
		Punctuality (W_{22})	0.706
		Incident handling (W_{23})	0.1161
Warehousing performance (W_3)	0.1146	Warehousing cost control (W_{31})	0.0603
		Inventory availability (W_{32})	0.7085
		Inventory damage control (W_{33})	0.2311
Customer performance (W_4)	0.2835	Customer satisfaction (W_{41})	0.637
		Complaint response and handling (W_{42})	0.2583
		Response to market (W_{43})	0.1047

(5) Calculation of the overall fuzzy comprehensive evaluation. B_1, B_2, B_3 and B_4 were introduced as elements of a second-stage fuzzy evaluation matrix (R).

$$R = \begin{Bmatrix} 0.6494 & 0.2893 & 0.0472 & 0.0140 \\ 0.2944 & 0.1642 & 0.4592 & 0.0822 \\ 0.1633 & 0.4889 & 0.3186 & 0.0291 \\ 0.3532 & 0.4791 & 0.0726 & 0.0951 \end{Bmatrix}, W = (0.0535, 0.5484, 0.1146, 0.2835).$$

The weight (W) of the first-stage index is $W = (0.0535, 0.5484, 0.1146, 0.2835)$. The result of the final fuzzy comprehensive evaluation was derived as follows:

$$B = W \times R = (0.3150, 0.2974, 0.3114, 0.0761).$$

According to the maximum membership principle, the potential logistics service provider was evaluated as "very good", which signified that it fulfilled the general evaluation requirements of the automaker for logistics outsourcing suppliers in terms of performance in finance, transportation, warehousing and customer service.

Table 9 The academics' scores of indices for the supplier

First-stage index	Second-stage index	Very good	Good	Passable	Bad
Financial performance (W_1)	Financial performance (W_1)	7	3	0	0
	Profitability (W_{12})	8	1	1	0
	Solvency (W_{13})	1	7	1	1
Transportation performance (W_2)	Transportation cost control (W_{21})	6	2	2	0
	Punctuality (W_{22})	2	1	6	1
	Incident handling (W_{23})	4	5	0	1
Warehousing performance (W_3)	Warehousing cost control (W_{31})	0	7	2	1
	Inventory availability (W_{32})	1	5	4	0
	Inventory damage control (W_{33})	4	4	1	1
Customer performance (W_4)	Customer satisfaction (W_{41})	4	5	0	1
	Complaint response and handling (W_{42})	3	5	2	0
	Response to market (W_{43})	2	3	2	3

5 Conclusion

As fierce competition prompts automakers to outsource automotive logistics, the paper tried to address the selection of an appropriate logistics outsourcing supplier. The author cited an automaker's evaluation of its potential logistics outsourcing supplier to conduct an investigation into the supplier selection index system and the comprehensive evaluation model. By analyzing the characteristics of automotive logistics demand, the author studied and established an evaluation index system, which comprised four first-stage indices (financial performance, transportation performance, warehousing performance and customer performance) and twelve second-stage indices, as well as the supplier comprehensive evaluation model and cases based on multistage fuzzy comprehensive evaluation. This investigation is anticipated to be of use to Chinese automakers in logistics service supplier selection and core competitiveness improvement.

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Sustainable Lean Implementation: An Assessment Tool

Timo Schröders and Virgilio Cruz-Machado

Abstract The lean management philosophy is applied to improve the productivity and customer satisfaction of an organization. Besides the manufacturing sector, where it has been a standard for a long time, it was adopted by other sectors like service, administration, and research. Though lean implementations often fail or are not sustainable. Failure reasons and success factors are named based on literature reviews. Furthermore, business models and awarding prizes for lean approaches are described and analyzed. Based on this, an assessment tool is developed. It consists of 24 criteria that are divided in the 4 categories: leadership, culture, knowledge, and process. The category culture is subdivided in: improvement, empowering, and partnering. The rating of each criterion works by interviews on the management and supervisor level, and surveys on all levels of the company. To get an objective third-party feedback, external experts can be consulted. The highest possible score is 10 and the lowest possible 1. To improve the score of low rated criteria, different countermeasures for each criterion are named. By gathering the knowledge of different research and case studies, this tool can help companies to implement lean in a sustainable way. Still it has to be considered, that every lean approach is individual and the proposed countermeasures have to be used properly. This tool is not verified in practice yet and needs of further research are mentioned as well.

Keywords Lean · Implementation · Evaluation · Assessment tool

T. Schröders
Faculty of Mechanical Engineering, Ruhr University Bochum, 44793 Bochum, Germany

V. Cruz-Machado (✉)
Department of Mechanical and Industrial Engineering, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal
e-mail: vcm@fct.unl.pt

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1 Introduction

In the past decades, lean as a process management philosophy has gained popularity in the manufacturing sector, and became a standard in large scale enterprises. During the last years, Jørgensen et al. [16] proposed that the implementation of lean increased also in small and medium-sized companies (SMEs), and the philosophy was adopted by other sectors like service, administration, and research. Bhasin [3] and Scherrer-Rathje et al. [25] discussed the goal of lean is to satisfy the customer through on time delivery and high quality products by focusing on identifying and eliminating waste throughout a product's entire value stream (including the company's supply chain network). Womack and Jones [30] defined waste as any human activity that absorbs resources but creates no value. Ohno [22] identified seven types of waste: defect, overproduction, transportation, unnecessary motion, waiting, inventory, and inappropriate processing. Later, Liker [19] added an eighth type of waste: unused employee creativity. Environmental waste is considered the ninth. Vinodh et al. [29] proposed that it embodies unnecessary or excessive usage of resources, as well as substances released to air, water or land, that could harm human health or environment.

Bhasin [3] proposed that the benefits of a lean state in a company are: shorter cycle times, shorter lead times, lower work in progress (WIP), faster response time, lower cost, greater production flexibility, higher quality, better customer service, higher revenue, higher throughput and increased profit. Scherrer-Rathje et al. [25] discussed that this is achieved through implementing a set of tools and techniques, e.g. kaizen (i.e. continuous improvement), six sigma quality, visual displays, kanban, and just-in-time supply systems. Vinodh et al. [29] and Jackson [15] proposed that a detailed description of the lean tools is provided in further literature.

Though lean is being studied extensively for more than 30 years, companies still face difficulties in the implementation of lean in a sustainable way. Scherrer-Rathje et al. [25], Liker and Rother [19], Miina [21] and Schlichting [26] discussed that question why lean implementations fail is discussed in literature. This paper focuses on finding a solution for these problems through developing an assessment tool. This tool includes countermeasures based on literature and the combination of different business models, tools/techniques and award systems.

2 Literature Review

The main problem of lean is that its implementation often fails or is not sustainable. As Bhasin and Burcher [4] state, just about 10 % of companies succeed at the implementation of lean practices. According to Pay [23] only 2 % of companies in the U.S. that have a lean program, achieved their anticipated results. Liker and Rother [19] said that even many past winners of the Shingo Prize (SP), an award for excellence in lean manufacturing, were not able to sustain their progress after winning the award.

This leads to the question why lean implementation fails or is not sustainable. Schlichting [26] for example names 7 categories of failure reasons: missing management support, lack of employee involvement, lack of customer focus, operational stability, lack of money, use of wrong tools and rapid lean conversion. Shortcomings in employee involvement and the lack of operational stability, which includes demand leveling and standard work, are regularly named as major reasons for lean implementation failures. Schlichting [26] said that experts also mention, that missing management support and a rapid lean conversion without a long-term strategy, are often responsible for problems during the lean approach. There is a lot of literature addressing this problem and offering possible solutions. Several success factors of a lean approach are mentioned in case studies and assessments. Furthermore, institutions developed business models to help companies during the implementation of lean.

2.1 Success Factors

According to Miina [21] and Liker [19] and Ohno [22] , the implementing of lean principles has to be continuous, involve multiple cycles of improvement, and can not be seen as a temporary and immediate working tool to fix problems. Consequently, the approach has to be planned step by step and every company has to have a clear vision and target about the implementation process. Liker and Rother [19] mentions that leaders have to develop people progressively by coaching them to reach a lean state.

Companies have to focus on certain steps of lean implementation process more than on others. Miina [21] proposed that these steps are named as critical success factors. Achanga et al. [1] mentioned 4 main critical success factors for a lean approach: leadership and management, finance, skills and expertise, and culture of the organization. The result of the lean implementation depends to 50 % on leadership, 30 % on finance, 10 % on organization and culture, and also 10 % on skill and expertise.

In a case study Scherrer-Rathje et al. [25] named 6 success factors for a lean approach which broadly match Schlichtings failure reasons: visible management commitment, autonomy of employees, openly disclose mid-to long-term lean goals, mechanisms for long-term sustainability of lean, communicate lean from the outset, and continual evaluation during the lean effort.

Hilton and Sohal [12] focued on success factors of lean itself and not on factors of process of implementation. Their detailed list of success factors contains: leadership, communication, behavior and awareness of Six Sigma; policies, culture and organizational support and strategy; education, training and competency of the Six Sigma experts; project improvement teams and project management; and performance evaluations based on quality criteria, information systems, data and measurement.

Beside the different success factors, there are business models that are developed to help organizations to improve their performance.

2.2 Business Models

Since most companies struggle with the implementation of lean programs, there is an increased demand for models that assist organizations to improve their performance. Most of these business models refer to the total quality management (TQM) approach, which embraces social and technical dimensions to achieve excellent results. The ideas of lean and TQM overlap in many areas and both approaches can assist each other. Duarte and Cruz-Machado [10] proposed that to facilitate the implementation of these business models, several of them are converted in awards, standards, and frameworks to analyze and assist companies during their journey to excellence. This paper focuses on the Awards. Duarte and Cruz-Machado [6] said further information about the other models can be found in literature.

Awards such as the Deming Prize (DP, in Japan), Malcolm Baldrige National Quality Award (MBNQA, in the USA), European Foundation for Quality Management-Model (EFQM-Model, in Europe), Shingo Prize (SP) and the International Standard ISO 9001 are frequently applied quality management models. While DP, MBNQA, EFQM and the ISO 9001 are based on TQM, Torielli et al. [28] proposed that the SP is designed to assess organizational lean management approaches.

Awards

In order to assess the improvement of organizations, professional institutions have developed awarding prizes to acknowledge the best practices. These prizes are based on models that provide guidelines and can be used for self-assessment during lean approaches and others. The most common models or awards worldwide are [27]:

(1) The DP, established in 1951 by the Union of Japanese Scientists and Engineers (JUSE).
(2) The MBNQA by the National Institute of Standards and Technology (USA), established in 1987.
(3) EFQM-Model, founded in 1991 as a counterpart of the MBNQA in Western Europe.
(4) The SP, established specifically for lean approaches in 1988.

Kumar [17] said that the assessment criteria differ by model: The DP for example focuses mainly on "core quality systems", while the other models focus on performance results. Duarte and Cruz-Machado [10] discussed that a detailed comparison of all models can be found in literature.

Since the EFQM-Model covers the most topics with its criteria of all TQM based awards, and the SP is especially designed for lean approaches, both models were chosen to be the basis for the tool developed in this project.

3 Assessment Tool

The objective of this paper is to develop an assessment tool that helps a company to implement lean in a sustainable way. This tool is based on the reviewed success factors, business models, and further literature. As illustrated in Table 1, the tool consists of 24 criteria which are divided in 4 categories: leadership, culture, knowledge, and process. Culture is subdivided in the subcategories: improvement, empowering, and partnering. Each criteria can be rated on a scale from 1 to 10 (10 being the highest possible score). This rating works by interviews on the management and supervisor level and surveys on all levels of the company. Additionally, external experts can be consulted for an objective third-party feedback. Furthermore, there are different countermeasures for each criterion, which can be applied if its rating is low.

Table 1 Assessment tool—Leadership

Criteria	Countermeasures
Business plans providing resources, encouragement and time for improvement	- Analyze the whole company with its stakeholders, strategic objectives, business processes and methods
	- Hoshin kanri
	- Develop lean house (how to implement lean in the company)
	- Lean accounting (focused on cost reduction)
Visible management commitment, participation and financial support	- (Weekly) management walks on floor level
	- Participation in strategic meetings
	- Include funding in business plan
Communication of the companies visions and values	- Regular info/team meetings
	- Info booklets/posters
Communication and measurement of improvement	- Pilot projects
	- Regular reviews
	- Present improvements at meetings/on posters/in newsletters
Philosophy that encourages and recognizes innovations and improvement	- Improvement culture
Employee involvement in lean approach	- Visual management (info/production boards)
	- Kaizen events
	- Job rotation ("cross-trained operator")

3.1 Leadership

The category leadership includes 6 criteria:

1. Business plans providing resources, encouragement, and time for improvement
For a successful and sustainable lean approach, it is essential that the company has clear visions and an elaborated long-term strategy. Beside the goal of every step, it has to be clear how to reach it. Resources (human, financial, and material), encouragement of employees, and enough time for improvement are important factors in the strategy. To achieve a high rating in this criterion, managers have to analyze the whole company with it stakeholders, strategic objectives, business processes, and methods. The score can be increased by the application of hoshin kanri, a method devised to capture and cement strategic goals. further information can be found in literature of Jackson [15]. By developing a lean house, the company can interpret their individual philosophy of lean in an own production system model. This concept is based on the theory that every company has its own understanding of lean and should focus on its own production philosophy. Miina [21] told that a detailed description of the lean house is available in literature. Another approach is the implementation of lean accounting where the focus lies on cost reduction, while standard accounting focuses on cost maintenance. Schlichting [26] defined that a lean accounting approach offers data that enables managers to create targets on the base of eliminating costs and track target achievement.

2. Visible management commitment, participation, and financial support
Visible and active management commitment is crucial for the success of a lean implementation. Scherrer-Rathje et al. [25] discussed that a lack of commitment may lead to a set of other issues like limited access to resources, lengthy decision-making processes, and communication breakdowns. Also, employees may not realize the importance of lean, and participating sufficiently. The importance of financial support is evident, since every change, especially an extensive one like a lean approach, is related to investments that will take some time to pay off. By weekly walks on the floor level (frequency can be reduced after lean is implemented), including conversation with the employees, the management can show their commitment and enhance the internal communication. The participation in strategic meetings is crucial to obtain information about all processes in the company and to show the importance of the approach. To ensure enough financial resources, the funding of the lean approach has to be appropriate and included in the business plan.

3. Communication of the company's visions and values
It is important that every employee of the company understands its visions and values, and identifies himself with them. It leads to an higher motivation, and changes in a process can be understood and accepted easier. In the absence of this understanding, workers could fall back to their old ways after changes, and the lean approach will not be sustainable. This can be counteracted by regular info and team meetings in

small groups, including all employees. Furthermore, the distribution or installation of info booklets and posters can improve the communication of a company's ideals.

4. Communication and measurement of improvement
The communication of lean benefits is important to motivate the employees and indorse the management in the lean approach. It is a crucial factor to convince everyone in the company that lean is the right choice, and to make sure that employees keep the new processes and do not fall back to old patterns. One way to measure and communicate the improvement trough lean, is to implement a pilot project in a small area of the company. Scherrer-Rathje et al. [25] said that the benefits can be shown very quickly, facilitating the implementation of lean in other areas. Another way to communicate the improvement, is to measure it by data in regular reviews (e.g. productivity of workspaces before and after the implementation, cost reduction, etc.) and present it at team meetings or on posters in the company. E-mail newsletters that communicate the improvement can also be applied.

5. Philosophy that encourages and recognizes innovations and improvement
An important aspect of lean is that it includes all employees. Dombrowski and Mielke [7] discussed that everyone should try to improve the process they are dealing with, since they might have the best impression of its weaknesses and failures. An improvement culture is crucial to make sure the employees feel free to develop ideas and innovations. It is based on a different understanding of failure: every failure shows possibilities for improvement and learning. The goal is to find the root cause of the failure and to make sure, it will not occur again. Furthermore, the employees need support from the management in order to maintain improvement activities at all levels and in all processes. Supervisors or Managers have to pick up the ideas and help to apply them in practice. To ensure the recognition of innovations and ideas, a recognition and reward system (see 3.2.1 in 3.2 Recognition and reward system) has to be installed.

6. Employee involvement in lean approach
The involvement of employees is a crucial factor for the success of a lean implementation. Schlichting [26] said that a lean conversion can not be implemented in a top-down manner and managers have to recognize the knowledge of their employees, and accept their input in problem solution processes. It keeps the workers motivated and enhances their contribution to the lean approach. Improvement will only be sustained, if the operators understand the reasons behind it and this can only be achieved by involving them early in the process. To improve the employee involvement, information about the lean conversion have to be made visual to the workers. Trough so called visual management, the operators will be enabled to identify and understand problems on the floor level and therefore feel the need to improve. It includes info boards with daily data, which help the employees understand the situation on the shop floor, and production boards, which shows the productivity per cell/unit and make the production numbers transparent to everybody. Additionally, kaizen events can be arranged. In these events, the operators, managers, and owners of a process come together, map the existing process, and improve it with buy-in from all parties

related to the process. Further information can be found in literature of Schlichting [26] and Jackson [15]. Trough job rotation, operators will be promoted to be "cross-trained" to work in more than one cell/process. Allwood and Lee [2] mentioned that employees will increase their knowledge and feel focused, involved, and motivated through job rotation. They will give up their daily routines which can improve their problem solving skills trough their increased involvement in the daily production problems.

Table 2 Assessment tool—Culture

	Criteria	Countermeasures
Improvement	Continuous improvement	- Kaizen and PDCA (plan-do-check-act system)
		- Systematic measurement of quality and non-quality costs
		- Use of benchmarking techniques to establish improvement standards
	Self-assessment	- Regular resumes and assessments of all processes
		- Implement self-controlling interdisciplinary teams
	Long term oriantation	- Hoshin kanri
		- Use short term measurement to support long term development
Empowering	Suggestion system	- Regular surveys
		- Suggestion meetings
		- Forms for suggestions (+ mailbox)
	Recognition and reward system	- Assessment of work processes (by shifts or workplace)
		- View the results on posters
		- Bonus system
	Formal teams (with autonomy)	- Meetings of interdisciplinary teams with autonomy to make decisions
		- Put up "decision rooms" (for team meetings)
	Employees at all levels meet with customers	- Events to connect staff with customers
Partnering	Company and suppliers or customers focus on improvement	- Regular meetings focused on improvement of interdisciplinary teams (suppliers/customers and staff)
		- Establish quality agreements
	Community, in terms of cooperative improvements	- Build up a network of different companies (competitors, companies in comparable sectors)
		- Exchange of information
		- Assessment of practices and results
		- Comparing results and discuss practices

3.2 Culture

The category culture is divided in the subcategories: improvement, empowering, and partnering. It includes 9 criteria in total (Table 2):

3.2.1 Improvement

(1) Continuous improvement
The concept of continuous improvement is crucial to keep a lean conversion sustainable and is mentioned as being the most important step in a lean journey by Miina [21] . It takes place in cycles, where a organization never stops to question its processes. A basic part of continuous improvement is to make the need for improvement visible, so it will be made with full conviction, to ensure it will take its full effect and be sustainable. Kaizen can be used to systematically detect and eliminate waste according to the Plan-Do-Check-Act-cycle (PDCA). There are different Kaizen activities, for example, value stream design, continuous improvement process workshops, periodic meetings, process reengineering, 5xWhy, or daily short stand-up meetings. A more detailed description can be found in literature of Jackson [15]. By measuring quality and non-quality cost systematically, needs for improvement can be illustrated and eliminated by using the PDCA. The use of benchmarking techniques helps to establish new improvement standards. By comparing processes, standards, or even organizations, Miina [21] proposed that improvement benefits can be made visible and they can be adopted to create new improvement standards.

(2) Self-assessment
As mentioned before, a company has to improve continuously to achieve a lean state. Self-assessments and reviewing all processes in the organization is crucial. Only by doing it regularly, mistakes or non effective processes can be eliminated and the quality of the work kept high. Scherrer-Rathje et al. [25] discussed that the implementation of self-controlling interdisciplinary teams gives a wide view from different perspectives on a process, and ensures that mistakes are found and handled in a proper way.

(3) Long term orientation
The management has to think in long term and devolve this type of thinking to the whole company. A lean approach does not always pay off financially in a short time, because every change is carried by investments. The productivity can also decrease on the short run, since the employees have to get used to the new standards. But, if an organization manages to keep lean sustainable and does not stop to believe in it, it will benefit from it on the long run. This has to be included in calculation and business plans, and everyone in the company has to be aware of it.

3.2.2 Empowering

(1)Suggestion system
To encourage the employees to be an active element in the lean conversion, and present suggestions, it has to be sure that these suggestions will be heard. If they are, the processes will be improved and the motivation of the workers will be higher, since they will feel as an important part of the company. Therefore, a suggestion system has to be established. This can be achieved by regular surveys, regarding improvement of processes, and meetings, where every employee can present his ideas and suggestions to his superior. Furthermore, there should be suggestion forms available at every workstation and a mailbox that is cleared and suggestions taken in consideration at least once a week.

(2) Recognition and reward system
Beside suggestions, good work has to be reconditioned and rewarded. In this way the employees keep their motivation and the productivity can be improved. The first step is to assess and compare the work processes, for example, by shift or workstation. The results should be presented on posters at the shop floor, to make them visible for everyone, so as to increase the motivation of each employee. A bonus system should be installed to reward good work. Losonci et al. [20] proposed that the employees of the most productive shift of a month/year can be, for example, invited to a diner or an extracurricular activity. Or each worker of the shift receives a bonus. Through this, a positive competition will be initiated, teambuilding will be supported, and the productivity of each shift or workplace will increase.

(3) Formal teams (with autonomy)
To ensure a fast decision making process, formal and interdisciplinary teams with autonomy to decide (without the need to ask a superior) should be installed. By regular meetings of these interdisciplinary teams, the problems in processes can be assessed with different points of view. Afterwards, the best solution can be found and directly implemented, without waiting days or weeks for the permission of a superior or the management. This is the most effective way to solve problems and increase the productivity. To encourage this process, “decision rooms” for these meetings can be put up.

(4) Employees at all levels meet with customers
Lean focuses on the customer. To enable this, a company has to know the customer and their needs in detail. Beside the management, which is usually in contact with the customers, every employee should meet the customers if possible. Events to connect the staff with customers can be arranged or different employees can be sent to fairs. This ensures that the workers know the needs of the customers and can use this knowledge to improve processes.

3.2.3 Partnering

(1) Company and suppliers/customers focus on improvement
To achieve a high productivity, a company has to work together with its suppliers and customers. As mentioned before, the needs of the customer have to be known by the company. In the same way the supplier needs to know the needs of the company. By cooperation, focused on improvement, the efficiency can be increased on both or all three sides. Regular meetings of interdisciplinary teams (of both or all three parties) ensure the exchange of knowledge and increase communication. Even special topics and problems can be discussed since the teams are interdisciplinary and know the subject matter. Based on these meetings, quality agreements should be established to ensure that the outcomes will be sustainable.

(2) Community, in terms of cooperative improvements
Knowledge is one of the most important factors to achieve improvement. By sharing information, practices, and experience with other companies that have similar processes, problems and mistakes that occur on the way to improvement can be avoided. Therefore, it is helpful to build up a community, for example, with competitors or companies in comparable sectors and exchange information and knowledge with them. To find the best method, the different practices and their results should be assessed, compared, and discussed.

3.3 Knowledge

The category knowledge includes 4 criteria (Table 3):

1. Skill of management
The management and its skill is crucial for a lean approach. It has to lead and motivate all employees. Dombrowski and Mielke [8] mentioned lean leadership as a way to make a lean implementation sustainable. For achieving this, the managers have to develop themselves over years and have a deep knowledge about the whole company with all of its processes. To get the skills necessary for becoming a good leader, managers can participate in workshops and trainings. Furthermore, self-improvement can be achieved by self-reflection and literature study.

2. Knowledge of and experiences with lean practices
A deep knowledge about lean and experiences with lean practices on the management level, are obligatory for a sustainable lean approach. It is necessary to make the right decisions at the right time, and choose the suitable tools. If the knowledge or experiences is not given, external experts can be hired to assist during the lean approach. Taking into consideration that this help is temporary, managers have to participate in workshops and trainings to improve in this field. Additionally, lean literature should be studied and applied in consultation with the external experts.

3. Skill of workforce/Training and improvement
Beside the management, also all employees of the company need to have the necessary skills to implement lean and apply the lean tools. The skill of workforce is another crucial factor, beside their motivation and understanding of the lean effort and its benefits. Even if the workers want to apply the changes of the lean program, it will not be sustainable if they do not have the necessary knowledge and capabilities. The employees are expected to conduct the lean program, for example, by the use of problem-solving skills, which requires long-term employee development. This can only be achieved through daily development by coaching, and as far as possible, every employee should be developed at its individual level. Dombrowski and Mielke [8] showed that these trainings should take place in short cycles based on PDCA. Workers should be encouraged to learn from each other. This can be accomplished by monthly communication meetings with workers from the same workplace or overlapping shifts, where workers can exchange their knowledge and practical experiences at a workstation. The development of employees is a never ending process, and the trainings have to be continuous as well. Knowledge and skills should be regularly reviewed to assess improvement and identify the training topic in need. A small leader-to-employee ratio ensures that every worker will be developed in a proper manner, because the leaders can pay attention to each single employee. Dombrowski and Mielke [8] recommend a ratio of 1:5 at operational level, while it can be up to 1:10 at higher levels.

3.4 Process

The category process includes 5 criteria (Table 4):

1. Systematic identification and elimination of all types of waste

Table 3 Assessment tool—Knowledge

Criteria	Countermeasures
Skill of managagement	- Deep knowledge about all company processes
	- Trainings and workshops
	- Self-improvement (literature)
Knowledge of and experiences with lean practices	- External experts
	- Trainings and workshops
	- Self-improvement (literature)
Skill of workforce	- Specific quality trainings and workshops (in short cycles)
	- Encourage employees to learn from each other
Training and improvement	- Review of knowledge and skills
	- Small leader-to-employee ratio

Table 4 Assessment tool—Process

Criteria	Countermeasures
Systematic identification and elimination of all types of waste	- Comprehensive documentation about work methods and organizational processes
	- Quality manuals and organizational processes are periodically revised
	- Systems of indicators are in place to revise changes in processes
Standardization of processes	- Meetings with workers to find the best process
	- Training/poster of the standardized processes
	- Check if the standardized process is applied
Cellular process arrangement and improvement	- Analysis of workflow and workplace disposal
Just-in-time (JIT)	- Fast, continuous and steady flow of information across all value streams
	- Pull system (customer orientation)
	- Simultaneous engineering
	- Quick changeover
Automation (Jidoka) and multiprocess handling	- Analysis of processes focused on opportunities for automation
	- In-station quality control
	- Andon line

As mentioned before, the nine types of waste are: over production, unnecessary stock, inefficient transportation, unnecessary motion, waiting times, rejects & defects, inappropriate processing. The basic idea behind lean is to eliminate all of them. Therefore, they have to be identified systematically in a process. Bou-Llusar et al. [5] said that all work methods and organizational processes have to be comprehensively documented and verified. Furthermore, all quality manuals and organizational processes have to be periodically revised, to keep the processes at its highest level. If a waste is identified, there have to be changes made in the process. These changes can be suggested by employees, found in literature, or developed in special meetings. After this changes are implemented by teaching the employees and placement of manuals at the workstations, they have to be made sustainable and reviewed regularly. A system of indicators should be installed to check if unwanted changes are made in a process.

2. Standardization of processes

Duarte and Cruz-Machado [10] said that the standardization of processes is one of the basics of lean and represents control of the process, constructing the process as simply as possible. It reduces improvisation or ineffective actions, makes work easier, and provides security. Dombrowski and Zahn [9] said that "standardization in the context of working standards means that specific methods (e.g. construction methods) have to be standardized, coordinated with suppliers, and be state of the art". To define standards, the best possible process has to be found. This can be made in meetings with workers, since they know their workplace and the process best. The implementation of new standards can be conducted by training the affected employees, and installation of posters of the standardized process to ensure it stays in the mind of the workers. Moreover, there should be reviews to check if the standardized process is applied.

3. Cellular process arrangement and improvement
Cellular manufacturing is a workplace design model, which takes advantage of the similarity between parts or processes. Similar machines are placed close together or machines are grouped together, according to the similarity of the parts produced. Bhasin and Burcher [4] discussed that Processes are more robust to machine breakdowns, the material flow improves (reduce of transport, waiting and process times), and lead times are reduced. To be able to implement a cellular process arrangement and improvement, Irani [14] proposed that the workflow has to be analyzed first. After this, the workplaces can be organized according to cellular manufacturing principles which can be found in literature.

4. Just-in-time (JIT)
JIT is one of the two pillars of the Toyota Production System (TPS), which is the system lean management is based on. Cruz [6] said that it reduces the inner waste of resources with the smallest investment achieving the biggest output. Santos [24] proposed that its main objective is to produce the required number at the moment the customer orders it (customer orientation). According to Haak [11], JIT means, the parts needed reach the next processes step at the time they are needed in a flow process. Furthermore, it is mentioned that a company which established this flow throughout can approach zero inventory. It is obligatory to have a fast, continuous and steady flow of information across all value streams, to be able to deliver the right item at the right time. A pull system helps to deliver only what the internal customer orders, by scheduling each step in the development process, and dividing the whole process into uniform working phases. Another method is simultaneous engineering (SE), where fixed contact persons in every department are responsible to ensure the parallelization of tasks. Dombrowski and Zahn [9] discussed that detailed information about the different methods can be found in literature. Quick changeover is a concept to reduce the downtime of equipment. Therefore, it can maintain the JIT process. It enables a company to produce small volumes of a large variety of products while still maintaining the advantages of mass production. Further information are provided in literature of Horbal et al. [13].

5. Automation (Jidoka) and multiprocess handling
The other pillar of the TPS is Jidoka, which can be translated as automation. It includes the concept of automation and of autonomous monitoring for defects and elimination of their causes. Every process has to be analyzed on opportunities for automation, and if it is possible and useful, the process should be automatized. Since a defect can cause an immediate standstill of the machines in automated processes, Haak [11] proposed that the production workers have to be in a position to find the

defect as soon as possible and fix it to minimize the production down time (in-station quality control). Schlichting [26] said that the so called Andon line, allows employees to call for help if they notice a problem and even stop the production line if the problem can not be solved directly. Multiprocess handling means that one operator works across several machines in one process, rather than have different operators. Since the product will flow with the operator, the workflow will be constant. There can be more operators working across several machines and following each other with their own work piece.

4 Discussion and Conclusion

The purpose of this paper is to develop an assessment tool that helps an organization to implement lean in a sustainable way. Initially, the success factors of a lean approach have been identified and different business models have been reviewed. The research has shown that there are 4 main categories of crucial factors (leadership, culture, knowledge and process), including 24 criteria in total. Based on the literature, different countermeasures were chosen for each criteria. A company can rate the criteria to reveal its needs for improvement, and react immediately by applying the respective countermeasures. This tool gathers a lot of knowledge and information, by combining various findings of different research and case studies. It helps organizations to implement lean, but the management has to be aware, that every lean approach is individual. The conditions and environment change from company to company, thus the proper use of the proposed countermeasures.

The limitations of this developed tool, are related to the lack of experience. Though the tool is partly based on case studies and assessments, it is still a theoretical approach and it has not been verified in practice. Further research is necessary to analyze the impact of this tool on lean implementations. Additionally, focus could be placed on the rating, and a model to measure the value of a criterion could be developed.

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One Year Substance Flow Analysis of Copper Cycle in U. S.

Minxi Wang, Wu Chen and Xin Li

Abstract Copper and its alloy products are widely used in the world. Considering of sustainable development, people are focusing on how to exploit and utilize copper resource to meet the needs of global sustainable development. In this paper, we attempt to use the Substance Flow Analysis (SFA) and Stocks and flows (STAF) model to analyze copper flows and stocks through its all life cycle from production, manufacture, use and recycling, based on data from U.S. in 2012. The most interesting results are the following: (1) The production of refined copper from electrolytic and electrowon way is 491 and 471 Gg/year. (2) In manufacture stage, domestic refined copper production accounted for 62 % of total copper consumption. (3) The most of copper consumption in use stage is building construction, accumulation in 2012 is 1172.52 Gg/year. (4) In waste management stage, American scrap generated is 587.48 Gg/year, majority of them are exported. Domestic and imported scrap average copper content is up to 82.69 % which recycled in the stage of copper production and manufacture.

Keywords Substance flow analysis (SFA) · Copper · Stocks and flows (STAF)

1 Introduction

Copper is a common metallic element in nature, which exists in the form of sulfide deposits, sulfate deposits, silicate deposits and pure "native" copper. Copper and its alloy products are widely used in building construction, electrical and electronic equipment, industrial machinery equipment, transportation equipment and general products, because of the excellent properties. Copper has made tremendous contributes to the economies of the world. With the rise of industrialization in developing countries such as Asia, they have a huge demand of copper. With the increasing

M. Wang · W. Chen · X. Li (✉)
College of Management Science, Chengdu University of Technology,
Chengdu 610051, People's Republic of China
e-mail: ericlee68@163.com

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concern of sustainable development, the global people are focusing on how to exploit and utilize copper resource to meet the needs of global sustainable development.

The United States is a representative of the industrialized countries, which has hundreds of years history of exploiting and utilizing copper. Their copper supply and demand structure and law of development is a reference for the emerging industrialized countries.

In this paper, we attempt to use the Substance flow analysis (SFA) and Stocks and flows (STAF) model to analyze copper flow and stock through its all life cycle from production, manufacture, use and recycling, combining USGS (www.usgs.gov) copper data in 2012. This paper try to reveal American copper flow law and configuration structure through those analyses and find out the rules to make reference for the development of new industrialized countries.

2 Literature Review

Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system predefined in space and time [1]. Leontief introduced this method in the field of economics in the 1930s, but the early studies in the fields of resource conservation and environmental management appeared in the 1970s [5]. MFA is based on the life cycle theory, following the law of mass balance and could give a quantitative analysis of the condition about material input and output in each stage of life cycle. On one hand, MFA can help people to find many hidden problems from the material numeral change in different stages. On the other hand, it can help people to observe the material change condition from the perspective of the whole system. MFA was applied widely, some researchers began to use SFA to trace noxious or some specific element in each stage within the spatial and temporal boundary to reduce pollution, improve efficiency and realize ecological civilization construction better [7]. Graedel [2] made a comprehensive description of definition and technology of copper cycles. Spatairi [8] studied European copper flow situation by the STAF model. The STAF model traced the copper flow and stock through its entire life cycle qualitatively and quantitatively, clearly reflecting the copper source and destination and estimate the copper stock in society. Kapur [4] had a research on Asian and Japan copper cycle through SFA and found that Japan's rates of use, waste generation, and recycling of copper rank first in the whole Asia while that of Asia had large gap compared with developed country in the world. Yue et al. [3, 6] gave a quantitative analysis based STAF model and corresponding indicators on the situation of China's copper flow.

From the literature research we know: there are many researches on substance flow analysis, which are the foundation of our study, but most of them didn't real obey the law of mass balance completely, because the data were difficult to get. For example, the copper input was not equal to the output in some stages. There are three reasons: one is the loss of some statistical data, and the other is researchers calculate some data in accordance with internationally recognized experience ratio, the third is the data note for gross weight not the substance content. These calculated data and gross weight data could not reflect the real situation of a specific element within the spatial and temporal boundary.

3 Methodology and Data Acquisition

Material flow analysis (MFA) is a way to analyze the impact of material input and output to the economy and environment from macro level. Substance flow analysis (SFA) can help trace the copper flow through copper life cycle from natural exploitation, production, fabrication and manufacture and recycling of copper in the temporal and spatial boundary.

In this paper, we use SFA method to give a visual display of copper entire life cycle in U.S. in 2012, then use STAF model to give a quantitative description and analysis of American copper flow and stock in each stage in 2012. Data was mainly obtained from official website of USGS, other data less detailed in USGS was supplemented by copper development association data. As shown in Fig. 1, according to copper life cycle, copper flow analysis involves four primary stages: production, manufacture, use and waste management. Each stage can be divided into some branch processes, e.g. production includes primary production and secondary production, primary production includes mine, smelter and refinery. This paper don't consider copper influence on the environment through its entire life cycle, based on the following assumptions: first, the copper loss to the environment in each stages would not be considered. Second, according to the law of mass balance in the SFA, the

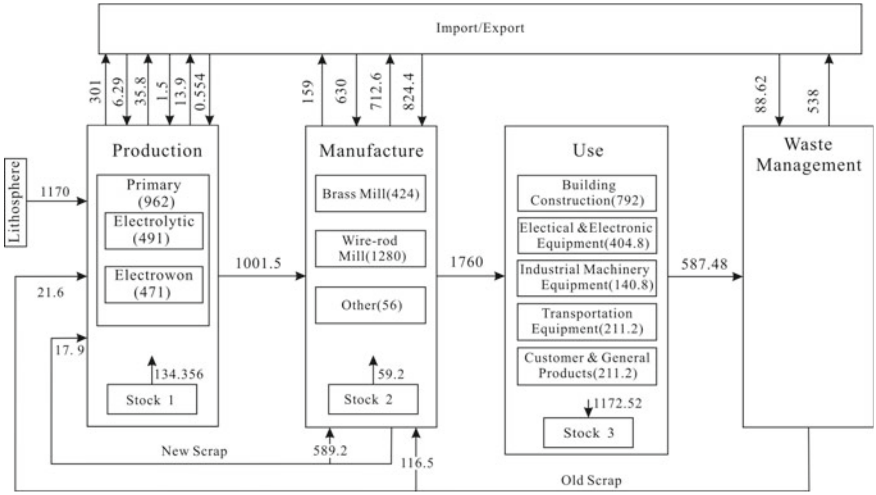

Fig. 1 Copper flows and stocks of U. S. in 2012

input is equal to the output in each stage. Third, the output from the previous phase is the input of the next stage. Fourth, data showed in this paper is not gross weight but copper content except specialized.

4 Substance Flow Analysis

4.1 Production

Copper production includes primary and secondary production. Primary copper production includes traditional methods and new technology. The traditional methods has three stages. The first stage is mine and milling of ore, which produce concentrates and tailing. The second stage is smelting, which produce blister and slag. The third stage is refinery, which produce refined copper. With the development of new technology, a new way called SX-EW process appeared after 1960s, which contains solvent extraction and electrowining. High purity copper can be obtained from a low copper content of the tailing, slag and low-grade ore through the SX-EW process and the output is the same as traditional refining way. Secondary copper production includes new scrap from fabrication and manufacture, recycled old scrap and imported scrap. These scrap is fed into smelter and refinery to produce refined copper, then put into the fabrication and manufacture.

In order to quantify the relationship of various stages of production, we give the mathematical expression of input-output relationship in the production stage as Eqs. (1) and (2).

$$\sum P_{in} = P_{\text{mine}} + P_s + P_{im} - P_{ex} + \text{Stock1}, \tag{1}$$

$$\sum P_{out} = P_p + P_s, \tag{2}$$

where, P_{in} is the whole input into the production, P_{mine} is the mine production, P_s is the recycled scrap in the production stage, P_{im}, is the imported copper in the production, P_{ex} is the exported copper in the production, $Stock1$ is the stock change in the production this year, P_{out} is the output of refined copper in the production of refined cooper, P_p is the primary production of refined copper.

In 2012, the copper input in the production includes: American domestic mine production contains copper 1170 Gg/year, net exports copper is 342.356 Gg/year in the form of ore and concentrate, matte, ash and precipitates and blister, scrap recovered into smelter and refinery includes new scrap 17.9 Gg/year and old scrap

21.6 Gg/year. The copper output from production includes: the amount of refined copper from primary production is 962 Gg/year, which includes electrolytic copper production 491 Gg/year and electrowon production 471 Gg/year. The amount of refined copper in the production is 39.5 Gg/year. As shown in Eq. (3).

$$\sum P_{in} = \sum P_{out} = 1101.5. \tag{3}$$

4.2 Manufacture

Raw material in the fabrication and manufacture includes three parts. The first one is the refined copper from domestic production. The second is the refined copper, copper and its alloy semi-products imported from trade. The third part is recycled scrap that includes new scrap such as leftover materials and lathed scrap retreated from fabrication and manufacture stage,domestic recycled scrap and old scrap from foreign trade. Considering the input and output in manufacture stage, the retreated new scrap is not from the recycling from outside manufacture system, belonging to the recycling of manufacturing system boundaries. So the following mathematical equation of manufacture does not consider the new scrap retreated from fabrication and manufacture stage.

Considering the input and output stages of manufacturing copper scrap recycling, new manufacturing systems are internal recycling, not manufacturing system boundaries outside of recovery, so the following mathematical Eqs. (4) and (5) are not considered investment in new waste.

$$\sum M_{in} = DRC + M_s + \sum M_{im} - \sum M_{ex} + \text{Stock2}, \tag{4}$$

$$\sum M_{out} = M_{bm} + M_{wm} + M_o, \tag{5}$$

where, DRC is domestic refined copper, M_s is the recycled old scrap (including imported old scrap), M_{im} is the import of copper and alloy products in the branch process of fabrication and manufacture, M_{ex} is the export of copper and copper alloy products in the branch process of fabrication and manufacture, Stock2 is copper and alloy products stock change in manufacture and fabrication stage, M_{bm} is the production of brass mills in manufacture stage, M_{wm} is the production of wire-rod mills in manufacture stage, M_o is the production of other copper products (including ingot, chemical products and miscellaneous products in manufacture stage.

The input into manufacture stage includes: The domestic refined copper production is 1001.5 Gg/year. The imported copper in the form of refined copper, brass mills, wire mills, powder products is 630, 413.43, 403, 403 and 8 Gg/year respectively. The exported copper in the form of refined copper, brass mills, wire mills, powder products is 159, 189.63, 505 and 18 Gg/year respectively. The total scrap from domestic recycling and foreign trade is 116.5 Gg/year. The exchange stock of copper and alloy semi-products is 59.2 Gg/year. The output from the manufacture stage includes 424 Gg/year brass mills, 1270 Gg/year wire-rod mills and other copper products such as ingot, chemical products and miscellaneous products are 57.6 Gg/year. As shown in Eq. (6).

$$\sum M_{in} = \sum M_{out} = 1760. \tag{6}$$

4.3 Use

The copper and its alloy products are applied in building construction, electrical and electronic equipment, industrial machinery equipment, transportation equipment and other general consumer products. These products through the use of social circulation turn to waste flows then going to the waste management stage. Waste flows includes municipal solid waste (MSW) construction and demolition waste (C&D), waste from electrical and electronic equipment (WEEE), end-of-life- vehicles (EOLV), sewage sludge (SS), industrial waste (IW) and hazardous waste (HW).

The use stage includes two parts: use and stock. It is very difficult to have a direct statistic of annual copper accumulation in the society because of different life of each kinds of copper and its alloy products, so this paper tried to calculated American copper accumulation in 2012 indirectly. Referring the thought of warehouse [6], this paper regarded the use stage as an "hourglass". We give the assumption: First, annual copper input into the use stage was like newly added sand. Second, domestic scrap generated each year was sand out of the hourglass during the period. Third, copper accumulation this year that was also called stock in the use stage was the sand remained in the hourglass. As shown in Eq. (7).

$$\text{Stock3} = M_{out} - WF. \tag{7}$$

Stock3 is the estimated copper accumulation in the society. *WF* is the scrap from the use stage then into the waste management stage.

Copper scrap generated in US is 1.2534 million tons (gross weight) in 2012. In this paper, whole copper flows meant the copper content not gross weight while the domestic scrap didn't indicate copper content. So it is necessary to estimate the amount of copper scrap generated in use stage. This paper assumed that price of copper scrap was linear with that of refined copper and total imported scrap in waste management was recycled in domestic copper production and manufacture. This paper calculate the copper content according to the price of copper scrap and refined copper. Through the calculation, assume that the copper content of unalloyed copper scrap and alloyed copper scrap was 60 and 35 % respectively. In 2012, American export of unalloyed copper and alloyed copper was 479 Gg/year (gross weight) and

Table 1 The numeral amount of American domestic copper flow in each stage

Stage	Amount
Production	867.144
Manufacture	1760
Use	1760
Waste management	138.1

716 Gg/year (gross weight) respectively, so the copper content of American exported copper scrap was total 538 Gg/year. In 2012, the copper content of domestic copper scrap recycled into production and manufacture was total 49.48 Gg/year. So the total domestic copper scrap was 587.48 Gg/year. So

$$\text{Stock3} = 1760 - 587.48 = 1172.56. \tag{8}$$

From the Eq. (8), we can know American social stock in 2012 was nearly 1180.26 Gg/year.

4.4 Waste Management

Previously mentioned waste flows, of which MSW, scrap C&D, WEEE, EOLV copper products are also called old scrap. These old scrap is collected and separated in the waste management stage. Some scrap is recycled into smelter or refinery in the production stage and some is directly reused in the manufacture stage and other is incinerated. In 2012, American total recycled copper scrap is 138.1 Gg/year, of which 21.6 Gg/year is recycled into smelter or refinery to produce refined copper in the production stage and 116.5 Gg/year is directly reused in the fabrication and manufacture stage. The foreign trade includes 88.62 Gg/year imported copper scrap and 538 Gg/year exported copper scrap.

From above analyses, we have a detailed awareness of American copper flow in each stage. Only copper flow occurred in the spatial boundary will have influence on the predefined region. As shown in Table 1.

5 Conclusions

This research showed:

(1) American copper production ranked second in the world, which 29 % of ore and concentrates are exported. The production of refined copper from electrolytic and electrowon way are 491 and 471 Gg/year.

(2) In fabrication and manufacture stage, domestic refined copper production account for 56.9 % of total copper consumption, which indicates that the U.S. is mainly relying on domestic production in the phase of refined copper. Others in the form of refined copper and semi-products is mainly relying on import. New copper scrap accounts for a large proportion, indicate that American copper scrap recycling rate is high in this stage.
(3) The most of copper consumption in use stage is building construction, followed by electrical and electronic equipment. American copper accumulation is 1172.52 Gg/year in 2012.
(4) In waste management stage, American scrap generated is 587.48 Gg/year, majority of which are exported. Domestic and imported scrap average copper content is up to 82.69 % which recycled in the stage of copper production and manufacture.

According to the numeral amount of copper flow, American domestic copper flows indicate that the process happening in the spatial boundary look like a rugby. Domestic larger copper flow in the manufacture and use stage is the middle of the rugby, domestic less copper flow in the production and waste management stage. The reason for the situation of copper flow is the United States established the environmental legal system after 1960s and paid more attention to domestic environmental protection, trying to reduce the pollution to the environment by shifting high polluting and high energy-consuming industries, as more people are focusing on environment.

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The Real Engine of China's Robust Economic Growth-More Mass and Rapid Transmission of Innovative Technology and Application

Hongchang Mei and Zhihua Zhang

Abstract This paper has built on the fact that the economy of China has been growing with an increasingly rising speed, exploring the truth of driving forces behind the economy. Paper measures empirical research method. It contrasts the differences of results in economic development between technology innovation countries, like America and technology application ones, like China. Besides, it also compares technology absorptive capacity between China and India which are both blessed with large size of population. It tries to find the reason why the economic development and technological innovation is not synchronous. Importantly, this paper has given an outcome that innovative technologies demonstrated with wider acceptance and more rapid spread are likely to be the real engine of China's economy rising again. Therefore, strengthening the cooperation between technology innovation states and technology application countries and creating an open environment which is embracing and disseminating innovative technology could boost economic growth for many nationalities.

Keywords National economics · China's economy · Empirical research

1 Put Forward the Question

Before the reform and opening up in 1979, China had been in poverty for hundreds of years. Statistics shows that, in 1978, Chinese per capita gross domestic product (GDP) is only \$155, which is less than one third of that in sub-Saharan African countries. At that time, about 81 % of Chinese population were living in rural areas, and 78 % of the population lived below the international poverty line, which is \$1.25

H. Mei (✉) · Z. Zhang
Chongqing Technology and Business School, Chongqing 600000,
People's Republic of China
e-mail: 534868879@qq.com

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Table 1 Chinese and India GDP growth rate

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
China GDP growth rate (%)	10.1	11.3	12.7	14.2	9.6	9.2	10.4	9.3	7.8	7.7
India's GDP growth rate (%)	7.9	9.3	9.3	9.8	3.9	8.5	10.5	6.3	3.2	4.68

Data source World Bank Database (data in 2004–2013)

per person per day. This situation sharply changed after 1979. The transformation began in 1979 made the annual growth rate of Chinese economy reach 9.8 % and lasted for thirty-five years. In 2013, Chinese per capita GDP reached $6800. Now, China has entered the ranks of the upper-middle-income countries and its per capita GDP is four times higher than that of the average number of sub-Saharan African countries. In that way, why did the changes happen in China? What is the real engine for solid growth of Chinese economy? (Table 1).

At present, TFP of the developed countries such as America, Japan, Britain and Germany etc. is generally above 50 %. From the data, there is a large gap between the total factor productivity of China and the developed countries. But it left some more interesting problems to us. First, it is the consensus of China and even the world that science and technology are primary productive forces. In the case that human resource and physical capital is limited, science and technology is the real "late-developing advantage", so why big innovation-oriented countries such as America whose IFP contributes more than 50 % to its economy for more than 30 consecutive years failed to achieve about 10 % GDP growth and this situation lasted for thirty years Secondly, compare China with India, both countries started under almost the same economic conditions, and the populations equivalent. Please see the following table for the GDP growth rate comparison in nearly ten years. Access to information shows that India is slightly better in the aspect of nonagricultural TFP growth. Then why higher innovation did not bring advantages for India's GDP growth?

From my point of view, technology spillover plays an important role in the rapid growth of Chinese economy. The use of technology at lower cost and larger-scale extensive application of scientific and technological achievements are the real reasons for the above phenomenon. The structure of the paper is as follows raise the question in the first part; the second part are reviews of the domestic and foreign related theories about the reasons of Chinese economic growth; The third part introduces the research model will be used in this paper, including the calculation of indexes related to TFP from 1980 to 2013 in China, the establishment of technology absorption model. The fourth part is the analysis and the responding interpretation of model fitting results, including through the comparison, propose likely causes of why GDP growth in America and India not as steady as the Chinese economy.

2 The Literature Review on the Reason of Chinese Economic Development

The reasons why Chinese economy continued steady in recent years have been a hot research, many scholars tried to explain. Chinese pioneering researcher Zou [20] thought that the main reason was capital accumulation from 1952 to 1980. Hu and Khan [13] extended the study of Chow [7] and pointed out that the accumulation of capital is the main factor of economic growth from 1952 to 1994 and they improve the TFP played a major role from 1979 to 1994. Total factor productivity increasing about 4 % a year made contributions to China's economic growth rate of more than 40 %.

Maddison [15] argued that total factor productivity (TFP) growth can explain Chinese growth (around 30–58 %) from 1978 to 1995. Hu and Khan [13] found that 3.9 % of the total factor productivity growth on average can explain China's reform and opening up more than 40 % in the early growth.

According to Young [19] series of growth factor calculation showed that the growth of China and the east Asian tigers mode (collectively known as the east Asian model) is very consistent. The growth factor is mainly the labor participation rate, education level, investment rate, a large amount of labor across departments and configuration (to non-agricultural sector and manufacturing transfer from traditional department).

Garnaut [10] argued that as long as met relevant conditions, sustained and rapid economic development will naturally occurring, rather than the miracle.

Perkins and Rawski [16] added the time trend of productivity and gave an empirical analysis of the influence of each factor of Chinese economic growth which based on the traditional Douglas production function, according to the 1953–2005 data. According to the model, he predicted the development path of China's economy will continue along the rapid grow within the 2006–2015, and the GDP average annual growth rate will be between 6 and 8 %.

Wang and Fan et al. [9] through reconstruction of the Lucas model, analyses how the various elements made contribution to China's thirty years of economic growth. Through the analysis, they thought the change of Chinese economic growth mode is happening, because the rate of GDP gradually increased when TFP was up.

Yifu Lin, World Bank vice president and chief economist (2010) said that the efficient investment of Chinese government in the field of infrastructure and Chinese urbanization process would ensure that Chinese economy continued to maintain rapid growth over the next 20 years. Lin [14] argued that developing countries innovation are mainly in imitation, in other words, it is the introduction of high income countries technology and industry. If developing countries knew how to make use of the advantage of this potential, the risk and cost of innovation would be much lower than higher income countries. Then the growth rate of the economy could reach several times in high income countries.

After a lot of research can determine the effect of TPF on the economy is very big, but what of TFP on the growth of China's economy how to play the role is still controversial, while in the following basic unity. First of all, after the reform and opening up, China's TFP contribution to GDP growth was higher than before the reform and opening up. Secondly, the contribution of TFP to economic growth is prominent and it is worth to research. Finally, TFP are caused by the different national income per capita differences the most important reason for the larger, and is also a key factor of economic growth.

3 Parameters and Variables

1. The Establishment of Calculation of Relevant Indicators Chinese TFP Model
   Suppose the production function of China economy:

$$Y_t = A_0 e^{\alpha_T t} K^{\alpha_K} L^{\alpha_L}. \tag{1}$$

The α_K represents the output elasticity of capital and the α_L represents the output elasticity of labor. In addition, we noticed this production function will change over time.

Take the logarithm,

$$LnY = LnA_0 + \alpha_T t + \alpha_K LnK_t + \alpha_L LnL_t. \tag{2}$$

When $\alpha_K + \alpha_L = 1$, namely, constant returns to scale at,

$$Ln\left(\frac{Y_t}{L_t}\right) = LnA_0 + \alpha_T t + \alpha_K Ln({}^{K_t}/_{L_t}). \tag{3}$$

In return, we may need to further consider some other factors, for example, we can use a dummy variable to reflect the effect of China economic reforms on China's economy after 1978.

We use D_i to represent the i dummy variables, then the Eq. (2) and (3) become into,

$$Ln(Y_t) = LnA_0 + \alpha_T t + \alpha_K Ln(K_t) + \alpha_L LnL_t + \sum \beta_i D_i, \tag{4}$$

$$Ln\left(\frac{Y_t}{L_t}\right) = LnA_0 + \alpha_T t + \alpha_K Ln({}^{K_t}/_{L_t}) + \sum \beta_i D_i. \tag{5}$$

Based on the Eq. (4) and (5) the regression, we can get the output elasticity of capital and labor α_K and α_L, then regularize it,

$$\alpha_K^* = {}^{\alpha_K}/_{(\alpha_K + \alpha_L)}, \quad \alpha_L^* = {}^{\alpha_L}/_{(\alpha_K + \alpha_L)}.$$

Define total factor productivity is,

$$TFP_t = \frac{Y_t}{K_t^{\alpha_K *} L_t^{\alpha_L *}}.$$

So we have the TFP growth rate in the year t,

$$tfp_t = \frac{TFP_t}{TFP_{t-1}} - 1.$$

TFP growth rates of between t_1 and t_2 are as follows,

$$tfp_{t_1 - t_2} = \sqrt[t_1 - t_2]{TFP_{t_2} / TFP_{t_1}} - 1.$$

(1) Output data

According to the 1990 constant prices for conversion, this article uses the gross domestic product (GDP) as the basic indicators of economic growth, and the basis of data is from the China statistical yearbook of calendar year (Table 2).

(2) Labor input data

In TFP calculation, labor input elements depend not only on the inputs, but also with elements of efficiency, quality and other factors. But considering the availability and scalability of data, at the end of this paper USES the employment as the labor input data to calculate.

(3) Capital input data

In this paper, according to the investment in fixed assets each year to calculate capital data for 1998–2013.

According to the above methods and the data regression results are as follows:

The regression result shows that the non standardized regression coefficient of the Y for two independent variables are $K = 0.647$ and $L = 1.238$ respectively. The corresponding significance test, T value are 44.906 and 44.906, and two regression coefficient significance level Sig. = 0.000 are less than 0.05 (Table 3).

Table 2 Anova[b]

Model	Sum of squares	Df	Mean square	F	Sig.
Regression	36.652	2	18.326	5981.269	0.000[a]
Residual	0.098	32	0.003		
Total	36.75	34			

[a]Predictor variable, (constant), labour logarithmic, capital logarithmic

[b]Dependent variable, output logarithmic

Table 3 Coefficient[a]

Model	Non standardized coefficient		Standardized coefficient	T	Sig.	Collinearity statistics	
	B	Standard error	The trial version			Tolerance	VIF
Constant	−10.868	0.849		−12.799	0.000		
Capital logarithmic	0.647	0.014	0.785	44.906	0.000	0.273	3.664
Labour logarithmic	1.238	0.090	0.241	13.814	0.000	0.273	3.664

[a]Dependent variable, Output logarithmic

3.1 Absorptive Capacity Calculation Model

The process of the transformation of scientific and technological achievements was transformed into real productive forces are a very complex science and technology economic activities. From the system point of view, the transformation of scientific and technological achievements can be divided into several subsystems. They are the subject system, support system, the policy environment system, intermediary system and the macroeconomic regulation and control system. And the main system involves participation in the transformation of scientific and technological achievements of the units of production, scientific research institutes and institutions of higher learning. Not only is the achievement transformation vector of the three is also the receptor. Support system including funds, personnel, materials and achievements of maturity, applicability, market prospects and so on. The policy environment system is through policy guidance to encourage scientific research institutes for economic construction, should develop appropriate preferential policies for the achievement of science and technology personnel engaged in the transformation of in-service, treatment, incentives and other aspects. Intermediary system is the bridge results of the transferor and the transferee, or the medium of providing demand information of scientific and technological achievements and the exchange, trade, scientific and technological achievements transfer, diffusion. Department of government regulation is the leaders and managers in the process of transformation of scientific and technological achievements, but also the functional departments of macro-control system. It mainly used economic, legal, administrative and other means to plan and guide.

Before proposing the variables and parameters we need emphasizes a concept—the ability to absorb technology. The ability to absorb technology from the initial level of human capital expansion into the comprehensive index of numerous factors which Include the R&D level of host country, the efficiency of financial market, the opening degree of trade etc. This part will make use of the system in the support system, policy environment, intermediary and macro-control system to buildup the index system to measure a country's ability to absorb technology.

Because part of the data availability is limited, so the index system is not comprehensive. The solution is selected for the index to build index system of representative (Table 4).

Suppose:
ROAD represents the total length of the highway network;
RAILWAY represents the total length of railway;
PHONE represents the number of mobile phone subscriptions;
INTERNET represents the number of Internet users per hundred;
APP represents the number of patent applications;
RESEACH represents the number of R&D and research personnel;
REDUG represents public expenditure on education as a percentage of GDP;
RRDU represents the research development expenditure as a percentage of GDP;
GDP stands for gross domestic product.

Table 4 a-Coefficient

System	Content	Index
Support system	Infrastructure	ROAD
		RAILWAY
	Communication facilities	PHONE INTERNET
	Human	APP
	Capital	RESEACH
	Money	REDUG
		PRDU
	Financial market	Economic freedom index
Policy environment system	Government policy	Ease of business environment
Intermediary system	Legal environment	International property rights index
Macroeconomic regulation and control system	Market system	Press free domestic index Science and technology journal articles

This paper will compare object as USA and India, Because USA as an innovative country is recognized by the world, and India is the only developing country that can be compared with China in population, resources and the growth of GDP. In addition, there are many research results of the two countries is more easily available.Because of limited space, here will not specifically numerated data. Data sources are the world bank, the International Monetary Fund etc.

Through the comparison of the three countries we find that, there is a positive correlation between indicators selected with GDP. That is to say when the index value increases, will have a positive effect on GDP.

4 The Empirical Analysis

4.1 Empirical Research on TFP Calculation Results

The contribution rate of scientific and technological progress to economic growth in developed countries today in the early 20th century was 5–20 %, rose to about 50 % by the middle of the 20th century, in the 1980 s increased to 60–80 %. The development of production of many knowledge intensive industries almost all rely on science and technology. According to 'Abramowitz balance method', some foreign economists calculated that the national science and technology progress of America, Japan and several western Europe in developed countries made contribution to economic growth between 41–75 % in general in twentieth Century 50–70 years. In twentieth Century 70 years later, the United States, Britain, France, Germany, Holland and Japan six countries labor productivity 80 % of growth rely on progress of science and technology. For units according to the model and the formula above China indexes related to TFP, we can get, $\alpha_K^* = 0.777$, $\alpha_L^* = 0.223$.

According to the above formula can calculate the TFP growth rate, growth rate of output, capital growth rate, the rate of labor force growth.

TFP's contribution rate of the economy = TFP growth rate/Output growth rate,

Contribution rate to economic growth = Capital growth rate* Capital elastic coefficient/Output growth rate,

Labor contribution to economy = labor growth rate* the labor elasticity coefficient/ Output growth rate.

Then we can get the following Table 5.

Table 5 a-Coefficient

Year	TFP[a]	TFP[b]	Output[c]	Capital(%)[c]	Labor[d]	Capital	Labor(%)	TFP(%)
1986	0.30	0.02	0.09	0.08	0.03	67.30	7.10	24.20
1987	0.30	0.02	0.12	0.12	0.03	77.70	5.60	15.70
1988	0.31	0.03	0.11	0.10	0.03	66.70	5.80	25.80
1989	0.30	−0.03	0.04	0.09	0.02	167.90	10.10	−71.80
1990	0.29	−0.05	0.04	0.08	0.16	165.20	90.10	−140.50
1991	0.29	0.03	0.09	0.08	0.01	67.70	3.40	27.50
1992	0.31	0.06	0.14	0.09	0.01	50.70	1.80	44.60
1993	0.33	0.04	0.13	0.11	0.01	62.60	2.10	33.00
1994	0.34	0.03	0.13	0.12	0.01	71.00	2.20	25.20
1995	0.34	0.01	0.11	0.12	0.01	85.10	2.40	12.30
1996	0.34	0.01	0.10	0.11	0.01	92.10	3.10	5.20
1997	0.34	0.00	0.09	0.11	0.01	96.30	2.80	1.70
1998	0.34	0.00	−0.01	−0.01	0.01	71.00	−26.40	55.30
1999	0.35	0.03	0.08	0.06	0.01	55.30	3.10	40.10
2000	0.36	0.03	0.10	0.09	0.01	69.10	2.10	27.40
2001	0.36	0.00	0.10	0.13	0.01	100.40	2.30	−1.40
2002	0.35	−0.02	0.11	0.17	0.01	121.90	1.40	−18.90
2003	0.33	−0.06	0.12	0.25	0.01	168.30	1.20	−55.00
2004	0.32	−0.02	0.13	0.20	0.01	117.60	1.20	−14.30
2005	0.31	−0.04	0.14	0.24	0.01	136.70	0.80	−29.00
2006	0.30	−0.03	0.15	0.25	0.00	126.20	0.60	−20.00
2007	0.31	0.02	0.17	0.19	0.00	86.10	0.60	13.00
2008	0.30	−0.03	0.12	0.19	0.00	126.40	0.60	−21.50
2009	0.27	−0.11	0.09	0.31	0.00	257.70	0.80	−122.30
2010	0.26	−0.01	0.14	0.20	0.00	110.20	0.60	−7.50
2011	0.28	0.07	0.12	0.06	0.00	41.30	0.80	55.50
2012	0.27	−0.04	0.13	0.24	0.00	143.50	0.70	−34.60
2013	0.26	−0.04	0.10	0.19	0.00	156.00	0.80	−47.00

[a]growth, [b]growth rate, [c]contribution rate, [d]contribution

Probable error, In addition to the Solow model error defect itself may have the following points: (1) Data processing error, which mainly includes human data(In the analysis of total factor productivity, strictly speaking, the input data should be within a certain period of time elements provide "service flow", it not only depend on the quantity of inputs from the elements, but also on the factors using factor efficiency, quality and other relevant factors. In terms of labor input indexes measuring by the standard labor intensity of labor time, it refers to the amount of labor input in the process of actual production) and capital stock data(according to the investment in fixed assets each year to calculate). (2) the error of the data processing (Figs. 1 and 2).

From the above table we can see the following contents,

Above graphic reflect capital's and labor's contribution of TFP to GDP. We can find the following problems, capital and the TFP contribution to the economy is basically in the backward state, which is when the economic contribution of capital rate is relatively large, it will reduce TFP contribution to the economy. It is worth to concern that China's TFP to the economy pulling appeared negative pull from 2002 onwards, and the TFP contribution to Chinese economy fluctuates greatly. Next we'll explain the above phenomenon in stages.

The average TFP growth rate during the period of 1980–2000 was about 2.5 %, the contribution of TFP growth in output growth is about 27.21 % (Neglecting the effect of 1989 and 1990). This period was the golden period Chinese economic growth of TFP. In the 21 years, in addition to 1989 and 1990, TFP has remained positive growth, and made a significant contribution to output growth. This fully shows that China's reform from planned economy to market economy transformation is successful. TFP growth is negative in 1989 and 1990 is likely to be in the late 80's and early 90's, the Chinese government dealt with the increasingly serious problem of inflation imposed as a result of tightening economic policy. In addition, the whole world economy recession and export growth slowed may also be an important reason.

During 2001–2013, the TFP growth except 2007 and 2011 are negative growth in the rest of the year. Refer to the development of China's economy, we know that China has been attracting FDI in the world most populous country since 2000, and FDI accounted for Chinese total GDP average value is 2.32 % (Data from UNCTND world investment report released). The 2007 financial crisis spread to global financial markets, and the developed countries are generally affected by American economic slowdown and financial market turmoil. In 2008, China plans to invest 4 trillion yuan (accounting for the GDP 16 %) to rescue the market in two years. In 2012 the world economy has been sluggish growth, the European debt crisis, a large fiscal deficits in the United States are all the probable reasons for negative TFP growth (Fig. 3).

(2) The Explanation of Economic Phenomenon Between China and India, China and the United States

Data from China and India above contrast diagram, we can more intuitively see that China technology absorption capacity is stronger. We discuss the points in module. The support system module is divided into infrastructure, communication infrastructure, human capital, money, financial markets in five parts. In the aspect of infrastructure, road and railway construction in terms of length of the gap between the two

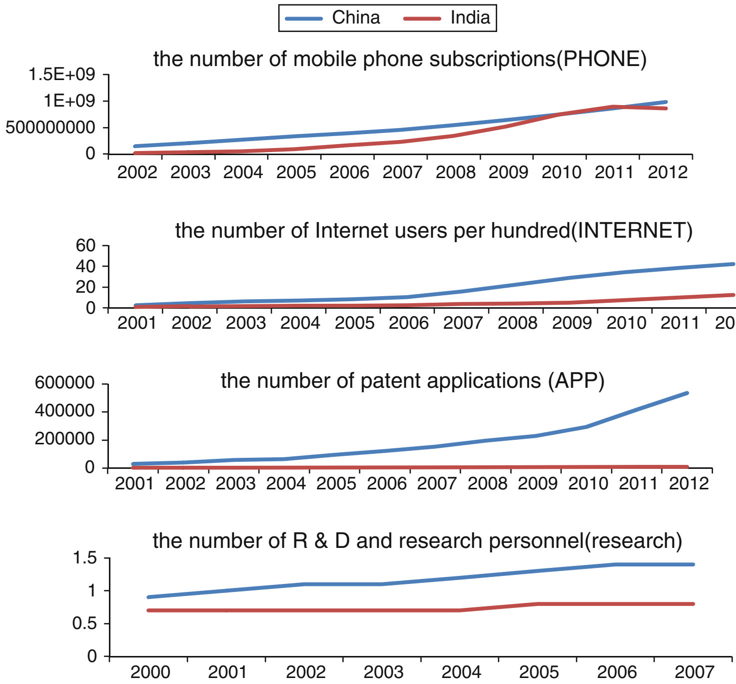

Fig. 1 Comparisons between China and India

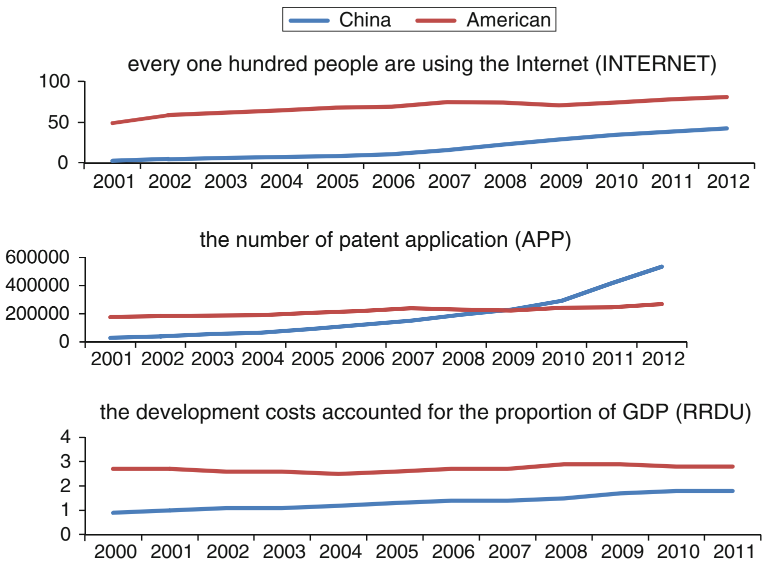

Fig. 2 The comparison between China and America

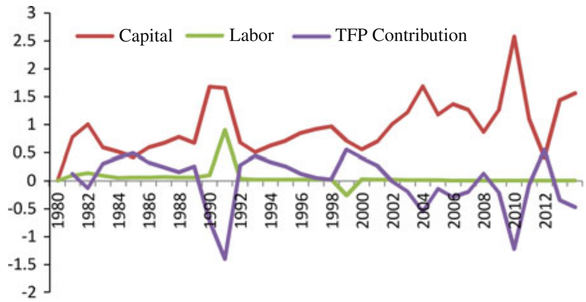

Fig. 3 The comparison between China and America

countries is very small, but India's infrastructure efficiency and speed technology level were significantly lower than in China. The Comparison in Communication facilities, human capital, assets is able to clearly see in the picture. Financial markets and the rest of several indicators were not involved in the diagram. Between China and India only a few indicators such as the international property rights index and business freedom degree difference are not large, the rest were significantly better than India.

Infrastructure as a basic condition of social production and life on economy has supply effect and also has the demand effect. So in the economic comparison of China and India, I would also like to stress that the spread of Chinese scientific and technological achievements and application with higher efficiency and lower cost, which is the real reason that Chinese economy can maintain high speed and steady growth (Table 6).

In each index contrast of China and the United States, we can find on the absorptive capacity of corporation in China is far behind the United States, but China is poised to pass on some indicators, such as patent number. Some indicators showed a rising trend for 'INTERNET' and R&D accounted for the proportion of GDP. But in the environmental assessment, Chinese international property index, business degree of freedom, press freedomindex and so on are far behind the United States. So we need to think about a problem, that is why the superior technology absorption ability and

Table 6 American wage (per hour) in different sector

Year	Private sector pay per hour ($)	Manufacturing sector pay per hour ($)
2007	17.41	17.26
2008	18.07	17.75
2009	18.61	18.24
2010	19.06	18.61
2011	19.44	18.93
2012	19.73	19.08
2013	20.14	19.3

Data sources Chinese Economic Net OECD national database innovation ability cannot promote the growth of American GDP keep high-speed steady?

For the cause of the slowdown in American economy growth, many scholars have been explained. Some scholars believe that the size of the economic dimension have an influence on economic growth, or have an impact on GDP growth. Empirical studies show that the low level of income countries have higher economic growth rate, but in poor countries and rich country's level of economic development is not necessarily absolute convergence trend, and we can see that developing countries also appear the trend of a slowdown in economic growth. In addition, the slowing economic growth and stag nation in developed countries performance as a kind of economic structure to adapt to the stable. And the domestic demand for the role of economic growth is always significantly larger than foreign demand. Therefore, endogenous growth is relatively stable, and economic growth indicators can be at a relatively low growth rate in a long time.

The author believes that a slowing U.S. economy mainly because of its failure to promote and apply the low-cost, large-scale innovation and technological achievements. Its main reason is as follows. First, USA technological absorptive capability is very strong, second, American wage level is very high.

In the same situation, for the same product paid labor costs in the United States is about 9.84 times of China. (According to Chinese current exchange rate to calculate, if you use the data corresponding to the year, we will see the distance between the two will be further widened).

Through the relevant data of the consumption structure, domestic demand is bigger than foreign demand in the United States, and the consumption of United States residents and government is more than 40 % of GDP. It means that American GDP pulling rely mainly on the domestic market. So the United States in such a high human cost pressure chose the way to 'go out' and to find a broader international market is very favorable.

5 Research Significance and Enlightenment

Through the above research, this paper argues that China should continue to encourage foreign investment in western region in China. After all, foreign capital on economic growth has a positive effect on the whole. At the same time, we should be effectively combined with independent innovation and the technology introduction and absorption. So we can lower the cost of introducing and absorbing external advanced technology so as to avoiding repeated development that leads to the waste of resources, but also can cultivate their ability of independent R&D and innovation system. On the other hand, we should create an appropriate environment to enhance China's ability to absorb technology, and enhance the level of human capital in China.

To the developing countries and the developed countries, open and free environment is essential. For developing countries, the government should continue to provide protection to certain industries in transition period on the other hand, the past is suppressed and accord with the comparative advantage of labor-intensive industries open to all kinds of enterprises. In this way can we bring in advanced technology and low cost of mass innovation application and promotion, simultaneously also increase domestic employment and create benefits. For developed countries, in order to find more low cost of mass innovation technology popularization and application of the market, they must open, at the same time to strengthen its technical innovation and enhance technical viability.

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Analysis of the Extension Chain of Year-Round Production Technology of Potato Industry

Xueshan Shen, Huijuan Qu, Gang Huang, Ran Hu and Hong Wang

Abstract Through the application of many measures such as the systematic conformity of three science and technology recourses, construction of technology chain with "five news linkage, six combined merits", the exploration of base demonstration mode with "three drives and three breakthroughs", the construction of cooperative mechanism with "six combination", etc. Long-term cooperative mechanism of close combination with Agricultural-Science-Education and Industry-University-Research Institution has been constructed by Sichuan potato innovation team. Meanwhile, a technology extension mode with "innovation and transformation as a whole" has been constructed that relying on multi-function core demonstration base, with integrated demonstration of key technology as breakthrough, new advanced technology training as vector, integral advance of core demonstration county as emphasis, Industry-University-Research Institution combined together to build modern science-technology industrial chain of potato. Meanwhile, through the application of some methods such as optimize the regional distribution, extend virus-free seed potato, strength high-yield production, continuous radiating drive, and provide disaster response capacity to strengthen the cooperative mechanism and technology extension mode, then promote the potato area and total yield ranking at the first position in China.

X. Shen
Soil and Fertilizer Institute, Sichuan Academy of Agricultural Sciences,
Chengdu 610066, People's Republic of China

X. Shen
Business School, Sichuan University, Chengdu 610064, People's Republic of China

H. Qu · G. Huang (✉) · H. Wang
Sichuan Academy of Agricultural Sciences, Chengdu 610066,
People's Republic of China
e-mail: huanggangsaas@163.com

R. Hu
College of Resource and Environmental Science, China Agricultural University,
Beijing 100193, People's Republic of China

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Keywords Potato industry · Technology extension chain · Innovation team · Cooperative mechanism · Technology extension mode

1 Introduction

As one of fourth most major grain crops which are most important in the word, the development of potato industry plays special roles on food security, poverty alleviation and income increase in poor mountainous areas and ethnic areas in Western China [1–3]. In recent years, potato industry was regard as dominant distinguishing agriculture in Sichuan, and the Project of "Sichuan Potato Innovation Team of National Modern Industry and Technology System" as the first action in the country [4, 5]. Since 2008, according to the main bottleneck in development of Sichuan potato industry, with giving full play to advantages according to themselves' features that Agricultural-Science-Education and Industry-University-Research collaborative innovation, through collaborative innovation and demonstration promotion, Sichuan Potato Innovation Team take the construction of potato plant patterns with multiple cropping and efficient and year-round production technology system as centre, to expand plant area of autumn and winter potato, increase yield and benefits of potato in each season, through the implementation of innovation of plant model, variety, key technology and extension mechanism, then formed year-round production technology system of potato with yield increase of spring, autumn and winter potato and synergism in the whole year [6]. National agricultural statistical data showed that the area and total yield of potato in Sichuan both were up to the first place in China in 2012 while that was the seventh place and fourth place, respectively in 2004. The rapid development of Sichuan potato has been based on the construction of long-term cooperation mechanism with the close combination of Agricultural-Science-Education and Industry-University-Research and formed technology extension mode of innovation and transformation as a whole, and five methods of strengthen the demonstration and extension by Sichuan Potato Innovation Team [7]. The structure of technology extension chain of year-round production and supply system of potato industry were as Fig. 1.

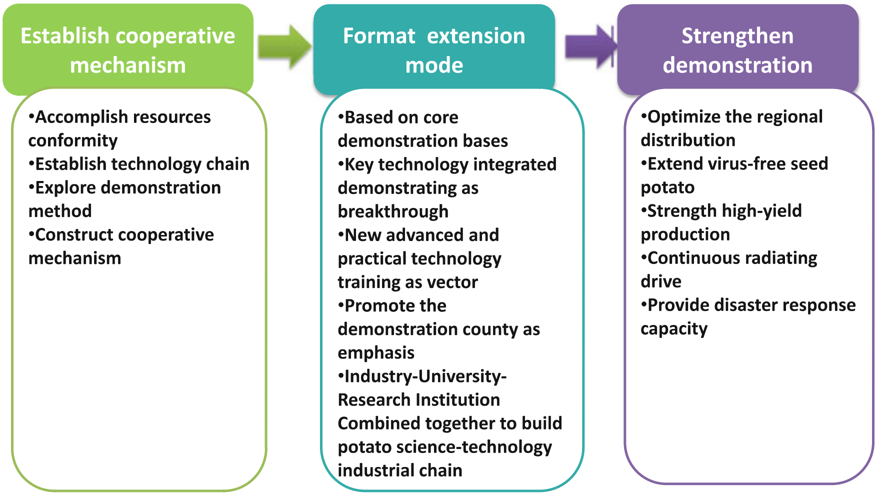

Fig. 1 Technology extension chain of year-round production and supply system of potato industry

2 The Construction of Long-Term Cooperation Mechanism with the Close Combination of Agricultural-Science-Education and Industry-University-Research

2.1 Realized Systematic Integration of Three Kind of Technology Resources

In the progress of developing potato dominant industry, Sichuan Potato Innovation Team effectively implements the systematic integration of three kinds of technology resources such as technological system, project investment and science and technology talents.

(1) To strengthen the integration of technological system

According to the problem such as the long chain of technological innovation, multi-node of key technology, disperse of technological innovation strength, the research project was difficult to adapt the urgent need of modern agricultural development for the innovation of industry technology system, strengthen competitive of potato industry was taken as the objective in this paper. Based on the value increment rule of agricultural science-technology industry chain, to systematic design technology innovation plan and organize related science and technology strength, energetically promote organic combination of technology innovation chain and potato industry chain, and form the effective interaction and orderly advancement of potato technology innovation and potato industry innovation [8, 9]. Sichuan Potato Innovation Team implements double creation strategy with technology innovation chain and industry innovation chain close combination, construct double creation platform that scientific and technical personnel provide technology support such as new model, new varieties, new technology, and new process for industrial department then scientific research achievements were transformed into productivity and formed new products, thus made the whole industry obtained upgrade. With the application of "three-chain" theory [10], technological chain innovation guide industrial chain innovation, industrial chain innovation promote technological chain innovation, then both promote value chain, and the sustainable development of potato industry with "technological chain supportion, industrial chain extension and value chain promotion" were constructed in Sichuan province.

(2) To strengthen the integration of science and technology project investment

According to the problem of broadening investment channel, decentralized investment, short operation period, higher proportion of inefficient and repeated work exist in potato science and technology project, Sichuan Potato Innovation Team has strength the integration of science and technology project investment, competed for long-term and stable financial of provincial finance support to the potato industry project, and improved technology innovation efficiency of scientific and technical personnel and output efficiency of agricultural technology extension investment. Besides existing potato special fund, in order to improve potato production ability in project area, with practice of some projects such as "National modern agricultural production development fund", "New capital subsidies of agricultural input was focused on the construction of food basic production", "Construction of conversion of cropland to forest and basic cropland", the potato demonstration county greatly improve middle and low yield field, develop the work of farmland flatting, soil thickening, and topographic regulation, repair farmland and water source, improve irrigation and drainage channels, etc. Through the application of "Cultivate soil project", strengthen the organic improvement of cultivated land, improve quality and sustainable high production ability of cultivated land, and thus lay a foundation for high yield and efficiency of potato.

(3) To establish high quality technology innovation team

Former research showed that regard improve industry core competitive as a goal while key project as guarantee, organize and cultivate high quality technology innovation team that multi-department, multi-organizations and interdisciplinary, develop collaboration innovation around important key industry technology of industry development, is the great measure to promote the leaping development of agricultural technology [11, 12]. In the past five years, Sichuan Potato Innovation Team has organized above 10 times important provincial activities per year, and the attendants of each activity including post experts and cooperative expert of Sichuan Potato Innovation Team, Sichuan experts of national potato industry system, technology directors of key demonstration county and business representatives, all wisdoms and efforts for industry development of Sichuan potato. During projects executing time, governments and the Party branches of different levels of potato project area has established leading group of potato project with in charge of the leadership as group leader, doing better the coordination and service for personnel, fund, material, technology and seed potato supply, and so on. Agriculture bureau of potato science and technology demonstration counties has established concrete implementation group and technical guidance group, taken motivation system of "more talents, achievement, yielding benefits, and the result was tied to annual assessment, evaluation of professional titles and bonuses", and thus fully mobilize the activity and responsibility of all aspects, effectively promoted the implement universal of technological measures.

2.2 Establish Technology Chain of "Five News Interaction, Six Goods Matching"

With the technology guidance of Sichuan Potato Innovation Team, potato science and technology demonstration counties bring the high yield construction as start point, insist on using template to promote demonstration, using demonstration to promote development. Establish high standard demonstration template, make efforts in scale, quality, and scientific and technological content of demonstration field areas, give all-out support to five news interaction (new model, new variety, new technology, new products, new mechanism) and six goods matching (good soil, improved variety, effective system, good method, good machinery and well irrigation). In the past five years, there were 3435 high yield demonstration area were established while the total area was $44.93 \times 104\,hm^2$, among them, 98 demonstration areas were more than $667\,hm^2$ and the total area was $7.70 \times 104\,hm^2$. Many typical high yields were created in project areas which fully demonstrate the huge yield potential of potato. For an example, "Potato/Maize" model was extension in the demonstration area in Wanyuan and the average yield was $27{,}000\,kg/hm^2$ in 2008; in 2009, the average yield of high yield demonstration area in Butuo county, that create high yield record of potato production in Liangshan.

2.3 Explored Base Demonstration Measure of "Three Drive and Three Breakthrough"

In the progress of extension in technology demonstration county, Sichuan Potato Innovation Team explored base demonstration measure of "three drive and three breakthrough", that is to say, the science and technology service industry mode with experts drive technicians to overcome technology barrier, specialized cooperatives drive farmers to overcome production barrier, and large household drive bases to overcome market barrier. Establish the system of scientific and technological personnnels contact specialized cooperatives and agriculture enterprise (owners), use the model of "scientific and technological envoys, specialized cooperatives (agriculture enterprise (owners)) and farmer" to construct potato science and technology industry chain. At the same time, Sichuan Potato Innovation Team active collaborate with local potato processing enterprises, potato marketing household and association, offer service for leading enterprises of potato processing and potato marketing household with the model of "enterprise (marketing household), association and farmer", organize order production for enterprise. In the past five years, 14 leading enterprises of potato processing has signed $22.6 \times 10\,\text{hm}^2$, purchase fresh potato $432 \times 104\,\text{t}$, according to each kilogram fresh potato could increase 0.2 Yuan, the total increase benefit was 864 million.

The implementation of project has driven the development of new variety breeding, propagation base and seed potato enterprises. Nowadays, 25 expanding propagation bases of free-virus potato have been established in mountain areas around the sichuan basin while the area is $2.33 \times 104\,\text{hm}^2$, 12 production and management enterprises of seed potato and a great mount of professional cooperative of seed potato such as Liangshan liangyuan potato seed industrial limited liability company, and Jiuzhaigou minshan agricultural science and technology limited company have been cultivated. Potato propagation system was continuously constructed and improved, thus laid a solid foundation for the extension of free viruses seed potato in project area.

2.4 Construct Cooperative Extension Mechanism of Six Combinations

With the cooperative extension mechanism of six combinations, that means the combination of administrative promotion and planning guiding, the combination of technological innovation and high yield establishment, the combination of scale management and specialized service, the combination of technology popularization and industrialization development, the combination of personnel training and industrial chain innovation and the combination of popularization and application and large-project-promoting, the extension and application of new model, new varieties and new technology quickly and efficiently were guaranteed.

3 The Formation of Technology Extension Mode with Innovation and Transformation as a Whole

The Sichuan Potato Innovation Team surrounding important technological requirement of new food production ability of 10 billion catty, developing dominant distinguishing crops, speeding up construction of modern agricultural industrial base and new demonstration area, stick on the working thoughts of innovation and transformation as a whole, experts and farmer face to face [13]. Sichuan Potato Innovation Team regard the development of dominant distinguish in gas industry is supported by science and technology as a goal, strengthen technology service for key county mainly from 4 aspects, and format characteristic technology extension mode with innovation and transformation as a whole, experts and farmer face to face.

1. Based on Multifunctional Core Demonstration Bases

Sichuan Potato Innovation Team put forward the model principles of lead local farmers to do so and help them make money, require every post expert according to the rules of exemplary base, radiation zone and extension area combination, with multiple cropping and efficient and year-round production technology system as centre, do well in the construction of multifunctional core demonstration bases that including scientific research test, presenting achievements, technological demonstration, technology training and personnel training. The core demonstration base was mainly being constructed as the unit of administrative villages. Through the technology diffusion channels of exemplary base, radiation zone and extension area, the innovation and transformation achievements of core demonstration base provide template for local science and technology extension. In the overall design scheme, the chair expert of Sichuan Potato Innovation Team has made strict demand for the experiment, demonstration, and training of every post expert in core demonstration base. Sichuan Potato Innovation Team require the experts do well in "two terminals, one process" of core demonstration base. One terminal is plant farmer (potato farmer), solve key technology problems of high yield and efficiency, promote potato farmer income increase, lay upstream foundation of potato industry chain and guarantee industry chain development. The other terminal is market, combine product positioning, pricing and quality design the management model, economic and social benefit of industry chain, and guarantee the industry chain developing excellent, sustainable and healthy. One process means the processes of production, storage, explore, processing of potato.

2. Key Technology Integrated Demonstrating as Breakthrough

The mission of Sichuan Potato Innovation Team is technology innovation and formation of modern industry. The team require each post expert according to the demand of system top design and own characteristics, make one to several key technology breakthrough innovation in key nodes of potato science and technology innovation industry chain around the construction of potato plant patterns with multiple cropping and efficient and year-round production technology system. That would be the most important technology foundation of promote core competitive of dominant industry and the important basis on checking post experts. Meanwhile, on the basis of excellent key technology innovation, systematic integrate new technology and existing advanced and mature technology and format one to several standardized industrial technology system that suitable for the particular area, then make demonstration template in large area, that be beneficial to local science and technology extension.

3. New Advanced and Practical Technology Training as Vector

The team requires each post expert making the construction of potato plant patterns with multiple cropping and efficient and year-round production technology system as center to design technology training plan. With the training focus on advanced and practical technology, strengthen training professional farmers and agricultural personnel in core demonstration county. At the same time, Sichuan Potato Innovation Team collected the training material of every post expert and provide to extension department, in order to promote latest achievements as soon as possible into three actions of agricultural science and technology in the whole province. In the progress of the implementation of the project, the implement unit has make three agricultural actions as vector. The first, by using the opportunity of rural working conference be held by governments at all levels, to training rural grassroots leader during the period of the conference. The second, governments and at all levels and agricultural sector publicizing implement opinion and main technology points by making full use of media instrument such as broadcast, TV, Board Newspaper, slogans and sciences and technologies (market) days. The third, held technology pantomime, distribute technology material, held sowing and cultivating pantomime in every potato sowing time, thus guarantee the overall popularization of agent technology.

4. Promote the Whole Advancement of Core Demonstration County as Emphasis

Sichuan Potato Innovation Team long-term adherence to arrive at core demonstration county to provide all-round service of potato industrial technology, and through the core demonstration county to radiate other county. The practice since the developing job of Sichuan Potato Innovation Team showed that, regard improve industry core competitive of dominant agriculture as a goal while core demonstration county as center, organize and cultivate high quality technology innovation team that multi-department, multi-organizations and interdisciplinary, develop collaboration innovation around important key industry technology of industry development, is the great measure to promote the leaping development of agricultural technology in Sichuan. Sichuan Potato Innovation Team take for 4 science and technology demonstration county such as Chaotian, Zhaojue county, Wanyuan city and Ebian county as emphasis, stick on holding many working conferences of Sichuan Potato Innovation Team and docking conferences of core demonstration county, strengthen the docking work with core demonstration county.

Sichuan Potato Innovation Team making the construction of potato plant patterns with multiple cropping and efficient and year-round production technology system as center, around the coordination of "five news" (new variety, new technology, new model, new products and new mechanism), according to actual situation of 4 core demonstration county, formulated "Docking measures between Sichuan Potato Innovation Team and core demonstration county", developed "2010–2015 development plan of potato in Sichuan Province" for each county, established leading group of demonstration base construction with main leader of base county as group leader, in charge of the leadership as vice-group leader and the main chief in the financial, development and reform commission, supervision and agriculture sector as members. Established technology guiding group of demonstration base construction be consists of main chief of agriculture sector in base county as members, and the expert and consultant group be consists of chair expert and post experts of Sichuan Potato Innovation Team as members.

The project has carried out the working mechanism that expert team take responsible for base, sector of county level take responsible for township while technology personnel take responsible for farmer, according to the difficulties and problems existing in potato industry implement, developing topic discussion and performing working plan of Sichuan Potato Innovation Team, thus improve the influence power of innovation team in potato industrial development.

5. Industry-University-Research Institution Combined Together to Build Potato Science-Technology Industrial Chain

Sichuan Potato Innovation Team adheres to government investment as guider, enterprises as multiple investment and innovation subjects, combined scientific research units, promote the research tackle on common key technology of potato industrialization, construct potato science-technology industrial chain, develop demonstration of technology innovation value industrial chain and promote the structural optimization, industrial upgrading and spanning development of potato science and technology in Sichuan province. In the implement process, pay attention to the combination of experiment and demonstration, and the corporation with enterprise, local agricultural technology sector and farmer association, according to the extension model of "enterprise + base + peasant household" and "expert + enterprise + peasant household", pass the new variety and technology to farmers and drive them to become rich. With the measure of enterprise leading peasant household, drive the farmer increase yield and income, then format closely integrated demonstrating to promote the development of industry chain. Meanwhile, the combination of Industry-University-Research Institution improves enterprise competitive and realizes enterprise transformation, thus enable the enterprise from single vermicelli development transformed into total nutrient development and promote industry upgrade. Enterprises pay more attention to science and technology while science and technology pay more attention enterprises demand, and solve the disengagement problem of technology and development.

4 To Strengthen Demonstration and Extension, and Promote the Total Yield of Potato Leaps into the Front Ranks in China

1. Optimize the Regional Distribution, and Realize the Year-Round Production and Supplying of Potato

The eleventh development planning of potato industry in Sichuan had been made. The potato industry in Sichuan was divided into three superiority areas that spring potato region including southwest mountainous region and mountain areas aroun basin, autumn potato region including plain and hill area, and winter potato region including southest of Sichuan and the valley of Jinshajiang River (Yangtse River) (Fig. 2).

2. Extend Virus-Free Seed Potato and Construct Three Generations Seed Potato Breeding System

The quality control system of seed potato in the whole course at a provincial level has been build firstly in China. The supply center of virus-free seeds potato has been constructed with the implement of virus-testing certificate system of virus-free seeds potato. In 2012, the extension area of virus-free seed potato in Sichuan was 21.62×104 ha while the extension rate of that was 30.4 %. be compared with 2007,

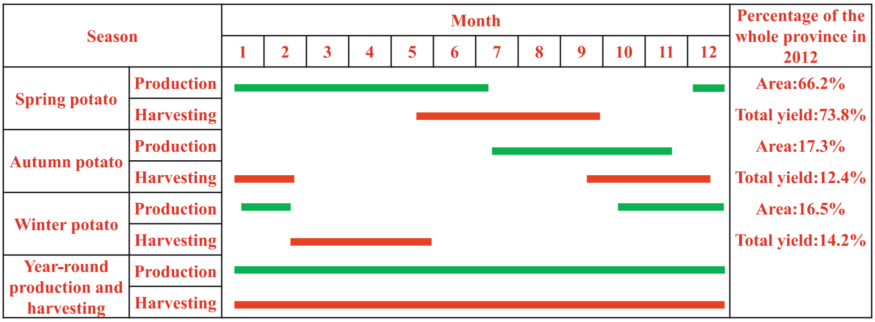

Fig. 2 Year-round production and supply system of potato industry

Table 1 Extension situation of virus-free seed potato in project area

Year	Extension of virus-free seed potato in project area		Yield increase situation of virus-free seed potato	
	Area (10^4 ha)	Extension rate (%)	Yield increase (Kg/667 m^2)	Total yield increase amount (10^4 t)
2007	12.75	26.3	271	51.84
2008	13.88	27.0	285	59.34
2009	17.25	30.9	293	75.83
2010	19.52	33.4	300	87.84
2011	20.51	34.1	309	95.05
2012	21.62	34.6	279	90.48

Table 2 Potato data of main province in China (China agriculture information network, 2012)

Province	Area (10^4 ha)	Rank	Yield (10^4 t)	Rank
Sichuan	74.67	1	275.00	1
Gansu	68.49	2	239.50	2
Neimenggu	68.14	3	184.73	3
Guizhou	67.63	4	179.74	4
Yunnan	51.67	5	175.00	5
Chongqing	35.02	6	118.27	6

the extension area was added 8.87 × 104 ha while the extension rate was added 8.3 points (Tables 1 and 2).

3. Strengthen High-Yield Production and High Yield Record was Constantly Refreshed

The average yield of potato in project area was from 1743 kg per 667 m^2 in 2007 raised to 2135 kg per 667 m^2 in 2012, with 22.49 % increased. The spring, autumn and winter all created high yield record. Such as in Wanyuan county, the highest yield of spring potato reached 4931 kg per 667 m^2 under sole cropping condition; in

Chaotian district, the highest yield of spring potato reached 3928.3 kg per 667 m^2 under sole cropping condition; in Rong county, the highest yield of autumn potato reached 2505 kg per 667 m^2 while in Jintang county, the highest yield of winter potato reached 2851 kg per 667 m^2 under sole cropping condition.

4. Continuous Radiation and Promote the Total Yield of Potato Leaps into the Front Ranks in China

From 2008 to 2012, the extension area of main technology was 3644.78 × 104 acre in Sichuan, while the total new increased potato yield was 995.0 × 104 t, and the total economic benefit was 0.69 million. Be compared with 2007, the total planting area and yield of potato in 2012was increased 29.0 and 42.6 %, respectively. Meanwhile, from 2009 to 2012, the ranking of total potato area and yield in Sichuan among all the provinces of China was from the seventh and fourth in 2004 increased to the fourth in 2012.

5. Provide Disaster Response Capacity and Gain Significant Effect in Post-Disaster Reconstruction

Potato is the important reseed crop of disaster prevention and relief in Sichuan. After the "5.12" great earthquake in Sichuan, the experts of Sichuan Potato Innovation Team had been positive into the rebuilding work of earthquake area refer to seed potato system and potato production. For the past 5 years, the potato production in 18 earthquake counties such as Beichuan, Pengzhou, Wenchuan, etc. has gain recovery and development gradually. The planting area in 2012 was 3333 ha higher than that in 2007 while the yield was increased to more than 1100 kg per 667 m^2 in 2012. The seed potato production in earthquake area such as Beichuan, Pingwu, Pengzhou, Chaotian, Qingchuan, Jiuzhaigou, Hanyuan all being recovery and development.

5 Promote the Rapid Development of Sichuan Potato Industry

1. Production Scale Ranks the First in China

In 2012, the potato planting area and total yield was 79.13 × 104 hm^2 and 1523 × 104 t, respectively increased by 29 and 42.6 % than that in 2007. The area and total yield of potato in Sichuan both were up to the first place in China in 2012 while that was the seventh place and fourth place, respectively in 2004. Establish 3 centralized production areas with unique characteristics and advantages that compatible type potato and seed potato in mountain areas around the Sichuan basin (spring potato), processing type potato in southwest Sichuan (spring potato) and vegetable use potato in plain and hilly area (autumn and winter potato), thus possesses distinct characteristics of "year-round production and supply" [14]. In 2012, the proportion of plant area of spring, autumn and winter potato was 66.2, 17.3 and 16.5 %, respectively.

2. Remarkable Effect on Increasing Yield and Income

In 2012, the proportion of potato yield in grain yield on the whole in Sichuan was 8.3 %, while the contribution rate of potato to the increased grain yield on the whole in Sichuan was reached to 50.6 %. the average output value was above 18,000 Yuan per hm^2 while the average pure income was above 10,500 Yuan per hm^2, the pure income of autumn and winter potato was reached to more than 15,000 Yuan per hm^2.

3. Remarkable Result of “Three News” Combination has been Obtained

Around digging potato yield and quality potential, to popularize new variety, new technology and new model of potato, provide solid science and technology support for improving unit yield. The potato unit yield was form 17,400 kg/hm^2 in 2007 increased to 19,245 kg/hm^2 in 2012 while that was increased by 10.6 %

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Study on Combination Forecasting Model of the Industrial Added Value Combined with PMI and Prosperity Index

Yue He, Jinxiu Tan and Yuting Liu

Abstract This paper first establishes Group Method of Data Handling (GMDH) and Auto-regressive Integrated Moving Average model (ARIMA) for Chinese quarterly industrial added value, then sets up the Auto-regressive Conditional Heteroskedasticity model (ARCH) by the Purchasing Managers' Index (PMI) and the industrial prosperity index and finally uses the GMDH self-organizing modeling method to establish the combination forecasting model. Empirical analysis shows that the forecast effect of combination forecasting model is far superior to single model, and the forecasting ability of ARCH model with PMI and industrial prosperity index is better than that of GMDH model and ARIMA model.

Keywords Industrial added value · PMI · Prosperity index · GMDH · Combination forecasting

1 Introduction

Industrial added value is the final money value of industrial production during a reporting period. It is the balance of total contribution of all the enterprises' activities after deducting the value of goods and services consumed or converted during the production process. In other words, it is the increase in value when enterprise produces products or services [4]. Scientific prediction of the industrial added value can help analyze and evaluate the industrial production scale and developing rate with more accuracy so as to provide government with a reference for regulating the industrial development with macroeconomic policies.

PMI is another important comprehensive leading indicator in the macroeconomic index system, which reflects the overall economic situation and the total change in trend. It is an important basis for decision making in financial institutions and investment companies, helping them judge industry supply and overall supply in a timely

Y. He · J. Tan (✉) · Y. Liu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 1019890979@qq.com

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manner. In addition to this PMI also serves as a tool for governmental agencies to maintain control. Manufacturing PMI index is calculated by weighting five indexes, which include production, new orders, employees, suppliers, distribution and inventory [9].

Prosperity index is an important part of modern economic data in investigation and statistics, and serves as a quantitative index for prediction of economic development status and development trend of turning point [18]. It qualitatively reflects the changing trend of production and operation of enterprises as well as the macroeconomic development.

Sentiment analysis can scientifically determine and forecast turning points in economic operation and then play a significant role in helping macroeconomic policy-making departments know and control the national economic operation situation timely and accurately.

In recent years, many prediction methods have been introduced in the economic field. Xu et al. [16] combined support vector machine and the differential evolution algorithm to forecast the Chinese industrial added value data; Xu [15] established ARIMA and GMDH auto-regressive model of Sichuan Province industrial added value and constructed the combination forecasting model by using GMDH self-organizing modeling method; Liu and He [12] established the combination forecasting model of industrial added value by using a similar complex model, the GMDH auto-regressive model and SPSS curve regression model; He et al. [8] applied a similar synthetic prediction method in GMDH and added prosperity index to establish industrial added value prediction model; He and He [7] combined with PMI index to build the prediction model of self-organization for Chinese combination GDP; Han and Gao [5] using seasonal ARIMA model and trend extrapolation to fit the CPI sequence, then they combined two kinds of model to forecast Combination; Deng et al. [3] established the GMDH forecasting model and GM(1, 1) prediction model of Chinese total retail sales of consumer goods firstly, then established GM(1, N) prediction model adding the consumer confidence index, finally combined both models and established GMDH-GM(1, N) combination forecasting model; Li and Chen [11] investigated a category of LASSO-based approaches and evaluated their predictive abilities for forecasting twenty important macroeconomic variables, and the result shown that the combined forecasts are significantly better than either dynamic factor model forecasts or the naive random walk benchmark; Lemke and Gabrys [10] identified an extensive feature set describing both the time series and the pool of individual forecasting methods in their work, and results shown the superiority of a ranking-based combination of methods over simple model selection approaches; Andrawisa et al. [1] researched on Forecast combinations of computational intelligence and linear models for the NN5 time series forecasting competition, and results shown the combination forecasting mode had a better effect. These studies have proved that combination forecasting model is superior to the single effect, and the introduction of leading indicators or prosperity index will achieve good results for macroeconomic data forecast.

It appears as if there is little research about combining PMI and prosperity index to predict industrial added value, In this paper first of all we established GMDH model, ARIMA model and ARCH model of Chinese industrial added value of quarterly data sequence, then set up ARCH model introducing PMI index and industrial enterprise prosperity index, and finally used the parameter type GMDH input and output model to do combination forecasting, prediction and detection of their effects.

2 Research Design

The study is mainly divided into the following steps:
Step 1. Established GMDH model for Chinese industrial added value of quarterly data sequence;
Step 2. Established ARIMA model for Chinese industrial added value of quarterly data sequence;
Step 3. Then set up ARCH model introducing PMI index and industrial enterprise prosperity index;
Step 4. Finally, combined the three single model using the parameter type GMDH input and output model, and got the combination forecast model.

According to the previous four steps, we obtained three single models and a combined model. Then, there are a comparative analysis for the GMDH model, ARIMA model, ARCH model and combined model. Finally, we found that the prediction effect of the combination model is better than the other three models, which suggesting that the model will reflect the tendency of economic development very well after the introduction of PMI and industrial enterprise prosperity index. The following section will describe how to establish the four models in detail. Research ideas shows as Fig. 1.

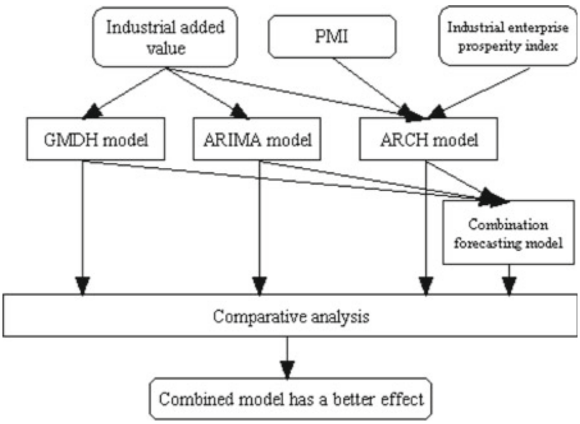

Fig. 1 Proposed the framework of the combination forecasting model

2.1 GMDH Model

Group method of data processing (Group Method of Data Handling, referred to as GMDH) was first proposed in 1967 by Najafzadeha et al. [13] at the Ukraine Academy of Science, since then it has become a very useful tool for data mining. It is based on "evolution—genetic—variation—choice" evolution method, its biggest advantage is its use of external criteria for intermediate candidate model selection, which can guarantee achievement of optimal balance between the fitting precision and prediction ability in a certain level of noise t, and won't show the over fitting phenomenon. The optimal GMDH model is obtained by least square method to get the local regression model and screening, based on regression and self-organizing algorithm [2].

The basic steps of GMDH algorithm:

Step 1. Putting the sample data into the training set A and testing set B;

Step 2. Establishing the function between input variables and output variables;

Step 3. Choosing one or several external criterion as the objective function;

Step 4. Using internal standards (least squares) in the training set for reference to obtain middle selection model;

Step 5. Using external standards in the testing set to select Intermediate candidate model;

Step 6. Repeat steps 4 and 5, until the outer criteria values can't improve, and finally obtain the optimal complexity model.

2.2 ARIMA Model

Auto-regressive Integrated Moving Average model, referred to as ARIMA [6], was first proposed by Box and Jenkins in 1970. It is a short term prediction method with high precision and has been widely used in the field of economics [6]. It is essentially the understanding of the time series structure and characteristics, to attain the optimum in predictions of minimum variance sense. But it may show collinearity and over fitting phenomenon.

The basic steps of ARIMA model:

Step 1. The stationary test: Doing the stationary test for the sample data and determining the differential coefficient.

Step 2. Model identification: Determining the possible values of the auto-regressive order P and the moving average order number Q of the ARMA model by the self-correlation coefficient and partial correlation coefficient.

Step 3. Model establishment: To do regression analysis for models, determine the parameter values, and determine the model according to the value of R-squared, AIC and SC criteria.

Step 4. Diagnostic analysis: Testing the suitability of model, and judging whether the residual sequence is independent or not.

2.3 ARCH Model

Auto-regressive conditional heteroskedasticity model, referred to as ARCH [15] was proposed by Engle in 1982. It is commonly used in the random disturbance on the main model for modeling, which can effectively extract the information from residuals. It has been widely used in each and every field of economics, especially in the financial time series analysis. In constructing the ARCH model, we introduce some economic data associated with GDP such as prosperity index, which can reflect the influence of other economic factors on the GDP, so as to get a better forecasting result.

Steps to establish the ARCH model:

Step 1. Establish time series data;

Step 2. Do LM test of time series to test whether the sequence ARCH effect exists or not, only the ARCH effect exists can build the corresponding ARCH model;

Step 3. Do ARCH model order and parameter estimation;

Step 4. Diagnostic analysis: Testing the suitability of model and the independence of residual according to the AIC criteria and SC criteria and then choosing the more suitable model by comparison.

2.4 Combination Forecasting

Combination forecasting [14] refers to combine the different forecasting methods properly, using information obtained by various methods to comprehensively improve the prediction ability. The combination forecasting method currently known mainly include the weight combination forecast method, the nonlinear combination forecasting method and self-organizing combination forecasting method. Among them, the weight combination forecast thought that it is shown a linear relationship between prediction models. In combination forecast; Although Nonlinear combination forecasting method can solve the non-linear problem, but is prone to over fitting phenomenon; Self organizing combination forecasting method will not only solve this problem, but can also solve the nonlinear problem and the over fitting problem effectively. Therefore, we have chosen the GMDH input and output model to do combination forecasting in this paper.

Combination forecasting is based on GMDH input-output model. Each forecasting method involved in combination is as the input of self-organization algorithm, while the result of combination forecasting is as the output. In this paper, we choose predictive values of GMDH, ARIMA and ARCH model as input, and combined the results of each individual prediction model, finally selected the optimal model through the multilayer iterative.

3 Empirical Research

The growth rate of Chinese industrial added value, PMI value and industrial enterprise prosperity index of all 28 groups of data were obtained from China's National bureau of statistics website in the first quarter of 2005 to the fourth quarter of 2011, and convert the growth rate to quarterly industrial added value as the original data of the combination forecasting model. 26 data groups from the first quarter of 2005 to the second quarter of 2011 were used to fit the model while another 2 groups of data from the third quarter of 2011 and the 4 quarter of 2011 data were used to test the model. China has not counted the PMI index until 2008, so we could only choose 16 groups sample data from the first quarter of 2008 to the fourth quarter of 2011 to establish the ARCH model with the PMI index and prosperity data.

1. Prediction of Industrial Added Value by GMDH Model

Chain index processing for the time series of industrial added value was done first in order to eliminate the influence of dimensions, then GMDH model was set up by using Knowledge Miner software, through continuous adjustment of Max. Time lag, Model Type and other parameters, after several attempts and inspection of the value of R-squared, the mean absolute error percentage and the square sum of error, and comprehensive analysis of each model we got the best complexity model with optimal fitting effect:

$$Y_{\mathrm{GMDH}} = 0.9926 Y_{\mathrm{GMDH}(t-4)} - 0.01534. \tag{1}$$

In the GMDH model, R^2 is 0.9352, close to 1, the fitting effect is good; the mean absolute percentage error is 2.1, $<5\,\%$, which is in acceptable range; the sum of prediction squared error is 0.069, less prediction errors.

2. Prediction of Industrial Added Value by ARIMA Model

From quarterly time series graphs of industrial added value of China, we found that the industrial added value shows an upward trend on the whole, a certain periodicity and non-stationary behavior. A series of processing for the data of the industrial added value by using Eviews software [17] are shown below:

(1) Pre-processing of data. Doing the first-order differential treatment after taking the logarithm of the industrial added value in order to meet the stationary condition;
(2) Determining the range of the order P and Q of ARMA models according to the self-correlation coefficient and partial auto-correlation coefficient, constructing multiple ARMA models and then estimating the parameters of each model using the least square method. After several attempts, we compared each model with AIC criterion, SC criterion and R-squared value and tested them with the significant of parameters, the rationality of the model and whether the residual series is white noise sequence or not. Finally we determined the optimal model as ARIMA (2, 1, 4) and the specific model is shown below:

$$Z = 0.035 + 1.457Z_{t-1} - 0.275Z_{t-2} - 0.314\mu_{t-1} - 0.296\mu_{t-2} - 0.267\mu_{t-3} + 0.716\mu_{t-4}. \quad (2)$$

In Eq. (2), $Z = \Delta X$, $X = \frac{\ln(Y_{\text{ARIMA}})}{\ln 10}$, μ is the random error term, so it is converted to the final math model of original data of the industrial added value as follow:

$$Y_{\text{ARIMA}} = e^{X_{(t-1)}+0.035+1.457Z_{t-1}-0.314\mu_{t-1}-0.296\mu_{t-2}-0.267\mu_{t-3}+0.716\mu_{t-4}}. \quad (3)$$

In the ARIMA model, every parameter has passed test, the model is reasonable; R^2 is 0.989, sufficiently close to 1, the fitting effect is good; the mean absolute percentage error is 2.525 %, the error is acceptable, the model achieves a better prediction effect.

3. Prediction of Industrial Added Value by ARCH Model

The ARIMA model is an auto-regressive model with itself as the foundation. It pays more attention to time series' inherent law and development trend. And when modeling, it only takes the influence of a sequence of the industrial added value has on its own into consideration while ignoring the relationship of industrial added value with other economic factors. So we built the prediction model by using ARCH model and some other economic data related with industrial added value.

Firstly we processed for the industrial added value, PMI and time series of industrial enterprise prosperity index by the chain index and using Eviews software [8] to do LM test for time series. The test results show that ARCH effect exist in the sequence so ARCH model can be established; then, adjusting the lag order number of industrial added value sequence, PMI sequence and industrial enterprise prosperity index sequence and estimating the parameters of ARCH model with the maximum likelihood estimation method; after several attempts we analyzed each model according to the AIC criterion, SC criterion and Adjusted R-squared value of each model and tested the compatibility and the independence of the residuals of each model. By comparison, the optimal model that was selected is the following:

$$Y_{\text{ARCH}} = -487.8 + 0.986X^1_{t-4} + 0.257X^2_{t-1} - 0.192X^3_{t-4}. \quad (4)$$

In the ARCH model introduced PMI and industrial enterprise prosperity index, X^1_{t-4} is the Industrial added value lagged four, X^2_{t-1} is the value of PMI lagged one, X^3_{t-4} is the Industrial enterprise prosperity index lagged four, each parameter have passed t test, the model is reasonable; R^2 is 0.965, close to 1, the fitting effect is good; the mean absolute percentage error is 2.239 %, the error is acceptable, The model achieves a better prediction effect.

4. Prediction by Combination Forecasting Model

The above three models were established from different angles: The single autoregressive of GMDH model is obtained from the optimal balance angle and the single auto-regressive of ARIMA model is developed from the angle of minimum variance while processing multivariate modeling from the angle of the PMI index effecting GDP. Therefore the combination of the above three models takes a holistic view and comprehensively collects useful information on various aspects. In this paper, we takes YGMDH, YARIMA, YARCH as the model input, and use the GMDH input and output model to combine the three single models. After the model automatically filters the ARCH model with the worst fit result, we get the final combined model as follow:

$$Y_{\text{combined model}} = -52.68 + 0.822Y_{\text{GMDH}} + 0.677Y_{\text{ARCH}} - 0.928Y_{\text{ARIMA}}. \quad (5)$$

In this combined model, R^2 is 0.997, sufficiently close to 1, showing the fitting effect is good; the average absolute percentage error is 0.56 % and the sum of prediction error square is 0.0045, which are both very small, indicting the model achieves a better prediction effect.

4 The Comparative Analysis of the Predicted Results

As can be seen from the prediction, the predicted results of the four models are satisfactory. The average error in prediction is controlled to 5 %, and the specific results as shown in Table 1.

As can be seen from the prediction, the predicted results of the four models are satisfactory. The average error in prediction is controlled to 5 %, and the average error in the combined forecasting model is only 0.885 %.

It is seen from Table 1 that the R-squared of combined forecasting model is the largest, the average error of prediction is the smallest, indicating that the effect of the fitting results and prediction of combination forecasting model is better than the single model. In predictability, the average error of prediction of combined forecasting model is not necessarily lower than single model at any time, but the average error of combined forecasting model are lower than that of single model from the whole observation. The fitting effect of the GMDH model is poor, but is better than ARIMA model, and the prediction effect of the ARCH model have been greatly improved with the introduction of PMI and industrial enterprise prosperity index, since the error is only 1.127 %, indicating when predicting industrial added value, the model will reflect the tendency of economic development very well after the introduction of PMI and industrial enterprise prosperity index.

Table 1 The predicted results of the 3 4 quarter of 2011

Time (Quarter) actual value (billion yuan)		2010.Q3	2010.Q4	R^2	The average error (%) of prediction
		43194.49	43803.03		
GMDH model	Predictive value (billion yuan)	42740.95	42852.50	0.935	1.609
	Relative error (%)	1.05	2.17		
ARIMA model	Predictive value (billion yuan)	43051.36	42203.04	0.989	1.992
	Relative error (%)	0.33	3.65		
ARCH model	Predictive value (billion yuan)	43617.79	44359.33	0.965	1.127
	Relative error (%)	0.98	1.27		
Combined forecasting model	Predictive value (billion yuan)	42905.09	43321.20	0.997	0.885
	Relative error (%)	0.67	1.10		

5 Conclusion

This paper establishes the GMDH model, ARIMA model, ARCH model and combined forecasting model by using the data of the industrial added value from the first quarter of 2005 to the second quarter of 2011. And predicts and test these models with the data from third quarter of 2011 to the 4th quarter of 2011 data. The empirical analysis shows that the forecast effect of combined forecasting model is far superior to the single models, and the forecasting ability of ARCH is better than that of GMDH model and ARIMA model after the introduction of PMI and industrial enterprise prosperity index. Therefore, the application of the combined forecasting model based on combining the leading indicators and the prosperity index is practically more significant.

The paper suggests introduction of PMI index and prosperity index to the building of prediction models of the industrial added value and achieves good prediction effect by doing so. But in order to achieve better prediction effects, we still need to continuously seek the index closely related with the index of GDP and improve the fitting and prediction effect of the single model so as to improve the prediction effect of combined forecasting model.

From the comparison of the fitting and prediction effect of the each model, the model with a good fitting effect is not necessarily one with a good prediction effect, and vice versa. Each prediction model has its own advantages, disadvantages and scope of application. Therefore, we should establish different models for different problems in the process of practical application.

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Analysis of Capital Stock from Guizhou Province

Hui Zhang

Abstract The capital stock's estimation is the key indicator of analyzing economic growth, and is the premise of understanding industrial upgrading in western regions of China. In the actual measurement process, the way of calculating capital stock is arguably different. By introducing the different capital stock estimation's models, the author recalculates the capital stock level of Guizhou Province with three kinds of methods, compares and analyses the varied results by different approaches. For Guizhou Province, the lowest of capital stock is 294.7 billion Yuan and the highest of capital stock is 622.1 billion Yuan in 2011. As a result, on the premise of the Perpetual inventory method, the main difference of different methods is how to deal the previous actual capital stock (K_{t-1}) and the current actual net investment (RNI_t). Especially, the key factors are the nominal total investment (GI), the nominal depreciation (DS) and the price index of fixed assets investment (PIF_t) which consist the RNI_t. Therefore, this comparison study can help us to understand the capital stock's level of different regions, and provides some solid basis to undertake the industrial transfer from east regions to the west regions of China.

Keywords Capital stock · Fixed-capital price index · Inventory · Depreciation · Guizhou

1 Introduction

Economic growth theories were the essential concern for economists for many less developed countries post WWII era. There were large number of researches emphasize the effect of capital is a key factor in economic growth. These thoughts were

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H. Zhang (✉)
School of Economics, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 24060565@qq.com

H. Zhang
School of Economics, The Northwest University for Nationalities, Lanzhou 730030, People's Republic of China

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reflected in Harold-Domar model [18], poverty vicious spiral theory and big push theory [16], Dual Sector model [8], Chenery [2] proposed double gaps model which is based on the Keynes' national income equilibrium and Harold-Domar's growth model, and emphasizes the impact of foreign exchange constraint and savings constraint on the economy. The new classical growth theory as the representative of Solow [14] and the new economic growth theory as the representative of Romer [13] developed further analysis on the role of capital. Above thoughts are well received in the economic development practices in China, especially in the western regions. Hence, accurately measuring and analyzing the capital stock is the basis of economic development become a very important work. Sun and Ren [15] calculated the capital stock and capital flow of China from 1985 to 2005 and find the speed of capital stock is normal, Jin [7] calculated the 31 provinces' capital stock of China and finds the rate of capital stock in west regions is faster than the east regions. Cao and Qing [1] established the capital stock's basic measurement framework and calculate the capital of China from 1994 to 2010. In order to better understand the actual situation, by using the different measurement methods, this paper calculates the Guizhou province's capital stock. This will provide useful theoretical support for western regions to undertake the industries' transfer from the eastern regions of China.

2 The Method of Estimation the Capital's Stock

How to decide the formula of calculation is the basic issue for the capital stock's estimation. Literally in the actual measurement, every scholar uses different method although they follow same theoretical origins. This kind of situation can be explained from the two aspects of the basic idea and the specific method.

1. The Basic Idea

The capital stock is the capital assets which is installed on a certain number of production units in the certain time, it is generally used to measure the capital investment that put into the process of production, especially is used on the measurement of fixed assets. There are many kinds of methods about the capital stock's calculation, Ren and Liu [12] pointed out the perpetual inventory method is the widely used method in the world which is created by Goldsmith in 1951. Therefore, the basic principle is that the previous actual capital stock and the current actual net investment compose the current actual capital stock. The capital stock's formula is:

$$K_t = K_{k-1} + RNI_t.$$

In the above formula, K_t means the current actual capital stock, K_{t-1} means the previous actual capital stock, RNIt means the current actual net investment. Li and Tang [9] used this method estimate the China's capital stock from 1978 to 2000, The formula of RNI_t is:

$$RNI_t = NI/PIF_t = (GI - DS)/PIF_t.$$

NI is nominal net investment, *GI* is the nominal total investment, *DS* is nominal depreciation, PIF_t is the price index of fixed assets investment. Combined these two formulas we can get:

$$K_t = k_{t-1} + (GI - DS)/PIF_t.$$

In order to analysis the K_t by using the above formula, we will consider the following variables: K_{t-1}, *GI*, *DS*, PIF_t, as long as we know the specific values of these variables, we can get a time series of the real capital stock.

2. The Specific Method

But in the actual measurement of the capital stock, there are different opinions in the details of the scholars. The differences are mainly manifested in the following scholars' opinion:

(1) Chow [3] used the formula: $K_t = K_{t-1}+$ current year's actual net investment. In Chow's article, the increasing of capital stock means the new productive and new non-productive social fixed capital and liquidity after depreciation. So, this method pays close attention to the depreciation.
(2) He [5] used the formula: $K_t = K_{t-1}+$ current year's actual net accumulation. In He's article, the accumulation is RNI_t, the accumulation is the ratio of current accumulation index divide with the base period accumulation index and multiply by the base period accumulation, in which the concern of this method is the ratio of accumulation index between the different period.
(3) Wang and Fan [17] used the formula: K_t (1952's constant prices) = K_{t-1} (1952 constant prices) + (current fixed capital formation−depreciation)/*PK*, in which PK is price index of investment in fixed capital. In Wang's article, the key of calculate capital stock is price index of investment in fixed capital. By using this price index, Wang and Fan adjust the current capital stock and make the amount of capital stock more accurately.

From the above existing research results we can find: the main reason of why measure a specific area's capital stock has different results with above method is how to determine the following several key variables: the capital stock of 1952s, the specific price index selection, the level of investment (depreciation and inventory). In order to understand the principle of calculating the capital stock and compare the characteristics of different calculation methods, this paper discusses these issues and gives the corresponding conclusion.

3 Several Key Problems' Disposal in the Calculation

In this part we discuss the following key questions.

3.1 How to Determine the 1952s Capital Stock

1. The basis of calculation

According to above mentioned studies, there are two base-years namely: new China's established statistic year-1952 and, the Reform and Opening-up year-1978. Considering the data's accuracy and availability, the beginning of calculating the current capital stock is identified the capital stock level of 1952, and the price of 1952 is determined as the constant price. In order to facilitate the analysis, we compare the existing research results of 1952s capital stock level in the (Table 1).

Because the early China statistical yearbooks did not report the fixed capital stock, and we only get the fixed assets and net worth data of enterprise owned by the whole people, so the capital stock of 1952 can be only estimated by calculating. Chow [3] calculated the capital stock of 1952–1985 by using the state-owned enterprises, urban collective enterprises, rural collective enterprises and individual fixed assets and current assets' yearly data, but he does not explain the way of calculation specifically. At last, he gets the whole country's capital stock is 103 billion Yuan without the land value in 1952. He [5] considered the average growth rate of capital is equal because of the stability of the economic system and national policy in 1964–1978, then he gets the capital stock which calculates with 1990s constant price is 94.6 billion Yuan in 1952. Wang and Fan [17] did not maintain the specific calculation methods but they explain that according to the repeated calculation, the capital stock is 160 billion Yuan in 1952 with same year's price.

We can find there are obvious differences exist between these conclusions. The key question is which one method is more correct when we use it to measure the Guizhou province's capital stock. According to analysis above different methods and results, we find that every one of three methods has its advantages and disadvantages, and if you fully trust or abandon any kind of method are not suitable. Finally, we make a compromise: because we can't find the best method, then we use each of the method at the same time, so we can find a conclusion from the three different results at last.

Table 1 The different scholars' capital stock

Chow	He	Wang and Fan
1030	679	1600

Note 1952s constant prices, *unit* 100 million RMB
Data sources according to the China statistical yearbook 2012 and related documentation

Table 2 The capital stock of Guizhou

Chow	He	Wang et al.
12.98	8.56	20.16

Note the Guizhou's GDP is 623 million RMB in 1952, the GDP of China is 67,900 million RMB in that year, *unit* 100 million RMB
Data sources according to the China, Guizhou statistical yearbook 2012 and related documentation

2. To determine the specific numerical of Guizhou province's capital stock in 1952

Now the new question is that when the capital stock of 1952' is fixed in whole country, how can we decide the Guizhou province's capital stock of 1952? By analyzing the related empirical results, this paper proposes year 1952 as the base-year. In 1952, the data of national capital stock is calculated from the different province's capital stock data, the formation of capital stock data in anyone province is closely related on the level of local economic development. Therefore, we use the 1952s GDP of Guizhou province in the proportion of whole country's GDP in the same year as the basis, we do the re-measure by using the above methods. The new results we get in the (Table 2).

3.2 How to Select the Price Index

For the accumulation of capital stock, the level of each year's vested capital is accounted with the current prices, and there are obvious differences based on the different stages of economic development within these years. Therefore, it is necessary to adapt a certain price index for processing the data of each year.

According the existing data, the statistical yearbook only shows the price indices of investment in fixed assets from 1992, we cannot get the price indices from 1952 to 1991. According to this constraint, researchers choose other indices instead of the price indices of investment in fixed assets or calculate the capital as proxies. Chow [3] uses the remains indices to calculate the remains implicit deflator indices according the data of statistical yearbook, but we cannot use this data directly because we don't get the raw data. According to comprehensive analyze the different scholar's research, we find there're two kinds of price index can be used.

1. Shanghai price index

Zhang and Zhang [19] found the fixed capital of Shanghai since 1950–2000 and the related index in the appendix of Yearbook of statistics in Shanghai 2001, they give their interpretation by analyzing these data. As one of the most developed city in China, the economic development of Shanghai can be regarded as the representative for the level and speed of Chinese economic development. Therefore, because the national capital price index is absent, we use the Shanghai's existing price index is reasonable.

2. The GDP price deflator index

Although the Shanghai price index can reflect the change of the capital stock at certain extent, but this index cannot completely reflect the gap between the regions. Because the Shanghai price index cannot reflect the price changes completely, this research also adopts a different method to make up this deficiency-the GDP price deflator index. The calculation of GDP price deflator index as follows:

(1) First, We collect the Guizhou province's actual value GDP and the GDP price index from 1952 to 2011.
(2) Second, we use the GDP in 1952 as the base year and multiply the other year's GDP price index and then divides by 100, so we can get any one year's real GDP which is reflected by the 1952s GDP.
(3) Finally, we apply the actual GDP of each year divides the any one year's real GDP which is reflected by the 1952s GDP, so we can get the correct GDP price deflator index.

3.3 How to Calculate the NI

Another key factor in the capital stock is how to calculate the RNI_t, and how to determine a more accurate current net investment is the biggest challenge before calculate the RNI_t. In the calculation of the annual new capital, most studies use the way of deducting the depreciation from the total social investment in fixed assets.

He and Chow use the accumulation to reflect the new capital. The accumulation is the material of product value which is used to expand reproduction and non-productive construction and increase the social reserve, the amount of accumulation equal the net national incomes which remove the consumption share of that year. But this way can't be used anymore because the new statistical system of China does not publish the data of accumulation from 1993. Wang and Fan [17] considered that there are huge wastes in the investment of China, so directly using the investment in fixed assets will make the amount of capital higher. They calculated the current fixed assets with fixed asset investment in the whole society investment multiplied the deliveries ratio of fixed assets before 1980, and directly using the fixed capital formation data are released by the National Bureau of Statistics after 1980.

Because of different understanding about the *NI*, three scholars' opinions are different. The main reason of this situation is due to the statistical data's uncertainty. For the sake of convenience, the question of how to calculate the *NI* will be summarized as follows:

1. How to understand the meaning of *GI*

In the above three methods, the key element of understanding the *GI* is the definition of the total investment, that means how to deal with the inventory. Because this problem can't be reflected in the above three scholars' article, the total investment will be defined as two types: the first method describes the total investment is directly represented by current fixed capital formation; the second way defines the total investment composes by the current fixed capital and inventory. (Because the gross capital formation = gross fixed capital formation + inventory).

2. How to decide the current fixed capital formation

Because we can only find the data of current fixed capital formation from 1985 to 2011, in order to get the data of 1952–1984, we use the data of expenditure approach GDP to reckon the current fixed capital. By comparing the data we can find: the mean of current fixed capital is very close, so we believe there is a relatively stable tendency between the two data.

3. How to decide the inventory

The processing method of inventory is same as the current fixed capital. Because the mean value of inventory is very close, so we believe there is a relatively stable tendency between the two data.

4. How to decide the depreciation

Because the depreciation has the same problem with fixed capital formation, so we take the same way to deal with: (depreciation of 1990–2011)/(total investment in fixed assets 1990–2011)×(total investment in fixed assets 1952–1989). Because the mean value of the depreciation is very close, so we believe there is a relatively stable tendency between the two data.

3.4 The Summary of Above Methods

Through the above introduction we can find, the different factors can constitute different conclusions. The specific combinations are as follows (Table 3).

Table 3 The combination of methods

	Method											
	Chow				He				Wang et al.			
RNI_t	①	②	③	④	①	②	③	④	①	②	③	④
1	Y	Y			Y	Y			Y	Y		
2			Y	Y			Y	Y			Y	Y
3	Y		Y		Y		Y		Y		Y	
4		Y		Y		Y		Y		Y		Y

Note Y means the way which can be used
1 means: Depreciation = current fixed capital formation
2 means: Depreciation = the current fixed capital + inventory
3 means: Shanghai price index
4 means: GDP price deflator index

According to the table we can see: when we calculate the capital stock with Chow, He or Wang's methods, based on the different understanding of NI and PIF_t, we can choose any kind of method from the above table and get different result. All of these results are the key content in the follow-up study.

4 Results and Conclusions

1. Results

There are many different methods of calculation and coupled with the use of specific differences of index, the main results show as follows (Table 4).

(1) From the table we can see: due to the different definition of total investment the result which uses the total investment composes by the current fixed capital and inventory is bigger than the result which uses the total investment is represented by current fixed capital formation regardless of which method you use.
(2) The result which uses the Shanghai price index is bigger than the result which uses the GDP price deflator index.
(3) The different of capital stock in 1952 is one of the reasons why the above methods have different result.

Table 4 The result of different methods

		Year						
		1952	1961	1971	1981	1991	2001	2011
C	1	12.98	41.20	129.01	255.98	529.60	1288.35	6221.32
	2	12.98	52.87	159.90	324.37	679.25	1553.46	5764.33
	3	12.98	34.17	78.90	139.85	263.11	632.58	3229.14
	4	12.98	44.37	98.78	178.27	339.49	722.34	3076.61
H	1	8.56	36.78	124.59	251.56	525.18	1283.93	5482.42
	2	8.56	48.45	155.48	319.95	674.83	1549.04	6273.19
	3	8.56	29.75	74.48	135.43	258.69	694.57	3142.28
	4	8.56	39.95	94.36	173.85	335.07	722.65	2947.16
W	1	20.16	48.38	136.19	263.16	536.78	1295.53	6326.57
	2	20.16	60.05	167.08	331.55	686.43	1560.64	7236.83
	3	20.16	41.35	86.08	147.03	270.29	658.91	3369.46
	4	20.16	51.55	105.96	185.45	346.67	800.53	3537.19

Note C-Chow, H-He, W-Wang and Fan, *unit* 100 million RMB
Data sources according to the Guizhou statistical yearbook 2012 and related documentation

2. Other Matters Need to Be Explained

(1) The stock of agricultural capital
For the calculation of agricultural capital stock, most scholars only calculate the short term data at the national level. For example: Pu and Chen [11] calculated the data from 1998 to 2010 and He and Xiao [6] calculated the data from 2003 to 2012. Although Li and Tian [10] gave the result of agricultural capital stock in Guizhou province from 1952 to 2011, but there is no introduces about their method. So this paper believes that the impact of the agricultural capital stock for the capital stock of China can be negligible in 1952. The reason is that there is a fairly long period of time after the new China established, most of the agricultural production process also belongs to the labor-intensive, the mode of production is given priority with simple labor and there are a few of fixed assets available for using. So we can deal the relatively small agricultural capital stock level as the research error which can be accepted in the study.

(2) The stock of human capital

The estimation of human capital is a very difficult thing, and we have to face a series of problems when we estimate the human capital of China. These questions include: the definition of human capital, the availability of data, the degree of full employment, the level of unemployment, the method of aggregating and processing data. Even the different ethnic minorities in Guizhou will have an impact on the formation of local human capital. Considering Du and Yang [4] found the direct effect of human capital on the economic growth is not obvious, so this paper does not analyze the question of human capital stock deeply.

3. Conclusions

There are following conclusions can be drawn:

(1) PIF_t is one of the key factors to decide the capital stock

All the data are divided into two groups, the data uses the Shanghai index are larger than uses the GDP price deflator index. That means the most important thing on the final result is the selection of index if other conditions are similar.

(2) The capital stock of 1952 is the main cause of difference between intergroup results

By specific analysis of each group's results, we will find the gap in the all groups with same number's method is simply due to the capital stock of 1952 which has been determined.

(3) How to understanding the *NI* is another key factor in the calculation

When the capital stock of 1952 and PIF_t are determined, the key is how to decide the impact of the net investment, which is used to calculate the inventory in certain year. Therefore, the inventory becomes the key and influences each method's result when the index is the same.

In conclusion, the capital stock is the important indicator to justify the level of economic growth in the different region. However, due to different estimation strategies and methods, the estimated results varied accordingly. Therefore, when we want to calculate the capital stock in a particular area, the difference among the different methods should be fully considered. Especially when considering particular region with specific research objectives, selection of specific calculation methods is of essence and value for the accuracy of explanation. Only in this way, we can get the relative correct capital stock in different regions, and provide useful ideas and suggestions to study the certain regional economic growth and questions of industries transfer.

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Study on the Contribution Rate of Scientific and Technological Progress to Economic Growth in a Coal Enterprise

Lin Zhuo, Yi Lu and Xuexiang Deng

Abstract To calculate the contribution rate of the scientific and technological (S&T) progress to economic growth in a coal enterprise, the improved production function model and the Solow residual value method are adopted in this paper. This method includes three steps: Firstly, according to the processed data, the unknown parameters are estimated by SPSS. Secondly, the annual growth rate of each production factor is calculated. Thirdly, the contribution rate of S&T progress to economic annually is obtained based on the Solow residual method. In this paper, the highest contribution rate of S&T progress to economic growth reaches 36.06 %, and presents a rising trend. Finally, based on the result, some suggestions and conclusions are provided accordingly.

Keywords Contribution rate · Technological progress · Solow residual model · Coal enterprise

1 Introduction

In order to realize the economic development in a continual, stable, and highly efficient way, we have to adjust the proportion of various input factors in the economy. Since the economical growth way of coal industry is an extensive form, whose traits are high investment, high consumption with low output and low quality. Transformation of the economic growth is the most important work in coal enterprise reform. So, it is important to obtain the contribution rate of each factor to economic growth, especially the contribution rate of S&T progress, which can help the managers make reasonable macro policies. Ayres [1] proposed that the contribution rate of S&T

L. Zhuo · Y. Lu (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: luyiscu@163.com

X. Deng
Technology Center, Yankuang Group Company Limited, Zoucheng 273500, People's Republic of China

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progress to economic growth, broadly speaking, refers to the sum of contributions rate of other factors to output increase, excluding those of the increase in labor force and capital.

It is essential to seek higher returns for enterprise, we must analyze if the investment is reasonable so as to determine how much input we should increase or decrease in the next round of production. Hence, the contribution rate of S&T progress to economic growth is a reference standard to determine whether the resource is effectively utilized. The configuration of science and technology resource mainly comprise two aspects: input and output. Right configuration is a key factor to improve the contribution rate of S&T progress. In coal enterprise, Science and technology input includes financial resources input and human resource input. And the output level can be measured either by raw coal production or gross industrial output value. The contribution rate of S&T progress reflects the relative relationship among capital, labor and technology progress in the economic growth.

Considering the contribution rate of S&T progress, some scholars conduct research from the perspective of S&T resources allocation about the S&T progress, such as Yu and Ju [2], Inekwe [3], Eddleston and Kellermanns [4]. Some scholars do quantitative research. Guo et al. [5] used the Cob-Douglas production function and the Solow residual value method to count thirty one Chinese regions at different categories of levels of S&T progress contribute to economic growth. Durlauf et al. [6] made contribute to a better understanding of the capacity of the Solow growth model to explain cross-country growth patterns. Moreover, Wang and Yu [7] constructed a agricultural production function of Anhui province agriculture, and measured each input factor's influence on total agricultural output, Li and Hu [8] made an empirical study on the contribution rate of land to economic growth to Shanghai. Also, Guo et al. [9] constructed a fuzzy neural networks to estimate the economic contribution rate of education in China. However, these researches about the contribution rate to economic growth rarely covered the coal field. Since the economic growth is influenced by many factors, especially the non-quantifiable factors, such as the policy factors, structural factors, market factors such as the information distortion, it is with a with a high level of uncertainty and it is difficult to make quantitative analysis by the Cobb-Douglas only. Meanwhile, the same S&T progress may make different contributions in different regions. Thus, Traditional statistic measures on the contribution rate of S&T progress are deficient. In this paper, aiming at measuring the contribution rate of a typical coal enterprise from the year of 2004 to 2013, the Cobb-Douglas production (C-D production function) and Solow residual value method is adopted, considering the three principal influence factors: production output, capital and labor input, which can display the interaction to the economic growth specifically. Then, on the basis of analysis of calculated results, corresponding countermeasures and suggestions about improving the contribution rate of S&T to economic growth are put forward.

2 Problem Statement

For a long time, the measurement for the S&T progress to economic growth has been active research area. But it is quite controversial about the calculation method. Besides, the parameter selection in the calculation process can have great influence on the final results, such as the measurement way of labor input. From the perspective of the enterprise, the right configuration of S&T resources plays an important role in the operation. Thus, a straight way about how to compute the S&T progress to economic growth and how to adjust the resource structure on the basic of comparative and analysis these data are in needed. Only the perfection of resources allocation can have their sustainable development really fulfilled. Moreover, through this approach, the enterprise can make reasonable resource input plan according to the work target (briefly speaking is the contribution rate in expectation). So, there is a need of conducting a comprehensive study on the way to compute the contribution rate of S&T progress and the extending researches.

3 Modelling

Coal production process is one to which various production resources are continuously devoted. In order to make a better understanding of how to compute the contribution rate of S&T progress to economic growth, the Solow residual model is established on the basic of C-D production function. And the deduction of calculation process is performed.

1. Assumption

To apply the Solow residual value approach, the following assumptions are made:

(1) The production factors only include capital, labor and time, which can be fully utilized at any time;
(2) The S&T progress is assumed to be the neutral technological progress defined by Hicks, namely the output-growth-oriented technological progress, which regards the marginal product of capital and labor rate as fixed;
(3) In a perfectly competitive market.

2. The Model

$$Y = f(K, L) = A_0 e^{\lambda t} K^{\alpha} L^{\beta}, \tag{1}$$

$$a = y - \alpha k - \beta l. \tag{2}$$

Equation (1) is the Solow neutral technical progress function, in which Y denotes the output, K denotes the capital input, L represents the labor input, A_0 indicates the level of technology at base period, λ represents the rate of technological progress. The value of α, β can be computed based on this Eq. (1).

Equation (2) is the Solow residual value method. Here, y is the growth rate of output, k is the growth rate of capital input, l is the growth rate of labor input. Equation (2) means that the contribution of S&T progress to economic growth is equal to the sum effect of other factors excluding the increase of capital, labor and human capital.

In the equation above, there are possibly three situations for $\beta + \beta$, if $\beta + \beta > 1$, the scale economy is increasing returns to scale, if $\beta + \beta < 1$, it's the decreasing returns to scale, if $\beta + \beta = 1$, then, it satisfies the constant returns to scale in the production process.

3. Production Factor Indexes

In the production above, the Y is measured by the gross value of industrial output, the fixed assets is used to measure the capital input K, the labor input L is measured by the number of the employers from the year of 2004 to 2013.

(1) The output Y

This paper calculates the contribution rate of the S&T in coal enterprise, considering the time lag effect of money, the data on gross industrial output value from 2004, which is also as the base year, are adjusted to the standard data.

(2) The fixed assets K

The net value of fixed assets refers to the total scale of fixed assets capital stock at a given time. Due to the lags on the economic benefits of capital input [10], the perpetual inventory method [11] is used to adjust the comparable prices of fixed assets stock of each year. The adjustment equation is as below:

$$K_t = (1 - \delta)K_{t-1} + X_t, \tag{3}$$

where K_t is the initial value of fixed assets of the tth year after adjustment; δ is the geometric depreciation rate of the fixed assets ($\delta = 5\,\%$ in this paper); X_t is the comparable price of the fixed assets investment in the tth year. $X_t =$ the fixed assets investment at the tth year $\times$ the price index of fixed assets investment at the base period $\div$ the price index of fixed assets investment at the tth year. The net value of fixed assets stock of the base period (the year of 2004) is supposed to be equivalent to the fixed assets investment, namely $X_0 = K_0$.

(3) The labor input L

The amount of the labor input refers to the process of the coal production. Current researches about the method to measure the total actual investment of labor force at home and abroad have the following categories: One way is to use the labor income. But using the income to measure labor input is clearly affected by many factors, and the authenticity of the data is poor. Another way is to use the number of the labor input, namely the number of the employed staff or the practitioners, which data is adequate, systematic and standardized and with no necessary to adjust the price. Therefore, the number of employees (million) of each year is directly used as labor input index.

4 Case Study

Based on the above mentioned approaches, this paper evaluates the contribution rate of S&T progress to economic growth of a coal enterprise. For the sake of confidentiality, we call it company C here, and make a brief introduction about it. Company C is an extra-large State-Owned-Enterprise (SOE) mainly engaged in coal mining and sales, coal chemical industry, power generation and aluminum production and machinery manufacturing. By applying the scientific outlook on development, restructuring business and transforming growth patterns, the company has experienced an extraordinary development for years. To achieve higher goals and measure the ability to transform the competitive power of S&T into real productive forces, we got the raw data. Due to the requirements of the model and confidentiality, appropriate modification and adjustments were made. Data of production factors in a typical coal enterprise is shown in Table 1.

Table 1 Data in coal enterprise from the year of 2004 to 2013

Year	Y	K_t	K_a	L
2004	2214453	100.00	5573.14	98652
2005	2510112.304	101.58	11182.64	99147
2006	2579178.331	103.11	17343.05	99303
2007	2645134.563	107.14	23136.71	101271
2008	3315253.702	116.74	29132.2	94035
2009	3984615.303	113.95	33014.77	99970
2010	4299164.901	118.03	37283.1	93827
2011	4614493.888	125.82	51692.53	96238
2012	4984442.121	127.21	58632.54	97373
2013	5074703.099	127.58	66171.43	94441

Note Data is from a coal enterprise from the year of 2004 to 2013. Y denotes the gross industrial output value after data smooth processing and the unit is ten thousand Yuan. K_t denotes the price index of fixed assets investment and the base year is 2004, this data come from the China statistical yearbook. K_a is the fixed assets after adjustment and the unit is million Yuan. L is the number of employers and the unit is people

4.1 The Estimation of the Parameters *α*, *β*, *γ*

The key point of calculating the contribution rate of S&T progress to economic growth is to get the α, β, γ. Currently, there are three main methods to determine the elasticity of output: the empirical estimation method, the ratio method and the regression method. Here, the sample data in this paper is actually in line with the requirements. So, the regression method is adopted. Seeking the partial derivative on K, L in Eq. (1), we can get,

$$\frac{\partial Y}{\partial K} = A_0 e^{\lambda t} \alpha K^{\alpha-1} L^{\beta} = \alpha \frac{Y}{K}, \tag{4}$$

$$\frac{\partial Y}{\partial L} = A_0 e^{\lambda t} K^{\alpha} \beta L^{\beta-1} = \alpha \frac{Y}{L}. \tag{5}$$

According to Eqs. (4) and (5), we can get Eqs. (6) and (7).

$$\alpha = \frac{\partial Y}{\partial K} \times \frac{K}{Y}, \tag{6}$$

$$\beta = \frac{\partial Y}{\partial L} \times \frac{L}{Y}. \tag{7}$$

From the above, it is clear that α and β are respectively the output elasticity of fixed assets stock, the output elasticity of labor. It indicates that the same level of S&T, if the investment on labor is constant, 1 % increase in fixed assets stock will lead to α% increase in output, if the investment of fixed assets stock in constant, 1 % increase in labor will result in β% increase in output. Then the value of α, β and λ are got by taking logarithm of both sides of the Eq. (1):

$$\ln Y = \ln A_0 + \lambda t + \alpha \ln \frac{K}{L} + \beta \ln L. \tag{8}$$

We use the sample data of the indexes Y, K and L from 2004 to 2013 in Table 1 and according to the Eq. (8), we use the SPSS software to do multiple regression analysis on the sample data. And the results are shown in Table 2.

From Table 2, we can find that R^2 is close to 1, fit is with high goodness and good effect. Similarly, regression coefficients α, β and λ also pass their respective t

Table 2 Result of analysis on the sample data

Number of samples	R^2	F	α		β		λ	
			Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
10	0.996	481.535	0.493	6.987	−0.054	−0.144	0.036	3.722

test when $\alpha = 0.493$. So, significance level of all indexes is high, which means the models all pass the examination successfully.

4.2 The Calculation of Average Annual Growth Rate of Each Index

Annual average growth rate is expressed as a multiple or percentage. It is equal to the average rate of development minus 1 (or 100 %). Here, we use the level analysis method to calculate the average growth rate. And the calculation equation is listed as follows:

$$\text{The growth rate of output: } y_t = \left(\sqrt[t]{\frac{y_t}{y_0}} - 1\right) \times 100\,\%. \tag{9}$$

$$\text{The growth rate of fixed assets: } k_t = \left(\sqrt[t]{\frac{k_t}{k_0}} - 1\right) \times 100\,\%. \tag{10}$$

$$\text{The growth rate of labor: } l_t = \left(\sqrt[t]{\frac{l_t}{l_0}} - 1\right) \times 100\,\%. \tag{11}$$

y_t, k_t and l_t denote the output, the fixed assets and the number of the practitioners in the end of a period respectively. y_0, k_0 and l_0 are the output, the fixed assets and the number of the practitioners in the base period respectively ($y_0 = y_{2004}$).

4.3 The Calculation of Contribution Rates of the Factors to the Total Output Growth

According to Eq. (3), the S&T progress rate can be calculated. By Eqs. (9)–(11), the contribution rate can be got as is shown in Table 3.

The contribution rate of S&T progress to economic growth during the period of 2004- tth year:

$$E_A = \frac{a_t}{y_t} \times 100\,\%. \tag{12}$$

The contribution rate of fixed assets to economic growth during the period of 2004–tth year:

$$E_k = \frac{\alpha k_t}{y_t} \times 100\,\%. \tag{13}$$

Table 3 The contribution rate of the production factors to economic growth

Year	y_t	k_t	l_t	a_t	E_A	E_k	E_l
2004	–	–	–	–	–	–	–
2005	0.133513	0.223612	0.005018	0.023544	0.176339	0.616337	0.004961
2006	0.079214	0.131356	0.003294	0.014633	0.184731	0.610234	0.005489
2007	0.061029	0.095269	0.008772	0.014535	0.238161	0.574469	0.018973
2008	0.106146	0.168979	−0.01191	0.022196	0.209112	0.585836	−0.01481
2009	0.124667	0.194164	0.002658	0.029088	0.233323	0.573145	0.002814
2010	0.116914	0.178648	−0.00832	0.028391	0.242835	0.562316	−0.0094
2011	0.110583	0.160611	−0.00353	0.031211	0.28224	0.534484	−0.00422
2012	0.106735	0.144331	−0.00163	0.035492	0.332525	0.497622	−0.00202
2013	0.096519	0.124653	−0.00484	0.034804	0.360592	0.475267	−0.00661

The contribution rate of labor to economic growth during the period of 2004–tth year:

$$E_l = \frac{\beta l_t}{y_t} \times 100\,\%. \tag{14}$$

According to the Eqs. (12)–(14), the contribution rate of the factors to the total output growth can be calculated as in Table 3. And in order to make an intuitive understanding of contribution rate of each factors involved in the production process, the trend chart is shown in Fig. 1. Also, the trend of the speed of output, capital input and labor input is shown in Fig. 2.

According to Table 3 and Fig. 1, we can see that capital contribution rate is the highest, the huge fixed assets investment promote the economy growth for a long time. And economy growth mainly depends on the S&T progress and the capital investment. Meanwhile, the contribution rate of the labor is especially low, which had reached below 0 for 5 years, brings negative value. That is to say with blindly increasing labor input, the production will not increase correspondingly. Besides, it

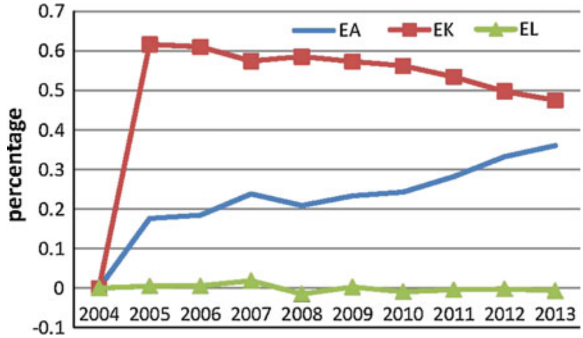

Fig. 1 The comparison of the contribution rate of three production factors from the year of 2004 to 2013

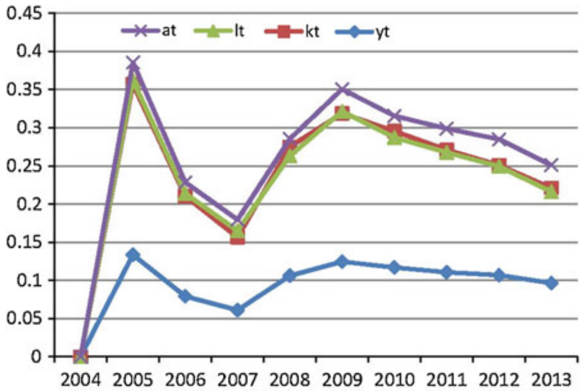

Fig. 2 The comparison of annual growth speed of y_t, k_t, l_t, a_t

is clear that the S&T presents a rising trend while the contribution rate of capital investment shows a down trend, and during this period, the highest contribution rate of S&T reached 36.06 %. Which also means that the coal enterprise is going through transform from quantity growth way to growth way of quality, the economic growth changes from extensive growth way into the intensive growth way. What enlightenment we can get from this phenomenon is that we should enhance the S&T level and make full use of scientific technology.

From Table 1 and Fig. 2, we know that, during the period of 2004–2007, the annual growth rate of each factor trending downward, this is because of economic crisis. And the reason for low contribution rate of labor lies in persistent low growth rate of labor, and it is in accordance with actual status. It must be made clear that the era of simply increase the number has passed, and now, the efficiency is the essence, which means personal output needs to be increased. In other word, the elasticity of labor should be increased. One effective way is to establish incentive system.

From Table 2 we know that $\alpha + \beta = 0.439 < 1$. It indicates that company C is at the decreasing stage of the scale return. So, business scale expanding cannot have effective influence on economic efficiency. The economic growth is the mutual interaction and restriction among every factor, one resource alone increasing or decreasing cannot achieve high returns. In order to maximize the effect of S&T progress on economic growth, the investment on scientific research cost in universities and other scientific organizations should be increased, such as the school-enterprise cooperation mode. This can guide the enterprise construct a self-directed innovation system, strengthen the cooperation of the scientific research organizations and enterprise, promote the application of the latest S&T progress and achieve the economic efficiency, thereby driving the growth of the contribution rate of other elements.

5 Conclusions

The measuring of S&T progress to economic growth based on longitudinal data, on certain countries or areas at certain period. But in fact, due to the lack of data sample, the parameter estimation in the production function can be affected. Thus, in order to avoid error and influence caused by different element selection in analyzing each factor, the data is normalized, including the capital investment and the output value. So, the proximity and comparability among various factors can be achieved. Through the analysis of the reasons, the conclusions can provide corresponding advisement to the enterprise.

In the process of estimation, there still exits three aspects that can be improved. The first is that the gross capital input was not subdivide and the second one is that the regression of explanatory variables is few, the third one exists in the methods of measuring elasticity coefficient, different parameter selection and calculation method will affect the accuracy of the result. If those three hard nuts are solved, more precisely result such as which input item plays a significant role, upon which we can adjust investment direction to improve capital utilization can be got.

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External Involvement and New Product Performance: The Mediating Role of New Product Advantage

Wei Liu, Huiying Zhang and Fan Yang

Abstract The focus of this study is on the effects of customer and supplier involvement on new product performance, as well as the mediating role of new product advantage. We established a conceptual framework in which external involvement is linked to new product advantage and new product performance. Subsequently, the model was tested by data collected from 124 manufacturing companies in China. The obtained results demonstrated that customer and supplier involvement can contribute to the improvement of new product advantage. And the new product advantage completely mediates the relationships between two types of external involvement and new product performance. These findings have valuable implications for academicians and practitioners in both the external involvement and new product development areas.

Keywords Customer involvement · Supplier involvement · New product advantage · New product performance

1 Introduction

As the product markets are becoming increasingly competitive, the management of new product development (NPD) is attracting more and more attention. However, new product development is a complex and difficult process. Facing the reality of dispersed resource, complicated technology and high-velocity environments, development of new product can no longer be accomplished by a single firm [3]. Numerous literature has highlighted the roles of external involvement in leveraging the knowledge and resources of their customers and suppliers [4, 10]. Thus, customer and supplier involvement provide opportunities for firms to reach high quality levels, fast and reliable delivery, satisfactory service and sufficient flexibility.

W. Liu · H. Zhang · F. Yang (✉)
College of Management and Economics, Tianjin University, Tianjin 300072, People's Republic of China
e-mail: yangfan890709@163.com

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Despite the growing research interest in external involvement, previous findings about the relationship between external involvement and new product performance (NPP) are inconsistent. While some researchers provide empirical evidence for the positive relationship between them [3, 12], other findings report a non-significant or even negative relations [13, 17]. In addition, there is little empirical evidence regarding how different dimensions of external involvement simultaneously affect new product performance. A deeper understanding of these relationships may help the managers to establish a more complete picture of how manufacturers benefit from external involvement.

In order to further study the concrete interaction process between external involvement and new product performance, we introduced new product advantage as a mediator in this research. With the fast developing trend toward mass customization and the growing heterogeneity of customer demand, the product advantage is emerging as an important factor to obtain superior performance for firms [1, 5, 11]. A prior meta-analysis suggests that, among the many drivers of new product performance, product advantage has the most profound influence [5]. By involving suppliers and customers into new product development, manufacturers can improve external innovation capability and obtain complementary resources [10], thereby enhancing their new product advantage. Consequently, new product advantage may act as an intermediate outcome of external involvement, which leads to the improvement of new product performance ultimately. To the best of our knowledge, detail report concerning the mediating role of new product advantage has been overlooked so far. In present work, we focus on obtaining deeper insights and understandings of the relationships between the three variables.

This study contributes to new product development and external involvement literature and practices in several ways. First, our research provides valuable empirical evidence on the relationship between different dimensions of external involvement and new product performance. This fine-grained view offers a more detailed picture of the relationship between external involvement and new product performance. Second, most existing studies have ignored the role of new product advantage in the relationship between external involvement and performance, so we conduct an in-depth theoretical examination which could move us from a simplistic understanding of the external involvement to a more precise model. Third, more and more multinational corporations have transferred their manufacturing bases to emerging economies such as China. Improved knowledge about China has significant managerial implications for them to operate here.

2 Literature Review and Conceptual Model

Drawing on the literature on external involvement, new product advantage and innovation management, the four constructs of interest as well as a series of hypotheses linking them are presented in this section. Figure 1 depicts the conceptual model.

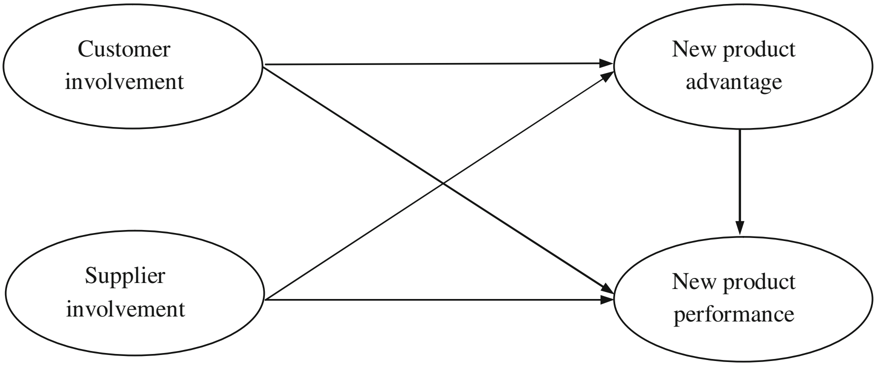

Fig. 1 Conceptual model

2.1 External Involvement and New Product Advantage

For the sake of clarity, the core construct of new product advantage is defined before proceeding. Among the various definitions of new product advantage, the definition proposed by Song and Montoya-Weiss [15] is adopted widely. This definition succinctly captures the essence of a cluster of traits setting anew product: a product's perceived superiority relative to competitive products. Product advantage mainly encompasses quality, uniqueness, problem solving capability, technical performance, innovativeness, and ability to meet customers' needs compared to other similar offerings [11].

The new product advantage is perceived as a key product characteristic in explaining the adoption and success of the new product. More and more firms are reconsidering the fundamental ways in which they can enhance new product advantage. Different factors influencing new product advantage have been investigated. Some scholars focus on strategic characteristics and argued that strategic orientation and product launch could provide guidelines for improving new product advantage [11]. Others highlight the role of project team structure such as product development team stability and proficiency in improving new product advantage [11, 15]. The positive effects of project characteristics (innovativeness and complexity) on new product advantage have also been studied [6, 9]. While these studies substantially enrich our understanding of new product advantage, the importance of external involvement have been ignored.

External involvement is defined as the extent to which manufacturers involve their external partners into new product development and subsequent improvement projects [4]. There are two types of external involvement: supplier involvement and customer involvement. Based on the perspective of knowledge-based view, the knowledge required by NPD can not obtained within the firm entirely. Feng et al. [3] and Menguc et al. [10] suggested that customer and supplier involvement represents an important source of knowledge.

Obviously, customers have information and knowledge about their own preferences and needs, which presenting chances to generate values for firms. The enterprise can broaden its knowledge's depth and breadth by adsorbing customer's knowledge, and the acquired knowledge substantially enrich the product assortment [3]. Involving customer in NPD process also provide enterprise a better understanding of the customer' requirements, thus finding accurate market localization for new product [16]. Meanwhile, customers offer firms complementary and first-hand information, which greatly reduce the probability of poor design. Furthermore, customers can share innovative and instructive ideas with the manufacturers when they specify their requirements and co-design the products. In summary, we posit this tie:

Hypothesis 1a. Customer involvement has a positive effect on new product advantage.

Another important source of knowledge derived from suppliers. Generally, suppliers possess greater expertise and knowledge concerning the specifications, parts and components, which is essential to a manufacturing enterprise's new product development [7]. Chen and Paulraj [2] documented that supplier involvement may range from giving minor design suggestions to engineering of a specific part of assembly, even responsible for the complete NPD process. In the stage of conceptual design, supplier involvement can provide relevant technical advice about products. Lawson et al. [7] found that collaboration with suppliers is conducive to product innovativeness. In the detailed design and manufacturing stage, the participation of suppliers can provide valuable solutions for the design of components and parts. It helps the manufactures to select the appropriate materials and improve the product's manufacturability and maintainability. Apart that, when a supplier directly participates in the process of decision making phase, it means that the supplier can prepare materials and other resources earlier, then the manufacturer can identify potential design problems and find solutions in advance. Undoubtedly, with the application of supplier's specialized technology resources and core competence, manufactures can develop more special and competitive products. We thus suggest that:

Hypothesis 1b. Supplier involvement has a positive effect on new product advantage.

2.2 New Product Advantage and New Product Performance

Selecting the appropriate performance measures is full of challenge, since existing literature has suggested a wide divergence of opinions. As recommended by new product strategy researchers, we incorporated multiple dimensions for this construct in terms of relative market share, relative sales, and relative profitability of all new products. It measures how well the firm does routinely in launching a series of key products through the product development process to become commercialized goods. New product advantage has become increasingly important for product development management in organizations due to providing a concrete picture of a firm's ability to meet customer needs. In other words, the degree to which a new product is perceived as superior to those of competitors mainly determines whether or not it is a marketplace winner [11].

New product with high quality is anticipated to positively influence customer satisfaction. Thus increasing customer adoption and purchase repetition, further increasing organizations' market share and profits. Products with good performance can substantially reduce the rate of return, which enhancing the product performance from another side.

Products offering a significant advantage over competitors' products also tend to be attractive. Introducing highly-innovative products which offering "new-to-the-world" functions that nobody can quickly compete with enables plants to achieve a first mover position in the market. By improving customer satisfaction and developing customer loyalty continually, first movers usually possess a larger market share [18]. In addition, first movers usually achieve better financial performance, due to they can extending sales life and charge a premium price. Therefore, in relation to innovation efforts, when advantages are incorporated into new products, the products should be better received in the marketplace. Accordingly, we propose:
Hypothesis 2. New product advantage has a positive effect on new product performance.

2.3 The Mediating Role of New Product Advantage

At present, it has been hypothesised that external involvement have positive effects on new product advantage, which in turn have influence on new product performance. It is reasonable to propose that new product advantage mediate the relationships between external involvement and new product performance. To better exploit the information and knowledge gained from external involvement, the firm needs to employ, internalize and transform them into the new product development process. Based on the internalized external knowledge, firms can improve new product advantage, and so further to achieve new product performance improvement. Secondly, the mechanisms to support external involvement are costly and technology intensive [3]. Therefore, the costs of implementing external involvement may outweigh the benefits contributed by customers and suppliers. If a firm can create products perceived as superior to those of competitors, the costs related to external involvement may be partly compensated.

Although the existing literature has established certain connexions between new product advantage and new product performance, there are few studies investigating the mediating role of new product advantage in this involvement-performance link. Some relevant hints has been mentioned by previous researches. For example, Li et al. [8] reveal that product innovativeness mediates the relationship between supply chain management practices and market performance. Akroush [1] stated that product quality mediates the relationship between organization ability and new product performance. These findings suggest that the association between external involvement and new product performance might be mediated by new product advantage.

Hypothesis 3a. New product advantage mediates the relationship between supplier involvement and new product performance.
Hypothesis 3b. New product advantage mediates the relationship between customer involvement and new product performance.

2.4 Control Variables

To avoid any unjustifiable influence of alternative factors, other than these included in our research model, on new product development performance, two control variables are included while analyzing the model. First, there is a control for firm size. On one hand, larger companies usually have more resources for supply chain activities. Thus, they may achieve a higher level of external involvement in comparison to small companies [18]. On the other hand, they might have larger resource pools to invest in new product development technologies and consequently higher levels of product development improvement. The second possible confounding effect relates to R&D expenses. We measured firm size and R&D expenses by asking respondents to indicate the sales volume and R&D costs of past year. Consistent with prior research, the control variables were transformed by taking the natural logarithm to alleviate univariate non-normalities and account for nonlinear effects [18].

3 Research Methodology

3.1 Sampling and Data Collection

To test the above hypotheses, we carried out a survey from 2013 to 2014 in China. As China is a country with economic development level varying across different regions, we strategically selected 5 cities for our sample to take geographic and economic diversity into consideration. These 5 cities are Chongqing, Guangzhou, Shanghai, Tianjin and Hong Kong, which are all important manufacturing centers with a wide variety of NPD activities.

In order to ensure the completeness and accuracy of the responses, the sampled companies were selected on the basis of recommendations from local government and universities. As indicated in Table 1, these companies represent a wide range of industries. During the pilot-testing process of the questionnaire, 10 companies was visited, and it was established that the optimal way forward was to get one key informant, who is familiar with NPD, knowledgeable in supply chain and customer and supplier relationship management [18].

Several methods were employed in this research to improve response rate. First, we gave a call to each firm to introduce the research objectives and identify a key informant. As an important participation incentive, we promised the respondent a

Table 1 Respondent profiles ($n = 124$)

Characteristics of firms	Frequency	Percentage
Industry type		
Arts and crafts	3	2.42
Building materials	7	5.65
Chemicals and petrochemicals	9	7.26
Electronics and electrical	17	13.71
Food, beverage and alcohol	6	4.84
Metal, mechanical and engineering	35	28.23
Pharmaceutical and medical	4	3.22
Publishing and printing	5	4.03
Rubber and plastics	11	8.87
Textiles and apparel	23	18.55
Wood and furniture	4	3.22
Sales (million RMB)		
<5	41	33.07
5–9	2	1.61
10–19	9	7.26
20–49	8	6.45
50–99	13	10.48
Over 100	51	41.13
R&D expenses (million RMB)		
<1	57	45.97
1–4	24	19.35
5–9	12	9.68
10–19	9	7.26
20–49	12	9.68
50–99	5	4.03
Over 100	5	4.03

free report based on the results of this research. Then, questionnaires were sent out to the respondents who agreed to take part in this study. Follow-up mailings and calls were made to increase the response rate. Out of 300 companies, a total of 171 survey questionnaires were received, but 47 of these were deleted because of excessive missing data. The data used in the following analyses contain 124 usable questionnaires, yielding a usable response rate of 41.33 %. By referring to several similar studies, we concluded that the response rate is considered satisfactory.

The data derived from single informants can lead to potential common method bias, which may artificially inflate observed relationships between variables. Analysis of Harman's single factor test of common method bias revealed four factors with eigenvalues greater than 1.0 that accounted for 67.60 % total variance. The first factor captured 33.61 % of the variance, which is not the majority of the total variance. These results suggest that common method variance was not a serious problem in this study.

3.2 Survey Questionnaire and Measures

According to previous researchers'suggestion, we employed two major dyadic relationships (manufacturer-customer and manufacturer-supplier) to represent the relational horizon of the manufacturer in the supply chain [4, 18]. Since a manufacturer may have many customers and suppliers, the degree of involvement might be distinct for different customers and suppliers, the questions on external involvement should be a response in reference to its key customer and supplier. The key customer is defined as the customer who buys the highest dollar value products from the respondent among all customers. Similarly, the key supplier refers to the supplier who supplies the respondent the highest dollar value of supplies [18].

The research questionnaire was developed based on a relevant literature review of customer and supplier involvement, new product competitive advantage, and new product performance. Whenever possible, we adapted the measurement items that have been validated in prior studies. When the constructs have not been validated in previous literature, we developed new items on the basis of our own understanding of the constructs, interviews with practitioners and observations during company visits. In all these questions, a 5-point Likert scale was used with “1” for “not at all” and “5” for “extensively”.

As the items were adapted from English literature, the standardised questionnaire was translated from English into Chinese and back again to ensure the equivalency, reliability and validity of the survey. Some survey questions were revised to improve the accuracy of the translation. Before pre-testing the questionnaire, the questionnaire was carefully examined by authoritative academicians and supply chain executives. We conducted a pilot-test with 10 randomly selected companies through semi-structured, in-depth interviews and then received their completed questionnaires. Then we visited these companies and check every question with them to ensure that they had understood them correctly. Based on the feedback, some revision and refinement was made so that the questionnaire was more relevant to the practices in China.

4 Data Analysis and Results

1. Assessment of Construct Measures

The hypotheses were tested using partial least squares (PLS) with the support of Smart PLS 2.0 M3 software. Before testing the hypotheses from the research model, an assessment of the constructs' psychometric properties including reliability, con-

Table 2 Construct measures assessment: reliability and validity

Construct	Item code	Cronbach	CR	Standardized factor loading	AVE
Customer involvement	CI1	0.841	0.881	0.91	0.606
	CI2			0.886	
	CI3			0.874	
	CI4			0.573	
	CI5			0.568	
Supplier involvement	SI1	0.892	0.925	0.831	0.756
	SI2			0.873	
	SI3			0.871	
	SI4			0.9	
New product advantage	NPA1	0.973	0.979	0.944	0.901
	NPA2			0.963	
	NPA3			0.965	
	NPA4			0.951	
	NPA5			0.924	
New product performance	NPP1	0.938	0.96	0.915	0.89
	NPP2			0.962	
	NPP3			0.952	

Notes CR composite reliability; *AVE* average variance extracted

vergent validity and discriminant validity was performed. As presented in Table 2, the scales were all reliable, with Cronbach α values ranging from 0.841 to 0.973, and composite reliability (CR) ranging from 0.881 to 0.979, which are all above 0.7. Content validity was established through extensive literature review, iterative construct review by researchers and feedback from executives. The items indicated adequate convergent validity as per their standardized factor loadings which are all above 0.5. Another indicator of convergent validity is that the average variance extracted (AVE) ranging from 0.606 to 0.901 (all above 50 %), indicating that the items share at least half of their variance with the construct (on average). As shown in Table 3, the square root of average variance extracted (AVE) value of each construct is greater than the correlation between construct and the other constructs, providing further evidence of discriminant validity (Fig. 2).

Table 3 Correlations matrix for construct

	Mean	S.D.	CI	SI	NPA	NPP	FS
Customer involvement (CI)	3.86	1.048	0.778				
Supplier involvement (SI)	3.9	1.019	0.758	0.869			
New product advantage (NPA)	3.83	0.703	0.66	0.641	0.949		
New product performance (NPP)	3.64	0.769	0.64	0.637	0.805	0.943	
Firm size (sales) (FS)	9.67	2.367	0.156	0.102	0.063	0.042	–
R&D expense (EXP)	6.51	1.821	0.12	0.023	0.074	0.054	0.624

S.D. standard deviation; Numbers in bold on the diagonal indicate the square root of AVE

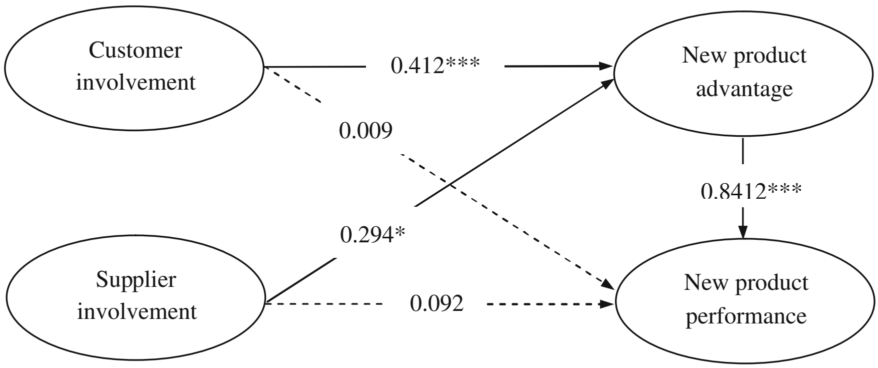

Fig. 2 Estimated structural equation model

Subsequently, we employed the 'goodness-of-fit' criterion (GoF) to assess the global fit of our structural model. GoF is referred to the geometric mean of the average communality, which equals AVE in PLS and average R^2 (for endogenous constructs). Our analysis reveals a GoF value of 0.712, which exceeds the suggested cut-off value of 0.36 for large effect sizes of R^2. Hence, we come to a conclusion that our model performs well with regard to the GoF criterion. Likewise, to assess the predictive performance of our structural model, we performed a blindfolding procedure (omission distance of 7). Since all corresponding Stone-Geisser Q^2 values are positive, the hypothesized model indicates strong overall predictive power.

2. Estimation of the Structural Model

Table 4 shows the path coefficients and the explained construct variances. The variance explained for each of the endogenous variables is adequate with 82.54 % for new product performance and 46.30 % for new product advantage.

The results indicate a positive and significant path between new product advantage and new product performance which supports Hypothesis 2 ($\beta = 0.842$; $p < 0.001$). The paths from customer involvement and supplier involvement to new product advantage were all significant, providing evidence to support hypotheses Hypothesis 1a ($\beta = 0.412$; $p < 0.001$) and Hypothesis 1b ($\beta = 0.294$; $p < 0.05$).

In order to test the possible mediating effect, first, an assessment of the path between customer involvement and the mediating variable (new product advantage) is needed: that path is positive and significant ($\beta = 0.414$; $p < 0.001$). Then, we examine the path between new product advantage and new product performance ($\beta = 0.906$; $p < 0.001$). The third step is to assess the direct path from customer involvement to new product performance when there is no path between customer involvement and new product advantage in the model: the path is also positive and significant ($\beta = 0.355$; $p < 0.001$). The result in Table 4 indicates that the path between customer involvement and new product performance in the full model (with all the paths) is non-significant: when combined with the result of the steps above, it can be concluded that new product advantage is completely mediating the impact of customer involvement on new product performance. A Sobel test was conducted to confirm the mediating effect. The Sobel test was significant ($z = 4.230$), providing support for H2a.

A similar procedure was applied to supplier involvement. The path between supplier involvement and new product advantage is positive and significant ($\beta = 0.292$; $p < 0.05$). When the direct path between supplier involvement and new product performance was assessed without any path to new product advantage, it is also positive and significant ($\beta = 0.341$; $p < 0.01$). The direct path is non-significant with the introduction of new product advantage in the model indicates that there is a completely mediating effect. The Sobel test was significant ($z = 2.189$), supporting the hypothesis H2b.

Table 4 PLS structural model results

	Model 1		Model 2		Model 3		Model 4	
	β	t-Value	β	t-Value	β	t-Value	β	t-Value
PS→NPA	−0.068	1.254					−0.069	1.271
EXP→NPA	0.061	1.399					0.061	1.376
CI→NPA	0.414	4.479***					0.412	4.505***
SI→NPA	0.292	2.421*					0.294	2.366*
PS→NPP			−0.01	0.418	−0.082	1.268	−0.024	0.854
EXP→NPP			−0.007	0.278	0.054	1.164	0.003	0.13
NPA→NPP			0.906	26.388***			0.842	12.599***
CI→NPP					0.355	3.722***	0.009	0.188
SI→NPP					0.341	2.664**	0.092	1.339
R^2								
NPA	0.462						0.46	
NPP			0.82		0.444		0.825	

Notes β: standardized path coefficient; Significant at: *p-value < 0.05, **p-value < 0.01, ***p-value < .001 (two-tailed test)

5 Discussion and Research Contributions

1. Discussion
By analyzing the above results, we conclude that both customer and supplier involvement have positive effects on new product advantage (Hypothesis 1a, Hypothesis 1b). External involvement can play an important role in firm's external knowledge search, it enables firms to access more complementary resources and capabilities [4], thus promoting the formation of new product advantage.

The results also support the claim that new product advantage has a significant influence on new product performance (Hypothesis 2). This result is consistent with several previous studies [3, 12]. Our research reinforces the importance of new product advantage in the process of improving new product performance. This finding is important since much of the existing literature has not included external involvement and new product advantage in a holistic model.

The empirical results of product advantage's mediating effects manifest that new product advantage completely mediates the relationships between two types of external involvement and new product performance (Hypothesis 3a, Hypothesis 3b). In other words, customer and supplier involvement mainly promote new product performance by reinforcing new product advantage. This study provides support for the mechanisms of how customer and supplier involvement impact on new product performance. It also provide valuable information for firms to achieve better performance.
2. Research Contributions
The findings in this study contribute to both theory and practice. First, many researches have focused on either customer involvement or supplier involvement separately. We discuss the two dimensions of external involvement in one comprehensive model, thus obtaining a deeper understanding of the impact of external involvement on new product performance.

Second, this study offers further evidence for the proposition that new product advantage has impacts on new product performance. It extends literature by introducing new product advantage as a mediator for there relationship between external involvement and new product performance. This finding provides preliminary evidence of a significant mechanism for fully leveraging external involvement's potential and capacity to improve performance. In view of the doubt exists in the economic justification of external involvement, particularly in the way of how external involvement can generate new product performance for firms. This finding is valuable for researchers and practitioners.

Third, the data used for empirical analysis is collected from 124 Chinese manufacturing companies, which adds to research on sources of external involvement and new product development in "developing countries, a context underlined as lacking in such field of research" [11]. Recently, there is a growing tendency for scholars to investigate these issues in China, whose dynamic competitive environment and increasing economic status provide fertile ground for topic. In today's highly competitive and dynamic business world, acquiring a good understanding of external involvement and new product performance has been necessary to sustain competitive advantage.

6 Conclusion

The importance of external involvement has received considerable attention in both literature and academic outlets. The reported benefits mainly include improvements in new product performance and firm performance. A basic research question is whether external involvement is indeed fruitful. This study examined whether and how external involvement impacts on firm performance. Using a sample of 124 Chinese manufacturing firms, the findings indicate that customer and supplier involvement can contribute to the improvement of new product advantage. And the new product advantage completely mediates the relationships between two types of external involvement and new product performance. In this fashion, we answered the calls of researchers who have stressed the need for empirical study examining the mechanisms of how external involvement enhances new product performance.

While this study enhances our understanding of the relationships among external involvement, new product advantage, and new product performance, there are also some limitations and more opportunities for future research. In the study, we measured external involvement by perceptual scales. Future research may operationalise external involvement with some other measures such as the number of involving customers, and supplier in new product development and the type of customers and suppliers. Second, this study depended on cross-sectional data to test the conceptual model. Although surveying corporate managers become increasingly costly and challenging, collecting data over time can offer more implications. Future research may validate the findings of this study using a time-series data. Third, the findings of our study are based solely on data from China. The roles of customers and suppliers in new product development may be different in other emerging countries. Future research should attempt to examine cross-cultural differences in the relationship between product performance and external involvement.

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Appendix

See Table 5.

Table 5 Construct measurement

Measurement items	Mean	S.D.
Customer involvement (adapted from Chen and Paulraj [2], Li et al. [8])		
CI1: We often communicate with key customer and hear its opinions on product prototypes when developing new products	4.34	0.816
CI2: We work with customers to design new products	3.98	0.965
CI3: We involve key customer in the product design and development stage	4.21	0.941
CI4: Customer is indispensable in product design/development	3.37	1.045
CI5: We involve our key customer in new product and project planning.	3.51	1.026
Supplier involvement (adapted from Chen and Paulraj [2], Li et al. [8])		
SI1: We often communicate with key supplier and hear its opinions on product prototypes when developing new products	4.02	0.965
SI2: We work with suppliers to design new products	3.75	1.051
SI3: We involve key supplier in the product design and development stage	3.51	1.049
SI4: Supplier is indispensable in product design/development	4.32	0.833
SI5: We involve our key suppliers in new product and project planning[a]	–	–
New product advantage (adapted from Nakata et al. [11])		
NPA1: Our new product contained more useful functions than competing products	3.76	0.727
NPA2: Our new product offered unique features or attributes	3.84	0.656
NPA3: Our new product offered better quality to customers compared to competing products	3.82	0.677
NPA4: Our new product met established standards better than competition	3.86	0.73
NPA5: Our new product had superior technical performance relative to competitive products	3.89	0.728
NPA6: Our new product was highly innovative[a]	–	–
New product performance (adapted from Nakata et al. [11])		
NPP1: Market share relative to competitors	3.73	0.795
NPP2: Profitability relative to competitors	3.59	0.77
NPP3: Return on investment (ROI) relative to competitors	3.62	0.742

[a] Items are deleted after reliability or validity analysis

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Low Carbon Optimization of Industrial Structure Based on Economy-Energy-Environment System Coordination

Lei Xu

Abstract Based on the sustainable development and low-carbon economic realities background, this paper modeled for the coordinated regional industrial structure optimization of Economic-Energy-Environment 3E system by utilizing of multi-objective chance constrained programming model. A typical representative of conflict between economic development and environmental protection Leshan City, the world's natural and cultural "double inheritance" areas was chosen as an example for the modeling, and the development trends of the key factors were analyzed and compared before and after optimization. The empirical studies shows that the reasonable optimization of industrial structure can realize an optimal and comprehensive benefits of overall economic growth and environmental protection, and has a far-reaching effect on the low-carbon sustainable development of economy and society in the western region.

Keywords 3E system · Industry structure · Optimization model · Low-carbon economy · Sustainable development

1 Reality Background of Sustainable Development

China is the world's largest developing country at present, whose economic agent is still the second industry and high economic growth mainly relay on the invested extensive growth, resulting in high carbon intensity and heavy environmental pollution. China is still in the process of industrialization, and the industrialization and modernization process still relies on coal-based carbon energy and the requirement is becoming higher, causing the increase in industrial economy high carbonation. China has to solve an economic transformation and multiple tasks such as climate change, and the new low-carbon growth model makes China's social and economic sustainable development face many problems and challenges. Thus, new requirements of

L. Xu (✉)
School of Economics, Xihua University, Chengdu 610039, People's Republic of China
e-mail: leihsu@163.com

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low-carbon transition regional industrial structure are proposed. Under the conditions that global climate is changing, carbon emissions increase rapidly, and fossil fuels are non-renewable, industrial development is the fundamental driving force for economic and social progress and become the fundamental way of the sustainable development in regional low-carbon economy. Different industrial structures and their adjustments have different effects on economic growth, natural resources and ecological environment. Therefore, how to make industrial structure development optimization decisions is one of the core problems related to the economic transformation, low-carbon and sustainable development [9].

Compared to the east and south economically developed areas in China, the west area faces dual pressures: accelerating economic development pressure and the accelerating economic transition pressure. The economic development pattern led by traditional industries in the western region and the long-standing investment-driven and resource consumption causing energy supply shortage has not changed yet. The overall ecological environment has improved but its overall governance problems remain daunting. With the economic development of the western region, the resource constraints and demand will become increasingly significant. Therefore, adjusting the structure and type' was proposed as the western development goals, and the sustainable development model for the low-carbon economy and circular economy was explored actively [3]. According to the spatial distribution of resources, infrastructure and other economic conditions, the western region will also become a major commitment to the country's energy supply system construction in future. Huge polarization effects generated energy development will make the very fragile ecological environment in the western region face enormous pressure. Apparently, the traditional industrial structure has not met the realization of sustainable development objectives in the west, even the whole country. In a word, there is a need to rationalize and optimize the industrial structure, accelerate the adjustment of industrial structure to achieve low-carbon transition in order to achieve the region sustainable socio-economic development.

In this paper, the realistic background scenarios under low carbon economy were firstly presented. Then, the industrial structure optimization connotation, and the importance of achieving a low-carbon sustainable development of Economy-Energy-Environment "3E system" Coordination in western area were explained. Combined with the actual situation in the region, the regional multi-objective constrained model for optimization of low-carbon industrial structure was built. Empirical studies were carried out to do comparative analysis of before and after optimization of industrial structure of the economic development and environmental protection at the same time. In the low-carbon industrial structure optimization model, the typical representative in western area: Leshan city was taken as an example to reach the relevant requirements of carbon emissions reduction and regional economic development, and systems based harmony in optimization of industrial structure in the social, economic, environmental entire area from the macro level can be achieved. This studies can provide a theoretical and practical help for the low carbon transition optimization decisions of industrial structure for regional economy sustainable development.

2 Low-Carbon Economy Based Industrial Structure Optimization

The low-carbon economy refers to an economic form of economic and ecological coordinated development through industrial restructuring, technological and institutional innovation and other means to lower carbon energy consumption and greenhouse gas emissions as possible under the concept of a is the framework of sustainable development. As proposed before, low-carbon economy is urgently needed, because it is significant for sustainable development of major socio-economic. Low-carbon industrial restructuring is the core of low-carbon economy [6].

2.1 Industrial Structure Optimization Connotation

The industrial is a collection of enterprises, which have products and services, production, or management and characteristics, and their activities in national economy [7]. Industrial system needs classifying to manage industrial system scientifically. Tertiary classification is the most commonly used industrial structure classification and statistical method, and it has become an important basis for industrial structure researches and decision-making guiding [12]. The industrial structure optimization in this study is based on tertiary classification.

Tertiary industry structure, i.e. the total structure formation according to their proportion, presents itself as centralization and rationalization of industrial structure two aspects. The sophistication of the industrial structure refers to the industrial structure evolution from low to high, focusing on industrial restructuring strategic issues. While the rationalization of industrial structure refers to overall performance capabilities of the coordination between industries. Sophistication and industrial structure rationalization of industrial structure in general is a dynamic process of evolution. Under certain period of time and the industry sophistication, rationalization of the industrial structure is the basis of industrial structure. Only the rationalization of industrial structure reaches a certain level it will promote the sophistication of industrial structure. The industrial structure evolves to a certain height after the rationalization of the industrial structure will have higher requirements for it. Therefore, to optimize the industrial structure is to optimize the proportion of tertiary structure to promote the rationalization of industrial structure in order to achieve the evolution of industrial structure.

2.2 Coordination of Environmental-Economy-Energy 3E System

Economic development, energy use and environmental protection form a mutually interrelated but conflicting ternary (three systems), none of which can be neglected. At the beginning, each of the ternary study was isolate. With the growing awareness of economic, energy and environmental development, the researches of an economy-energy-environment 3E system are rising to achieve the overall balance and coordination between economy, energy and environment three subsystems' development in the American and European countries. These researches focus on methods and models related to interaction between the various subsystems, and the latest researches were taken into the country's long-term development strategy. China is also increasing emphasis on researches related to 3E system [10, 13, 14]. 3E system logic is shown in Fig. 1. The industrial structure adjustment theory has been proposed for many years, and most related researches are completed by people in developed countries. C. Klark firstly revealed the change in industrial structure and its importance for economic development [2]. The industrial structure optimization theory developed from the industrial restructuring management. In recently years, more and more scholars began using statistical and econometric methods to solve industrial structure prediction and optimization problems [5, 15]. These researches bring new perspectives for the study of industrial structure, meanwhile, there are some limitations. Firstly, these models emphasize economic reality factors while ignoring other factors, and most of them don't compare different scenarios. There are very few theoretical models considering the dynamic equilibrium between the

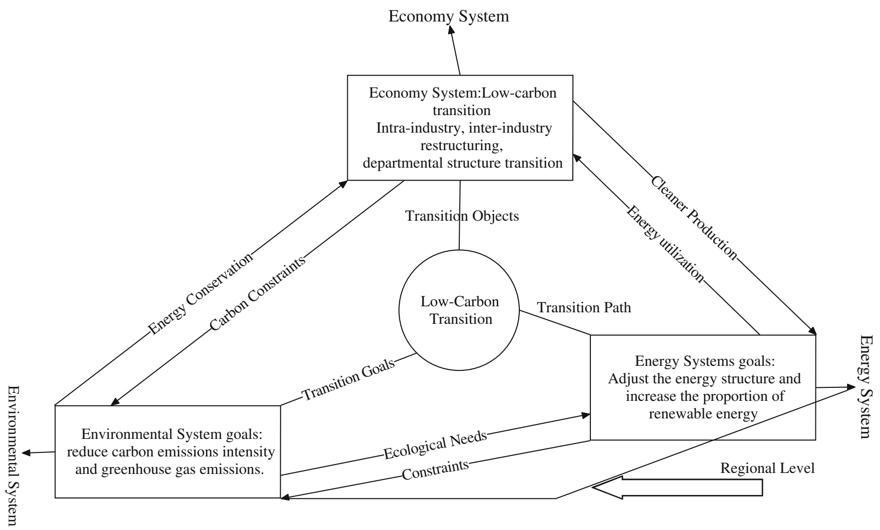

Fig. 1 Logic relationship of Economy-Energy-Environment 3E system

economic growth and industrial, between energy and environmental constraints in the modeling process. Therefore, the industrial structure optimization model based on coordinated3E system is significantly necessary. For the industrial structure optimization based on coordinated 3E system, it aims at maximizing the overall comprehensive benefits, and considers industrial restructuring-related constraints fully to promote coordination between industries so that the final proportion of industrial structure are more reasonable by adjusting the dynamic structure proportion of tertiary industry.

3 Coordination of Environmental-Economy-Energy 3E System

Multi-objective planning techniques and chance-constrained models were utilized to achieve a low-carbon industrial structure optimization of the coordinated 3E system. To evaluate a planning program, multiple objectives comparison are required. Sometimes, these objectives are contradictory and even mutual conflicted. Multi-objective optimization, i.e. study on the optimization problem of multi-objective function under given constraints, has been applied in many areas, such as economic management, systems engineering, military science and so on [4]. In this paper, for the multi-objective optimization model of industrial structure, its objectives are to maximize total economy GDP, minimize emissions and energy consumption so as to seek the industry structure model with the best overall efficiency of economic growth, industrial employment and environmental protection. The chance constrained method was used to process the uncertain variables in the model. And the related variables are listed in Table 1.

3.1 The Objective Function

The objective function of multi-objective optimization model is composed of three parts: the economic benefits, energy consumption and pollution emissions.

1. The Economic Benefits The overall economic benefits are the economic benefits of all industry, and the objective function is to maximize the economic benefits, noted as $\max f_3 = \sum_{i=1}^{3} b_i x_i$, b_i represents the unit economic benefits of industrial i.

2. The Energy Consumption
For the sake of minimizing energy consumption, the minimum objective under the chance constraint is chosen to describe the total energy consumption, and is noted as $\min \overline{f_1}$, $Pos\{\Pr\{\sum_{i=1}^{3} \tilde{\bar{e}}_i x_i \leqslant \overline{f}_1\} \geqslant \alpha_1\} \geqslant \beta_1$, where $\tilde{\bar{e}}_i$ is the fuzzy random parameter for unit energy consumption of industrial i, α_1 is the feasible Interval, β_1 is the given confidence intervals, Pos are possible fuzzy measures, and P_r are possible measures.

Table 1 Related variables of the model

Name	Symbol	Notes
Decision variables	x_i	The output of industrial i
The objective function	$\overline{f_1}$	The energy consumption goal
	$\overline{f_2}$	The emissions reduction goal
	$\overline{f_3}$	The total economic benefits goal
Subscript factors	j	Time factor, $j \in \phi,\ \phi = 1, 2 \ldots, j-1$
	i	Industry type coefficient, $i \in \varphi,\ \varphi = 1, 2, 3$
Identify factors	e	Energy consumption coefficient
	c	Pollution emission coefficient
	b	Output coefficients of economic unit
	p	Employment coefficient
Uncertainties	$\overline{\tilde{e}}_i$	Fuzzy random coefficient of industrial i unit energy consumption
	$\overline{\tilde{c}}_i$	Fuzzy random coefficient of industrial i unit emission
	α_1	The probability level of energy consumption
	α_2	The probability level of pollution emission
	β_1	The confidence level of energy consumption
	β_2	The confidence level of pollution emission

3. Pollution Emissions
The environmental objectives are set for minimizing environmental pollution, and the objective function is min $\overline{f_2}$. Then, $Pos\{\Pr\{\sum_{i=1}^{3} \overline{\tilde{c}}_i x_i \leqslant \overline{f}_2\} \geqslant \alpha_2\} \geqslant \beta_2$, where $\overline{\tilde{c}}_i$ is the fuzzy random parameter for unit emission of industrial i, β_2 is the given confidence intervals, Pos are possible fuzzy measures, and P_r are possible measures.

3.2 Constraints

The constraints of the low-carbon industrial structure optimization model are as follows.

1. Capacity Constraints
According to the national long-term economic data analysis, the GDP growth is typically less than 0.15. The second industry is the core composition of the industries in developing countries, and there are many polluted enterprises in this industry. Therefore, the capacity constraints can be defined by the second industrial development speed as.

$$0.85x_{2(j-1)} \leqslant x_{2j} \leqslant 1.15x_{2(j-1)}. \tag{1}$$

2. The Constraints of Energy Consumption Intensity
According to China's relevant regulations, the annual energy consumption intensity is required to maintain an annual reduction of 0.05 or more. Thus,

$$\frac{\sum_{i=1}^{3} e_{ij} x_{ij}}{x_j} \leqslant \frac{\sum_{i=1}^{3} e_{i(j-1)} x_{i(j-1)}}{x_{j-1}} (1 - 5\,\%). \tag{2}$$

3. The Pollution Emissions Constraint
The environmental pollution emission constraints must satisfy the expected value, and the pollutant emissions should decline annually. Thus,

$$\frac{\sum_{i=1}^{3} c_j x_j}{x_j} \leqslant \frac{\sum_{i=1}^{3} e_{j-1} x_{j-1}}{x_{j-1}}. \tag{3}$$

4. The Unemployment Rate Constraint
The employment rate is an important indicator that has great impact on industrial development and social stability. According to China's policy, the urban unemployment rate should be maintained at 0.05 or less. Thus,

$$L_i - \sum_{i=1}^{3} p_i x_i < 5\,\%. \tag{4}$$

5. The Industry Proportion Constraint
The industry data represents the proportion of three industries, and their sum is 1. That is $\sum_{i=1}^{3} x_i = 1$.

6. The Non-Negative Constraint
The regional output can't be negative, then $x_i \geq 0$. Based on the objective function and constraints proposed before, the chance constrained multi-objective optimization model of low-carbon industrial structure is as Eq. (5).

By finding a series of solutions to reach the global optimum rather than a single and local optimal solution. Decision makers often have different tendencies and choices based on their characteristics. The decision makers' different tendencies belong to different objectives. To find the Pareto frontier, the two minimum objectives are defined as $\min \overline{f_1} = \max -\overline{f_1}$, $\min \overline{f_2} = \max -\overline{f_2}$, and then $\max F = (-\overline{f_1}, -\overline{f_1}, f_3)$.

4 Empirical Analysis

As proposed before, a very typical representative of conflict between economic development and environmental protection, Leshan city was chosen as the example. Three different scenarios were compared and analyzed to achieve the reduction of environmental damage while economy developing.

The data were got from Leshan's local statistics for 2004∼2008, 2010 field research and statistical yearbook. Observation, interviews and document research methods were applied in getting the data. Some uncertainty parameters were determined by experts and policy makers empirically, so expectations and values of decision-makers were taken into account in the determination process of the parameters optimization. Partial correlation statistics are shown in Table 2.

$$\begin{cases} \min \overline{f_1} \\ \min \overline{f_2} \\ \max f_3 = \sum_{i=1}^{3} b_i x_i \\ s.t. \begin{cases} Pos\{\Pr\{\sum_{i=1}^{3} \tilde{\overline{e}}_i x_i \leqslant \overline{f}_1\} \geqslant \alpha_1\} \geqslant \beta_1 \\ Pos\{\Pr\{\sum_{i=1}^{3} \tilde{\overline{c}}_i x_i \leqslant \overline{f}_2\} \geqslant \alpha_2\} \geqslant \beta_2 \\ 0.85 x_{2(j-1)} \leqslant x_{2j} \leqslant 1.15 x_{2(j-1)} \\ \frac{\sum_{i=1}^{3} e_{ij} x_{ij}}{x_j} \leqslant \frac{\sum_{i=1}^{3} e_{i(j-1)} x_{i(j-1)}}{x_{j-1}} (1 - 5\,\%) \\ \frac{\sum_{i=1}^{3} c_j x_j}{x_j} \leqslant \frac{\sum_{i=1}^{3} e_{j-1} x_{j-1}}{x_{j-1}} \\ L_i - \sum_{i=1}^{3} p_i x_i 5\,\% \\ \sum_{i=1}^{3} x_i = 1 \\ x_i \geqslant 0. \end{cases} \end{cases} \tag{5}$$

In Leshan, the original proportion of tertiary industry structure in 2009 was 11.0:46.5:42.5. The optimal results for tertiary industry proportion of the objective optimization model solved using Lingo were 10.7:43.8:45.5. Then the statistics were put into Vensim software and the system dynamics model [16] for 3E system to get the original industrial structure and the optimized industrial structure. Therefore, the main factors in the development trends before and after optimization of the 3E system in next decade could be compared as shown in Fig. 2.

As shown in Fig. 2, the economic benefits of the industrial structure after optimization are better than that of before optimization from the long-term perspective. However, the GDP growth after optimization is lower than that before optimization. In 2020, the GDP after optimization can reach 1000 trillion RMB, while the GDP before optimization is only 750 trillion RMB. The emissions in the same amount of carbon dioxide emissions intensity after optimization are much lower than that before optimization with the increasing of the third industry proportion in industrial restructuring process. It is apparently that the industrial structure optimization has an important role in controlling pollution emissions. At the same time, the optimized

Table 2 The correlation statistics

Variables	Unit	2004	2005	2006	2007	2008
Population	One	556223	560619	569107	575479	579982
Employment	One	364536	381044	387219	392713	390549
The first industry employees	One	161835	162520	163049	163524	164095
The second industry employees	One	106855	111809	116954	119870	119437
The third industry employees	One	95937	106729	107133	104928	107153
GDP per capita	Yuan	9865	11362	13294	16078	19572
Emissions	104 ton	1629	1558	1421	1382	1146
Greening ratio	%	31.5	38.57	40.18	40.68	41.28
Low-carbon industries proportion	%	0.23	0.246	0.25	0.257	0.254
Unit energy consumption	%	0.83	0.77	0.88	0.97	1.08
Carbon dioxide emissions	Ton	301808	324863	438807	592180	805947
Carbon intensity	Ton/10^4 Yuan	0.55	0.51	0.58	0.64	0.71

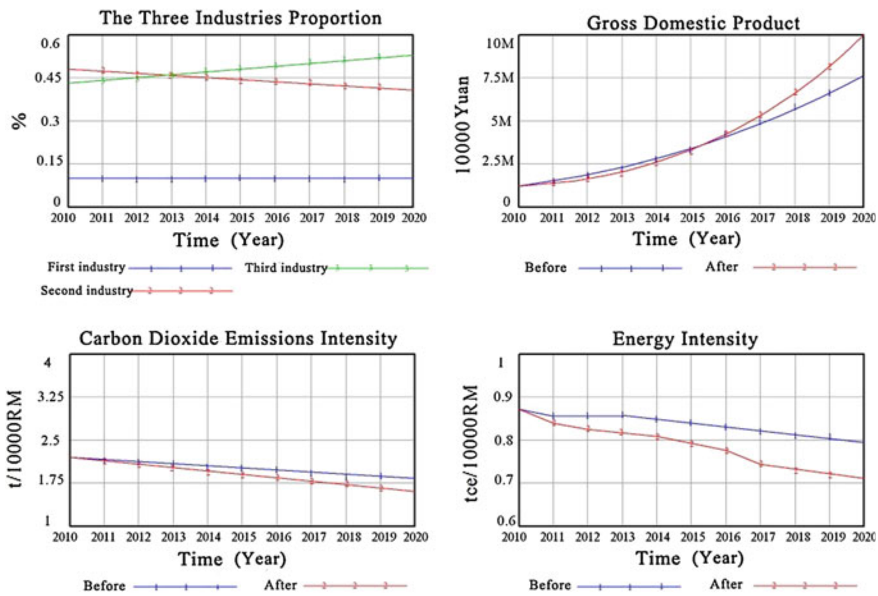

Fig. 2 The development tendency comparison of before optimization and after optimization

energy intensity after optimization is lower than that before optimization with the increasing of the third industry proportion. This situation indicates that the optimization model constraints on energy consumption aiming at reducing energy intensity has a significant effect. The huge gap between before and after optimization can be seen through the comparison results. The results also show that although the industrial structure optimization theory has been widely applied in all aspects of theoretical and applied research, there is still in the lack of sufficient practical attention on this model application.

5 Conclusion

As shown in the empirical analysis, for the economy development, the GDP growth after optimization is lower than that before optimization in short term. Because the proportion of secondary industry is reduced. However, in the long-term, the GDP after optimization is much big than that before optimization. This discovery can be explained by two aspects. First, China, as a typical developing country, is still in the middle of industrial development, especially for the western China area and the GDP growth there in the production relies heavily on the second industry which is energy-intensive. Second, the environmental constraints in the optimization model have some bad effect to GDP growth in the short term, but this effect is not significant. Because when the economy develops to a certain extent, the environmental constraints don't do adversely impact on the economy at all but make the economy develop more healthy and rapidly. These findings are consistent with the researches related to short-term and long-term relationship between the economic development, energy efficiency and pollution emissions and other systems [1, 8, 11]. This study indicates the reasonable optimization of the industrial structure can reduce the damage to the regional ecological environment and its effect on economic development is weak. In the long term, the reasonable optimization of the industrial structure can ensure the sustainable development of low-carbon economy in the area, meet the requirements of reducing carbon emissions and regional economic development, and become comprehensively optimal of overall economic development and pollution reduction. Then the harmony of the society, economy and environment can be realized systematically from the industrial structure optimization in the entire region. So a theoretical and practical reference for the industrial structure of regional economy sustainable development and low carbon transition optimization can be provided for decision makers.

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Analysis of the Recruitment and Selection Process

Asif Kamran, Jawad Dawood and Saad Bin Hilal

Abstract This research is based on the pure and practical facts which the HR personnel's deal with in their daily work routine, either it is regarding to salary issues, personal issues or regarding any form of change in the staff's own contracts or anything regarding to job and organizations requirements. The purpose of the research was to identify the problems relating to the recruitment and selection methods and sources used in different ways by organizations. The finding of the research was merely or purely based on the opinions and results from the Human Resource Department of English Heritage. To provide the best available information and research materials on the different procedures adopted by organizations on the recruitment and selection methods and analyze their expectations and outcome of the procedures. A design of questionnaire was produced and was given to different executives in this field to provide us with the results based on that questions and a questionnaire was used in it. The feedback from the questionnaire has findings which are based on the primary and secondary researches. This Research study includes the feedback from the HR personnel's from the Organization's and my own research findings from previous and primary reports. This research is very practical study which provides further insights for academics and managers of both large and small organizations.

Keywords HRM · Recruitment · Selection · Appraisals · Training · Department for Culture, Media and Sport (DCMS) · English Heritage (E.H.) · National Trust (N.T.)

A. Kamran (✉)
School of Management & Economics, University of Electronic Science & Technology of China, Chengdu 610054, People's Republic of China
e-mail: asifkamrankhan@gmail.com

J. Dawood · S.B. Hilal
Hamdard Institute of Management Sciences, Hamdard University, Karachi 74200, Pakistan

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1 Introduction

An analysis of HRM requires that some kind of a conceptual framework, general one be defined, to better understand the complexity of such a context. HRM practices in companies can thus be seen as an amalgamation of foreign methods and techniques rather than specifically developed tools. This is once an example of the positive and negative aspects of the country's pragmatism. The personnel function must be analyzed both via its activities and the various structures within it work. The personnel function has changed over the years and has followed a certain "chronology" which can be accounted for by outside constraints affecting a company and by inner conflicts which management has to resolve. Finally as well as the diversity of situations affecting companies, the "limited rationale" of the agents (employers, managers, personnel, unions) and the diversity of their respective strategies must also be considered. Having in mind the above mentioned aspects and the fact that the companies also tend to react strongly to current managerial practice and ideas, several phases in personnel function may be following;

Personnel Administration: The formalization of personnel administration is closely linked to the widespread development of the scientific organization of work. Personnel manager's initiatives were limited to social benefits (pensions, sick benefits) and the correct management of social institutions.

Management of Human Resources: Economic growth and increased competition combined with the troublesome development of dysfunctional behaviour (absenteeism, staff turnover, sabotage, vandalism) in large industrial and administrative concerns made employers look for new concepts in management.

Organizational Management: The past ten years have been characterized by a growing number of interactions between the company and other groups (competitors, financiers, customers) and by dual need for flexibility and quality, the somewhat contradictory role. It is essential that management master the internal interaction among the various members of the organization.

Whether you eventually start working for a business self employed, you have to see how business or companies uses HR department to recruit, select and manage their main key power which is people or employee's if business are to achieve their objectives, the organizations must be planning about their Human Resources functionality so they can have the right number of employees with the right kind of qualifications and training to meet the needs of the business. To develop/establish a research on an understanding that those individuals who are recruited or selected through the traditional and new methods are fit for the organization and the analysis of the HRM team who undertake this responsibility of fulfilling this task. The main idea of research is the analysis of the organizations gain's and loss on the finance used for the recruiting and selection of the persons and what have the outcome been there for the organization. The aim of the research is to find out the main drawbacks in the Recruiting and Selection processes involved in the HRM department in any organization. The research conducted by me on this topic was quiet interesting and I did came across a very vast area of these processes and tried to figure out how to have a solution to the problems faced by the HRM personnel's. The main aim was to gather information on my research work which has been stated and to find the best possible answers to it. The aim is to target the organization and get the required information and data in regard's to the recruitment and selection procedures. Gathered the sufficient amount of data through questionnaires and interviews and used it in my research. The other aim of the research was to find the negative or unanswered scenario's happening in the department by itself as the procedures of recruitment and selection were not up to the requirements of the organization, but still the work is going on. The aim and objective of the research is thoroughly briefed and examined. According to Biz Mag [6] businesses have to plan carefully to ensure they have the right number of employees for their needs. To do this they need a good understanding of the labour market and have the full use of Human Resources. Human Resources planning also involve looking at how labour or workforce is organized within the company or business.

2 Literature Review

2.1 Human Resource Management (HRM)

Human resource management is a unique term for the old version or Personnel management or we can say that to deal with the staff or manpower this new term has been evaluated. According to Murad [7] "Human resource management is regarded as the method in which the activities of the staff are monitored or to provide them with the best efficient way of working in a friendly and good environment and to coordinate between themselves and with the higher management". The HR department in any organization is the core of its existence and hence it is proved by other researchers as well that without the HR department the multinational companies won't be in existence. In addition to wages and salaries, organizations often spend a large amount of finances on their human resources, selection and training and other major departments to enhance the productivity of the company or organization. Taylor [11] Human resource functions refer to those tasks and duties performed to provide for and coordinate human resources. Human resource functions encompass a variety of different methods that are or have influence on all the areas of the company or organization. There are six major functions of human resource management: (1) Human resource planning, recruitment, and selection; (2) Human resource development; (3) Compensation and benefits; (4) Safety and health; (5) Employee and labour relations; (6) Human resource research.

This research mainly focuses on the first and second functions i.e. recruitment, selection sources or procedures. Training and development of employees is the process or requirements of the organization after the selection of new employee's. In Kneeland [5] HR recruitment is defined as any practice or activity carried out by an organization with the primary purpose of identifying and attracting potential employees. Recruiting and selecting new personnel are both complex processes.

2.2 Recruitment

The strategic needs of the organization are specifically designed and the implementations of it are to be taken by the departments by itself and there is a major role of the HR section to provide the basic needs of the in self departments. As soon as the needs of the organization are met the executives and managers take responsibility to fulfil them. The next step in the staffing function is recruitment. This activity makes it possible for a company to acquire the people necessary to ensure the continued operation of the organization. In Roberts recruitment is the process which involves the attraction of a span of people who are the potential candidates that or will be chosen for the organization in the specific departments. This involves communicating with actual or potential job seekers, inviting them to have a go at the opportunity and try to convince them to work for the organization in any means of the fields. The target to achieve the best quality result is to have the best quality in the best way and numbers. Recruitment is the process of discovering potential candidates for actual or anticipated organizational vacancies. Or, from another perspective, it is a linking activity bringing together those with jobs to fill and those seeking jobs. According to Falcone [4], an organization can choose from a number of different sources to recruit personnel depending on the type of job vacancy. There are different types of recruitment to follow and fulfill management requirements. Once we get the requirement or job description from the technical person's, we should not rely on one type or one source rather search and implement the best type. Internal Sources, Existing Employee's, External Sources, Advertising, E-Recruitment According to Plumbley [9], HR is perceived as a part of the administration that results in the formulation and introduction of spontaneous and ad hoc human resource practices. This is against the basic rule of independence of the policy makers from the executive. There is little HR planning and forecasting. Recruitment criteria become hazy in the absence of a proper job analysis; and no reliable information about job description and employee specification is available.

2.3 Selection

Selection is a later stage of recruitment. It involves choosing not only new members of the organization but also ensuring that the selection process can manage to attract competent and qualified applicants suited to the job. The focus in the selection process is on: (1) Selection methods and skills in terms of contribution to the reliability of decisions made; (2) The criteria defined and applied (explicitly and implicitly) by decision-makers. And how these reflect their comprehension of "necessary competence"; (3) How the selection processes encompass the assumptions and commitments, the generalities, truths and confusions—of decision-makers about the imperatives of organization culture and how they seek to maintain and change this.

Selection activities typically follow a standard pattern, beginning with an initial screening interview and concluding with the final employment decision. The selection process may consist of following steps:

(1) Initial screening interview;
(2) Completing the application form;
(3) Comprehensive interview;
(4) Background investigation;
(5) Medical/Physical examination;
(6) Final job offer.

Each of these steps represents a decision point requiring some affirmative feedback for the process to continue. Each step in the process seeks to expand the organization's knowledge about the applicant's background, abilities, motivation, and it increases the information from which decision makers make their predictions and final choice. However, some steps may be omitted if they do not yield data that aids in predicting success, or if the cost of the step is not warranted.

2.4 *Orientation*

According to Whiddett et al. [12], Orientation is the introduction of new employees to the organization, their work units, and their jobs. Employees receive orientation from their co workers and from the organization. An effective orientation program has an immediate and lasting impact on the new employee and can make the difference between his or her success and failure.

2.5 *Employee Development*

According to an article by Barnerjee [1], employee development, in sharp contrast to training, is more future oriented and more concerned with education than employee training. Development focuses on planting a sound reasoning process in employees. It enhances their ability to understand and interpret knowledge rather than imparting a body of facts or teaching a set of skills. A development path for an employee, imparts in him analytical, human, conceptual and specialized skills. It makes him able to think and analyze in different situations. Development, therefore, focuses more on the employee's personal growth. It is important to consider one critical component of employee development: All employees, at no matter what level, can be developed.

2.6 Performance Appraisal

According to Murad [7] "Performance appraisal is the process of determining and communicating to an employee how he or she is performing on the job and, ideally, establishing a plan of improvement". When properly conducted, performance appraisals not only let employees know how well they are performing but also influence their future level of effort and task direction. Effort should be enhanced if the employee is properly reinforced. The task perception of the employee should be clarified through the establishment of a proper plan for improvement.

3 Methodology

1. Research Methodology

The research design and the methods used to conduct the research. It will discuss the methods used in the research and the reasons of using such methods. Hence the research comes to the part where the research methodology was to be selected.

2. Problem Statement

This research is based on the major problems faced by the HR department of an organization in regards to the recruitment and selection methods or sources and these are stated below:

(1) Do the HR personnel's pay due attention to the recruitment and selection methods or do they follow their own way of doing it?
(2) Analyze the outcome of the traditional and modern way of recruitment and selection methods. The recruitment and selection of the person intended for the job or not?
(3) Do the standards and requirements of the recruitment and selection sources or methods turns out to be feasible or not?

3. Theoretical Framework

The theoretical frame work of the research is to find the best possible solution of the problems stated above and to this some analysis and findings had to be done and to do this the research methods were used to identify the problems and then analyze it to find the conclusion and recommendations. The research method used is the methods used to conduct the research are interview which is the qualitative method of the research and questionnaire which is the quantitative method of conducting the research. And the audiences for the research are the HR personnel and employees from English Heritage and National Trust. Interviews were held and questionnaires were given out to management and staff in the organizations, which were found out to be very useful for the research and the outcome of the analysis and findings. While we conducting the research, we used both primary and secondary data. The questionnaire and its analysis is discussed and shown the analysis and discussion. There were 10 questions asked to the respondents and the rate of return, analysis and answers have been included.

4. Methodology

The methodology used for this research is given below, it has been described in brief and some other methods are also there. Methodologies can be classified in different ways; some writers (e.g. Saunders et al. [10]) distinguished between Qualitative and Quantitative methodologies reflecting the distinction between various paradigms.

(1) The Sample Size (Population)

The population or the sample size for this research was derived from the Managers and staff of English Heritage and National Trust and some of the staff working on the higher levels of management in the organization. The other respondents of the research method were the new recruits who were recently appointed in the organization. The sample size was minimized due to the shortage and non availability of members and hence still was able to find the answers to the most of the part of the research.

(2) Measures of Variables

The variables involved in this research were the HR policies for the recruitment and selection which was an independent figure and the other was the company's productivity after the recruitment and selection was done. The questionnaire was based on 10 questions which were administered and distributed in the levels of management and staff to find the results and put the results in the analysis phase, and from the result it was analyzed that the HR policies implemented in the organization in regards to recruitment and selection sources comes to the ratio of 75 %.

(3) Data Collection Method

Table 1 shows the close-ended questionnaires were given out and some interviews were held with the managers and staff of English Heritage (E.H) and National Trust (N.T). The questionnaire was finalised keeping in mind the nature of the job and the organizations portfolio and culture.

The questionnaire was handed back in confidence of no material to be published hence only for the use of the research, it comprised of about six parts and hence is attached in the appendix. The three factors to keep in mind when collecting data are the Validity, Reliability and Easy to use.

(4) Quantitative Data

What is quantitative data? The answer to this question comes in mind that the data gathered in quantity depending upon the size of the sample used and the validity, reliability and authentication of the material. There are levels of quantitative data used now days. Denscombe [3], The lowest level of quantitative data used is the Nominal Data which is commonly used; the next level of data is the Ordinal Data, which is based on the counts of things or happenings and is used for specific categories, the

Table 1 Data collection method

Primary data	Secondary data
E.H & N.T managers	Internet
E.H & N.T staff	Books/magazines
E.H & N.T HR policies	Articles/journals

next level of data is the Interval Data; it is used on the scaling purpose; like in the case of 'more than' or 'less than' scenarios. The next level is the Ratio Data which is based on the scale of 'true zero' and it is the highest level of data. The last of all is the Discrete Data; it comes in the chunks and is naturally based in whole units.

(5) Qualitative Data

What is qualitative data? We say words or images either of them are the process of interpretation, they become data if and if they are treated in the form of data; they don't exist as data until they are treated as data and a positive approach towards them is needed. Qualitative data is concerned with meanings and how people perceive it and thinks about it, they follow a way of a pattern which is the main quality of this data. Hence qualitative data is the Tran scripted data which is used in the research methods to produce more accurate and firm results after the analysis of the data collected.

5. Questionnaire

Questionnaire is used in the variety of context in the research, the design and method of obtaining data from the questionnaire depends upon the researcher by itself, it is formally a data collection method for research or questioning which formally sets a way of result orienting path. The questionnaire is based on three major parts i.e. introduction, body of the text (questionnaire) and basic data. Graham Birley et al. [2], The successful use of the questionnaire depends upon the time spend on it in the initial stage of the research cause once printed and send there is no return back, the planning from the initial stage means that the Costs, Production, Organization, schedule, permission and feedback all should be kept in mind when developing the questionnaire. It should have the information about the research and researcher, purpose and confidentiality.

6. Interview

According to Nickols [8], "An interview is a verbal interchange, often face to face or on the telephone, in which the one person (Interviewer) tries to elicit information, beliefs or opinions from another person". In the interviews I have collected the in depth and comprehensive information from the managers and hiring staff of English heritage and National trust

4 Findings

1. Research Findings

Recruitment and selection is the major part of any organization's HR team or department which has to justify the recruitment and selection for the desired post set up by the organization. The problem statement is discussed below:

(1) Why Recruitment and Selection sources or methods are not up to the standard required by the organization?
(2) The Recruitment and Selection methods or sources used by the HR personnel's nowadays: why is it changing day by day and getting complex not suitable?

(3) The other problem to find out was the selection of the staff in regards to the job, which is not his position to be.

2. Analysis

The data analysis is one of the most important and significant part of the study. Without the data analysis it is very hard to learn from the data which has been collected through research questionnaires and interviews. The research methodology chapter has discussed the information on how the data has been collected. This chapter will closely analyze and examine the data.

3. Analysis of Recruitment Procedures

The analysis of the recruitment procedures and methods is fairly adequate and elaborated by the HR department of English Heritage. The analysis of the recruitment methods in the organization came to the point where I saw that fairness is sometimes not done with the employee while the positioning of the job ifs invalid and amount of thinking and preference is not given in appropriate manner.

4. Analysis of Selection Procedures

The analysis of the selection methods is given below in the form of a chart which I analyzed while researching on the organizations selection methods, the best thing seen in this procedure was the detailed and thorough search on the candidate and efficiency of the HR personnel's to consult the relevant department.

The Fig. 1 selection process chart shows the detail way of selection in the English Heritage organization, where the needs of the company are kept in mind and the

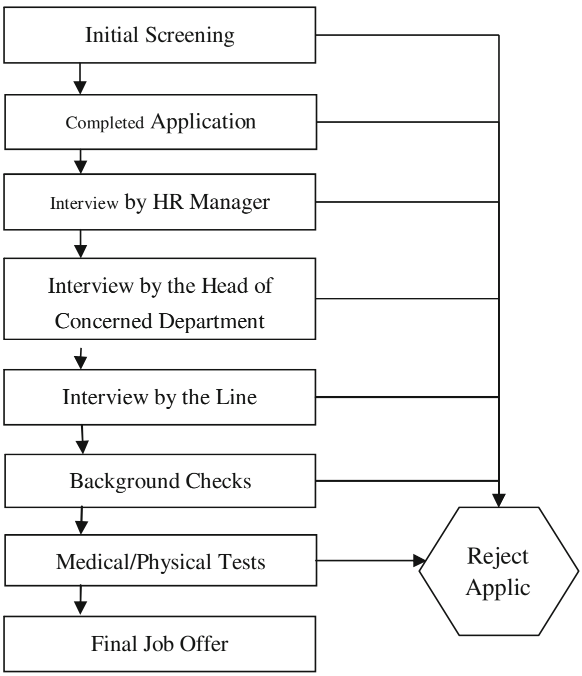


Fig. 1 Selection process chart

formal way of selection is used. It is to be stated here that this is a formal way of selection as well, but in my findings and analysis I found that sometimes the boundaries have to be crossed and the methods and ways have to be amended for the best to secure.

5. Analysis of the Challenges Faced by HR Departments of the Two Organizations

According to the findings through the interview's there were some common challenges faced by the HR team's in both the organization's, which have been discussed below.

6. Staff and Management Relations

One of the internal challenges faced by the HR department is the relationship between the staff and management. The union and the management have to run good terms for either of them to be secure.

7. Current Trends

The current new trends coming up in the HR field is also one the internal challenge to be faced, the new duties, environment, skills, future needs and current issues related to the staff.

8. Conflict Management

The conflicts between the staff itself and conflicts between the management and staff is a great issue internally which has to seen through and the diversification should tendered to its minimum state to produce the best of the results.

9. Diverse Workforce

The diverse workforce or people from different cultures and understanding are also an external problem or challenge faced by the HR department which has to resolve within its limits so no one gets disturbed.

10. Skilled Workforce

This is also one of the external challenge faced by HR, the trained workforce is not normally hired up in low levels other than the high levels with a substantial amount of experience. The unskilled or untrained workforce also becomes a challenge for the HR to tackle with, which is presumed to be taken up by the line manager to fulfil.

5 Government Policies

One of the other external challenge faced by the HR team which states that there are some limitations and implications by the government which has to taken in control and regards to fulfil the organizations needs and demands. These were some challenges faced by the human resource department which I found out while gathering the data and information and my findings are based on my organization which is English Heritage and the findings gave me clue to start of my analysis and selecting methodology to progress my research report.

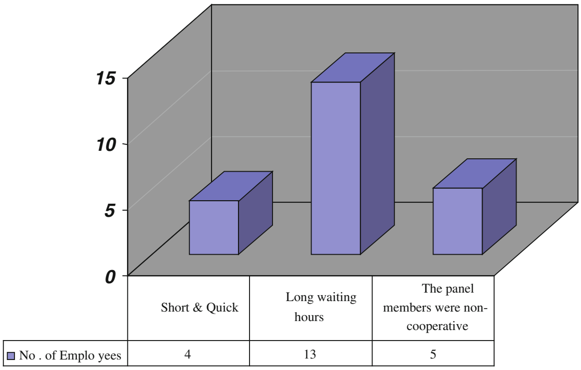


Fig. 2 On time selection process

5.1 Analysis and Discussion from the Questionnaire

Q.1: Please mark the following-
The interview process was: (1) Short & Quick; (2) Long waiting hours; (3) Panel Member were non-cooperative.

This analysis would help us to know if the selection process took place on time or candidates had to wait for long hours. There opinion about the panel members. The Fig. 2 on time selection process shows that maximum number of respondents said that they had to wait for hours before the selection process that constitutes of around 13 respondents, 4 respondents said that the interview process was short and quick, few had an opinion of the panel members being non- cooperative, that constitutes of 5 employees.

Q.2: How would you rate the whole recruitment and selection process?

This analysis would help in knowing the opinion of employees regarding the process. The new joiners have gone through it recently so this would tell us their views about these processes.

The recruitment and selection process Fig. 3 show that when asked about the Interview Process most of the employees said that the interview process was Strong,

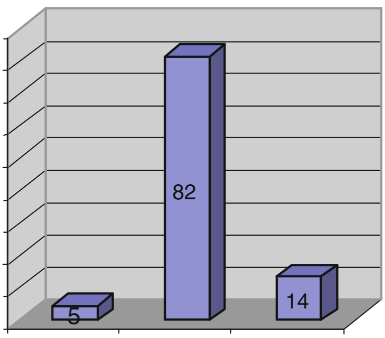


Fig. 3 Recruitment and selection process

which constitutes of 82 % of new joiners in last 6 months, 14 % of respondents had an opinion of interview process being Moderate and the rest 5 % said it was mild.

Q.3: According to you what kind of selection procedure is best?

This analysis would help us in understanding Employees views about the selection procedure. According to them what kind of selection procedure should be most effective? This pie Fig. 4 depicts that around 50 % of new joiners were satisfied with existing selection process of having a panel interview, the next majority is formed by those who believed Series of interview should take place by different interviewers that forms 32 % followed by 18 % respondents who believed Individual Interview would be most effective.

Q.4: Do you think that psychological testing is required?

This analysis would help us to know the views of new joiners and management about requirement of Psychological Testing being part of the selection process. It was made sure if they were aware what Psychological Testing is.

The Fig. 5 depicts that majority of respondents believed Psychological Testing was not required to be a part of Selection Process, which constitutes of around 50 % of new joiners, 32 % had new joiners opted for can't say as they were not sure if it would be useful in the selection process or not, as being a pharmaceutical company it was difficult to say, 18 % contributed saying yes Psychological testing should be a part of Selection Process.

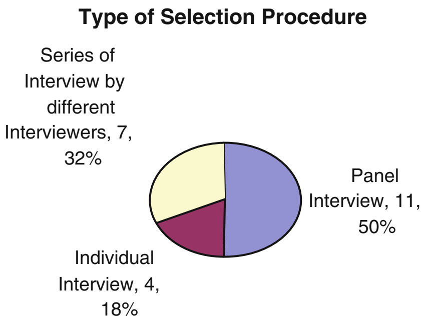


Fig. 4 Type of selection procedure

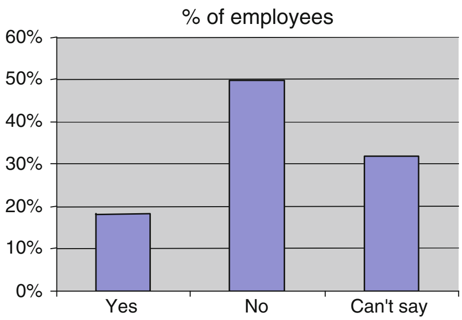


Fig. 5 Psychological testing

Q.5: Were you clear about your job role and responsibilities before joining the company?

This analysis will help us in knowing if the HR of the division makes it clear to the employees what is the job role and responsibilities of the post the employee is joining in the company.

The Fig. 6 depicts majority of employees which is around 41 %, employees said that they were not aware of the job role and responsibilities before joining the company. Around 32 %, employees said till an extent they were aware of the job role and responsibilities before joining the company. 27 %, employees said they were made aware of job role and responsibilities before joining the company.

Q.6: According to you has the organization placed you at the right post and position according to your past experience and qualification?

This analysis helps in knowing according to new joiners what are their views about the post and position they have got in the company, they think they are placed according to their past experience or qualification or not.

The Fig. 7 depicts that majority of respondents are not satisfied with their current post and position, this constitutes of 59 % of new joiners of last 6 months. 41 % were satisfied with their post and position in the company.

Q.7: Today the work done by you is same as it was described in your offer letter?

This analysis would give an idea if the presently work done by the employees is same as explained in the offer letter (Fig. 8).

Fig. 6 Job role and responsibilities

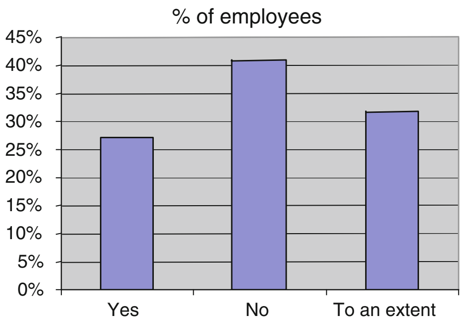
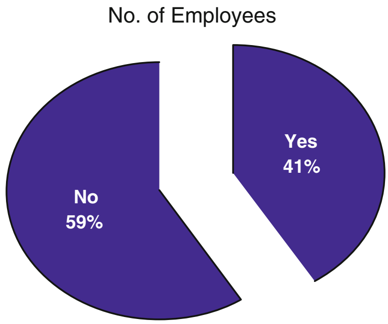


Fig. 7 The post and position



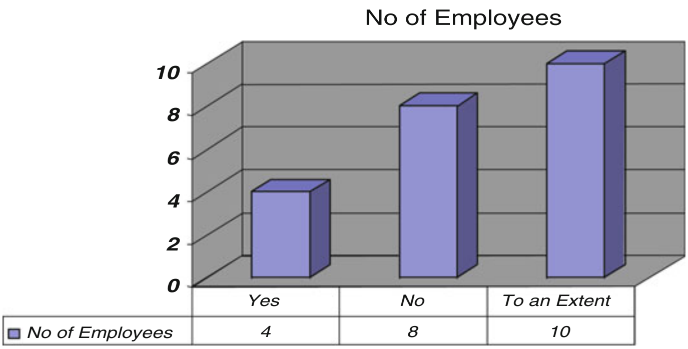


Fig. 8 Work analysis

The above figure depicts that majority of respondents believed that, to an Extent, the work done by them presently was same as described in the offer letter; this constitutes around 46 % member of employee. Around 36 % said NO the work done by them presently is different from what was in the offer letter. Around 18 % said YES they were doing the work same way as was explained in the offer letter

Q.8: The organization has facilitated me in following areas. Listed below:-
(1) Administration; (2) Human Resource; (3) Finance.

This analysis will help us in knowing if the new joiners were facilitated with the most important departments of the organization after joining the company.

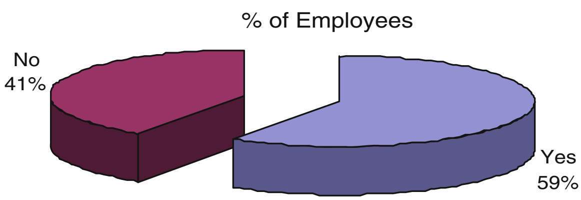
The Fig. 9 depicts 59 % of new joiners were facilitated with Administration, HR, Finance and the remaining 41 % new joiners said that they were not facilitated in the following areas.

Q. 9: Does HR team take timely feedback from you regarding your performance and satisfaction level at work? This analysis will give an idea if the HR department keeps track of well being of new joiners and their performance at work.

The Fig. 10 depicts that majority of respondents said that HR didn't take any feedback from them regarding their satisfaction level at work and performance, which constitutes of around 64 % of respondents; remaining 36 % employees said HR takes timely feedback regarding performance and satisfaction level at work.

Q. 10: Are you satisfied with the recruitment & Selection procedure carried out with you?

Fig. 9 Analysis facilities



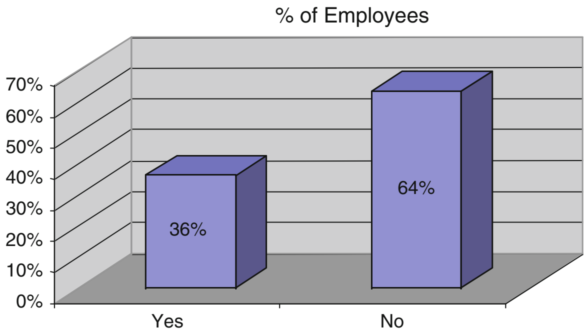


Fig. 10 Performance feedback

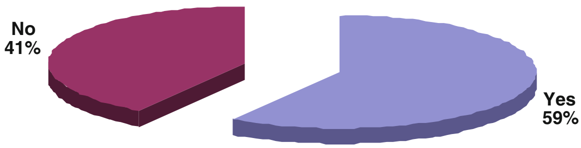


Fig. 11 Analysis of recruitment & selection Process

This analysis helps us to know if the new joiners are satisfied with the recruitment and selection process carried out in the company.

The Fig. 11 depicts 59 % of respondents are satisfied with the recruitment and selection process carried out in the company, remaining 41 % are not satisfied with the process. They believe certain changes needs to be made for the effectiveness of the process.

5.2 Measure of Central Tendency

The findings from the questionnaire were analyzed and then put into the correlation and central tendency analysis and hence the result was generated. The relationship between the HR personnel's and the techniques of recruitment and selection methods were then put into the tendency test and results were generated. The next step was using the Pearson correlation where the skills of the recruits and the selection were put up to test and result was generated. Hence they are shown below; the data for the recruitment and selection level was put up in the Table 2 below and hence the result was driven out;

The response was good as highest mean of 5.32 was taken and the feedback from the questionnaire was 4.86 which were lower than the expectations. The range of standard deviation was between 1.25 and 1.35 was due to the sample taken mostly from the management, hence the perceptions varies.

Table 2 Measure of central tendencies

	Skill variety:	Task identity:	Task significance	Autonomy	Feedback
Mean	5.17	5.18	5.32	5.20	4.86
Standard error	0.16	0.16	0.15	0.15	0.16
Median	5.30	5.40	5.60	5.20	5.00
Mode	7.00	7.00	7.00	7.00	7.00
St. Deviation	1.35	1.31	1.25	1.25	1.32
Sample variance	1.83	1.72	1.56	1.57	1.75
Kurtosis	(0.96)	(0.03)	(1.05)	(0.68)	(0.30)
Skew ness	(0.33)	(0.58)	(0.29)	(0.30)	(0.18)
Range	4.60	5.60	4.20	4.40	5.20
Minimum	2.40	1.40	2.80	2.60	1.80
Maximum	7.00	7.00	7.00	7.00	7.00
Sum	361.80	362.60	372.20	364.00	340.40
Count	70.00	70.00	70.00	70.00	70.00

Table 3 Pearson correlation matrix

	Skill variety	Task variety	Task significance	Autonomy	Feedback
Skill variety:	1.00				
Task identity:	0.64	1.00			
Task sign	0.63	0.76	1.00		
Autonomy	0.63	0.58	0.69	1.00	
Feedback	0.57	0.70	0.68	0.66	1.00

5.3 Pearson Correlation

This dimension of correlation was made to see the overall satisfaction of the recruitment and selection methods, the summarized findings are down below in Table 3.

The skill variety dimension is with higher correlation as compare to task identity; task significance and autonomy have lower correlation with feedback. This shows all matrixes dimension will increase the skill variety except the feedback.

Hence high correlation b/w task identity and task significance means task is significant enough to make its identity. The next is task significance has higher correlation with feedback, which shows weaker link. Hence the selection and recruitment of personnel's in relation to the skill, tasks, autonomy and feedback are shown in the correlation matrix.

The main factor lies with the best Recruitment and Selection methods to be used and it has to in commitment from the Human Resource department or personnel's to deliver the best out of them for the organization for its betterment and future prospects. The need in the organization should be real and factual rather than being on assumptions and statistics which sometime in future fail to respond, the commitment towards the recruitment and selection procedures should be 100 % as it is the main core of the organization as if the right person for the right job is not selected the organization may suffer on his hands. The other thing to discuss is that when the recruitment and selection procedures are implemented or taking place the process should be well defined and has a quick response so that the process and selection is done on quick basis but keeping in mind the codes and policies of the organization because actions taken in haste turn out to be nasty and disastrous too. In this market of human workforce the organizations compete to get the best available workforce, hence this should be implemented in policies and actions.

6 Conclusion and Recommendations

1. Conclusions

The Research has investigated or come to the point that the Recruitment and Selection processes used in the Organization (s) is varying in nature. As per the small firms are concerned the way of recruiting and selection is on a little scale and sometimes have influence of others as well, but coming to large organizations the influence is not there but the large scale or recruiting and selection is quiet lengthy and time consuming. The available literature and discussion clearly supports that the importance of having and following a well structured Recruiting and Selection policy should be used and followed by the HR personnel's in order to gain the best of the staff and new recruits for the organization as the management of the organization or company depends upon its HR department and it should not let the company executives down, maximum benefits do also occur when these policies are developed and implemented in the company's policies and memo's.

This study has revealed that the organization's executives and line managers were a little satisfied with the recruitments and selection process but still there is very much to come in the future for the line managers and the personnel's to tackle with, which they are not aware of. Another point to be concluded is that there is no vast way of recruiting the new staff as the large firm's normally goes within the population of its internal manpower and does not go out to recruit as it has got a lot of many staff in their own organization to fulfil their needs. At the end the organization is more confident in their mature staff rather than going out for a new recruit who might take time to settle down and learn the outcomes. The line managers take a key responsibility in training the new recruits after their selection and have to go through this burden as the HR manager's haven't got anything to do with this, so it becomes a little more complicated then it is thought to be.

If the Human Resource department is to be treated as the inimitable competencies for the organization, then the recruitment and selection has a critical and good role to play as it s part too. It does not mean that payroll and solution to different problem is the only job for the HR department but to convince for the best needs of the organization is their main role to play. Several new and interesting things did occurred while going through the research and new findings were found as well too, but this does not mean that the main problem solving was let down. The end came with a good bang of knowledge and skills that the recruitment and selection in an organization should be in measures to the policies made. The interviews and the questionnaire's feedback were good but it still did lack the knowledge of best and good judgment of a new staff. Internal selections are widely held in a large organization and hence the chance for new recruit to join the growing industry fails off and the selected personal for the new post is already a member of the organization, but sometimes when his or her post gets empty the chance for the new staff to join starts to grow up. The other thing noticed in the research carried out was that the recruitment is done only on the needs basis but still if there is an opportunity of a recruitment but the need is not there, hence the HR would save the finance's for the organization as the need is not important then the finances.

2. Recommendations

The Following are some recommendations which I would like to make in my research for further study to be taken by other researchers, hence the recommendations a purely on merit and is based on my findings and analysis and research and would like to see some change in the recruitment and selection process when held by the Human Resource department of any organization regardless of its choice and organization's policies and culture.

(1) The process of Recruitment and Selection should be well defined for a rapid response from the person applying.
(2) The response time from the HR team should be quick and criteria should be judged in accordance with time limit, hence they will not loose the employee to rivals.
(3) he traditional recruitment and selection methods or procedures should be changed and unconventional methods, like moving towards universities and fresh candidates would help in getting energetic and willing full recruits.
(4) Panel interviewing is most suitable for now days and is less time consuming so by traditional means of different stages interview should be cut down and this method should be implemented on regular basis.
(5) The amounts of money spend on the recruitment and selection procedures should be taken in account and more specialized and new ways of procedures should be adopted, which will be beneficial for the organization.
(6) Staff with greater versatility and flexibility should be recruited to face the upcoming market challenges and who can tackle the unexpected situations.
(7) The recruiting and selection of staff should be in accordance with the manuals and policies of the company rather than being in favouritism or lack of knowledge.
(8) The selection criteria should be broadened up and should be regulated and updated regularly to monitor the desires of the company's changing policies and amendments.

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A Water Allocation Model for Qujiang River Basin of China

Changting Wei and Zhineng Hu

Abstract With rapid development of economy and society, water deficit is a worldwide problem now. As a consequence, water allocation managers face an increasing pressure when they make the decisions. This paper build a bi-level model to solve the water allocation problem in Qujiang river (running across Sichuan province in southwestern China). First a allocation framework in Qujiang river basin, considering the principle of equality and stability for river basin, stress-based and economic efficiency principle for subareas' (Bazhong subarea, Nanchong subarea, Dazhou subarea, Guangan subarea and Guangyuan subarea) managers, is development. The concept of Gini coefficient and Power index, traditionally used in economic field are introduced in this paper to measure equality and stability of water allocation strategy of Qujiang river basin. The model results indicate that the bi-level model is suitable and feasible to practice and it can help the managers to solve the difficult situation well.

Keywords Water allocation · Bi-level programming model · Gini coefficient · Equality · Power index

1 Introduction

Water is a necessary resource for life and social, economic development for a country. With rapid population rise, urbanization progress along with industry development, water shortage has became a worldwide critical problem. Traditional water users, domestic, agriculture, and industry water demands, has been increasing while other water demands, such as ecology and tourism are getting people's concern. As a consequence, there is an ever-increasing pressure for river basin committee to decide the water allocation strategies. Equality, stability and efficiency must be taken into

C. Wei · Z. Hu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: huzn@scu.edu.cn

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consideration in the same time. As long as water is scarce compared to total water demands, the conflicts of different water users are intense. A feasible and efficient water allocation model is needed.

Variety research has been done on equality, stability, sustainable and efficiency water allocation methodologies in the las few decades. As the demand for natural resources intensifies, Suzukit and Nakayama put forward a cooperative game theory to consider the fairness in water allocation problem. Cai et al. [2] used Benders decomposition, the way to solve discontinuous quadratic programming problems (many water allocation model often resulted in), to solve large nonconvex water resources models. Moreover, mathematical and heuristic models have been conducted to deal with water allocation problems in different region [1, 6, 12, 16, 17]. However, more works still to be done to meet the practice needs.

Economic efficiency concerns that with a given resource how much value can be generated, while equality and stability concerns the way that resources are distributed to the society. Tsur and Dinar [22] proposed that involving subjective judgement, equality and stability get less attention than economic efficiency. Equitable access to water, or to the benefits derived from using water, is critical to eradicating poverty and promoting growth [7]. While stability measurers the feasibility (water users' will to cooperate) of the water allocation solution. Both of equality and stability is critical for social stabilization. Basically, single and multiple objective model are two approaches used in water allocation problems. Most of the existing plans are either too theoretical or too complicated which makes then hard to be implemented. To get over this difficulties, Gini coefficient and Power index, both applied in economic, are be used to deal with the fairness and stable in water allocation problems [3, 17]. Even Gini coefficient and Power index is most popular in economic, the theory of them can be applied in other field. For example, Fellman [8] proposed Gini coefficient has been used to measure the biodiversity in ecology. Owing to self-optimizing behavior, Pareto-optimal (social optimal solution) solution may be hard to be implemented. Read et al. [17] used Power index to show that optimality and stability can produce different allocation solutions. As mentioned above, there has been already a lot of literature studied economic efficiency. And varieties methods has been developed to estimated the economic benefit of different water use sectors, namely agriculture, domestic, industry, ecology and so on [4, 10]. However, those methods have many parameters which is hard to obtain.

Equality, stability and economic efficiency are the target of this paper. This paper aims at building a model to tackle the water deficit of Qujiang river basin. Thus a bi-level model is build with the upper level having two objective-minimize equality (measured by Gini coefficient) and stability (measured by Coefficient of variation). And the maximize the economic benefit is the objective of five subareas (Lower level),namely BaZhong county, Nanchong county, Dazhou county, Guangan county and Guangyuan county. The rest of the paper is organized as follow: Section 2 has a brief introduction of Qujiang river basin; Section 3 details the model component and the framework of the water allocation problem of Qujiang river basin; Section 4 shows the techniques to solve the model and the results of the model. Section 5 concludes remarks and future research possibilities to extends the proposed model.

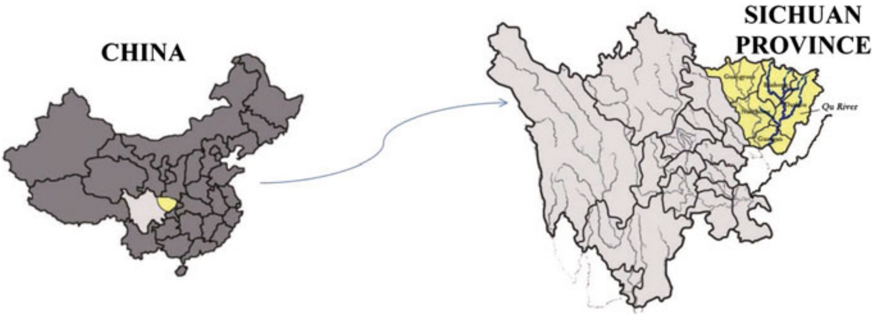

Fig. 1 Location of the Qujiang River Basin

2 Study Area: Qujiang River Basin

The Qujiang River, running across three provinces in southwestern China, is the largest tributary of the Jialinjiang River in the upper Yangtze River Basin (Fig. 1). In Sichuan Province, Qujiang River basin supplies water to Bazhong subarea, Dazhou subarea, Guangan subarea, and Nanchong sbu-basin with an area of 3,4151 km^2 (8,913 km^2 of irrigation area), covering 22 counties, 14.52 million people with GDP RMB 12.48 billion Yuan in 2012.

The total runoff volume generated in Sichuan province is estimated at 19.3 billion m^3. The water in the Qujiang River Basin has a surplus during the wet season (May–October) and a serious deficit during the dry season (November–April). This indicates the limited available water should be managed efficiently for sustainable economic development in the dry season. The water use of different sectors within the five subareas are presented in Table 1. The demand for various sectors has increased rapidly in the last 5 years with significant rise in Domestic and industrial sectors.

Because space-time location of the precipitation every year is not well balanced, even there are much rainfall in wet season, sometimes the water demand exceed the total available water. The water allocation plan of Qujiang river basin is always done through a discussion process. The discussion process usually starts in December every year to determine water allocation in the next year for different sectors based on the information provided by subarea water managers, departments/technical offices

Table 1 Water use of different sectors in Qujiang River Basin (10^3 m^3, 2012)

Sub-basin	Domestic	Industrial	Agricultural	Ecological	Total
Guangyuan	2550	5660	870	170	9260
Bazhong	47,690	76,290	40,860	2850	167,690
Dazhou	102,460	445,640	78,800	5980	632,870
Guangan	24,920	135,720	27,840	1490	189,970
Nanchong	23,190	48,710	7730	1630	81,260
Total	200,800	712,030	156,090	12,120	1,081,040

and other stakeholders. Generally, the water is allocated with a priority to use sectors in the following order: domestic, agriculture, industries, and ecological.

In recent years, in the midstream and downstream of Qujiang River basin, there has been a great development in regional economy. Since the tenth five-year plan period in China, the industry, agriculture, and economy in these subareas have rapidly developed, and the water demands have significantly increased during the last two decades. Due to the growing population, urbanization, industrialization and more irrigation, the seasonal water deficit in Qujiang River basin has become more severe. As a result, the traditional water resource allocation plans cannot deal with the water demand conflicts in the different subareas and therefore many problems relevant to equity, efficiency, and stability and stainability have arisen. These change the government planning water allocation mechanism to the combination of government planning mechanism and market planning.

Qujiang River Basin Committee has several responsibilities: guarantee the basin safety against flood during the wet season; guarantee the water supply for different sectors of all subareas; operationalize the development of the sectors involving the water and coordinate to solve the conflicts among subareas and different sectors; maintain the sustainable ecological process. To achieve these targets, The QRB Committee would allocate the water rights to the subareas under the equitable and stably cooperation objectives in the river basin, and after obtaining these water rights, each subarea water manager makes water allocation to different sectors with the aim of achieving efficient water use.

3 Model Development

3.1 Conceptual Framework

The designed water allocation system is a bi-level decision making mechanism with the upper-level decision maker (Qujiang basin management committee) deciding the amount of water allocated to competing subareas based on equality and stability principles and the lower-level decision makers (Bazhong subarea, Dazhou subarea, Guangan subarea, Guanyuan subarea, and Nanchong sbu-basin water managers) deciding the water volume for allocating to different demand sectors aiming at maximization its own economic benefits. And the designed model considers four different demand sectors, namely agriculture, domestic, industrial and ecological.

As the conceptual framework of the designed model depicted in Fig. 2, the water allocation plan depends on the available water (AW) and the sectoral demands. Basically, two types of water demand are defined in the model: the actual demand of a sector i $(i = 1, 2, 3)$ is defined as normal demand d_{ij}^{nor} and the minimum demand as d_{ij}^{min}. If the total available water exceeds the sum of all normal demand, then there in no optimal necessity and the water is supplied by (d_{ij}^{nor}) among various sectors. If the total available water is less than the sum of minimum demands, the water is

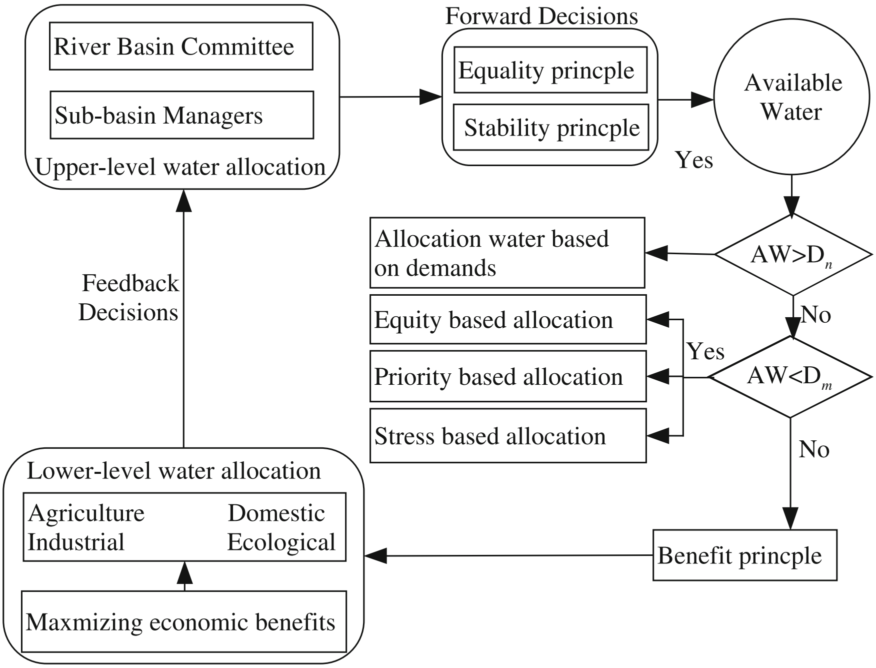

Fig. 2 Conceptual framework of water allocation model

allocated either or stressed or priority-based. If the AW fall between total (d_{ij}^{nor}) and total (d_{ij}^{min}), then the model would give a allocation plan which can let the subareas to maximize its' economic returns on the basis of Equality and stability principle. To simply, clearly state the following modeling process, the frequently-used model variables are presented in Table 2.

Table 2 Description of the model variables

Variable	Description
Index i	Subarea i ($i = 1, 2, \cdots, 5$)
Index j	Sector j in each subarea ($j = 1, 2, 3$)
EB_{ij}	Economic benefit of sector j in subarea i
MEB_i	Marginal economic benefit efficiency of sector j in subarea i
EBE_i	Economic benefit efficiency in subarea i
Q_i	Allocated water quota for subarea i
d_{ij}^{min}	Minimum requirement of the water use of sector j in subarea i
d_{ij}^{nor}	Normal requirement of the water use of sector j in subarea i
β_i^{loss}	Loss ratio of water-transfer from the origin to subarea i
WS_i	Other water source such as the groundwater and precipitation in the subarea i
α_i	power index of subarea i

3.2 Objective Functions

Gini coefficient.
Equality is defined as the state of being equal. Equitable access to water, or to the benefits derived from using water, is critical to eradicating poverty and promoting growth, so the river basin committee must consider the equality when established the water allocation plan [7]. The Gini coefficient which was traditionally applied to the measurement of income inequality is one of the most commonly used indicators for measuring distribution [9]. Gini coefficient falls between 0 and 1, and the closer to 0, the more equal is the distribution. The Gini Coefficient is calculated from un-ordered size data as the "relative mean difference", i.e., the mean difference between every possible pair of individuals y_i and y_j, divided by the mean size $\overline{y}$ [3].

$$\text{Gini} = \frac{1}{2n^2\overline{y}} \sum_{i=1}^{n} \sum_{j=1}^{n} |y_i - y_j|, \tag{1}$$

where n is the total number of individual. Using Lorenz curve, the Gini Coefficient can be displayed graphically as the distribution of the size fractions of ordered individuals [3].

There has been plenty of studies attempting to approximation the Gini coefficient with different techniques, but no one is always optimal under any circumstance. The trapezium rule is the simplest and the most popular method, but yields a positive bias for the area under the Lorenz curve and, hence, underestimated the Gini coefficient [8, 11]. So in analogy to its application into the measurement of income inequality, given an initial distribution program Eq. (1), the Gini coefficient for water allocation is figured out as follow:

$$G = \frac{1}{2m \sum\limits_{i=1}^{5} \frac{Q_i}{\mathrm{EB}_i}} \sum_{i=1}^{5} \sum_{j=1}^{3} \left| \frac{Q_i}{\mathrm{EB}_i} - \frac{Q_j}{\mathrm{EB}_j} \right|, \; i = 1, 2, 3, 4, 5, \; j = 1, 2, 3, \tag{2}$$

where EB_i is the economic benefit within the subarea i; Q_i/EB_i is the allocated water amount per unit economic benefit within subarea i.

3.2.1 CV: coefficient of variation.

In water allocation system, subareas who base decisions on individual rationality may find the social planner solution to not be directly proportional to it's comprehensive strength, and this could be an important barrier to an agreement. Thus it's necessary to consider the willingness to cooperate and practicality of a cooperative allocation solution [19]. The power index originally was applied in economics literature to identify stable solutions to cooperative problems in which the parties are negotiating agreement on the incremental benefits of cooperation [5, 14, 21]. Normalized power index formulation is presented in Eq. (5) as [13]:

$$£_j = \frac{\Theta_j - v(\{j\})}{\sum\limits_{j \in N} (\Theta_j - v(\{j\}))}, \quad j \in N, \sum_{j \in N} £_j = 1, \tag{3}$$

where *pounds* is the index value for player j from the set of N players; Θ_j is the ideal benefit allocation to player j, and $v(\{j\})$ is actual benefit amount allocated to player j. The power index method can be rewritten in terms of allocation to measure stability in a water allocation problems as [17]:

$$\alpha_i = \frac{w_i(Q_i^{\max} - Q_i)}{\sum\limits_{i=1}^{5} w_i(Q_i^{\max} - Q_i)}, \sum_{i=1}^{5} \alpha_i = 1, \tag{4}$$

where w_i is the weight of subarea i; α_i is power index of sector i; $Q_i^{\max}$ is the ideal water allocation to sector i. The index compares the difference between the ideal and the actual water allocation of a sector to the total gains of the group with $m(m = 5)$ sectors. Obviously, the power index method indicates that the most stable and acceptable solution is one that distributes power most equally between sectors [5].

Read et al. [17] proposed to measure the stability with multiple decision makers water allocation problems as the coefficient of variation (CV), which is presented as:

$$CV = \frac{\delta}{\overline{\alpha}}, \tag{5}$$

where $\overline{\alpha}$ is the mean power index value calculated across $m(m = 5)$ players. Solutions with the lower values of CV indicates the greater chance of stability (feasibility).

3.2.2 Lower-level objective function: maximize each sectors' economic benefit efficiency.

Being a key factor in local area development, water was optimally allocated to three sectors, including domestic, industrial and agricultural sectors on the basis of economic efficiency principle by every subarea. Economic benefit efficiency is defined as the ratio of the total economic benefits value of subarea i to the maximum potential economic benefits value (maximum marginal economic benefit of the sectors in subarea i products the total available water allocated to subarea i). And the objective function is represented as:

$$\mathrm{EBE}_i = \left[\frac{\sum_{j=1}^{3} (\mathrm{MEB}_{ij} \times q_{ij})}{\mathrm{MEB}_{i\,\max}((1-\alpha_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i)} \right], \quad i = 1, 2, 3, 4, 5, j = 1, 2, 3, \tag{6}$$

where EBE_i is water economic benefit efficiency of subarea i; MEB_{ij} is the marginal economic benefit per unit volume (US/m^3) of water from sector j in the subarea i. Maximization of economic benefit efficiency for subarea i; $\mathrm{MEB}_i^{\max}$ is the max marginal economic benefit among sectors in subarea i.

For the lower-level decision maker, estimating the economic benefit of water use of different sectors and allocating water to different sectors based on efficiency of economic benefit criterion are their main job. Various literatures have studied the economic benefit estimation of agriculture, domestic and industry [6, 15]. However, too many subjective parameters was involved in those estimation method. To get net economic benefit of different water uses more reasonably and more efficiently, on the basis of historical data, economic benefit and marginal economic benefit MEB_{ij} can be estimated, their relationship is:

$$\mathrm{EB}_{ij}(q_{ij}) = \mathrm{MEB}_{ij} \cdot q_{ij},\ i = 1, 2, 3, 4, 5,\ j = 1, 2, 3.$$

3.3 Constrains

Constrains of the upper level model

(1) Water availability constraint:

$$\sum_{i=1}^{5} Q_i \le \mathrm{AW}. \tag{7}$$

Apparently, the tota allocation water volume cannot exceed the resource availability at Qujiang River Basin. And the minimal ecological and environmental water requirement in/out of the river should be excluded at first.

(2) Technique constraint:

$$Z_i^{\min} \le Q_i \le Z_i^{\max}, \quad i = 1, 2, 3, 4, 5, \tag{8}$$

where $Z_i^{\min}$ and $Z_i^{\max}$ are the minimum and maximum capacities of the Watercourse (from Qujiang river basin to subarea i).

(3) Water supply constraints:

Obviously, the total allocated water together with other water source WS_i (such as the groundwater and rainfall) in the i-th subarea should be no more than the maximal store capacity of sector i,

$$(1-\beta_i^{\text{loss}})Q_i + \text{WS}_i \le S_i^{\max}, \quad i = 1, 2, 3, 4, 5, \tag{9}$$

where $S_i^{\max}$ donates the maximal store capacity.

Constrains of the lower level model
(1) Water availability constraints

The total water amount, the subarea allocated to different sectors, can not exceed the summation of the available water (allocated by river basin committee) and water from other resources WS_i(ie.ground water and rainfall) in subarea i, and ecological water needs and each sector's demand should be taken into consideration by the subarea water managers.

$$\sum_{j=1}^{3}(q_{ij}) \le (1-\beta_i^{\text{loss}})Q_i + \text{WS}_i \quad i = 1, 2, 3, 4, 5. \tag{10}$$

Obviously, the water allocated to each sector should fall between the minimum demand and maximum demand of sector j in subarea i,

$$d_{ij}^{\min} \le q_{ij} \le d_{ij}^{\text{nor}} \quad i = 1, 2, 3, 4, 5 \quad j = 1, 2, 3. \tag{11}$$

(2) Ecological water requirement

The subareas must consider the use of water for ecological and environmental preservation,

$$(1-\beta_i^{\text{loss}})Q_i + \text{WS}_i - \sum_{j=1}^{3}(q_{ij}) \ge \text{WEC}_i^{\min}\, i = 1, 2, 3, 4, 5, \tag{12}$$

where $\text{WEC}_i^{\min}$ is the minimum ecological water requirement in subarea i.

3.4 The Optimization Water Allocation Model

In Qujiang river basin system, the river basin authority provides the upstream flow to the subareas (Zigong, Zizhong, Dazhou and Nanchong). The subarea manager need to allocate the water to three sectors: agriculture, industry and domestic under the condition of satisfying the ecological water requirement first. The river basin committee must consider equality and stability in the same time when the water allocation plan was established. Under the situation of meeting the demands from different sectors, the subareas water managers try their best to seek proper water allocation to maximize the economic benefit in accordance with the river basin authority allocation decision. Obviously, there is an interactive relationship between the upper (river basin committee) and lower (subarea water managers) level decision makers. Integrating above constraints and objective functions, a full model for optimizing the bi-level water allocation in a river basin system is represented as:

$$\min_{\boldsymbol{Q}} G = \frac{1}{2m\sum_{i=1}^{5}\frac{Q_i}{EB_i}}\sum_{i=1}^{5}\sum_{j=1}^{3}\left|\frac{Q_i}{EB_i}-\frac{Q_j}{EB_j}\right|$$

$$\min_{\boldsymbol{Q}} CV = \frac{\delta}{\overline{\alpha}}$$

$$\text{s.t.}\begin{cases}\alpha_i = \frac{w_i(Q_i^{\max}-Q_i)}{\sum_{i=1}^{5} w_i(Q_i^{\max}-Q_i)}, \quad i=1,2,3,4,5\\ \sum_{i=1}^{5} Q_i \le \mathrm{AW}\\ Z_i^{\min} \le Q_i \le Z_i^{\max}, \quad i=1,2,3,4,5\\ (1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i \le S_i^{\max}, \quad \imath=1,2,3,4,5\\ \max_{\boldsymbol{q}} \mathrm{EBE}_i = \left[\frac{\sum_{j=1}^{3}\mathrm{MEB}_{ij}\cdot q_{ij}}{\mathrm{MEB}_{i\max}((1-\beta_i^{\mathrm{loss}})Q_i+\mathrm{WS}_i)}\right], \quad i=1,2,3,4,5\\ \text{s.t.}\begin{cases}\sum_{j=1}^{3} q_{ij} \le (1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i, \quad i=1,2,3,4,5\\ (1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i - \sum_{j=1}^{3} q_{ij} \ge \mathrm{WEC}_i^{\min}, \quad i=1,2,3,4,5\\ d_{ij}^{\min} \le q_{ij} \le d_{ij}^{\mathrm{nor}}, \quad i=1,2,3,4,5 \quad j=1,2,3,\end{cases}\end{cases} \tag{13}$$

where $\boldsymbol{Q} = (Q_1, Q_2, \cdots, Q_m)$, and $\boldsymbol{q} = (q_{ij})_{mn}$ are decision variables.

3.5 Optimal Solutions

As mentioned above, priority-based and benefit-based water allocation principle were applied by the subarea decision makers in terms of different amount of AW. If $(1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i < \sum_{j=1}^{3} d_{ij}^{\min} + \mathrm{WEC}_i^{\min}$, the subarea need to allocate the water priority-based. If $(1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i \ge \sum_{j=1}^{3} d_{ij}^{\min} + \mathrm{WEC}_i^{\min}$, the subarea will meet every sectors' minimum needs and allocate the water by principle of benefit.

If

$$Q_i \le \sum_{j=1}^{3} d_{ij}^{\min},$$

that means Qujiang river basin can not guarantee the minimum water demand of each subarea, and the principle of priority will be implemented by subarea i. The subareas' allocation strategies will be considered before the Qujiang river committee making the decision based on equality and stability. Usually, subarea i will consider domestic demands, agriculture demands then industry demand sequentially. So with every Q_i, the rational reaction of the subarea i is:

$$q_i^* = \begin{cases} (0, 0, SQ_i)^\tau, & \text{if } \; SQ_i < d_{i3}^{\min} \\ (0, SQ_i - d_{i3}^{\min}, d_{i3}^{\min})^\tau, & \text{if } \; d_{i3}^{\min} \le SQ_i < d_{i3}^{\min} + d_{i2}^{\min} \\ (SQ_i - d_{i3}^{\min} - d_{i2}^{\min}, d_{i2}^{\min}, d_{i3}^{\min})^\tau, & \text{if } \; d_{i3}^{\min} + d_{i2}^{\min} \le SQ_i < \sum_{i=1}^{3} d_{ij}^{\min}. \end{cases} \tag{14}$$

where $SQ_i = (1 - \beta_i^{\text{loss}})Q_i + \text{WS}_i - \text{WEC}_i^{\min}$.

If

$$SQ_i \ge \sum_{j=1}^{3} d_{ij}^{\min},$$

subarea i could use the redundant water to achieve high economically benefit efficiency on the basis of guarantee the minimum water demand and satisfying the ecological requirement. Generally, assume $\text{MEB}_{i1} > \text{MEB}_{i2} > \text{MEB}_{i3}$ ($i1$ donates industry sector of subarea i, $i2$ donates agriculture sector of subarea i and $i3$ donates domestic sector of subarea i). And the rational reaction of subarea i will be:

$$q_i^* = \begin{cases} (SQ_i - d_{i2}^{\min} - d_{i3}^{\min}, d_{i2}^{\min}, d_{i3}^{\min})^\tau, & \text{if } \; SQ_i < d_{i1}^{\max} + \sum_{j=2}^{3} d_{ij}^{\min} \\ (d_{i1}^{\max}, SQ_i - d_{i1}^{\max} - d_{i3}^{\min}, d_{i3}^{\min})^\tau, & \text{if } \; d_{i1}^{\max} + \sum_{j=2}^{3} d_{ij}^{\min} \le SQ_i < d_{i3}^{\min} + \sum_{j=1}^{2} d_{ij}^{\max} \\ (d_{i1}^{\max}, d_{i2}^{\max}, SQ_i - d_{i1}^{\max} - d_{i2}^{\max})^\tau, & \text{if } \; SQ_i \ge \sum_{j=1}^{2} d_{ij}^{\max} + d_{i3}^{\min}. \end{cases} \tag{15}$$

Taking the optimal allocation strategies of all subareas in to Eq. (2), the Gini coefficient can be rewritten as:

$$G(\mathbf{Q}) = 1 - \frac{\sum_{i=1}^{5} \sum_{k=1}^{5} \left| \frac{Q_i}{\text{MEB}_{i1} q_{i1}^e + \sum_{j=2}^{3} \text{MEB}_{ij} d_{ij}^{\min}} - \frac{Q_k}{\text{MEB}_{k1} q_{k1}^e + \sum_{j=2}^{3} \text{MEB}_{kj} d_{kj}^{\min}} \right|}{2m \sum_{i=1}^{5} \frac{Q_i}{\text{MEB}_{i1} q_{i1}^e + \sum_{j=2}^{3} \text{MEB}_{ij} d_{ij}^{\min}}}. \tag{16}$$

With this feedbacks, the upper-level model will be converted into a non-linear programming with linear constrains. For instance, when $SQ_i \ge \sum_{j=1}^{3} d_{ij}^{\min}$, and $q_i^* = (d_{i1}^{\max}, d_{i2}^{\min}, d_{i3}^{\min})$, the optimal model is:

$$G(\mathbf{Q}) = 1 - \frac{\sum_{i=1}^{5}\sum_{k=1}^{5}\left|\frac{Q_i}{\mathrm{MEB}_{i1}q_{i1}^e + \sum_{j=2}^{3}\mathrm{MEB}_{ij}d_{ij}^{\min}} - \frac{Q_k}{\mathrm{MEB}_{k1}q_{k1}^e + \sum_{j=2}^{3}\mathrm{MEB}_{kj}d_{kj}^{\min}}\right|}{2m\sum_{i=1}^{5}\frac{Q_i}{\mathrm{MEB}_{i1}q_{i1}^e + \sum_{j=2}^{3}\mathrm{MEB}_{ij}d_{ij}^{\min}}}$$

$$\text{s.t.}\begin{cases}\sum_{i=1}^{5} Q_i \le \mathrm{AW} \\ (1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i - \mathrm{WEC}_i^{\min} - \sum_{j=2}^{3} q_{ij} \ge d_{i1}^{\max} \\ (1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i - \mathrm{WEC}_i^{\min} \ge \sum_{j=1}^{3} d_{ij}^{\min} \\ 1-\beta_i^{\mathrm{loss}})Q_i + \mathrm{WS}_i \le \mathrm{S}_i^{\max}\ i = 1,2,3,4,5, \\ \mathrm{Z}_i^{\min} \le Q_i \le \mathrm{Z}_i^{\max}\ i = 1,2,3,4,5.\end{cases} \tag{17}$$

4 Results and Discussion

4.1 *Determining the Parameters*

Estimation of the subarea decision makers' weights w_i is the most challenging step in modeling the QRB water allocation based on the proposed methodology. In this paper, all subareas are given equal weights in the calculation progress of CV(i.e., $w_i = 1$ for all subareas).

For each subarea, two kinds of demand was defined, namely normal demand and minimum demand. The normal demand was the total water amount put forward by the subareas themselves. As mentioned above, every sector has self-optimizing behavior so $\sum_{j=1}^{3} d_{ij}^{\mathrm{nor}}$ is the ideal and maximum water demand ($Q_i^{\max}$). The EB_{ij} (economic benefit per unit volume of water from sector j in subarea i) and MEB_{ij} (Marginal economic benefit of sector j in subarea i) should be determined according to the historical data. According to the history data in the resent five years (2008 $\sim$ 2012) and reasonable forecast,the detail of parameters can be found in Table 3 and Table 4.

4.2 *Model Results*

As mention above, present available water in Qujiang river basin is about 1.93 million m^3. And basis on the equation: $\mathrm{AW} < \sum_{i=1}^{5}(\sum_{j=1}^{3} d_{ij}^{\min} + \mathrm{WEC}_i - \mathrm{WS}_i)/(1 - \min\{\beta_i^{\mathrm{loss}}\})$, it's clearly that principle of priority allocation stratify will be applied by subareas' manager. In accordance with the importance of the equality and stability, different weights should be given to those two objectives. The importance of equality

Table 3 Parameters 1

	β^{loss}	$WS_i(10^4m^3)$	$WS_i(10^4m^3)$	$DIca(10^3m^3)$		$MEB_i(Yuan/m^3)$		
				Z_i^{min}	Z_i^{min}	Industry	Agriculture	Domestic
BZ	0.45	42,764	50000	47905	53157	60.61	42.55	43.86
NC	0.38	23,870	40000	39514	45320	54.35	34.48	32.26
GA	0.3	33,997	40000	18622	46889	67.57	47.62	47.17
GY	0.5	2874	30000	12448	38543	74.07	31.25	37.88
DZ	0.32	115,382	60000	26308	67832	86.96	43.11	45.45

Table 4 Parameters 2

	Industry		Agriculture		Domestic		Ecology
	d_{i1}^{max}	d_{i1}^{min}	d_{i2}^{max}	d_{i2}^{min}	d_{i3}^{max}	d_{i3}^{min}	
BZ	48,848	11,715	76,465	51,917	15,510	11,410	285
NC	47,202	5643	42,032	36,349	7845	5675	163
GA	45,149	16,356	44,277	33,187	9616	6697	149
GY	35,988	653	4224	3422	812	659	17
DZ	78,174	52,444	141,104	104,172	28,092	21,702	598

and stability varying from a particular situation, and the two objective are given equal weights (i.e., both the objectives assign the weight 0.5) which represented the common case. Table 5 reveals the allocation strategy of Qujiang river basin when the bi-level model is applied. The Gini coefficient is 0.244 and the value of CV is 0.519, which means this allocation strategy is basically fair and stable. The result shows that subarea Dazhou is assigned the largest volume of water and the economic benefit of Dazhou is also the most.

5 Conclusion

The study develops a water allocation model which is a bi-level model with the upper level aiming at maximum equality and stability of the allocation strategy and lower-level aiming at maximum the economic efficiency of every subarea separately. Therefor emphasis the importance of equality and stability in the decision making progress of water allocation problem. With the appliance of this model the water allocation problem is well solved. Therefore the Qujiang river basin water allocation problem has demonstrated the suitable and feasible of this model, thus the use of this model can help the manager the solve the water deficit pressure and conflict between the competing water users. The w_i in Eq. (4) are just presume to be equal, but in real situation w_i is varying from subareas for the sake of social, economic, population and environment factors, so further study need to be done on how to estimated the w_i of every subarea. And the weights of the two objective and some other parameters should be studied more deeply.

Table 5 Allocation strategies of Qujiang river basin

Weights		Allocation amount ($10^4 m^3$)				Economic benefit billion Yuan RMB				Gini coefficient	Coefficient of variation
		q_{i1}	q_{i2}	q_{i3}	Q_i	EB_{i1}	EB_{i2}	EB_{i3}	EB_i	$G(\mathbf{Q})$	$CV(\mathbf{Q})$
	BZ	5580	51,917	11,410	48,052	3.38	22.09	5.00	30.48		
$\theta_1 = 0.5$	NC	6182	36,349	5675	39,514	3.36	12.53	1.83	17.72		
$\theta_2 = 0.5$	GA	9426	33,187	6697	22,088	6.37	6.37	3.16	25.33	0.244	0.519
	GY	5000	3422	659	12,448	3.70	1.07	0.25	5.02		
	DZ	29,710	104,172	21,702	60,000	25.84	44.91	9.86	80.61		

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Part VIII
Decision Making Systems

Improving the Efficiency on Decision Making Process via BDD

Alberto Pliego Marugán and Fausto Pedro García Márquez

Abstract For a qualitatively and quantitatively analysis of a complex Decision Making (DM) process is critical to employ a correct method due to the large number of operations required. This paper presents an approach employing Binary Decision Diagram (BDD) applied to the Logical Decision Tree. LDT allows addressing a Main Problem (MP) by establishing different causes, called Basic Causes (BC) and their interrelations. The cases that have a large number of BCs generate important computational costs because it is a NP-hard type problem. This paper presents a new approach in order to analyze big LDT. A new approach to reduce the complexity of the problem is hereby presented. It makes use of data derived from simpler problems that requires less computational costs for obtaining a good solution. An exact solution is not provided by this method but the approximations achieved have a low deviation from the exact.

Keywords Decision making · Efficiency · Logical decision tree · Binary decision diagram

1 Introduction

DM processes are done continuously by any firm in order to maximize the profits reliability, etc. or minimize costs, risks, etc. There are softwares to facilitate this task, but the main problem is the capability for providing a quantitative solution when the case study has a large number of BCs. The DM problem is considered as a cyclic process in which the decision maker can evaluate the consequences of a previous decision. Figure 1 shows the normal process to solve a DM problem.

A.P. Marugán (✉) · F.P.G. Márquez
Ingenium Research Group, Escuela Técnica Superior de Ingenieros Industriales, Campus Universitario s/n, 13071 Ciudad Real, Spain
e-mail: Alberto.Pliego@uclm.es

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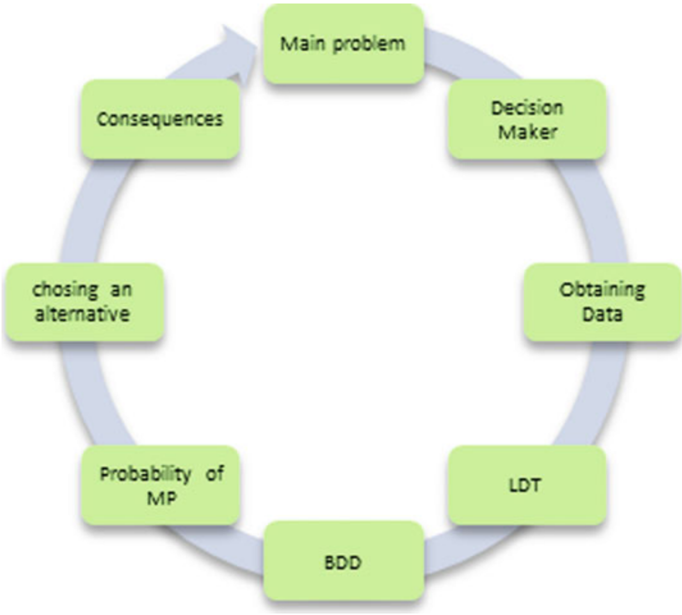

Fig. 1 Decision making process

2 Defining the MP via LDT

This paper considers a new approach based on breaking down the problem into different causes that could lead to non-desired situations. This disaggregation leads to determine the number of BCs and also identifies the manner in which all these BCs are logically interrelated. With this purpose, LDT are proposed in this paper as a useful tool being able to addressing the MP. LDT is introduced as an alternative method to draw a DM, considering the interrelation between each BC [11]), that will take into account the logical operators 'AND' and 'OR' [13]. Annex 1 shows a LDT case study composed by:

1. 1 Top event or MP.
2. 63 Logical gates: they determine the logical relation between BCs.
3. 6 Levels: it is related to the depth of each logical gate.
4. 64 BCs: possible causes of the MP.

It is showed only with OR gates because its topology will be changing in the experiments in order to analyse different scenarios

3 LDT to BDD Conversion

LDT conversion to BDD provides some advantages in terms of efficiency and accuracy see [1, 5, 10, 15]. BDD helps to show the occurrence of a serious issue in the business in a disjoint form, which indeed provides an advantage from the computational point of view.

BDD is a directed graph representation of a Boolean function, where equivalent Boolean sub-expressions are uniquely represented. A directed acyclic graph is a directed graph with no cycles, i.e. to each vertex v there is no possible directed path that starts and finishes in v. It is composed of some interconnected nodes in a way that each node has two vertices. Each can be either a terminal or non-terminal vertex. BDD is a graph-based data structure whereby the occurrence probability of a certain problem in a DM is possible to be achieved. Each single variable has two branches: 0-branch corresponds to the cases where the variable is 0; 1-branch cases are those where the event is being carried out and corresponds when the variable is 1.

The transformation from DT to BDD is achieved applying some mathematical algorithms. Ite (If-Then-Else) conditional expression is one of the BDD's cornerstones [2], see Fig. 2:

Figure 2 is defined as: "If BC_i variable occurs, Then f_1, Else f_2". The solid line always belongs to the ones as well as the dashed lines to the zeroes. Having into account the Shannon's theorem it can be obtained the following expression:

$$f = BC_i f_1 + \overline{BC_i} f_2. \tag{1}$$

It can be also expressed as:

$$f = BC_i f_1 + \overline{BC_i} f_2 = ite(b_i, f_1, f_2). \tag{2}$$

In the transformation from DT to BDD is necessary to establish a correct ranking of BCs, further detailed information about the conversion and variable ordering methods can be found in [8]. In this paper only AND and OR gates are used in the LDTs presented to express the interrelation between the BCs. Figure 3 shows the conversion from LDT to its corresponding BDD using the following order for BCs: $BC_1 > BC_2 > BC_3 > BC_4$. Once the conversion from DT to BDD is done, it is

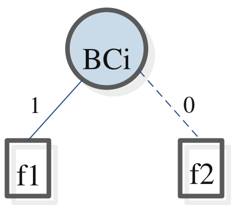

Fig. 2 ITE applied to BDD

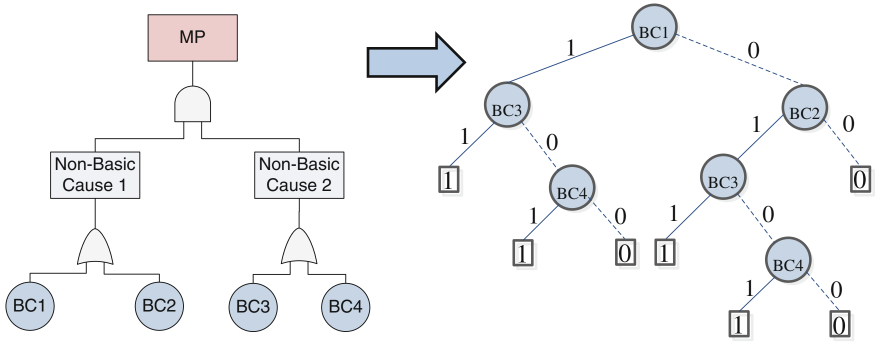

Fig. 3 Conversion from LDT to BDD

possible to obtain an accurate expression of the probability of occurrence of the MP (Q_{MP}) by assigning a probability value to each BC.

3.1 Cut-Sets and the Analytical Expression from BDD

Cut-sets (CS) turn into an important concept when referring to BDDs. They are the paths "from the top to the ones" that provide significant information due to the fact that the probability of occurrence of the MP could be achieved from them. The following CSs have been obtained from the BDD in Fig. 3.

$$\begin{aligned} CS_1 &= \{BC_1, BC_3\}, \\ CS_2 &= \{BC_1, \overline{BC_3}, BC_4\}, \\ CS_3 &= \{\overline{BC_1}, BC_2, BC_3\}, \\ CS_3 &= \{\overline{BC_1}, BC_2, \overline{BC_3}, BC_4\}. \end{aligned}$$

The MP probability is possible to be achieved due to the fact that the different paths (CSs) are mutually exclusive and may be expressed as the sum of probabilities of all the BDD paths, i.e. an analytic expression consisting of the sum of each analytic expression that forms the CSs. This expression will represent the utility function in the DM process.

3.2 The Importance of a Correct Ranking of BCs

It is very important to set a proper ranking for the BCs before carrying out a conversion from LDT to BDD. This ranking determines the size of the resulting BDD and, consequently, the number of CSs. An inefficient variable ranking usually produces a large BDD. If the number of CSs increases, then the computational time required for calculating the MP probability of will rise. The problem of finding the optimal variable ranking is NP-complete and it cannot be solved on a reasonable time, therefore, heuristic methods are widely used in order to find an efficient ranking. These methods do not provide an optimal solution but a good enough one. The main methods are described below:

(1) The Top-down-left-right (TDLR) method generates a ranking of the events by ordering them from the original FT structure in a top-down and then left-right manner [3]. The listing of the events is initialized, at each level, in a left to right path adding the BCs found in the ordering list.
(2) The Depth First Search (DFS) approach goes from top to down of a root and each sub-tree from left to right [6]. This procedure is a non-recursive implementation and all freshly expanded nodes are added as last-input last-output process.
(3) The Breadth-First Search (BFS) algorithm begins ordering all the basic events obtained expanding from the standpoint by the first-input first-output procedure [9]. The LDT is read from left to right and the events are ranked according to the order in which they are found. It must be stated that if a repeated event is found it must be ignored.
(4) The "Level" method creates the ranking of the events according to the level of them [4]. The level of any BC is understood as the number of the gates that has higher up a tree until the MP. In case that two or more events have the same level, the event will have highest priority if it appears early in the tree.
(5) The AND criterion establishes that the importance of the BC is based on the "AND" gates that are between the k event and the MP, because these gates imply that there are redundancies in the system [17]. Consequently, a BC under an "AND" gate can be viewed as less important because it is independent to other BCs occurrences. Furthermore:
BCs with the highest number of "AND" gates will be ranked at the end.
In case of duplicated basic events, the event with less "and" gates has preference.
BCs with the same number of "and" gates can be ranked as the TDLR method approach.
(6) Other methods, such as Weights method, Method of flows, Method of fathers, Level Method, Heuristic method based on the structural importance are described in references [4, 7, 12, 16].

There is not a specific heuristic method appropriate for all the LDTs. Some methods are more appropriate than others depending on the logical function. The most appropriate method should be chosen for each case. The heuristic methods described hereby are static. There are also dynamic heuristic methods however, they are not suitable for large or complex LDTs. They present some drawbacks such as they need to store in memory the BDD or a part of it [14].

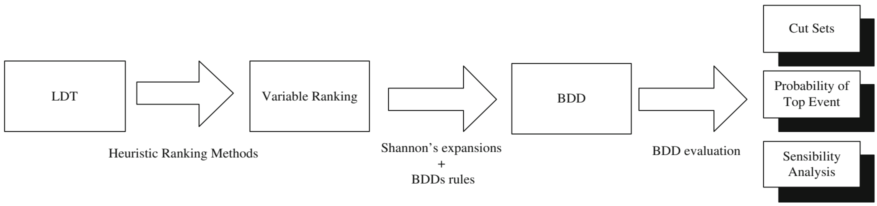

Fig. 4 Evaluation of BDDs

3.3 *Evaluation of BDDs*

The information that can be gathered from a BDD is:
• MCSs and Minimal Path Sets.
• Probability of occurrence of the top event.
• Sensitivity analysis and importance measures.

Figure 4 shows the different steps required to carry out a complete LDT via BDD analysis. The information that this analysis provides is very useful but not easy to obtain. The computational cost of the evaluation of the BDDs is one of the most important obstacles when a large LDT is required to be analysed. In the following section, an estimation of the results of the LDT in Annex 1 is performed to find the MP probability depending on the topology of the tree. It is important to remark that this approach aims to reduce computational time when a large LDT has to be solved but it can be useful only if an exact result is not required.

4 New Approach to Reduce Computational Cost

The DM problem described is a NP-hard type problem and, therefore, for a large number of BCs, or a complex topology, it can be not recommended to find a solution. This paper presents a novel approach for finding a good solution minimizing the computational cost. This approach is based on the logical gates, especially the AND gates, the number and the position on the tree (level), and their effects to the solution and the computational cost of the system. The reference solutions, or experimental solutions, are obtained in simple systems, where it can be extrapolated to complex systems via polynomial regression functions. These functions are setting according to the reference solutions, where it will be more precise with more reference solutions.

Figure 5 shows the probabilities and CSs for different LDT cases studies in Annex 1. The probability of occurrence of MP and the CSs are obtained for different amounts of AND gates in each level.

The LDT has been calculated for the cases marked in black in Fig. 5, and red are estimated results. The calculated results have been obtained using the aforementioned AND criterion to ranking the BCs. The estimations have been obtained through

Probability of Occurrence of MP						Number of AND Gates	Number of Cut-Sets					
Level 1	Level 2	Level 3	Level 4	Level 5	Level 6		Level 6	Level 5	Level 4	Level 3	Level 2	Level 1
0,0756	0,291	0,3864	0,4313	0,4531	0,4638	1	63	64	72	112	288	1024
	0,0436	0,2836	0,3846	0,4308	0,453	2	63	72	144	672	4608	
		0,1637	0,3341	0,4077	0,4419	3	65	104	536	5840		
		0,027	0,2795	0,3837	0,4306	4	71	208	2528	15616		
			0,2205	0,3587	0,4191	5	85	528	7400			
			0,1578	0,3326	0,4074	6	115	1496	16432			
			0,0911	0,3036	0,3954	7	177	3673	30904			
			0,0204	0,2752	0,3832	8	303	7836	52095			
				0,2458	0,3727	9	527	14952				
				0,2154	0,3604	10	896	26177				
				0,184	0,3479	11	1463	42860				
				0,1516	0,3352	12	2294	66544				
				0,1182	0,3223	13	3462	98961				
				0,0838	0,3092	14	5048	142036				
				0,0484	0,2959	15	7144	197888				
				0,012	0,2824	16	9850	268825				
					0,2687	17	13276					
					0,2548	18	17540					
					0,2407	19	22770					
					0,2264	20	29103					
					0,2119	21	36684					
					0,1972	22	45669					
					0,1823	23	56221					
					0,1672	24	68513					
					0,1519	25	82729					
					0,1364	26	99058					
					0,1207	27	117701					
					0,1048	28	138869					
					0,0887	29	162778					
					0,0724	30	189658					
					0,0559	31	219744					
					0,0392	32	253283					

Fig. 5 Experimental results and estimations

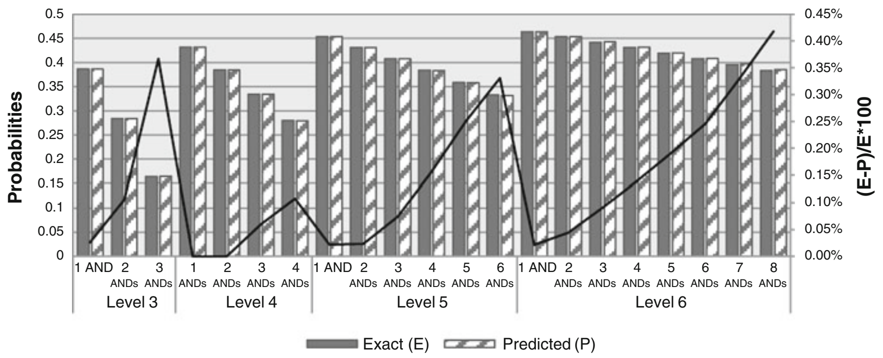

Fig. 6 Probability analysis

polynomial expressions, where the polynomial degree depends on the number of experimental points obtained. The experimental solutions have been obtained using the algorithms developed by [2].

Figure 6 shows the results of probabilities found exactly (E) by BDD and the predicted (P) results found by new approach. It is observed that the probability is indirectly proportional to the number of AND gates, and proportional to the level, which is expected. Moreover, the consequences of adding a new AND gate is indirectly proportional to the level. Figure 6 is also plotted (black curve) the absolute deviation expressed as abs$((E - P)/P)$. The deviation is proportional to the number of gates, and with values always inferior to 0, 45 %. It demonstrates that the accuracy of the solutions founds by the new approach is in every case very good.

The deviation has been estimated for different levels and number of AND gates. It has been estimated through quadratic polynomial expression. It is useful in order to know approximately the accuracy of the probability estimated and showed in Fig. 7.

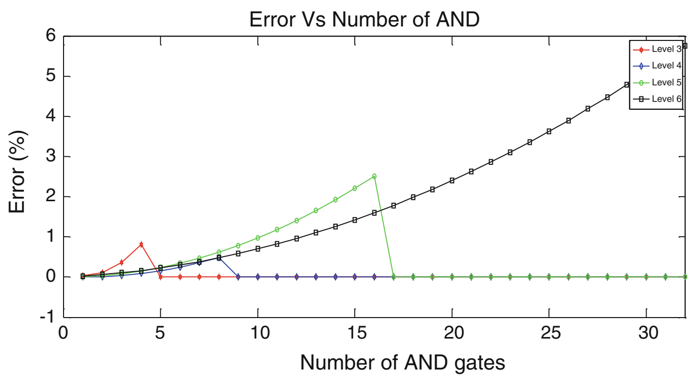

Fig. 7 Deviation versus number of AND

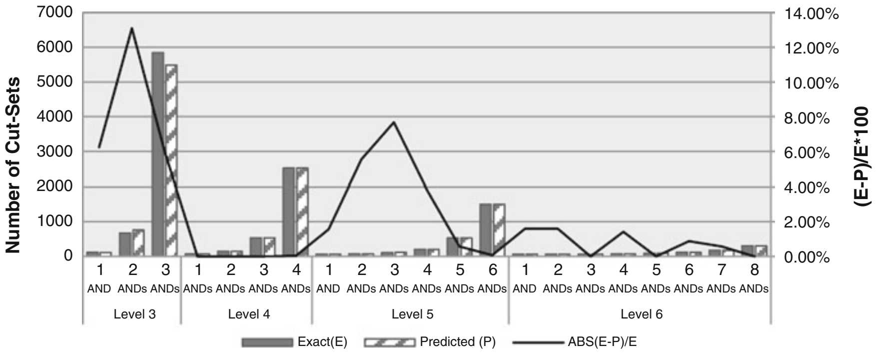

Fig. 8 CS analysis

A similar to the study presented in Fig. 6 has been done taking into account the number of CSs, and showed in Fig. 8. The number of CSs is larger in each level when the number of AND gates increase, and the number of CSs is smaller when the level is larger taking into account the same number of AND gates. The error is not as relevant for CSs than for the probabilities, because is the same independently of the number of CSs. It is relevant in order to estimate the computational cost for solving the problem. Exponential expressions have been used to evaluate the size of the CSs.

5 Conclusions

DM via LDT and the conversion to BDD is presented in this paper. This approach often requires decision maker to obtain a complex analytic expression of the occurrence probability for a MP. The complexity of this expression depends of the number of BCs and the topology of LDT.

An analysis of different scenarios regarding to the AND gates and levels is done in this paper. It has been demonstrated that the number of CSs, and therefore the computational cost, can increase significantly and do not viable to find a solution in a reasonable time. One of the most influent factors in the computation cost is the ranking of the BCs. In this paper, different heuristic methods are presented in order to establish a proper order for them.

This paper also presents a novel approach for not complex topologies that allows, employing simplex regression techniques, to estimate the solution of different scenarios for a LTD problem. Polynomial and exponential expression have been used with this purpose. It leads solutions with very good accuracy associated to scenarios associated to a large number of CSs. It leads therefore to reduce the computational cost for solving the problem.

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Appendix

See Fig. 9

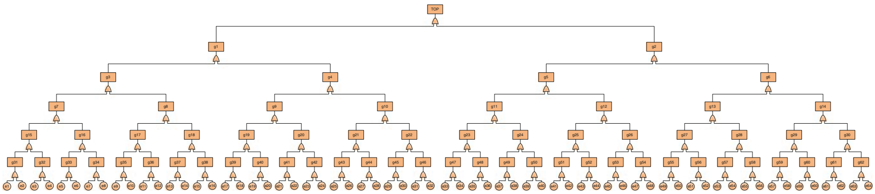

Fig. 9 Annex 1

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Evolution Characteristics of Agricultural Drought Disasters in China

Zongtang Xie and Hongxia Liu

Abstract Drought disaster is one of the severe meteorological disasters and causes of serious losses for agricultural productions, and early evolution characteristics of agricultural drought disasters is critical in management of farming. Based on a series of drought data from 1952 to 2011, the evolution characteristics and changing trend of agricultural drought disasters in China are analyzed by using quantitative and qualitative methods in this paper. It is found that: (1) In terms of a long period of time, droughts of various levels occur in successive years, during which, the frequency of small-scale and mild droughts is the highest and severe calamity and catastrophic disasters occur every 2 or 3 years after 1970; (2) Drought-affected area ratio and drought-suffering area ratio take on high volatility in the time sequence. Light and heavy agricultural droughts appear alternatively; (3) Anomaly indices of drought-affected area ratio and drought-suffering area ratio appear periodic and isochronous ascending and descendant, with episodic reverse fluctuation.

Keywords Drought disaster · Evolution characteristics · China

1 Introduction

Drought disaster is one of the most seriously natural disasters. It can have devastating effects on water supply, crop production, and rearing of livestock. They may lead to famine, malnutrition, epidemics and displacement of large populations from one

Z. Xie (✉)
Uncertainty Decision-making Laboratory, Sichuan University,
Chengdu 610064, People's Republic of China
e-mail: zongtangx171@126.com

H. Liu
School of Economics, Northwest University for Nationalities,
Gansu 730030, People's Republic of China

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area to another [1]. More importantly, its impacts on agriculture are enormous. The drought events also have huge harm to economies, societies and environments [2]. It has an important impact on the development of world instability and becomes bottleneck of the sustainable development of national economy. In recent decades, the impacts of drought have escalated in response to population increase, environmental degradation, industry development, and fragmented government authority management [2]. The damage from droughts to agriculture in some countries was extensive, and the amount of losses caused by drought ranks first in the list of all natural hazards [3]. China is one of the countries where drought disasters occur particularly frequently. China is a great agricultural country. A basic industry of the national economy, agriculture is easily affected by agro-meteorological hazards (particularly drought). The frequent occurrence of drought, coupled with the impact of global warming, poses an increasingly severe threat to the Chinese agricultural production [4–7]. Especially in the recent years, drought disasters continuously happen and cause serious impact to people's production and life. For example, 2009–2010, in the southwest of China, the five regions (Yunnan, Guangxi, Guizhou, Sichuan and Chongqing) happened serious droughts. Therefore, it is significant to master the time characteristics and distribution of agricultural drought evolution and adopt effective disaster prevention measures.

2 Data and Methodology

Agricultural drought disaster index generally have the drought-affected area, drought-suffering area, quantity of grain damage, etc., and various derived indicators, each indicator reflects the intensity of drought disasters from different angles on the harm of agricultural production system. This paper selected the area of drought disaster affected and suffering and the total sown area of crops in China from 1952 to 2011. As each year's crop sown area is different, even the drought-affected area and drought-suffering area are equal in different years, the relative loss and the harm caused by disaster are distinct. Therefore, only using the absolute value of the drought-affected area and drought-suffering area to analysis time of dynamics of disaster cannot really reflect the characteristics of disaster. For ease of comparison time distribution characteristics of Agricultural drought disaster, it is necessary to carry out data processing appropriately.

Defined as the ratio of the drought affected area with the total sown area of crops is drought-affected rate, it can reflect the effects of drought disasters basic scope and scale. Similarly, the ratio of the drought-suffering area with the total sown area of crops is drought-suffering rate, it reflects the degree of hazard-formative drought disasters.

According to definition, the paper calculated the calendar year ratios of drought-affected area and drought-suffering area; and on the basis of the calendar year drought-affected area ratio and drought-suffering area ratio and formula (1), the paper calculated anomaly indices of drought-affected area ratio and anomaly indices of drought-suffering area ratio.

$$\zeta_i = \frac{M_i - \overline{M}}{\delta}. \tag{1}$$

In the formula, ζ_i is the anomaly indices of drought-affected area ratio and anomaly indices of drought-suffering area ratio of the corresponding year; M_i is the drought-affected area ratio and drought-suffering area ratio of the corresponding year; $\overline{M}$ is the mean of drought-affected area ratio sand drought-suffering area ratio of the corresponding year; δ is the mean square error.

When $\zeta \prec 0$ is small; when $0 \leq \zeta \prec 0.5$ is light; when $0.5 \leq \zeta \prec 1.0$ is severe; when is $\zeta \geq 1.0$ catastrophic.

3 Evolution Features of Agricultural Drought in 60 Years

Agricultural drought disaster has distinct uncertainties, thus, up to a point, showing a certain mutability (leap) and gradual variation (overall trend) within a specific range of time and space. This paper uses anomaly indices of drought-affected area ratio and anomaly indices of drought-affecting area ratio, both of which indicate drought magnitude and degree, to analyze the evolution characteristics of China's agricultural drought disaster in recent 60 years.

3.1 The Frequent Occurrence of the Evolution of Agricultural Drought Disaster

The frequency of drought disaster indicates the ratio of the occurrences of a certain level of drought disaster and the number of years concerned in a series of drought disaster samples. It shows the sparseness of the droughts disaster in time series and reflects the change in the condition of drought disaster as well. As each period, during which, the combinations of factors such as the construction condition of hydraulic projects, socioeconomic levels and agricultural land type are diverse, the time series of droughts disaster can be divided into six periods and the evolution process of drought disaster frequency of different levels in time series is shown in Table 1. From Table 1, the major manifestations of evolution features of drought disaster frequency are as follows:

(1) In terms of a long period of time, droughts of various levels occur in successive years, during which, the frequency of small-scale and mild droughts is the highest and severe calamity and catastrophic disasters occur every 2 or 3 years after 1970. The reason behind this is that most part of China belongs to warm temperate continental zone, and the precipitation is under the influence of land-sea contrast

Table 1 Decadal variation of the drought grade in China

	Small ($\zeta \le 0$)				Light ($0 < \zeta < 0.5$)				Severe ($0.5 \le \zeta < 1$)				Catastrophic ($1 \le \zeta$)			
Statistical	Affected		Suffering		Affected		Suffering		Affected		Suffering		Affected		Suffering	
Time	Year /a	Hz /%	Year /a	Hz /%	Year /a	Hz /%	Year /a	Hz /%	Year /a	Hz /%	Year /a	Hz /%	Year /a	Hz /%	Year /a	Hz /%
1952–1959	6	75	7	87.5	1	12.5	1	12.5	0	0	0	0	1	12.5	0	0
1960–1969	7	70	8	80	1	10	0	0	0	0	0	0	2	20	2	20
1970–1979	1	10	8	80	4	40	0	0	4	40	1	10	1	10	1	10
1980–1089	3	30	2	20	4	40	3	30	1	10	3	30	2	20	2	20
1990–1999	4	40	4	40	2	20	2	20	2	20	0	0	2	20	4	40
2000–2011	7	58.3	5	41.7	1	14.3	1	8.3	2	16.7	3	25	2	16.7	3	25

and topography and other factors. Also the distribution varies considerably in each region and seasonal distribution is uneven within a year. The change from one year to another is enormous. Most areas are affected by the southeast and southwest winds, so a distinguishing feature comes into being that the southeast is humid and rainy while the northwest is dry and with little rainfall. In eastern areas it rains a lot but intensively, so seasonal droughts occur quite often.

(2) Looking at each period, during 1950s, 1960s and the first 11 years in 21st century, the frequency of small-scale and mild droughts is relatively high while that of severe calamity and catastrophic disasters is not. But from the year of 1959 to 1961 and in the year of 2000, the situation of drought disaster is extremely serious. It gets much more severe during 1959–1961 which is known as the three year natural disaster of China. During those years, there were large-scale droughts three years in a row all over the country, which as a result led to a significant drop in agricultural production. The market then was very tight and it was rather hard for people to survive. The number of unnatural death increased sharply. According to statistics in 1960, there were 10 million less in total number of population. In the year of 2000, it was the most serious drought disaster since the foundation of China. The drought-affected area and the drought-affecting area are respectively 4054×10^4 hm^2 and 2678×10^4 hm^2.The most frequent occurrence of severe calamity and catastrophic disasters is during 1970s, 1980s and 1990s, among which from 1978 to 1983 there have been severe droughts continuously. The total affected area was 6.21×10^7 hm^2 then. In 1978, the precipitation from January to October in some provinces was less 30–70 % than usual and it was more obvious in the mid-low reaches of Yangtze River during summer drought. At that time the national affected area was 4×10^7 hm^2 and the damage area was 1.8×10^7 hm^2, which is the highest value of statistical data. The volatility of droughts from 1986 to 1999 became larger and every 1 or 2 years there came a heavy-disaster disaster year of drought and the magnitude of the affected area ratio over usual rate is bigger than that of suffering area ratio, which indicates that the droughts tended to be aggravated further.

(3) The suffering area frequency of small-scale droughts, mild droughts, severe calamity and catastrophic disasters tend to increase and decrease in tandem. Although the frequency of suffering area and that of affected area is roughly equal in 2000–2011, the ratio of suffering area is more than that of affected area, simultaneously, the average of droughts-suffering area is 1335.40×10^4 hm^2 during this period, which is the highest average of all six stages. It means that the disaster-carrying capability of agricultural hazard bearing body is relatively weak at this stage.

3.2 High-Level Volatility of the Evolution of Agricultural Drought

Figure 1 shows that the agricultural drought disaster take on high volatility in the time sequence, which mains that the tendency of the agricultural drought disaster

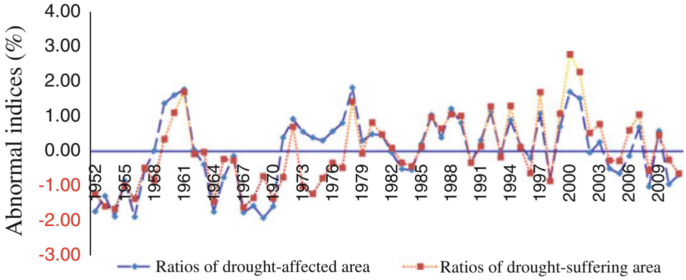

Fig. 1 Variation of drought abnormal indices in China

alternate between the peaks and valleys. In terms of the ratio of affected area, the ratio of affected area is at the stage of valleys from 1952 to 1959 and from 1960 to 1969, and the ratio of affected area is 0.0891 and 0.1134, which is lower than the average 0.1458 of nearly 60 years. But, the ratio of affected area is at the stage of peaks from 1970 to 1979, from 1980 to 1989 and from 1990 to 2001, and the ratio of affected area is 0.1758, 0.1694 and 0.1796, which is higher than the average 0.1458 of 60 years. While the ratio of affected area is at the stage of valleys from 2002 to 2011. In terms of the ratio of suffering area, the ratio of suffering area is at the stage of valleys from 1952 to 1959, from 1960 to 1969, from 1970 to 1979, and from 2002 to 2011, and the ratio of suffering area is 0.0280, 0.0541, 0.0504, and 0.0607, which is lower than the average 0.0652 of 60 years. Simultaneously, the ratio of suffering area present two stages of peaks from 1980 to 1989, and from 1990 to 2001, and the ratio of suffering area is 0.0823 and 0.0928, which is higher than the average of 60 years. It suggests that the ratio of affected area and suffering area has the cyclical regular of synchronous rise or decline. In other words, the ratio of suffering area is high, and the ratio of suffering area is high. But, in the process of periodical evolution of drought disaster, the ratio of affected area and suffering area take on opposite directions. For example, compared with the other six stages, the stage of 1970∼1977 has significantly different characteristics that the ratio of affected area and suffering area take on opposite directions. The ratio of affected area is more than the average, on the other hands, the ratio of suffering area is lower than the average. It may be related to the difference of the efficient ability of farmland irrigation at different periods. In the aspects of frequency fluctuations, since the year of 1986, the volatility of droughts disaster becomes larger and a heavy-disaster year of drought existed every 1 or 2 years, and the magnitude of the suffering area ratio over usual rate is even bigger than that of affected area ratio, meaning that drought disaster render a more severe future. Take the most violated stage (1985–1999) as an example, the absolute irrigated area in the four light drought year (1990, 1993, 1996 and 1998) increased with an average speed of 2.53 % annually, and relative irrigated area (irrigation area and the total sown area ratio) increased 1.72 %. While the absolute irrigated area in the seven drought disaster year grew 0.94 % and relative irrigated area increased 0.53 %. The increment rate of absolute irrigated area of the former is 2.68 times as the latter while increment rate of relative irrigated area of the former is 3.27 times as the latter one. Along with the lack of water and global climate change, effective irrigation capacity increment is limited. Some parts of China's agricultural production may face even more severe drought challenges in the future.

3.3 The Tendency of the Evolution of Agricultural Drought Disaster

Trend is used to describe the inclination of drought disaster sequence with time increasing, decreasing or remaining constant. So the paper uses the trend analysis to reveal the general laws of agricultural droughts in the evolution of time series.

This article uses Mann-Kendall rank correlation test to examine the tendency of China's agricultural anomaly indices of drought-affected area ratio ζ and anomaly indices of drought-affecting area ratio ζ. We use Kendall statistics τ, variance Var, and standardized invariant U to get the formula as follows:

$$\tau = \frac{4\Sigma P_i}{N(N-1)} - 1, \tag{2}$$

$$Var(\tau) = \frac{2(2N+5)}{9N(N-1)}, \tag{3}$$

$$U = \frac{\tau}{Var(\tau)^{\frac{1}{2}}}. \tag{4}$$

We use anomaly indices of drought-affected area ratio ζ and anomaly indices of drought-affecting area ratio ζ to analyze tendency. The degree of significance in Table 2 is expressed as the ratio of U statistic in Mann-Kendall rank correlation test and $U_{\alpha/2}$ statistic at a level of significance of $\alpha = 0.05$. When $U_{\alpha/2}$ is positive, it means the time series are on the rise. When $U_{\alpha/2}$ is negative, it means the time series show a decrease trend. That is to say, when the absolute value of $U/U_{\alpha/2}$ is greater than 1, it means the trend is significant under the $\alpha = 0.05$ significance level. When the absolute value of $U/U_{\alpha/2}$ is smaller than 1, it means the trend is not significant. As the result of Mann-Kendall rank correlation test show, in the recent 60 years, the general trend of China's agricultural anomaly indices of drought-affected area ratio ζ is not significant while it renders a growing tendency during 1952~2011 ($U = 1.5052 > 0$). Except that there is an obvious trend in 1952~1960, the evolution trend of other stages is unstable, which means agricultural droughts disaster show relatively strong randomness. While the general trend of anomaly indices of drought-affecting area ratio is significant and it present a growing trend in 1952~2011 ($U = 3.6069 > 0$). And the evolution of each stage is quite obvious, especially for the period from 2001 to 2011, during which ratio of suffering area and ratio of affected area are on the decline while ratio of suffering area is always bigger

Table 2 Tendencies of the agricultural drought-affected ratio and drought-suffering ratio in China

Ratios	Times	Kendall statistic τ	Variance Var	Variance variable U	Significance level α	Critical value $U_{\alpha/2}$	Test	Tendency
Agricultural drought-affected ratio	1952–2011	0.1333	0.0078	1.5052	0.05/0.01	1.96/2.58	$\lvert U\rvert < U_{\alpha/2}$	No
	1952–1960	0.6667	0.0710	2.5022	0.05/0.01	1.96/2.58	$\lvert U\rvert > U_{\alpha/2}$	Significant
	1961–1967	−0.6190	0.1005	−1.9524	0.05/0.01	1.96/2.58	$\lvert U\rvert < U_{\alpha/2}$	No
	1968–2000	0.1288	0.0149	1.0536	0.05/0.01	1.96/2.58	$\lvert U\rvert < U_{\alpha/2}$	No
	2001–2011	−0.3818	0.0545	−1.6348	0.05/0.01	1.96/2.58	$\lvert U\rvert < U_{\alpha/2}$	No
Agricultural drought-suffering ratio	1952–2011	0.3198	0.0078	3.6099	0.05/0.01	1.96/2.58	$\lvert U\rvert > U_{\alpha/2}$	Significant
	1952–1960	0.6667	0.0710	2.5022	0.05/0.01	1.96/2.58	$\lvert U\rvert > U_{\alpha/2}$	Significant
	1961–1967	−0.7143	0.1005	−2.2528	0.05/0.01	1.96/2.58	$\lvert U\rvert > U_{\alpha/2}$	Significant
	1968–2000	0.4356	0.0149	3.5637	0.05/0.01	1.96/2.58	$\lvert U\rvert > U_{\alpha/2}$	Significant
	2001–2011	−0.4909	0.0545	−2.1019	0.05/0.01	1.96/2.58	$\lvert U\rvert > U_{\alpha/2}$	Significant

than ratio of affected area, which means that the irrigation mechanisms are faulty at that time. During this period, especially the drought in 2009, southwestern part of China suffered the most. For example, this was the most severe drought disaster of all the meteorological records in Yunnan Province lasting from autumn to spring, and the recurrence period of integrated meteorological drought would be once in more than 80 years. In Guizhou Province it never happened in over 80 years or so throughout autumn and winter, and the drought like this never occurred in centuries. The damage was severe. Up to March 23rd 2010, the drought disaster has hit Guangxi, Chongqing, Sichuan, Guizhou and Yunnan five provinces and affected 61,306 thousand people, leaving 18,071 thousand people and 11,724 thousand livestock without adequate water, affecting 5.034 million hectares of crops and 1.115 million hectares crop failure. The direct pecuniary loss was up to 23.66 billion yuan.

4 The Causes of Agricultural Drought Disaster and Strategy for Disaster Reduction

The uneven distribution of time and space distribution of precipitation, which is caused by the special geographic location, is the major cause of agricultural drought disaster. Being not portfolio balance of water and soil resource is another major cause of frequent occurring natural factors of agricultural drought disaster. The unreasonable development and utilization of water resources, water pollution, and some inappropriate human activity factors have contributed to intensifying the extent of agricultural drought disaster.

4.1 The Dominant Factors of Inducing Agricultural Drought Disaster

1. The uneven distribution of time and space distribution of precipitation and being not portfolio balance of water and soil resource.

The distribution trend of China’s water and depth of runoff decrease from southeast coast to inland northwest and does not accommodate the distribution of population and cultivated land. The 81 % of the total is intensively distributed in the Yangtze rivers and the south of its, but the cultivated land area accounts for only 36 % of the whole nation. However, the cultivated land area of the Huaihe River and north of its accounts for 64 % of the whole nation, while the water resource account for only 19 % of the country. Thereinto, the cultivated land area in the basin of the Yellow River, Huaihe River, Haihe River and Liao River accounts for 42 % of the whole nation, While the water resources accounts for only 9 %. Eventually, much less arable land and abundant water in the south, much more arable land and water shortage in the north. It makes agriculture appear severe drought disaster and catastrophic drought disasters every 1–2 years, and increase drought disasters in this area.

2. Water environment is worsening, the conditions of drought and water shortage is aggravating

The deterioration of water environment in China is especially expressed in soil erosion and water pollution. China is one of the most serious soil erosion countries in the world. Soil and water loss leads to decrease ability to land water-fed and soil moisture, intensifies the sedimentation of rivers and lakes, increases the harm of drought disaster disasters. At present, the area of water and soil loss has reached 35600×10^4 hm^2, which accounts for 31.7 % of the total land area. Among them, the area of soil and water loss in Shanxi Province, Shaanxi Province and Hebei Province accounts for 69.1, 65.5 and 43.6 % of its Province's area. Eventually, the soil and water loss makes the agricultural drought disaster more serious.

3. Social and economic factors

(1) Industrial and agricultural development and economic construction

Since the founding of the China, the area of arable land has been reduced, but there is a growing trend in multiple cropping index. And the area of staple crops planting grow rapidly, such as the national total sown area of China is 14125.6×10^4 hm^2 in the year of 1952. Among them, the area of rice is 2838.2×10^4 hm^2, the area of wheat is 2478.0×10^4 hm^2, the area of oil plants is 488.2×10^4 hm^2. While the national total sown area of China is 16228.32×10^4 hm^2 in the year of 2011. Among them, the area of rice is 3005.7×10^4 hm^2, the area of wheat is 2427.0×10^4 hm^2, the area of oil plants is 1385.5×10^4 hm^2. Therefore, the demand of agricultural water increases rapidly. On the other hand, the development of industry, which affected the agricultural drought, is an important factor, too. Since 1952, China's urbanization construction and industry develops rapidly. The gross industrial production is 349.0×10^8 yuan in 1952, while the gross industrial production is 844269×10^8 yuan. The total population of the first nationwide population census in 1953 is 60193×10^4, the urban population is 13046×10^4; while the total population is 134735×10^4 in 2011, the urban population is 69079×10^4. With the growth of the industrial output value, increase of population and improvement of living standards, the industrial water and urban water increases correspondingly.

(2) Being insufficient of water conservancy irrigation facilities and difficult to play their role to fight the agricultural drought

Timely irrigation is the most effective measures to reduce agricultural drought disaster, the area of crops increase from 14125.6×10^4 hm^2 in 1952 to 16228.32×10^4 hm^2 in 2011, while the effective irrigation area increase from 1995.9×10^4 hm^2 to 6168.16×10^4 hm^2. The effective irrigation area accounting for the total grain planting area increases from 14.1 % in 1952 to 38.01 % in 2011. By 2011, the effective irrigation area is less than 40 % of the total grain planting area. Namely, the most of the national cultivated land is rain-fed and subject to the vagaries of weather, the ability to withstand natural disasters is very low. The effective irrigation area accounting for the total grain sowing area has reached 30 % in 1978, the reservoir number increased from 84585 in 1978 to 88605 in 2011. It illustrates that the most of the water conservancy facilities was built before 1978, which has been running

40–50 years. By now, parts of the engineering facilities fall into disrepair or disuse. When in case of continuous annual drought, the existing water conservancy facilities is difficult to play their role in drought resistance.

4.2 Strategy for Disaster Reduction

Temporal distribution and trend prediction of agricultural drought disasters provides an important reference for the effective work of disaster reduction, but this is only one small step for a whole system of the work of disaster reduction. The work of agricultural drought disaster reduction is a complicated system engineering, which involved the coordination and cooperation of the government functional departments and agricultural scientific research institution. In order to effectively deal with the next 15 years tendency of increasing drought in China, this paper put forward the measures of strengthening the prevention of agricultural drought disaster and the reduction of agricultural drought disaster.

(1) Establishing and improving the network system of the agricultural drought disaster integrated monitoring and early warning prediction, strengthening the agricultural drought disaster monitoring and prediction, and improving the overall of agricultural drought disaster prevention function. The monitoring and prediction of agricultural drought disaster is the basis and prerequisite for effective work of agricultural drought disaster reduction and relief. Therefore, Chinese government must further strengthen observation of the environmental system of causing agricultural drought disaster and monitoring of the process of agricultural drought disaster. One step is to improve the warning accuracy, early and timeliness of agricultural drought disaster forecast. The second step is to build the information system network of agricultural drought disaster, especially, to build up the comprehensive network of information and communication of the agricultural drought disaster. The third step is to strengthen the monitoring of agricultural ecological environment, the accurate control of soil erosion, grassland degradation, desertification and the decreasing of the underground water level, acid rain and the other ecological environment situation. The aim is to provide the scientific basis for the protection and management of agricultural ecological environment and the agricultural infrastructure construction.

(2) Improving and perfecting the management system of agricultural drought disaster reduction, strengthening the society ability of agricultural drought disaster reduction. Improving and perfecting the management system of agricultural drought disaster reduction is fundamental guarantee for the work of agricultural drought disaster prevention and mitigation. In order to ensure the comprehensive coordination and unification of the management of department organization of the agricultural drought disaster prevention and mitigation, China must carry out the policy of "prevention first, combining prevention, resistance, save, with integrated agricultural drought disaster reduction", in the process of improving and adjusting the management system of the drought disaster reduction. China must establish special management entities for the work of agricultural drought disaster reduction step by step, which is

responsible for the planning, organization and coordination of agricultural drought disaster. Secondly, China should refine the responsibility, right of the government functional departments and scientific research institutions, establish strict responsibility for the work of agricultural drought disaster reduction. Thirdly, China should explore the sources of broadening the relief funds, gradually establish the structure of financial allocation, civil administration, collective personal self-help reserves, the social insurance investment, in order to ensure agricultural drought disaster preparedness and mitigation.

(3) Strengthening regional and seasonal agricultural drought disaster research, improving the efficiency work of agricultural drought disaster prevention and mitigation. Different climate zones have different types of agricultural drought disasters, and the same types of agricultural drought disasters in different regions have different characteristics and occurrence time. Based on this characteristic, in the prevention and mitigation work of the agricultural drought disaster, China should plan different disaster prevention and mitigation planning and set up different levels of management in disaster relief funds, according to different regional natural climate characteristics and social economic conditions. In view of this, China will minimize disaster losses and improve the efficiency work of agricultural drought disaster prevention and mitigation.

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Influence Mechanism Research of Store Image for Consumer Brand Loyalty: Empirical Study for Medicine Retail Industry

Gaofu Liu and Xiaohui Liu

Abstract That store image influences consumers' brand loyalty has been a hot issue in the drug retailing industry. Based on the background of the drug retailing industry, this thesis establishes a mechanism model on how store image influences consumers' brand loyalty in the drug retail. It discovers that store image influences brand loyalty through four different approaches, in which there are three mediating variables of perceptive value, consumer satisfaction and brand trust. Thereinto, store image does not remarkably and directly influence consumer satisfaction, brand trust and brand loyalty. Consumers'perceptive value plays a key mediating role. At the same time, brand trust is the most important variable of direct cause. The conclusion provides the important guiding significance to optimize the marketing strategies of the drug retail enterprises.

Keywords Store image · Perceptive value · Consumer satisfaction · Brand trust and functional mechanism

1 Introduction

According to the statistics from Ministry of Commerce of the People's Republic of China Department of Market Supervision, there had been 16,300 drug wholesalers, 3107 drug retail chain enterprises and 423,700 retail pharmacy stores in China by the end of 2012 [16]. The brand competition among drug retailers has been in the white-hot stage. Because of drug being a special commodity, 62 % of consumers will more trust and rely on the brand and go to their favorite drugstores to consume, when they

G. Liu (✉)
Guanghua School of Management, Peking University,
Beijing 100871, People's Republic of China
e-mail: gaoyanzl@163.com

G. Liu · X. Liu
School of Business, Jiangxi Normal University,
Nanchang 330022, People's Republic of China

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choose drugstores [8]. Therefore, it is a competitive key for a drug retail enterprise to establish a good store image in the minds of consumers, make consumers trust the drugstore brand and generate the drugstore brand loyalty.

How store image influences customers' purchasing decisions is an important research topic in the retail area. Store image is an important means for a retail business to attract customers [3]. However, store image study is insufficient in the retail marketing research. At first, the research on store image focuses on the relationship between store image and perceptive value, customer satisfaction, decision-making pattern and decision-making style [20, 24]. Secondly, an integrated framework is lacked on how store image influences the several variables of perceptive value, customer satisfaction, brand trust and brand loyalty. Again, the retailing research focuses on hypermarkets and department stores, but the highly specialized retail formats of drug retail stores are rarely involved. To compensate for the lack of these studies, based on the background of the drug retailing industry, this thesis will establish a research framework of store image, perceptive value, customer satisfaction, brand trust and brand loyalty, and explore the mechanism on how store image influences perceptive value, customer satisfaction, brand trust and brand loyalty. This thesis will also provide theoretical support for drug retail enterprises to make marketing decisions of store image.

2 Research Hypothesis and Model Building

1. Store Image
Store image is a sum of perceptive attributes for consumers' experience in a store, is a definition shop way in customers' mind and is a consumers' perception for shop character. Store image influences consumers' perception and subsequent behavioral intention. Customers' perception value is generated by impression or experience related to product or non product in shop. Store atmosphere can strengthen the shopping experience and increase customers' shopping value. Customers will assess their perceptive value for shop, according to the risk of shop image. The enterprises of good reputation, large scale, high brand awareness and fine reputation will win more consumers' trust [21]. An active and positive shop image will reduce consumers' perception risk to buy drugs. In the relationship research between financial services industry enterprise image and consumer trust, Flavian et al. [9] discover that enterprise image would importantly influence consumer trust. Some important dimensions in retail stores, such as price, commodity, environment or convenience, can establish store image preferred by consumers, which easily increases customers' satisfaction and leads to consumers' patronage behavior [20]. The functional properties and the psychological characteristics of store image will be conducive to consumers' loyalty for store. Bloemer and Ruyter research to show that shop image would influence store loyalty by store satisfaction [1]. Castro et al. [2] find that tourism destination image would influence travelers' future behavior intention by the two intermediary variables of service quality and tourist satisfaction. In addition, Imran et al. [12]

research to indicate that there is an active and positive impact between store image and store loyalty. Therefore, we put forward the following hypothesises:

Hypothesis 1. Store image influences perceptive value directly and positively.
Hypothesis 2. Store image influences brand trust directly and positively.
Hypothesis 3. Store image influences customer satisfaction directly and positively.
Hypothesis 4. Store image influences brand loyalty directly and positively.

2. Perceptive Value
During customers' process for purchase, consumption and service, customers' value perception is an experience for paid fee and actual benefit. Lin [14] found that perceptive value directly and positively influences customer satisfaction and perceptive value is an antecedent of customer satisfaction. There are few existing literatures in the relationship research of value and trust. Jin [13] made his empirical research to show that customers' perceptive economic value would positively influence their brand trust. Han [11] thought that online consumers' different perceptive value would influence different trust and faith. Before customers purchase, value perception will affect purchase intention. Although customer satisfaction is necessary for customers' loyalty, value would only and finally drive loyalty. Verma [19] found that the customers' value perception of a clothing retail store has an important impact on store loyalty. Therefore, we put forward the following hypothesises:

Hypothesis 5. Perceptive value influences customer satisfaction directly and positively.
Hypothesis 6. Perceptive value influences brand trust directly and positively.
Hypothesis 7. Perceptive value influences brand loyalty directly and positively.

3. Consumer Satisfaction
After customers compare perceivable effect (or result) and expectation for product or service, customer satisfaction is a feeling state of pleasure or disappointment [23]. Customer satisfaction importantly influences customers' trust and loyalty. Trust is an experience response of customer satisfaction. Customer satisfaction for one enterprise is an important prerequisite for customer trust in the study of the relationship between enterprise and customer in the service industry. Delgado-Ballester [7] made his empirical research to show that satisfaction is a powerful antecedent variable to explain brand trust. Christou's [5] study also showed that customer satisfaction for hotel service actively and positively affects customer trust for hotel service. Luk et al. [15] made his financial service industry study to find that customer satisfaction significantly and directly influences the two dimensions of brand reliability and brand intentionality. A high level of customer satisfaction can reduce service providers' marketing cost and improve customers' repurchase intention. Customers' repurchase and recommendation behavior intention is a positive role and result for them to perceive service satisfaction and service quality. Debabi [18] found that customer satisfaction influences customers' attitude and assessment for store brand. Therefore, we put forward the following hypothesises:

Hypothesis 8. Customer satisfaction influences brand trust directly and positively.
Hypothesis 9. Customer satisfaction influences brand loyalty directly and positively.

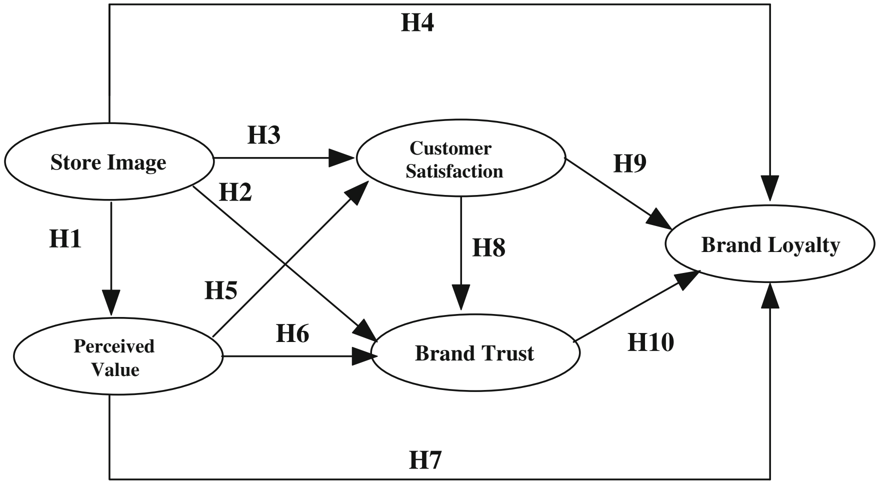

Fig. 1 Research hypothesis model

4. Brand Trust

Consumers' trust for brand will cause their positive actions. Trust can create the exchange relationship of high value and brand trust can lead to brand loyalty. Chaudhuri and Holbrook [4] made their empirical study to find that brand trust actively and positively influences consumers' two dimensions of brand behavior loyalty and brand attitude loyalty. In addition, Delgado-Ballester et al. [6] made their empirical research to show that brand trust actively and positively influences purchase intention and brand loyalty. Therefore, we put forward the following hypothesis:

Hypothesis 10. Brand Trust influences brand loyalty directly and positively (Fig. 1).

Based on the above analysis, the following research model is proposed in this thesis:

3 Study Design

3.1 Variable Measuring

This questionnaire items are from two main ways. The first is the focus group interview and 20 students (including 10 marketing major students and 10 non-market marketing major students, respectively) participate in the interview activity. Through this interview, the students encode the vocabulary about store image as the reference to select the measuring item. The second is to extract the ready-made scale in the related research literatures. Finally, the measuring items of this questionnaire are formed after the semantic contents and the expression habits are appropriately modified according to the result of the qualitative interviewed students. Based on the measuring scales of the store image models of Bloemer and Ruyter , Ryu et al. [17] and CCSI, the store image questionnaire is appropriately modified. The revised measuring scales are composed of the four measuring items. The perceptive value questionnaire draws on the experience of the measuring scales of Ryu et al. [17] and it is composed of the three items. The customer satisfaction questionnaire draws on the experience of the measuring scale of Wang Xuhui and Xu Jian and it is composed for the four items. The brand trust questionnaire mainly draws on the experience of the measuring scales of Delgado-Ballester and JinYufang, and it is composed of the four items. The brand loyalty questionnaire mainly draws on the experience of the measuring scales of Imran et al. [12] and it is composed of the four items. The seven point scale of LIKERT is adopted for the all measuring items.

3.2 Study Samples

A Management Consulting Company is cooperated with in this research. The research data are collected through the combination of online survey and off-line actual research. The online survey data show that the vast majority of the respondents are basically all over the domestic provinces and cities, almost involving the main occupations of all sectors. 262 questionnaires are collected altogether and 206 questionnaires are valid. Chengdu is the most competitive city for drug retail, where there is the highest drugstore density per capita in China. Moreover, the domestic main enterprises of drug retail all go into Chengdu. In order to facilitate the sampling, the off-line research questionnaires are mainly issued in the downtown areas of Chengdu. The total is 600 questionnaires, the recycling is 548 and the valid questionnaires are 397. Therefore, there are 603 online and offline effective questionnaires totally.

The descriptive statistics of the valid questionnaires is shown in Table 1. From the descriptive statistics of the samples, we can see that women, middle aged consumers

Table 1 The descriptive statistics result of the study sample

Statistical variables	Sample distribution
Gender	Male is 44.8 % and female is 56.2 %.
Age	5.6 % is under 20 years old, 17.3 % is between 20 ∼ 30 years old, 19.8 % is between 30∼40 years old, 27. 2 % is between 40∼50 years old, and 30.1 % is above 50 years old
Education background	18.3 % is for high school and below high school, 61.5 % is for technical secondary school and junior college, and 20.2 % is above junior college
Monthly income	16.1 % is under1000 Yuan, 46.8 % is between 1000 Yuan and 2999 Yuan, 20.5% is between 3000 Yuan and 4999 Yuan, and 16.6% is above 5000 Yuan
Work unit	19.6 % is in foreign-funded enterprises, 10.3 % is in government departments, 19.2 % is in institutions, 11.3 % is in state-owned enterprises, 33.9 % is in private enterprises, and 5.7 % is in the others

and elderly consumers are too many. This sample characteristic basically conforms to the basic feature of the drug consumption crowd in China to satisfy the need of this study.

3.3 Statistics Method and Analyzing Thinking

In this research, SPSS 16.0 and Amos 7.0 are adopted for statistical analysis. The specific statistical analysis includes as follows: SPSS 16.0 is used for the statistical analysis of consistency reliability of descriptive statistics, correlation and interior; Amos 7.0 is adopted to make the verification factor analysis for the involved variables in the research and to investigate the discrimination validity of the used scale; and the path analysis of structural equation model is adopted to investigate the relationship among store image, perceptive value, customer satisfaction, brand trust and brand loyalty.

4 Inspection Results

1. Scale Reliability and Validity Analysis
(1) Reliability Analysis
In this thesis, the confirmatory factor analysis is adopted to inspect measurement model, including internal consistency reliability analysis and inside collect validity inspection. Reliability is measured with composite reliability (C. R.) and Cronbach's Alpha value. From Table 1, all variables of C. R. value are greater than 0.7 and all variables of Cronbach's Alpha value are also greater than 0.7. The sample data show that internal consistency is higher and reliability is better.
(2) Validity Test
Including convergent validity and discriminant validity, validity is the extent of psychological or behavioral traits measured by measuring tools. The AVE (Average Variance Extracted, called AVE value) quantity can be adopted to test convergent validity and discriminant validity of each latent variable. Convergent validity is to measure the correlation degree among the different items of the same dimension. If the average variance extracted (AVE value) quantity is greater than 0.5, the more than 50 % variance of the factor is explained in the measurement items and it indicates that the latent variable has good convergent validity [22]. The AVE test results in various research dimensions of this study are shown in Table 2. The AVE values in each research dimension are between $0.524 \sim 0.611$ and are greater than the minimum standard value of 0.5. This indicates that each research dimension has a better convergent validity.

Table 2 Confirmatory factor analysis results and the values of C. R. and Cronbach's alpha

Research dimensions	Measurement items	Standardization factor loading	Standard error	T value	AVE	C. R.	Cronbach's alpha value
Store image	SI1	0.70	–	–	0.5243	0.8145	0.8062
	SI2	0.80	0.108	11.657			
	SI3	0.72	0.107	10.614			
	SI4	0.67	0.103	10.352			
Perceptive value	PV1	0.80	–	–	0.5692	0.7981	0.7951
	PV2	0.70	0.061	14.229			
	PV3	0.76	0.073	16.135			
Consumer satisfaction	CS1	0.79	–	–	0.5932		0.8523
	CS2	0.76	0.059	17.012			
	CS3	0.75	0.057	16.664			
	CS4	0.78	0.062	17.503			
Brand trust	BT1	0.79	–	–	0.6110	0.8622	0.8565
	BT2	0.84	0.069	15.466			
	BT3	0.79	0.067	16.341			
	BT4	0.70	0.074	15.528			
Brand loyalty	BL1	0.71	–	–	0.5060	0.8032	0.7931
	BL2	0.78	0.089	13.391			
	BL3	0.67	0.089	11.536			
	BL4	0.68	0.099	10.655			

Table 3 The comparison between correlation coefficient matrix and average variance extracted square root

	Store image	Perceptive Value	Consumer satisfaction	Brand trust	Brand loyalty
Store image	0.7240				
Perceptive value	0.507	0.7545			
Consumer satisfaction	0.476	0.540	0.7702		
Brand trust	0.452	0.438	0.479	0.7817	
Brand loyalty	0.486	0.551	0.483	0.516	0.7113

Note AVE square root is above the diagonal. The correlation coefficients of all variables are on the lower left of the diagonal

Because discriminant validity is the characteristics difference degree among the items of measuring different concepts, Fornell and Larcker propose that the measurement model has good discriminant validity, when the square root of AVE value is greater than the correlation coefficient among other latent variables [10]. To test the discriminant validity of each research dimension, the square root of AVE value in this study and the correlation coefficient summary between this variable and the other variables are the results shown in Table 3. Thereinto, the number above the diagonal is the square root of the AVE value of each variable. There is the correlation coefficient between each variable and other variables on the lower left of the diagonal. In Table 3, it can be seen from the results that the square root of AVE value in each research dimension is significantly greater than the correlation coefficient among other latent variables. This indicates that there is good discriminant validity in each research dimension, which is necessary for an independent existence.

2. Hypotheses Test

In this thesis, the structural equation model method is adopted to test the rationality of the theory model. Store image is an exogenous variable. Perceptive value, customer satisfaction, brand trust and brand loyalty are the endogenous variables to inspect the relationship among the latent variables. The evaluation results are shown in Table 4. Except H2, H3 and H4 being not inspected, the other hypothesises have passed the significance test. The model fitting indexes are as follows: $\chi^2/df = 1.936$, $GFI = 0.915$, $AGFI = 0.908$, $RMSEA = 0.082$, $NFI = 0.925$, $RFI = 0.913$, $IFI = 0.928$, $TLI = 0.909$ and $CFI = 0.926$. From the fitting indexes, we can see that the rest of the fitting indexes show good fitting model, in addition to RMSEA value being slightly higher than the standard value. Therefore, the final inspection results of this model are shown in Fig. 2.

Table 4 The test results of the structure equation model

Original hypothesis	Standardization path coefficient	T value	P	Conclusion
Hypothesis 1. Store image influences perceptive value directly and positively	0.607	8.633	***	Support
Hypothesis 2. Store influences brand trust image directly and positively	0.095	1.778	0.075	Not Support
Hypothesis 3. Store image influences customer satisfaction directly and positively	0.101	1.604	0.068	Not Support
Hypothesis 4. Store image influences brand loyalty directly and positively	0.081	1.342	0.179	Not Support
Hypothesis 5. Perceptive value influences customer satisfaction directly and positively.	0.776	10.805	***	Support
Hypothesis 6. Perceptive value influences brand trust directly and positively.	0.238	2.301	0.021	Support
Hypothesis 7. Perceptive value influences brand loyalty directly and positively.	0.148	3.678	***	Support
Hypothesis 8. Customer satisfaction influences brand trust directly and positively.	0.516	5.251	***	Support
Hypothesis 9. Customer satisfaction influences brand loyalty directly and positively.	0.471	4.754	***	Support
Hypothesis 10. Brand Trust influences brand loyalty directly and positively	0.547	5.862	***	Support

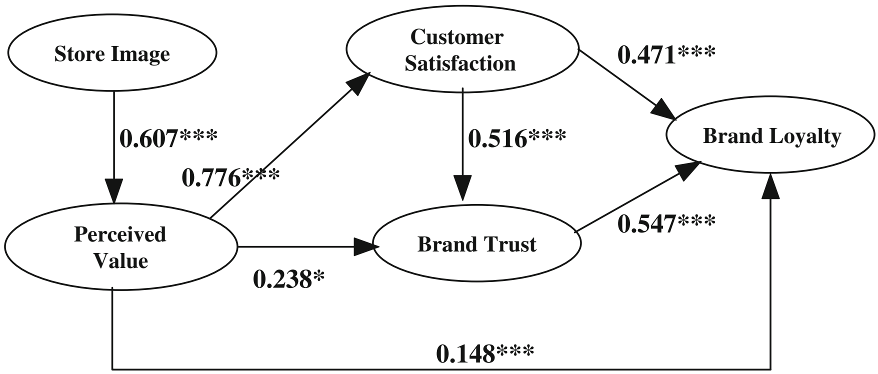

Fig. 2 Research result model (Note: ∗ represents $P < 0.05$, ∗∗ represents $P < 0.01$ and ∗ ∗ ∗ represents $P < 0.001$)

5 Conclusions and Outlook

Based on the related study and the industry background of drug retail, this thesis establishes a mechanism model, in which shop image influences consumers' brand loyalty and the empirical analysis is carried on. According to the empirical result of this thesis, we draw the following research findings and management revelations:

5.1 Conclusions

Store image is an important antecedent of consumers' perceptive value, customer satisfaction, brand trust and brand loyalty. From Fig. 2, shop image influences perceptive value significantly, directly and positively, and its standardization path coefficient is 0.607. There is no direct and positive influence for customer satisfaction, brand trust and brand loyalty (not pass the significance test), but they are indirectly influenced through perceptive value. Thereinto, the indirect effect coefficients of customer satisfaction and brand trust are 0.471 and 0.387 respectively. Store image influences brand loyalty through four different mechanism paths, in which there are three mediating variables of perceptive value, consumer satisfaction and brand trust. The indirect coefficient of shop image influencing brand loyalty is 0.523. The above research results show that shop image expands the traditional value-satisfaction-loyalty research model, after shop image is introduced as an exogenous variable model. Shop image further expands the influence factor of brand loyalty and better explains the influence factor and the formation mechanism of consumers' brand loyalty.

Perceptive value influences customer satisfaction, brand trust and brand loyalty significantly, directly and positively. The direct effect standardization path coefficient on customer satisfaction is the largest and 0.776. The direct effect coefficient on brand trust is the second and 0.238. The direct effect coefficient on brand loyalty is the least and 0.148. At the same time, via the first mediation function of customer satisfaction and the second mediation function of customer satisfaction and brand trust, perceptive value also influences brand loyalty indirectly. The total effect coefficient of perceptive value influencing brand loyalty is 0.862. This indicates that perceptive value plays a very important intermediary role in the behavior of store image influencing customers' loyalty.

Customer satisfaction influences brand trust directly and affects brand loyalty directly and indirectly. Customer satisfaction directly and positively influences brand trust, and the direct effect standardization path coefficient is 0.516. Customer satisfaction directly and positively influences brand loyalty, and the coefficient is 0.471. There is indirect and positive influence by brand trust, and the indirect effect coefficient is 0.282. Customer satisfaction's total effect coefficient on brand loyalty is 0.798, which is the second only to perceptive value. This indicates that customer satisfaction is another important intermediary variable for customers' brand loyalty.

Brand trust influences brand loyalty directly and positively, and the direct effect standardization path coefficient is 0.547. This indicates that customer satisfaction and brand trust are the two most important direct antecedent variables for brand loyalty. But in comparison, brand trust is the most important direct antecedent variable. This conclusion is an important finding in this study. As a special commodity, there is a certain degree of risk in purchase and use of drug.

5.2 Suggestions

The drug retail enterprises should invest a certain amount of capital to improve hardware facilities and business environment of drugstores. By employee training and continuing education, staff's service awareness could be increased and employees' professional service level could be improved. Tangible or intangible contact points could be strengthened between drugstores and consumers. A unique and professional store image could be established in customers' mind.

In the pharmaceutical retail industry, customers' perceptive value is very important intermediary variable. If a drugstore wants to make customers be satisfactory, trustful and loyal, the drug retail enterprise must create value for customers. Only after drugstore creates value for customers, customers' brand loyalty for drugstore will finally be driven. Drugstore needs to be more concerned about patients, tries to consider for patients, and sincerely provides good service and safe, effective and affordable medicines for patients. These will make patients feel and accept good services and reasonable prices in the process of purchasing drugs. Then, patients will taste a profound value for services and products in drugstore.

The drug retail enterprises should timely pay attention to monitoring customer satisfaction, and analyze the reasons for customer satisfaction and dissatisfaction. The factors of customer satisfaction should be continued to carry forward and optimize.

The factors of customer dissatisfaction should timely be eliminated and improved, and the remedial measures should be taken. As for drugstore, satisfied customers not only have repurchase inclination and reduce to look for alternative drugstore, but also make praise propaganda to others. It will be helpful for drug retail enterprise to exploit new customers. In the same way, dissatisfied customers will bring a certain negative impact for drugstore.

Finally, the drug retail enterprises should pay attention to shaping customers' trust for enterprise brand. If consumers are satisfied with drugs and services in drugstore, they will gradually establish a trust relationship with drugstore to form a good emotion relationship for drugstore brand. Ultimately, consumers will produce their loyalty of high reliability and high durability for drugstore brand. This loyalty is the most precious resource for enterprises and is also an important target for enterprises' marketing strategy. Therefore, the drug retail enterprises should try to make customers be satisfactory and do the utmost to make consumers believe in drugstore brand.

Although the drug retail industry is a background for this research, the action mechanism of shop image influencing perceptive value, customer satisfaction, brand trust and brand loyalty is explored. Some revelatory conclusions are obtained. However, this research also has the following limitations. First, the research samples of offline survey mainly focus on the very competitive urban areas of drug retail in Chengdu. There are relatively few samples from the other cities in China. Second, although this data analysis results show that each measurement scale has good reliability and validity on the whole, some individual indicators are not ideal. Third, the function for consumers' brand trust tendency and brand emotion regulating brand trust and brand loyalty is not considered in this research. The above problems in this field will be the focus of further research.

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Comprehensive Evaluation of Urban Competitiveness in Chengdu Based on Factor Analysis

Weiwei Zhang, Fumin Deng and Xuedong Liang

Abstract The main factor extending its influence on a city's development in the rat race is its comprehensive competitiveness. In this paper, the engineering theory of "4M1E" method is selected to put forward a multi-level evaluation index system of urban competitiveness. Then comprehensive evaluation on the competitiveness of the 19 districts and counties of Chengdu is performed based on factor analysis method. Furthermore, with SPSS statistical software, the rankings of these regions are demonstrated. Finally, some suggestions are presented for Chengdu's future development based on the research results.

Keywords Urban competitiveness · Factor analysis · 4M1E · Index system

1 Introduction

Many cities in China are facing a significant process of urbanization and market economy transformation in the 21st century. It is a big problem for a city to find its advantages and disadvantages for better development. Urban competitiveness research can help learn more about a city, and it is very helpful to a city's development.

Evaluation of urban competitiveness has been a hot spot for academic research in recent years in every nation [1]. The identification of the main factors of competitiveness is proved very important in improving competitiveness of cities [2]. In the definition of the urban competitiveness, scholars especially emphasized the ability of cities about creating wealth and value. Porter pointed, competitiveness at the national level only concerns the concept of the national productivity; to a city, competitiveness is productivity of the city, he regarded city competitiveness as the ability of creating wealth, and increasing income [3]. Many scholars have already studied the urban competitiveness from different levels. D'Arcy and Keogh reviewed the role of the property market as a determinant of urban competitiveness [4]. Rutkauskas

W. Zhang · F. Deng · X. Liang (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: liangxuedong@scu.edu.cn

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defined the competitiveness as a three-dimensional indicator, which depends on the fields of activity, dominating in the country, international economic relations and legal, financial, ecological, natural resources and geographical location environment competitiveness [5]. What's more, the competitiveness of milk processing sector by macro environment (distant, general or social environment) and factors excluded in Porter's model were also studied by Startiene and Genyte [6]. In China, scholars began to study urban competitiveness in 1990s, and they took urban competitiveness as the ability of creating wealth in reality and potentiality [7]. There are more and more researches about urban competitiveness in recently years. Jiang and Shen discussed urban competitiveness in economic determinants and strategic determinants [8]. The measurement of urban competitiveness were discussed based on three-level components: economic, social and environmental competitiveness [9]. What's more, Jia and Jia studied urban competitiveness of Sichuan province from the definition perspective of urban competitiveness [10, 11]. However, previous researches studied urban competitiveness mainly from an economic perspective, and few of them were undertaken on urban competitiveness in transitional socialist economies in China.

First of all, this paper puts forward a multi-level evaluation index system by using the "4M1E" method. Then, factor analysis method is applied in the empirical analysis of Chengdu, to make quantitative analysis on the index system to draw some possible conclusion.

2 Methodology

2.1 Factor Analysis

The concept of factor analysis originated in the early 20th century in the statistical analysis of intelligence test conducted by Karl Pearson, Charles Spearmen and others. This analysis uses a matrix of association to reduce the correlation between variables to reduce the amount of variables and data loss [10]. After that, all the rating data on different attributes will be declined to several important dimensions.

The main method of factor analysis is to divide variables into groups by their correlation. Each group represents a basic structure, which is called common factor. Then a comprehensive evaluation function with common factors' variance contribution will be built to reach an objective comprehensive evaluation. To simplify the process of analyzing, it is advised to use factor analysis method to find typical indexes to reduce the number of variables.

Table 1 Competitiveness evaluation index system

Index class	Index items
Economic strength	Gross Domestic Product (10,000 yuan) X1
	Per Capita Gross Domestic Product (10,000 yuan) X2
	Local Government Public-budgetary Expenditure (10,000 yuan) X3
	Local Government Public-budgetary Revenue (10,000 yuan) X4
	Total Investment in Fixed Assets (10,000 yuan) X5
	Total Retail Sales of Consumer Goods (10,000 yuan) X6
Opening degree	Total Export (USD 10,000) X7
	The Proportion of Foreign Investment of Fixed Assets Investment (%)
	Foreign Capital Actually Used (USD 10,000) X8
	International Tourism Receipt (10,000 yuan)
Human resources (Man)	Residence Population (10,000 persons) X9
	Number of People Employed Persons (10,000 persons) X10
	The Number of Professional and Technical Personnel (person)
	Talent Density Index (%)
Infrastructure (Machine)	Per Capita Using Space (square meter)
	Per Capita Road Area (m^2)
	Main Services Revenue of Post and Telecommunication (10,000 persons)
	The Local Gas Penetration Rate (%)
	Number of Hospital Beds (unit) X11
	Public transport vehicles (unit)
Material resources (Material)	Grain Yield (10,000 tons)
	Output of Meat (ton) X12
	Oil Bearing Crops Yield (ton)
	Gross Output Value of Farming, Animal Husbandry
	and Fishery (10,000 yuan) X13
Rules and regulations (Method)	Legal System Perfect Degree (%)
	Property Protection Degree (%)
	Market Development Degree (%)
	Individual Economic Freedom in Decision-making (%)
Environment (Environment)	Urban Green Coverage Rate (%) Per Capita Public Green Areas (m^2)
	Industrial Waste Water Discharge (10,000 tons)
	Industrial Waste Water Discharge Qualification Rate (%)
	Comprehensive Utilization Rate of Industrial Solid Waste (%)
	Sewage Treatment Rate (%)

2.2 Index System and "4M1E"

Index system should be practical and scientific, which can illustrate the situation objectively. Since there are some similarities and differences between regions, indexes should be representatively and have as large coverage as possible. However, there was not an uniform index system of urban competitiveness in relevant researches. In this paper, the index system was set according to index systems in previous studies [10, 12], combined with the industrial engineering method of "4M1E".

"4M1E" is short for five main factors influencing the quality of products in the total quality management theory, which are "Man, Machine, Material, Method and Environment". Man means people in charge of manufacturing products; machine is the indispensable tools affect the quality directly; material mainly points the materials in the manufacturing process; method refers to the methods used in the manufacturing; environment stands for the environment of the manufacturing. In this paper, "Man, Machine, Material, Method and Environment" in a city stand for human resources, infrastructure, material resources, rules and regulations, and environment, respectively. Then competitiveness index system was divided into seven parts in this paper: economic strength, opening degree, human resources, infrastructure, material resources, rules and regulations, and environment [10]. Considering some indexes are uncounted soft indexes, some indexes are less correlated with others, and some data is hard to get, these indexes are abandoned. Finally, 13 indexes (X1–X13) are chosen in Table 1.

3 Data Analysis and Results

1. Data Collection and Analysis

Chengdu, as the capital of Sichuan province, is the biggest city of southwest China. In the year 2013, the economic aggregate of Chengdu ranked third among all vice-province cites of China (only second to Guangzhou and Shenzhen) and ranked 8th in Mainland China. So this paper applied the factor analysis to Chengdu, to get some helpful suggestions for the development of Chengdu and other cities in China.

All data is gathered from 'Sichuan statistical yearbook 2013' and 'Chengdu statistical yearbook 2013'. Because many indexes have different economic meaning and different units of measurement, Z-score standardization can remove the influence of different units. Therefore Z-score standardization is adopted to standardize the original data. Then KMO (Kaiser–Meyer–Olkin) Test and Bartlett Test of Sphericity are used to examine the appropriateness of data in factor analysis [13].

KMO Test can be adopted to assess the appropriateness of using factor analysis. The values of KMO Test represent the correlativity between variables, higher value represents better correlativity. Generally, the value is greater than 0.5 when the sample is adequate. The value in this paper is 0.706, which is suitable for factor analysis. Bartlett's test of sphericity tests the hypothesis that the all the variables are uncorrelated, and the correlation matrix is an identify matrix. If the Sig. value of this test is less than our alpha level, we reject the null hypothesis that the population matrix is an identity matrix. The Sig. value of this paper is 0.000, which shows that there are correlations in the data set. The value of KMO Test is 0.702 (>0.5), and the Sig. value of Bartlett Test is 0.000. Both results show the data is suitable for factor analysis.

After that, with SPSS17.0 statistical software, the rankings of these regions can be demonstrated. According to principal component analysis, eigenvalue should be greater than 1, and the contribution of the accumulated variances is 92.425 percent of total variance. Some values of three common factors (F1, F2 and F3) are show in Table 2. The factors are extracted by principal component analysis and then rotated by varimax. The rotated component matrix is shown in Table 3.

2. Comprehensive Score and Rankings

The score of each factor can be achieved with regression method. The formula is that $F = (F1 \times 0.35067 + F2 \times 0.31498 + F3 \times 0.2586)/0.92425$. Each region's comprehensive score and ranking is obtained and list as following in Table 4.

Table 2 Some values of common factors

Common factor	Eigenvalue	The variance contribution rate (%)	The cumulative variance (%) contribution rate (%)
F1	8.471	35.067	35.067
F2	2.179	31.498	66.564
F3	1.365	25.860	92.425

Table 3 Rotated component matrix

Index	Common factor		
	F1	F2	F3
X1 Gross Domestic Product	0.758	0.500	0.379
X2 Per Capita Gross Domestic Product	0.598	0.729	−0.197
X3 Local Government Public-budgetary Expenditure	0.848	0.232	0.456
X4 Local Government Public-budgetary Revenue	0.856	0.368	0.338
X5 Total Investment in Fixed Assets	0.977	0.101	0.170
X6 Total Retail Sales of Consumer Goods	0.276	0.727	0.560
X7 Total Export	0.681	0.319	0.522
X8 Foreign Capital Actually Used	0.360	0.801	0.271

Table 4 Regional competitiveness score and ranking

District	F	Ranking
Jinjiang District	0.72	4
Qingyang District	0.77	3
Jinniu District	0.80	2
Wuhou District	1.05	1
Chenghua District	0.47	6
Longquanyi District	0.27	7
Qingbaijiang District	−0.27	11
Xindu District	0.05	8
Wenjiang District	−0.17	10
Jintang County	−0.46	15
Shuangliu County	0.65	5
Pixian County	−0.09	9
Dayi County	−0.65	17
Pujiang County	−0.76	18
Xinjin County	−0.45	14
Dujiangyan City	−0.34	12
Pengzhou City	−0.44	13
Qionglai City	−0.65	17
Chongzhou City	−0.52	16

Table 5 Competitiveness classification of Chengdu

Classification	Competitiveness evaluation value	District
Very strong	>1	Wuhou District
Strong	$0-1$	Jinniu District, Qingyang District, Jinjiang District, Shuangliu County, Chenghua District, Longquanyi District, Xindu District
Weak	$-0.4-0$	Pixian County, Wenjiang District, Qingbaijiang District, Dujiangyan City
Very weak	<-0.4	Pengzhou City, Xinjin County, Jintang County, Chongzhou City, Dayi County, Qionglai City, Pujiang County

4 Discussion

4.1 Regional Competitiveness Rankings

According to the regional competitiveness rankings, the 19 regions can be divided into 4 grades as Table 5 shows. Wuhou District is the region owns strongest comprehensive competitiveness in Chengdu; half of the strong-level districts (Jinniu District, Qingyang District, Jinjiang District and Chenghua District) are central urban areas which has obvious geographical advantages; as suburban areas, Shuangliu County, Longquanyi District and Xindu District have strong competitiveness because of their tertiary industry and industrial development; only four regions own weak competitiveness, but the government is spending greater efforts in developing their emerging industry; seven outer suburban districts have very weak competitiveness compared with others, that is because of the disadvantages of their geographic position and infrastructure construction. However these places will develop faster with more and more investments in industry and tourism [11].

4.2 Improvement Suggestions of Regional Competitiveness

1. Spatial Optimization

Central urban areas would better withdraw from manufacturing industry, traditional industry and low-end industries gradually. Instead, they should focus on high-end service industry to raise the competitiveness of central urban areas and help suburban districts' development. In the meantime, suburban districts should take the responsibility as main regions of advanced manufacturing industry, and be active in developing corresponding modern service industry. As for outer suburban districts, they should learn more from other regions, develop advanced modern manufacture industry, and promote featured agriculture and advantaged tourism. Thus there will be a clear divided multi-level development structure in Chengdu's development.

2. Regional Coordination

According to the results above, production factors are not rational distributed but gathered in several certain regions. Rational distribution will stimulate economic development and be a catalyst for economic growth. To solve it, manufacture industry in central urban areas should be removed to suburban and outer suburban districts, and act as motive force driving the city to higher-level urban morphology. In terms of outer suburban districts, the cooperation with central urban areas and suburban districts strengthened more tightly. That is helpful for Chengdu's harmonious development.

5 Conclusion

On the basis of previous researches, this paper made an empirical analysis on the competitiveness of 19 districts and counties of Chengdu. The innovation: this paper introduced industrial engineering's "4M1E" method to build comprehensive indexes system. The key work:

(1) the paper adopted factor analysis method and worked out the rankings of 19 regions with SPSS statistical software;

(2) the 19 regions were divided into 4 grades according to the rankings;
(3) the paper put forward spatial optimization and regional coordination suggestions for 4 grades of regions.

Combined with theoretical analysis of urban competitiveness analysis, the paper utilized multi-disciplinary knowledge to finish the empirical study of Chengdu. Hope the research can provide some suggestions for Chengdu's development, as well as future studies about urban competitiveness.

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Research on Urban-Rural Income Gap Influenced by Regional Urbanization and the Upgrading of Industrial Structure

You Zheng, Liuliu Kong and Limin Yang

Abstract Using the constant coefficient model with random effects as well as the error correction model, the paper empirically studies the urban-rural income gap influenced by urbanization and the upgrading of industrial structure, from the three levels of the East, Middle and West area, based on the Chinese provincial panel data of 1993–2012. Results show that there is a long-term equilibrium relationship among them. Urbanization helps to narrow the urban-rural income gap, and the impact is most significant in West area, followed by the East and Middle areas. While the upgrading of industrial structure will widen the urban-rural income gap and the impact have significant regional differences in East, Middle and West areas.

Keywords Urbanization · Upgrading of industrial structure · Urban-rural income gap · Constant coefficient model with random effects · The error correction model

1 Introduction

Since the opening reformation, China's regional economic growth has made great progress. However, with the prosperity of regional economy, the problems of unbalanced regional economic development and income inequality have become increasingly prominent. As an important part of income gap, the urban-rural income gap has caused widespread concern at home and abroad in recent years.

Using the constant coefficient model with random effects as well as the error correction model, the paper aims to empirically study the urban-rural income gap influenced by urbanization and the upgrading of industrial structure from three levels of East, Middle and West area, based on the Chinese provincial panel data of 1993–2012.

L. Kong (✉) · Y. Zheng · L. Yang
University of Shanghai for Science and Technology, Shanghai 200093,
People's Republic of China
e-mail: kongll2003@aliyun.com

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2 Literature Review

The domestic and foreign literature fully revealed many factors that affecting the urban-rural income gap. Greenwood and Jovanovic [3] found that, with the economy and financial development, the income gap presented narrowing trend after the first expansion. Li and Zhao [5] showed that the level of rural human capital had significant influence on the urban-rural income gap. Xu [10] studied the urban-rural income gap since China's reform and opening up, and found that the economic growth have the long-term stable equilibrium relationship with the urban-rural income gap. While this paper aims to analyze the regional differences of the urban-rural income gap from the aspect of urbanization and upgrading of industrial structure.

At present, there are a lot of research literatures about the urbanization and urban-rural income gap. Some believed that the urbanization can widen the urban-rural income gap. For example, Li [4] found that urbanization has a positive correlation with the urban-rural income gap. But there was a negative correlation between rural financial development and urban-rural income gap. Others thought that the urbanization will narrow the urban-rural income gap. Besides, there are about two perspectives on the upgrading of the industrial structure and the urban-rural income gap. One is that it will widen the urban-rural income gap. For example, Xia [2] empirically studied the relationship between upgrading of industrial structure and urban-rural income gap, the results showed that there was a positive long-term equilibrium relationship between them. The other is that the upgrading of the industrial structure will narrow the urban-rural income gap. For example, Li [7] thought that as the rise of the second and third industry ratio, the urban-rural income gap will be narrowed. While Liu [8] also empirically studied the relationship among the first and second industry development with the income gap, and the results showed that it will narrow the urban-rural income gap. Zhang [11] studied that the total factor productivity will contribute to the upgrading of industrial structure, which can also help narrow the urban-rural income gap. Li and Luo [6] believed that urban-rural income gap had become a prominent problem hindering economic and social development. Clarke [1] thought that urban-rural income gap was expanding in China, due to the urbanization development lags behind relatively.

The above analysis preliminary discussed the urban-rural income gap influenced by urbanization and upgrading of industrial structure. Though different scholars have different opinions, it is still difficult to determine the relationship among them. This paper will introduce the urbanization, the upgrading of industrial structure and the urban-rural income gap to research the relationship among them and its regional differences in area of East, Middle and West, based on the constant coefficient model with random effect as well as the error correction model.

3 Data Selection and Variable Description

1. Data Selection
All raw provincial panel data are from Economy Prediction System (EPS) global statistics analysis platform from 1993 to 2012, and the portion of missing data was obtained by the linear interpolation method. Besides, the Chongqing was separated from the Sichuan province in 1997, its data is not complete, and so we merge it into the Sichuan province.

The paper divides China into three areas: the East (including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Shandong and Hainan), the Middle (Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan) and the West (Guangxi, Sichuan (including Chongqing), Guizhou, Yunnan, Tibet, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang and Inner Mongolia).Then it comes to the comparative study on the three areas.

2. Variable Description
(1) Measuring index to the urban-rural income gap

We defined the index to measure the urban-rural income gap as. And it was measured by the Theil index. According to the research, made by Wang [9], could be measured by the following formula.

$$\mathrm{URIG}_{i,t} = \sum_{j=1}^{2} (Y_{ij,t}/Y_{i,t}) \ln\left(\frac{Y_{ij,t}/Y_{i,t}}{N_{ij,t}/N_{i,t}}\right), \tag{1}$$

where $\mathrm{URIG}_{i,t}$ represents the Theil index in year t of i area, $j = 1$ represents rural area, $j = 2$ represents urban area, Y means total income, N represents total population. The greater to the value of Theil index, the greater the income gap between urban and rural areas.
(2) Measuring index to the urbanization

As the urbanization means the population shift from rural area to urban areas, it can be measured by the Eq. (2):

$$UR_{i,t} = UN_{i,t} \,/\, N_{i,t}, \tag{2}$$

where UR is the rate of urbanization, UN means the population in urban areas, while N means the total population.
(3) Measuring index to the upgrading of industrial structure

In this paper, the upgrading of industrial structure refers to the optimization from the first industry to the second and third industry. Therefore, ISU can be measured with Eq. (3):

$$\mathrm{ISR}_{i,t} = (\mathrm{GDPS}_{i,t} + \mathrm{GDPT}_{i,t})/\mathrm{GDP}_{i,t}, \tag{3}$$

where ISU is the measuring index to the upgrading of industrial structure, GDPS is the gross domestic product of the second industry, while GDPT is the gross domestic product of the third industry.

4 Model Estimation

4.1 Stability Test

In order to avoid spurious regression, and to ensure the validity of model results, the stability test should be carried out for panel data. The results will be shown in Table 1.

From Table 1, we can see that the Sequences of ΔURIG, ΔUR and ΔISU are all stable. That is, the three variables are smoothly.

4.2 Panel Co-Integration Test

To determine whether there is a long-term equilibrium relationship among the urbanization, the upgrading of industrial structure and the urban-rural income gap, we need to do the co-integration test. The Null Hypothesis is that there is no co-integration relationship among them. The result was shown in Table 2.

Table 2 shows that the results of panel co-integration test are all rejects the Null Hypothesis, which means there exist a long-term equilibrium relationship among the three variables, not only in East area, but also in Middle and West areas.

Table 1 The results of stability test

Variables	Area	LLC	Fisher-ADF	Result
ΔURIG	East	−4.2102(0.000)	52.7999 (0.0002)	Stable
	Middle	−4.5732(0.0000)	41.6805 (0.0004)	Stable
	West	−5.5183(0.0000)	68.4501 (0.0000)	Stable
ΔUR	East	−10.5711(0.0000)	74.5371 (0.0000)	Stable
	Middle	−8.8996(0.0000)	51.0275 (0.0000)	Stable
	West	−8.8697(0.0000)	68.4978 (0.0000)	Stable
ΔISU	East	−9.8071(0.0000)	85.2421 (0.0000)	Stable
	Middle	−6.7960(0.0000)	78.0976 (0.0000)	Stable
	West	−7.0321(0.0000)	105.868 (0.0000)	Stable

Note Δ represents the one order difference. The values in parentheses represent the P-value

Table 2 The results of panel co-integration test

Pedroni test	East	Middle	West
Panel *v*-statistic	−2.3586 (0.0247)	−2.7766 (0.0084)	0.8430 (0.2796)
Panel *rho*-statistic	1.9685 (0.0575)	−0.2493 (0.3867)	−3.7803 (0.0003)
Panel *PP*-statistic	2.5220 (0.0166)	−2.9027 (0.0059)	−5.7075 (0.0000)
Panel *ADF*-statistic	2.6997 (0.0104)	−2.8746 (0.0059)	−5.5163 (0.0000)
Group *rho*-statistic	3.6781 (0.0005)	0.7968 (0.2904)	−2.4335 (0.0207)
Group *PP*-statistic	4.7129 (0.0000)	−2.6738 (0.0112)	−6.6939 (0.0000)
Group *ADF*-statistic	4.9269 (0.0000)	−2.4988 (0.0176)	−5.3394 (0.0000)

4.3 Model Specification

(1) Model test
Panel data contains information from three directions: cross-section, period and variables. To avoid deviation of model specification and improve the effectiveness of parameter estimation, we, firstly, need to confirm the form of model specification. The process is shown in Table 3.

Table 3 shows the models are all not declined to the hypothesis H2, which means the constant coefficient model should be built. And there is no need to carry on the F_1 test. Besides, the values of Hausman-test show that the three models are all about random effects. In conclusion, the models of East, Middle and West can be defined as the constant coefficient models with random effects.

(2) Model specification
Based on above information, the constant coefficient models with random effects can be stetted as follows:

$$\mathrm{DURIG}_{j,it} = \alpha_j + \beta_{j1}\mathrm{DUR}_{j,it} + \beta_{j2}\mathrm{DISU}_{j,it} + \mu_{j,it}, i = 1, 2, \cdots, N_j, \quad (4)$$

where $j = 1, 2, 3$ represents the East, Middle and West areas, N_j respectively indicates the number of the cross-section in the East, Middle and West areas, t

Table 3 The result to the form of model specification

Statistics		East	Middle	West
(N, K, T)		(11, 2, 20)	(8, 2, 20)	(11, 2, 20)
F_2		0.05 (1.00)	0.06 (1.54)	0.03 (1.00)
F_1		2.44* (1.57)	3.18* (1.72)	1.89* (1.57)
Hausman test	W	0.9369	3.0018	1.4725
	P	0.6260	0.2229	0.4789

Note *means the tests are passed in the significant level of 5 %. (N, T, K) mean the number of cross-sections, dependent variables and the periods represents the time period. α_j is the average level of the income gap, β_j is the coefficient corresponding to each interpretation variable. $\mu_{j,it}$ is a random error term. Setting residual sequence derived from estimation model (1) as the error correction term, let

$$\mu_{j,it} = ecm_{j,it} = \mathrm{DURIG}_{j,it} - \alpha_j + \beta_{j1}\mathrm{DUR}_{j,it} + \beta_{j2}\mathrm{DISU}_{j,it}. \tag{5}$$

Build the error correction model:

$$\Delta\ \mathrm{DURIG}_{j,it} = \gamma_{j0} + \gamma_{j1}\Delta\mathrm{DUR}_{j,it} + \gamma_{j2}\Delta\mathrm{DISU}_{j,it} + \gamma_{j3}\mathrm{ecm}_{j,it-1} + \varepsilon_{j,it}, \tag{6}$$

where β_1, γ_1 respectively represent the long- and short-term impact of urbanization to urban-rural income gap. While β_2, γ_2 respectively represent the long- and short-term impact of industrial structure upgrading to urban-rural income gap.

Equation (5) reflects the long-term equilibrium relationship between variables, Eq. (2) reflects the short-term fluctuations of the urban-rural income gap. We could find that the short-term fluctuations of the urban-rural income gap is not only related to the short-term fluctuations of urbanization and the upgrading industrial structure, but also related to the deviation degree from equilibrium trend.

4.4 Results of the Model Estimation

1. The long-term equilibrium relationship on urban-rural income gap
Using the method of GLS (cross-section weights) to estimate the Eq. (1), the results were shown in Table 4.

From Table 4, we can draw the conclusions as follows: (1) The coefficient of urbanization is negative, which means the urbanization will narrow the urban-rural income gap. Besides, the effects is more obvious in west area, the possible explanation is that the west development strategy makes the economic growth faster than other areas, then it increases the employment opportunities and income. (2) The coefficient of upgrading of industrial structure is positive, indicating that the upgrading

Table 4 Long-term impacts on urban-rural income gap influenced by regional urbanization and upgrading of industrial structure

Variable	East coefficient	P	Middle coefficient	P	West coefficient	P
α	$-7.34E-05$	0.9200	−0.0013	0.2011	−0.0015	0.3422
β_1	−0.0589*	0.0000	−0.0677*	0.0086	−0.1042*	0.0000
β_2	0.3123*	0.0003	0.3728*	0.0000	0.4681*	0.0000

Note *indicates significant under 1 % confidence level of industrial structure will widen the urban-rural income gap, and the effects is significant in west area, followed by the middle and east areas. For the second and third industries development has higher requirements of workers' skills and quality, the urban and part of rural residents become rich firstly, which widened the urban-rural income gap. In addition, there is weak economic foundation and natural conditions in West area, which doesn't benefit to rural residents' income, so the urban-rural income gap in west area is more significant than east and middle areas.

2. The estimation of the error correction model
Firstly, make the stationary test for error correction term in Table 5.

The results show that the data of error correction term are stable. so the error correction model can be estimated based on the Eq. (6). The results are shown in Table 6.

We can draw the following conclusions based on Table 6: (1) Urbanization has significantly negative effect on urban-rural income gap in the short term, and it is more serious in west area than in middle and east area. Possible explanation is that: although the weak natural conditions and economic foundation, the west area had obtained a series of government policy support, which improved health care and people's living standard, and eventually narrowed the urban-rural income gap. (2) The upgrading of the industrial structure has a positive effect on urban-rural income gap in the short term. And the effects are more significant in west area, followed by middle and east areas. Because the level of economic development in west area is lower than that in east and middle areas. (3) The coefficients of error correction term have differences in three models, they are, respectively, −0.7289, −0.5969 and −0.8026 in East, Middle and West areas, which means that the deviations of urban-rural income gap return to the equilibrium state at different rates.

Table 5 The results of the stationary test for error correction term

	East	Middle	West
LLC	−2.3523 (0.0093)	−3.7052 (0.0001)	−6.9550 (0.0000)
ADF-fisher	49.3309 (0.0007)	40.5395 (0.0006)	88.8123 (0.0000)
Results	Stable	Stable	Stable

Table 6 The estimation results to the error correction model

Variable	East coefficient	*P*	Middle coefficient	*P*	West coefficient	*P*
β_0	−0.0005	0.3839	−0.0004	0.6637	−0.0014	0.2669
β_1	−0.0584	0.0000	−0.0538	0.0025	−0.1080	0.0000
β_2	0.1977	0.0050	0.3247	0.0000	0.3901	0.0000
β_3	−0.7289	0.0000	−0.5969	0.0000	−0.8026	0.0000

5 Conclusion and Recommendation

Using the constant coefficient model with random effects as well as the error correction model, the paper aims to empirically study the urban-rural income gap influenced by urbanization and the upgrading of industrial structure from the three levels of the East, Middle and West area, based on the Chinese provincial panel data of 1993–2012.

The results indicate that: there is a long-run equilibrium relationship between urbanization, upgrading of industrial structure and the urban-rural income gap. In the short term, the urbanization will narrow the urban-rural income gap, while from the long-term trend of economic development, the urbanization have significant negative effects on east, middle and west areas. In addition, the upgrading of the industrial structure will widen the urban-rural income gap both in the long term and short term. But the influence showed significant regional differences.

Based on the above conclusions, the policy implication of this paper is: (1) Accelerating the modernization process of agricultural development, and increasing the per capita net income of rural residents. For example, accelerate the process of machinery production in rural areas. (2) Improving the social security system, speed up the process of urbanization to narrow urban-rural income gap. (3) The government should create conditions to increase farmers' income, for example, strengthen the skill training to the rural labors.

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Research On Impact of Auto Recall on Consumer Attitude

Hong Wang and Wei Li

Abstract In recent years, auto recall has happened frequently, and it has become an important factor of affecting the consumer attitude towards brand. This paper has analyzed attributes and features of different types of auto recalls-voluntary recall and passive recall based on the product recall theory and the consumer attitude towards brand. Moreover, we have done some research on empirical study. The method of empirical study is experimental research. Similarly, we have analyzed the three dimensions of consumer attitude towards brand-cognitive consumer attitude towards brand, emotional consumer attitude towards brand and decisive consumer attitude towards brand. Moreover, moderator has been introduced to study the relationship between voluntary auto recall, passive auto recall and cognitive consumer attitude towards brand, emotional consumer attitude towards brand and decisive consumer attitude towards brand under consumer expectation.

Keywords Auto recall · Consumer attitude · Experimental research

1 Introduction

Auto recall has been used as a type of remedial measures for the event of product harm, and it has happened more and more frequently. The earliest event of auto recall happened in 2004. By the end of June of 2014, there have been more than 420 cases of auto recalls in total, which involve 6 million vehicles and many brands like Geely, Volkswagen, Volvo, Cadillac, Bentley and so on. It is very interesting that many car brands are not afraid of auto recall, but to recall their own products voluntarily. Their aim is to advertise their brand in an unconspicuous way and set up a good image of being responsible. Under different consumer expectations, different auto recalls cause different results. Therefore, the enterprises should take strategic action to promote consumer attitude towards brand after auto recall.

H. Wang (✉) · W. Li
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: 781617414@qq.com

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For one thing, auto recall are generally classified into voluntary auto recall and passive auto recall [9], and brands take auto recall into consideration to make up for their mistake. In addition, former scholar also notes that auto recall is able to comfort consumers. However, the principle that auto recall is able to comfort consumers is not clear enough. For another thing, the theory of attitude is very mature, and the relationship among attitude, behavior willingness, behavior has been demonstrated a lot. However, we have to say that the relationship between auto recall and brand attitude has not been researched a lot, and the way how auto recall influences brand attitude is valuable for us to study. Consequently, the main purpose of this study is to find out the relationship between auto recall and brand attitude and the principle how auto recall influences brand attitude.

Therefore, there are 3 issues for us to study deeply. First of all, we should know different types of product recalls, and find out what influences consumer attitude towards brand. Second, how many dimensions there are to influence consumer attitude towards brand, and what kind of relationship between different dimensions? Thirdly, what kind of action should brand take to deal with different types of product recall? And which strategy should brand take to promote consumer attitude towards brand? This research provides a more nuanced view of formulation of consumer brand towards brand that is caused by auto recall. Conceptually, this research is the first to link auto recall to to consumer attitude towards brand, and this is overwhelmingly crucial because it is extremely helpful for brand to promote the appraisal from consumer when auto recall happens.

In order to solve these problems, this paper reviews the theories about product recall, consumer attitude towards brand and consumer expectation firstly. Secondly, this paper puts forward the research hypothesis based on the theory review. Finally this paper proves the research hypothesis and gets conclusion and revelation.

2 Literature Review

2.1 Product Recall

Considering the reason of product recall, product recall can be divided into 3 types. The first type is product related recall, including product defects and product performance; the second type is sales related recall including the violent way to sell and nonviolent but threatening way to sell; the third type is other product recall, including the damage of intellectual property rights, issue of product trademark, obeying relevant law and so on [4]. According to the recall of post-processing method, product recall can be classified as returned to the factory repair recall, unconditionally cancel recall, product switch recall and destruction recall [12]. According to the willingness of product recall, we could divide product recall into voluntary recall and passive recall. Voluntary recall refers to after manufacturer and distributor finding out the product defects, they could declare the product defects to relevant authorities and recall product voluntarily. Passive recall refers to the fact that manufacturer deny the product defects intentionally and refuse to undertake the responsibility. Given these findings, we formally explore the fact that the willingness of product recall could explain the phenomenon that is caused by auto recall. What is more, the willingness of product recall is the reflection of brand behavior. Based on the research needs, this paper will utilize the theory of willingness of product recall, and it means that auto recall can be divided into voluntary recall and passive recall.

2.2 Consumer Attitude Towards Brand

Consumer attitude towards brand is about consumer's overall impression of a brand. According to the outstanding characteristic and value, consumers will judge the influence and form their impression of the brand. Thus it can be seen that consumer attitude towards brand comes out of comprehensive evaluation of a variety of attributes [5].

Garretson and Fisher [8] held that brand attitude has three main characteristics: the first characteristic is that brand attitude is a relative concept, and the reason why consumer choose a certain brand is relative and convertible. The second characteristic is that brand attitude consists of cognitive factor and emotional factor, and the two factors could affect consumer brand collectively. We can see that cognitive factor leads action and emotional factor stimulates action. The third characteristic is that cognitive factor is not attitude but the reason that leads attitude to change. Based on the above analysis, we can see that attitude is a kind of tendency that measures degree of emotion [3]. For another, attitude is long-term stable and doesn't change without the influence of outward things. In the last place, attitude is the reflection of action, and attitude will change with the feedback of action [6].

Among the lots of models that measure brand attitude, Fishbein model and TRA model have been widely accepted. TRA model is also called Multi-attribute model of attitude. This model refers to the fact that consumers form brand attitude through brand attribute. If a brand means a positive image and the image of brand is deep in consumer's heart, it is much more probable that consumers are fond of this brand. According to Fishbein [7], attitude is learned disposition to respond to an object or behavior. It is one of the critical factors in explaining consumer behavior and become as one of the most studied concepts. The concept of attitude has been considered important inunderstanding human behavior.

TRA model originates from social psychology, and the scholar of social psychology believes that attitude includes cognitive factors and behavioral factors, attitude and behavior have a positive correlation. Allport [1] also mentioned that attitude and behavior is a multi-dimension system, and it consists of belief, feeling and tendency of object.

Consequently, we can take attitude as individual a kind of affection toward aspecific object or a willingness to respond to certain stimuli. Later on the meaning of attitude has evolved to refer to individual evaluations of an object. Since Fish be in assumed a causal relation between attitude and behavioral intention in the theory of reasoned action, researchers have investigated the attitude-intention relationship in various contexts including that of auto recall. Furthermore, TRA model tells us that behavior originates from attitude. Therefore, we are aware of the fact that attitude comes from affection in the first place. Secondly, emotion comes into being cognition, and it gives rise to behavior willingness. On the basis of behavior willingness, it will lead to behavior in the condition of unstable environment. In a sense, the reason why different types of auto recall would cause different outcome comes out, and we can tell the difference between emotion and cognition. Based on the above analysis, we can get a conclusion: consumer attitude towards brand consists of cognitive brand attitude, emotional brand attitude and decisive brand attitude. Cognitive brand attitude refers to the fact that when consumers get influenced by influencing factors, consumers analyze these influencing factors and form the perception and knowledge of object. It represents that consumers believe the object has some characteristics. Emotional brand attitude means that the emotion of consumer would change immediately when it comes to the appearance of various influencing factors, and emotional brand attitude would influence on inner feeling and assessment of consumers. In the last place, decisive brand attitude refers to the consumers' willingness of purchasing goods.

2.3 Consumer Expectation

Consumer expectation refers to the inherent expectation and understanding that consumers have, and the inherent expectation and understanding would maintain the same in the long term [11]. From the perspective of psychology, consumer expectation is the concrete representation of "halo effect". In fact, it means that everybody adopts a prejudiced attitude towards everything, and people would judge objective things by their prejudice [10]. It is undeniable that due to the differences of company strength, position and technical strength, the psychological gap of "top grade, intermediate grade, low grade" do exist in consumer's mind. This kind of psychological gap forms consumer expectation and affects their judgement about the auto recall events. Even more, This kind of psychological gap would affect the formation of consumer attitude towards brand. Foreign car brands are usually historical and aim high, and foreign car brands positioning is usually higher. So under the psychological expectation of Chinese consumer, the expectation of foreign car brands is usually higher. As the base of Chinese car brands is poor, and Chinese car industry aims to support planned economic system before the policy of reform and opening. The expectation of domestic car brands is usually higher in terms of foreign car brands.

Currently, auto recall has happened more and more frequently, and lots of brands are confused with product harm crisis. Previous studies of auto recall fail to solve the problem that what brands should do after product harm crisis. In addition, Studies of brand attitude suggest that such analogies might not be broadly applicable, and it is necessary that new method should be found to connect auto recall with the theory of brand attitude.

3 Hypotheses

When consumers get the information and stimulation of brand attitude, consumers would base on information and stimulation to form new brand attitude. Since consumers get affected by influencing factors, cognitive brand attitude and emotional brand attitude would be constrained by the inherit consumer attitude towards brand. Voluntary auto recall is a kind of emotional positive behavior. under strong consumer expectation, voluntary auto recall could easily fix cognitive brand attitude and emotional attitude with the help of "halo effect". Accordingly, this paper put forward hypothesis 1 and hypothesis 2:

Hypothesis 1. Under strong consumer expectation, voluntary auto recall would not have negative effect on cognitive brand attitude.
Hypothesis 2. Under strong consumer expectation, voluntary auto recall would not have negative effect on emotional brand attitude.

In contrast, Great Wall Motors which is under weak consumer expectation declared on June 21, 2012 that 8970 HAVAL H5 which were manufactured between March 12, 2012 and March 25, 2012 would be recalled. After that, the industry and consumers argued a lot on this event. Some experts hold a opinion that the series of events of recall are a result of engine defect. In other words, the essential reason of it is the technical strength of Great Wall Motors is not strong enough. The technical strength of Great Wall Motors could not come up with the speed of market, and the technical gap between Great Wall Motors and other famous brands is still huge. Under the condition of weak consumer expectation, the event of auto recall could easily make consumers associate quality problem with poor technical strength and corporate strength. As voluntary recall is a kind of measure that acknowledge the product defects and try their best to solve this problem, voluntary recall could evoke the sympathy of consumers. Accordingly, this paper put forward hypothesis 3 and hypothesis 4:

Hypothesis 3. Under weak consumer expectation, voluntary auto recall would have negative effect on cognitive brand attitude.
Hypothesis 4. Under weak consumer expectation, voluntary auto recall would not have negative effect on emotional brand attitude.

On the premise of passive auto recall, the event of product harm would cause long-term and deep harm to consumer mentality. Whatever kind of consumer expectation is could not comfort consumer mentality completely. Therefore, no matter under what kind of consumer expectation the emotion of consumers would get hurt anyway. However, cognitive brand attitude is about inherit awareness like brand strength and technical strength, and it is hard to change. Thus it can't be changed by the event of passive auto recall. Strong consumer expectation stands for inherit and long-term belief that the quality of product is reliable [2], and it won't easily change with the change of something else. Accordingly, this paper put forward hypothesis 5 $\sim$ hypothesis 8:

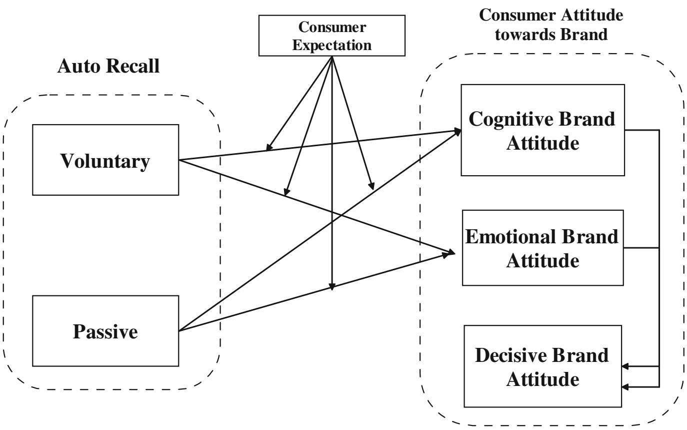

Fig. 1 Concept model

Hypothesis 5. Under strong consumer expectation, passive auto recall would not have negative effect on cognitive brand attitude.
Hypothesis 6. Under strong consumer expectation, passive auto recall would have negative effect on emotional brand attitude.
Hypothesis 7. Under weak consumer expectation, passive auto recall would have negative effect on cognitive brand attitude.
Hypothesis 8. Under weak consumer expectation, passive auto recall would have negative effect on emotional brand attitude.

The concept model of this paper is shown in Fig. 1.

4 Experimental Design and Hypothesis Testing

4.1 Experimental Design

This paper use experimental method to test hypothesis. In the experimental method, experiment is used to dictate and control consumer expectation, voluntary auto recall and passive auto recall. In real life, there is a big chance that consumers have already had inherit consumer expectation and attitude. In order to prevent this problem, this research decides to adopt fictional brand. One reason why we adopt fictional is that we can make equal the consumer expectation, and the other reason is that we can test whether the explanation based on consumer expectation is effective.

This research is divided into 2 groups (strong consumer expectation VS weak consumer expectation) $\times$ 2 groups (voluntary recall VS passive recall), and 4 experimental groups in total (Table 1).

Table 1 Item of measuring consumer attitude towards brand

Variable	Measuring item
Cognitive brand attitude	I still trust the quality of product series of x. This event of auto recall is just a small accident
	I still trust the quality of other product series that belongs to the same brand that product series x belongs to. This event of auto recall is just a small accident
	I still trust the quality of other series that belongs to A (or B) . This event of auto recall is just a small accident
Emotional brand attitude	After this event of auto recall, I like A (or B) better than before
	After this event of auto recall, I trust A (or B) better than before
	After this event of auto recall, I am more interested in A (or B) compared with the same product series
Decisive brand attitude	After this event of auto recall, I am more likely to purchase A (or B)

Strong consumer expectation can be described as the following: brand A is an enterprise that comes from Europe and have a long history, and the user of product is around the world. In Chinese market, the product of brand A is usually higher than the product that belongs to domestic manufacture. The consumers of brand A consider its product as a symbol of identity. So far, the product of A haven't had any quality problems during many years.

Weak consumer expectation can be described as the following: brand B is an enterprise that is domestic and just establish after the reform and opening up policy and its product users are mainly in China. In Chinese market, the price of its product is usually lower than the import product. Because of the lower price, many consumers choose to buy the product of brand B. So far, the quality of brand B has been praised for many years.

The event of voluntary auto recall can be described as the following: brand A (or B) recalled product x and tested, fixed, replaced product x before consumers found any issues of product x.

The event of passive auto recall can be described as the following: according to the report of media, product x that was produced by brand A (or B) had quality problem. Brand A (or B) had to recall product x and test, fix, replace product x.

In terms of measuring consumer attitude towards brand, this paper curtail and amend some index in order to prevent respondents from being tired and annoyed by lots of questions and promote the accuracy of the answers. We also added the measurement of decisive brand attitude, and all the items are measured by Likert scale level 5. The measuring items are as following:

Experimental method requires the number of sample around 50. So this experiment requires 200 samples approximately. The samples come from website and acquaintance (Website occupied 80 %, and acquaintance occupied 20 %. They distributed evenly in the four groups of experiment). Samples are chosen randomly, and it is not influenced by demographic factors. Under this situation we can consider the sources of sample meet the requirements. In order to test the reliability, we retest the

Table 2 Effective questionnaire distribution

Effective questionnaire distribution	
Strong consumer expectation and voluntary auto recall	48
Strong consumer expectation and passive auto recall	40
Weak consumer expectation and voluntary auto recall	36
Weak consumer expectation and passive auto recall	42

Table 3 Effective questionnaire distribution

	Kappa	Gradual standard error	Approximate value T	Approximate value Sig.
Kappa consistency coefficient	0.471	0.257	2.000	0.046
Effective case number	40			

acquaintance, and there are five days between the two experiments. Randomness, comprehensiveness and integrity can be guaranteed in this way, and data reliability also can be guaranteed in this way. What they have to do is to follow their heart and willingness to give the most realistic idea. We issue 214 questionnaires at first time, and the number of invalid questionnaires is 48, so the efficient of questionnaires is 77.6 %.

The scale used in this paper is a mature scale that many researches have used before. Therefore we don't test validity in this paper. Before we test hypothesis, we must test reliability of the questionnaires. Reliability test comes from repeating the questionnaires, namely test-retest reliability. The method adopted is to test whether the answers' frequency distribution of test-retest is the same. Under this situation, we can use Kappa consistency coefficient to test reliability.

We can see from the Table 2. That the Kappa consistency coefficient is 0.471, that is greater than 0.45 (general standard), so we can say that this questionnaire has eligible reliability (Table 3).

4.2 Hypothesis Testing

As we have mentioned before, independent variables of this paper are voluntary recall and passive recall, and dependent variables are cognitive brand attitude, emotional brand attitude. Therefore, we calculate the average of the three questions that represent each brand attitude. Above all, we match the same event of auto recall that is under different consumer expectation with the same brand attitude. We make use of contrasting hypothesis to test hypothesis. The contrasting hypothesis group 1 is hypothesis 1, hypothesis 3, hypothesis 5 and hypothesis 7.

Table 4 Effective questionnaire distribution

	Quadratic sum	df	Mean square	F	Sig.
Interblock	2.220	1	2.220	0.825	0.045
Intra-class	10.764	4	2.691		
Sum	12.984	5			

Table 5 One-way ANOVA of hypothesis 5 and hypothesis 7

	Quadratic sum	df	Mean square	F	Sig.
Interblock	10.323	1	10.323	1.563	0.032
Intra-class	1.035	4	0.259		
Sum	11.358	5			

In the first place, we use One-Way ANOVA to contrast hypothesis 1 with hypothesis 3. Here is the result (Tables 4, 5):

Under strong consumer expectation, the average of three subordinative dimensions of cognitive brand attitude that is under the situation of voluntary recall are: Q1-4.066, Q2-4.618, Q3-4.324. Under weak consumer expectation, the average of three subordinative dimensions of cognitive brand attitude that is under the situation of voluntary recall are: Q1-1.518, Q2-1.342, Q3-1.452. They exist significant difference ($F = 0.825$, $P = 0.045 < 0.05$). This shows that consumer expectation has a strong influence on cognitive brand attitude under the premise of voluntary recall. Consumer expectation does have adjustive effect on cognitive brand attitude. As we can see that the average of three subordinative dimensions of cognitive brand attitude that is under the situation of voluntary recall are: Q1-4.066, Q2-4.618, Q3-4.324, and they are all greater than 3 which means the average of Likert scale. Thus we can get the conclusion that under strong consumer expectation voluntary recall would not have negative effect on cognitive brand attitude. Under weak consumer expectation, the average of three subordinative dimensions of cognitive brand attitude that is under the situation of voluntary recall are: Q1-1.518, Q2-1.342, Q3-1.452, and they are all less than 3 which means the average of Likert scale. Thus we can get the conclusion that under weak consumer expectation voluntary recall would have negative effect on cognitive brand attitude.

Next step is to continue to take One-Way ANOVA to test hypothesis 5 and hypothesis 7. Here is the result:

Under strong consumer expectation, the average of three subordinative dimensions of cognitive brand attitude that is under the situation of passive recall are: Q1-4.082, Q2-4.641, Q3-4.761. Under weak consumer expectation, the average of three subordinative dimensions of cognitive brand attitude that is under the situation of passive recall are: Q1-1.091, Q2-1.323, Q3-2.342. They exist significant difference ($F = 1.563$, $P = 0.032 < 0.05$). Hypothesis 5 and hypothesis 7 are tenable.

Table 6 Interaction of hypothesis 3 and hypothesis 5

	Quadratic sum	df	Mean square	F	Sig.
Calibration model	10.251a	1	10.251	59.381	0.078
Intercept	65.259	1	65.259	378.032	0.000

Table 7 Interaction of hypothesis 1 and hypothesis 7

	Quadratic sum	df	mean square	F	Sig.
Calibration model	6.120a	1	6.120	47.077	0.086
Intercept	67.742	1	67.742	521.104	0.000

We continue to take advantage of Two-Way ANOVA to analyze the interaction between different consumer expectation and different kinds of auto recalls and its influence on cognitive brand attitude. First of all, we compare H3 with H5. The result shows that there is no significant difference among groups ($P = 0.078 > 0.05$). It proves that consumer expectation influences cognitive brand attitude in its way, and auto recall influences cognitive brand attitude in its way. The interaction between different consumer expectation and different kinds of auto recall influence on cognitive brand attitude is not obvious. Therefore, hypothesis 3 and hypothesis 5 get support from data (Tables 6 and 7).

In order to test result further, we continue to take advantage of Two-Way ANOVA to compare hypothesis 1 with hypothesis 7. It comes to the fact that there is no significant difference among groups ($P = 0.086 > 0.05$), and we can tell from the data that different consumer expectation and impacts that different kind of auto recalls have on cognitive brand attitude have no significant interaction.

Contrasting hypothesis group 2 is hypothesis 2, hypothesis 4, hypothesis 6 and hypothesis 8. In the first place, we take advantage of One-Way ANOVA to test hypothesis 2 and hypothesis 6. The result is shown as Table 8.

Under strong consumer expectation, the average of three subordinative dimensions of emotional brand attitude that is under the situation of voluntary recall are: Q4-4.122, Q5-3.882, Q6-4.198. Under strong consumer expectation, the average of three subordinative dimensions of emotional brand attitude that is under the situation

Table 8 One-Way ANOVA of hypothesis 2 and hypothesis 6

	Quadratic sum	df	Mean square	F	Sig.
Calibration model	1.378	1	1.3780	0.419	0.026
Intercept	13.170	4	3.293	521.104	
Sum	14.548	5			

of passive recall are: Q4-1.462, Q5-1.846, Q6-1.821. The difference is significant ($F = 0.419$, $P = 0.026 < 0.05$). As we can see that the average of three subordinative dimensions of emotional brand attitude that is under the situation of voluntary recall are: Q4-4.122, Q5-3.882, Q6-4.198, and they are all greater than 3 which means the average of Likert scale. Thus we can get the conclusion that under strong consumer expectation voluntary recall would not have negative effect on emotional brand attitude. Under strong consumer expectation, the average of three subordinative dimensions of emotional brand attitude that is under the situation of passive recall are: Q4-1.462, Q5-1.846, Q6-1.821, and they are all less than 3 which means the average of Likert scale. Thus we can get the conclusion that under strong consumer expectation passive auto recall would have negative effect on emotional brand attitude.

Next step is to continue to take One-Way ANOVA to test hypothesis 4 and hypothesis 8. The result is shown as Table 9.

Under weak consumer expectation, the average of three subordinative dimensions of emotional brand attitude that is under the situation of voluntary recall are: Q4-4.2122, Q5-4.0892, Q6-4.362. Under weak consumer expectation, the average of three subordinative dimensions of emotional brand attitude that is under the situation of passive recall are: Q1-1.091, Q2-1.323, Q3-2.342. They exist significant difference ($F = 0.192$, $P = 0.015 < 0.05$). Hypothesis 4 and hypothesis 8 are tenable (Tables 10 and 11).

We continue to take advantage of Two-Way ANOVA to test the interaction that different consumer expectation and different kind of auto recall influence on emotional brand attitude. First of all, we compare hypothesis 2 with hypothesis 8. The result shows that there is no significant difference among groups ($P = 0.083 > 0.05$). It proves that consumer expectation influences emotional brand attitude in its way, and auto recall influences emotional brand attitude in its way. The interaction that different consumer expectation and different kind of auto recall influence on emotional

Table 9 One-Way ANOVA of hypothesis 2 and hypothesis 6

	Quadratic sum	df	Mean square	F	Sig.
Calibration model	0.179	1	0.179	0.192	0.015
Intercept	3.722	4	0.930		
Sum	3.901	5			

Table 10 Interaction of hypothesis 2 and hypothesis 8

	Quadratic sum	df	Mean square	F	Sig.
Calibration model	5.857a	1	5.857	55.456	0.083
Intercept	74.193	1	74.193	702.514	0.000

Table 11 Interaction of hypothesis 4 and hypothesis 6

	Quadratic sum	df	Mean square	F	Sig.
Calibration model	6.410a	1	6.410	16.044	0.073
Intercept	37.928	1	37.928	94.930	0.001

brand attitude is not obvious. Therefore, hypothesis 2 and hypothesis 8 get support from data.

In order to test result further, we continue to take advantage of Two-Way ANOVA to compare hypothesis 4 with hypothesis 6. It comes to the fact that there is no significant difference among groups ($P = 0.086 > 0.05$), and we can tell from the data that the interaction that different consumer expectation and different kind of auto recall influence on emotional brand attitude is not obvious. hypothesis 4 and hypothesis 6 get support from data.

5 Conclusion and Revelation

1. Conclusion

We get 4 main conclusions from this research. First of all, under strong consumer expectation, voluntary recall would not have negative impact on cognitive and emotional brand attitude. The main reason is that voluntary recall has something special to dilute the feeling of getting hurt. To some extent, it can minimize the degree of mistake that is caused by quality problem. Secondly, under strong consumer expectation, passive recall would not have negative impact on cognitive brand attitude. When it comes to cognitive brand attitude, consumer usually consider cognitive brand attitude under rational thinking, and it is a kind of inherit attitude and wouldn't easily change. Thirdly, under weak consumer expectation, voluntary recall would have negative effect on cognitive brand attitude. However, under weak consumer expectation, voluntary recall would not have negative effect on emotional brand attitude. The main reason is that people would have mercy on the brand which is under weak brand expectation. If the brand recalls the cars voluntarily, it is very possible that consumer wouldn't have negative impression on brand on the premise of having mercy. Fourthly, under weak consumer expectation, passive recall would have negative effect on cognitive and emotional brand attitude. In a sense, the event of passive auto recall is somehow impressive and unmodifiable. No matter what action the brand takes, it is hard to cure the pain of brand's irresponsibility. The passive recall means unwilling to admit mistake. Therefore, under the situation of passive recall, consumer expectation wouldn't have strong influence on brand attitude.

2. Revelation

Revelation 1: The brand should take responsibility voluntarily. Find out defect and fix it.

The event of voluntary recall has something special to dilute the feeling of getting hurt, and it could save the image of brand in consumer's mind. When a brand finds out defect, it should recall product voluntarily on the basis of economy and responsibility. Recalling product voluntarily could not only promote trust but fix the problem of getting hurt. Eventually, brand loyalty could be established in this way.

Revelation 2: Various ways should be tried to promote consumer expectation, and the strategy of brand occupying should be adopted.
Similarly, we are aware of the fact that there exist a kind of phenomenon named halo effect. When the event of product harm happens, "halo effect of strong consumer expectation is able to ease the product harm crisis. Therefore, it is significant for us to occupy a high place in consumer's mind and have strong consumer expectation. The strategy of brand occupying means a brand should change the image and position in consumer's mind through marketing activities, operating strategy and so on.

Revelation 3: Establish mechanism of crisis prevention and reaction
Perfect merchandise doesn't exist in this world, and product harm can't be avoided sometimes. Accordingly we should establish mechanism of crisis prevention and reaction. When the event of product harm happens, the brand should respond immediately and handle this problem in a fair and just way. If a brand takes passive action, it's pretty possible that consumers would not forgive this brand. Consumers would be angry and disappointed at the time of realizing being cheated. Thus, the brand should show the attitude that the brand is with consumers no matter what happens, and this is the key to get sympathy from consumers. In order to test and deal with various events of product harm at once, the brand should establish mechanism of crisis prevention and reaction on the basis of comprehensive assessment of the cost.

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A Fuzzy Multi-Criteria Group Decision Making Model for Measuring Risks in a Supply Chain Using Extended VIKOR Method

Muhammad Nazam, Jamil Ahmad, Muhammad Kashif Javed, Muhammad Hashim, Adnan Sarwar and Shahid Rasheed

Abstract In this paper, we quantify risks in a supply chain process from an aviation's perspective. Due to globalization, supply chains are getting more and more risky than before. As risk is inherent and uncertain activity, if it occurs then all of the supply chain partners will be impacted with a significant loss. To deal with this problem, a comprehensive risk evaluation index system has been proposed, which captures the level of risk faced by a supply chain in a given situation. For measuring risks in a supply chain we formulated a fuzzy multi-criteria group decision making model based on extended VIKOR method to determine the best feasible solution according to the selected risk parameters. A practical case study is conducted to test the applicability of the proposed methodology. Finally, we discuss the effectiveness of the proposed framework and rank the risk alternatives in descending order.

Keywords Supply chain risk management · Multi-criteria group decision making · Fuzzy VIKOR · Risk index · Aviation sector

1 Introduction

In todays scenario, supply chain risk management has become a significant issue for supply chain management [4]. An important factor of the rapidly evolving global business environment, spurred on by significant technology shifts, innovation,

M. Nazam (✉) · J. Ahmad · M.K. Javed · A. Sarwar
Uncertainty Decision-Making Laboratory, Sichuan University,
Chengdu 610064, People's Republic of China
e-mail: nazim_ehsas@yahoo.com

M. Hashim
Department of Business Administration, National Textile University,
Faisalabad 37610, Pakistan

S. Rasheed
School of Economics and Management, Beijing University of Posts and Telecommunications,
Beijing 100876, People's Republic of China

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communication technologies and globalization, is the increasing prevalence of risk in almost every aspect of our lives. The companies face so many risks because they can never know exactly what will happen in the future. With the ever-increasing push for efficiency, supply chains environment recently are getting more and more risky [7]. An important element of the risk management procedure is the identification, evaluation and mitigation of risk. The procedure of risk assessment involves understanding the reasons that give rise to potential problems, and then evaluating the likelihood and severe impact of such kind of problems [11]. The major hurdles in evaluating risks comes from the fact that there is a lot of subjectivity involved [9, 10]. The observations and input of the experts on the subject mainly comes in the form of subjective assessments. Therefore, this necessitates the application of theories such as fuzzy or grey analysis which are useful tools of dealing with uncertainty and subjectivity. To deal with this kind of problem, most of the previous researchers used multi-criteria decision making techniques. Liou et al. [5] proposed a modified VIKOR multi-criteria decision method for improving domestic airlines service quality but did not consider the risk of whole supply chain.

In this study, we applied the extended VIKOR method, which was developed for multi-criteria optimization for complex systems, to find a compromise priority ranking of supply chain risks according to the risk parameters in supply chain environment of aviation industry. Linguistic variables, expressed in trapezoidal or triangular fuzzy numbers, are used to assess the ratings and weights for each risk against three selected criteria, namely probability of occurrence, impact of the risk on supply chain if it occurred and how easily the mitigation would be for the impact of that risk. The extended VIKOR method is used to quantify risks in a supply chain and consolidate the values into a comprehensive risk index. Consequently, a new fuzzy multi-criteria group decision-making model based on fuzzy sets theory and VIKOR method is proposed to deal with the risk measuring problems in a supply chain system.

The rest of this paper is structured as follows. Following the introduction, in Sect. 2, the key problem for the aviation industry with different kinds of risks in a supply chain under uncertain environment is described. The formulation of a fuzzy (MCGDM) model for measuring risks in a supply chain and its conversion into a crisp value can be explained in Sect. 3. In Sect. 4, a practical case study is presented to demonstrate the applicability of the proposed model. In the final section, the conclusions and directions for future research are discussed.

2 Key Problem Statement

In this problem, we classified supply chain risks into ten major types. One simple classification can be external or internal risks but another classification can be of strategic, tactical or operational risks. Based on the literature review, supply chain risks can be categorized in many different ways with different perspectives [1, 2]. In this study, a comprehensive risk index has been proposed in manufacturing facility of

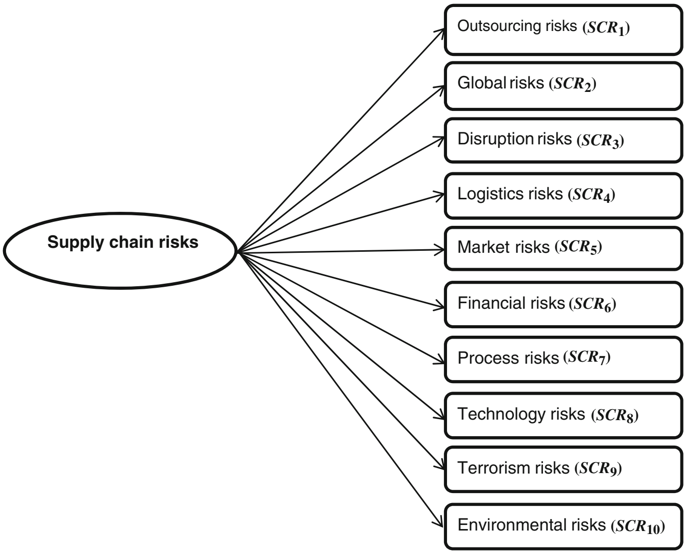

Fig. 1 Classification of supply chain risks

an aviation industry. Major potential risks are identified by a group of supply chain risk management team in the manufacturing process of high-tech products. The experts categorized most important supply chain risks (SCR) such as: outsourcing risk (SCR_1), global risk (SCR_2), disruption risk (SCR_3), logistics risk (SCR_4), market risk (SCR_5), financial risk (SCR_6), process risk (SCR_7), technology risk (SCR_8), terrorism risk (SCR_9), environmental risk (SCR_{10}). The detailed classification of risks is structured in Fig. 1.

3 Formulating a Fuzzy MCGDM Model for Measuring Risks in a Supply Chain

Multi-criteria decision making problems are mostly consider under fuzzy environment. In the fuzzy environment, the uncertain parameters are the decision maker (DM)s degree of optimism, which has a significant effect on the results. It has been extensively argued that supply chain risks are not easy to be precisely evaluated and traditional techniques take no account of relative importance of the risk parameters [8]. In this paper the risk parameters and their relative importance weights are taken as linguistic variables. A systematic approach to apply the VIKOR is proposed to determine risk priorities of supply chain risks under a fuzzy environment [6]. The general framework of our proposed model is shown in Fig. 2. The VIKOR method is started with the following form of Lp-metric.

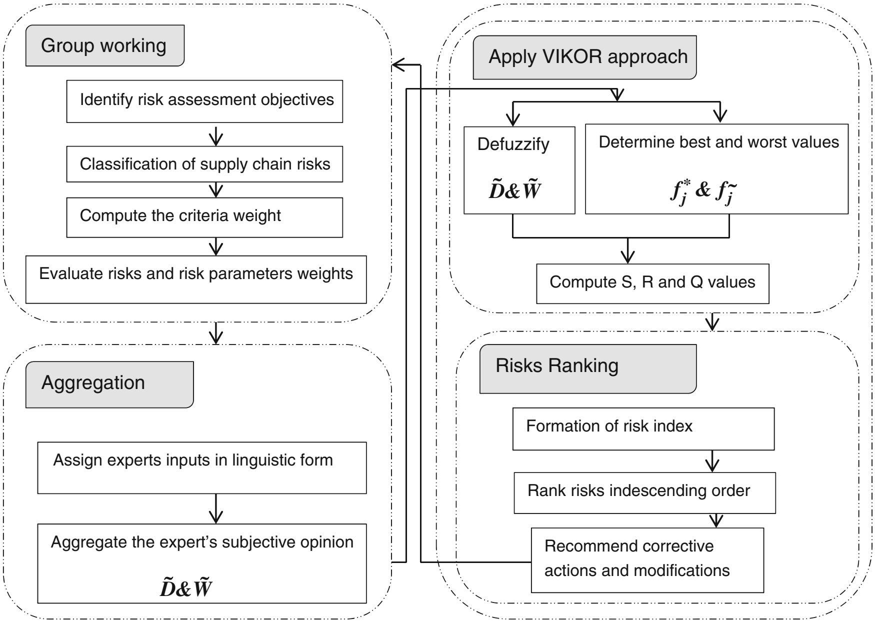

Fig. 2 The general framework for the fuzzy MCGDM model of supply chain risk evaluation

$$L_{p,i} = \sum_{j=1}^{n} [w_j (f_j^* - f_{ij}/(f_j^* - f_j^-))^p]^{1/p}, \quad 1 \leq p \leq \propto, \; i = 1, 2, \ldots, m. \quad (1)$$

In order to sum the risk priorities of supply chain risks, following are the steps which we determined:

Step 1. Defining the problem importance and identifying the objectives of the decision making process. Firstly, our objective is to categorizing risks in a supply chain and then consolidating the the values into a comprehensive risk index.

Step 2. Forming the group of decision-makers and state a finite set of relevant attributes. For our measuring risks in a supply chain problem we have three different risk criterion and ten different alternatives.

Step 3. In this step, the appropriate linguistic variables for the importance weight of criteria, and the fuzzy rating for alternatives with respect to each criterion these linguistic variables can be expressed in positive trapezoidal fuzzy numbers, as in Figs. 3 and 4 must be defined. The decision makers use the linguistic variables shown in Figs. 3 and 4 to evaluate the importance of the criteria and the ratings of alternatives with respect to qualitative criteria.

Step 4. To construct a fuzzy decision matrix, pull the decision makers? advices to get the aggregated fuzzy weight of selected criteria and rating of alternatives: Let the fuzzy rating and importance weight of the kth decision maker be $\tilde{x}_{ijk} = (x_{ijk1}, x_{ijk2}, x_{ijk3}, x_{ijk4})$ and $\tilde{w}_{jk} = (w_{jk1}, w_{jk2}, w_{jk3}, w_{jk4})$; $i = 1, 2, \ldots, m$ and

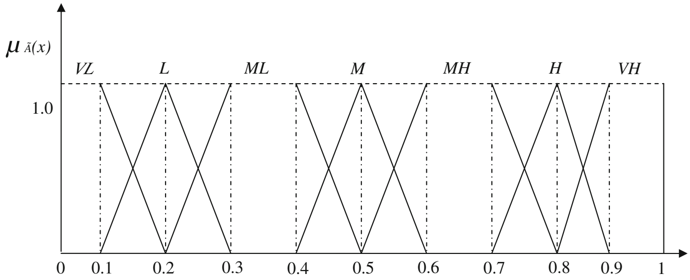

Fig. 3 Membership function for rating the weight of risk parameters

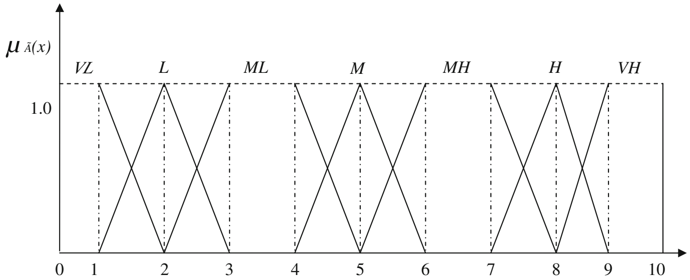

Fig. 4 Membership function for rating the supply chain risks

$j = 1, 2, \ldots, n$ respectively. Hence, the aggregated fuzzy ratings $(\tilde{x}_{ij})$ of alternatives with respect to each criterion can be computed as: $\tilde{x}_{ijk} = x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4}$, where $x_{ij1} = \min\{x_{ijk1}\}_k$, $x_{ij2} = \frac{1}{K}\sum_{k=1}^{K} x_{ijk2}$, $x_{ij3} = \frac{1}{K}\sum_{k=1}^{K} x_{ijk3}$, $x_{ij4} = \max\{x_{ijk4}\}_k$. The aggregated fuzzy weights $(\tilde{w}_j)$ of each criterion can be calculated as:

$$\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3}, w_{j4}), \tag{2}$$

where $w_{j1} = \min\{w_{jk1}\}_k$, $w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2}$, $w_{j3} = \frac{1}{K}\sum_{k=1}^{K} w_{jk3}$, $w_{j4} = \min\{w_{jk4}\}_k$.

$$\widetilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \quad \widetilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n], \tag{3}$$

where $\tilde{x}_{ij}$ the rating of alternative A_i with respect to C_j, $(\tilde{w}_j)$ the importance weight of the j th criterion holds, $\tilde{x}_{ij}$ $x_{ij1}; x_{ij2}; x_{ij3}; x_{ij4}$ and $(\tilde{w}_j)$ $w_{j1}; w_{j2}; w_{j3}; w_{j4}$; $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$ are linguistic variables can be approximated by positive trapezoidal fuzzy numbers.

Step 5. Defuzzify the fuzzy decision matrix and fuzzy weight of each criterion into crisp values: This calculation is done by using center of area defuzzification method. The centroid defuzzification method can be expressed by following relation:

$$\bar{x_0}(\widetilde{A}) = \frac{\int x\mu_{\widetilde{A}(x)dx}}{\int \mu_{\widetilde{A}(x)dx}}, \tag{4}$$

where $\bar{x_0}(\widetilde{A})$ is the defuzzified value. For trapezoidal fuzzy number (a_1, a_2, a_3, a_4), the centroid-based defuzzified value turns out to be [3].

$$\bar{x_0}(\widetilde{A}) = \frac{1}{3}\left[a_1 + a_2 + a_3 + a_4 - \frac{a_4 a_3 - a_1 a_2}{(a_4 + a_3) - (a_1 + a_2)}\right]. \tag{5}$$

Step 6. Determine the best f_j^* and the worst f_j^- values of all criterion ratings, $j = 1, 2, \ldots, n$ and $i = 1, 2, 3, \ldots, m$

$$f_j^* = \{\max x_{ij},\ \text{for benefit criteria},\quad \min x_{ij},\ \text{for cost criteria}\}, \tag{6}$$

$$f_j^- = \{\min x_{ij},\ \text{for benefit criteria},\quad \max x_{ij}\ \text{for cost criteria}\}. \tag{7}$$

Step 7. Compute the values S_i and R_i, $i = 1, 2, \ldots, m$, by the relations:

$$S_i = \sum_{j=1}^{n} w_j (f_j^* - x_{ij})/(f_j^* - f_j^-), \tag{8}$$

$$R_i = \max\ w_j (f_j^* - x_{ij})/(f_j^* - f_j^-), \tag{9}$$

where w_j are the weights of criteria, expressing their relative importance.
Step 8. Compute the values Q_i, $i = 1, 2, \ldots, m$, by the relation

$$Q_i = v(S_i - S^*)/(S^- - S^*) + (1 - v)(R_i - R^*)/(R^- - R^*), \tag{10}$$

where $S^* = \min_i S_i$, $S^- = \max_i S_i$, $R^* = \min_i R_i$, $R^- = \max_i R_i$ and v is introduced as a weight for the strategy of maximum group utility, whereas 1 v is the weight of the individual regret. The value of v is set to 0.5 in this study.
Step 9. Rank the alternatives, sorting by the values S, R and Q in descending order. The results are three ranking lists.
Step 10. Propose a compromise solution, the alternative $(A^{(1)})$, which is the best ranked by the measure Q (minimum) if the following two conditions are satisfied:

$$QA^{(2)} - QA^{(1)} \geq DQ \tag{11}$$

where $A^{(2)}$ is the alternative with second position in the ranking list by Q; $DQ = 1/(m1)$. C_2 (Table 1).

Table 1 Linguistic variables for rating the supply chain risks and weight of risk parameters respectively

Linguistic variables	Trapezoidal FNs	Trapezoidal FNs
Very low (VL)	(0, 0, 1, 2)	(0.0, 0.0, 0.1, 0.2)
Low (L)	(1, 2, 2, 3)	(0.1, 0.2, 0.2, 0.3)
Medium low (ML)	(2, 3, 4, 5)	(0.2, 0.3, 0.4, 0.5)
Medium (M)	(4, 5, 5, 6)	(0.4, 0.5, 0.5, 0.6)
Medium High (MH)	(5, 6, 7, 8)	(0.5, 0.6, 0.7, 0.8)
High (H)	(7, 8, 8, 9)	(0.7, 0.8, 0.8, 0.9)
Very high (VH)	(8, 9, 10, 10)	(0.8, 0.9, 1.0, 1.0)

- C_2. Acceptable stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be: voting by majority rule when $v > 0.5$ is needed, or by consensus v is 0.5, or with veto $v < 0.5$. Here, v is the weight of decision making strategy of the maximum group utility. If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:
- alternatives $A^{(1)}$ and $A^{(2)}$ if only the condition C_2 is not satisfied.
- alternatives $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ if the condition C_1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(M)})\ Q(A^{(1)}) < DQ$ for maximum M (the positions of these alternatives are in closeness).

4 Practical Application

The proposed model has been applied in aviation industry to the understand the status of supply chain risk management. A supply chain management or logistics team of five decision makers, DM_1, DM_2, DM_3, DM_4, and DM_5, has been formed to provide the desired information on supply chain risk management. We analyze the internal or process risk of aviation industry because its higher level of risks. The steps of the risk measuring process can be defined as follows:

Step 1. The manufacturer desires to identify several most serious supply chain risks during production process to take appropriate measures. After preliminary screening, ten supply chain risks (SCR_1, SCR_2, SCR_3, SCR_4, SCR_5, SCR_6, SCR_7, SCR_8, SCR_9, and SCR_{10}) remain for further evaluation.

Step 2. Each risk is measured against three parameters, namely probability of occurrence, impact of the risk on the supply chain if it occurred and how easily the mitigation would be for the impact of that risk.

Step 3. A team of five decision-makers use the linguistic weighting variables shown in Fig. 3 to assess the relative importance of the risk parameters. The importance weights of the risk parameters determined by these five decision makers are shown

Table 2 Importance weight of risk parameters from five supply chain team members

Risk parameters	Decision maker				
	DM1	DM2	DM3	DM4	DM5
Probability	M	VH	H	MH	MH
Impact	MH	H	MH	VH	H
Mitigation	H	M	MH	MH	M

in Table 2. The experts also use the linguistic rating variables shown in Fig. 4 to evaluate the ratings of supply chain risks with respect to each risk parameter. The ratings of the ten supply chain risks by the decision makers under the three risk parameters are shown in Table 3.
Step 4. The linguistic evaluations shown in Tables 2 and 3 are converted into trapezoidal fuzzy numbers. Then the aggregated weight of risk parameters and aggregated fuzzy rating of supply chain risks are calculated to determine the fuzzy weight of each risk factor and construct the fuzzy decision matrix, as in Table 4.
Step 5. The crisp values for decision matrix and weight of each risk parameters are computed as shown in Table 5.
Step 6. The best and the worst values of all risk parameters ratings are determined as follows:

$$f_P^* = 4.000,\ f_I^* = 4.889,\ f_M^* = 2.600,\ f_P^- = 6.778,\ f_I^- = 6.900,\ f_M^- = 4.933.$$

Step 7. The value of S is calculated by Eq. (8) for all risks as shown in Table 6.
Step 8.The value of R is calculated by Eq. (9) for all risks as shown in Table 6.
Step 9. The value of Q is calculated by Eq. (10) for all risks as shown in Table 6.
Step 10. The ranking of the alternative supply chain risks by S, R and Q in decreasing order is shown in Table 7.

From the Table 7, it can be seen that the supply chain risk SCR_3 is apparently the most serious supply chain risk according to Q values and should be given the top risk priority by the the company, this will be followed by supply chain risks SCR_6, SCR_9, SCR_{10}, SCR_2, SCR_7, SCR_8, SCR_1, SCR_4 and SCR_5.

5 Conclusions and Future Research

In this study, we proposed a new comprehensive risk index under uncertain environment and can be applied in any industry situation. To formulate this risk index we take experts opinion as its input and delivers a crisp number as the risk score. In the proposed model, we first categorize the risk status for the said environment, secondly identification of the weights of the supply chain risks, then computation

Table 3 Judgment on ten supply chain risks by supply chain team members under risk parameters

R[a]		Probability Impact Mitigation														
D[b]		DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5
Supply chain risks	SCR_1	M	M	ML	M	ML	M	ML	MH	MH	MH	ML	ML	M	M	ML
	SCR_2	MH	ML	M	H	M	ML	MH	H	MH	M	MH	M	ML	M	ML
	SCR_3	ML	MH	VH	H	H	MH	MH	MH	MH	MH	M	ML	MH	MH	M
	SCR_4	L	ML	M	L	MH	ML	M	MH	MH	M	VL	L	ML	MH	M
	SCR_5	ML	M	M	M	M	MH	M	ML	M	M	M	ML	VL	ML	L
	SCR_6	H	M	MH	MH	ML	H	H	MH	MH	H	L	L	ML	L	ML
	SCR_7	MH	ML	H	VH	ML	M	ML	ML	H	M	M	L	M	L	L
	SCR_8	L	L	VH	L	L	H	MH	H	L	L	ML	L	L	MH	MH
	SCR_9	VH	H	MH	M	M	H	MH	ML	M	M	MH	M	L	L	VL
	SCR_{10}	MH	H	M	MH	MH	M	MH	M	MH	H	VL	VL	M	L	L

a Risk parameters.
b Decision-makers

Table 4 Aggregated fuzzy rating of ten supply chain risks and aggregated fuzzy weight of risk parameters

Supply chain Riks	Probability	Impact	Mitigation
SCR_1	(2, 4.2, 4.6, 6)	(2, 5.2, 6, 8)	(2, 3.8, 4.4, 6)
SCR_2	(2, 5.4, 5.8, 8)	(2, 5.6, 6.2, 9)	(2, 4.4, 5, 8)
SCR_3	(2, 6.2, 6.8, 10)	(5, 6, 7, 8)	(2, 5, 5.6, 8)
SCR_4	(1, 3.6, 4, 8)	(2, 5, 5.6, 8)	(0, 3.2, 3.8, 8)
SCR_5	(2, 4.6, 4.8, 6)	(2, 4.8, 5.2, 8)	(0, 2.6, 3.2, 6)
SCR_6	(2, 5.6, 6.2, 9)	(5, 7.2, 7.6, 9)	(1, 2.4, 2.8, 5)
SCR_7	(2, 5.8, 6.6, 10)	(2, 4.8, 5.2, 9)	(1, 3.2, 3.2, 6)
SCR_8	(1, 3.4, 3.6, 10)	(1, 5.2, 5.4, 9)	(1, 3.8, 4.4, 8)
SCR_9	(4, 6.6, 7, 10)	(2, 5.4, 5.8, 9)	(0, 3, 3.4, 8)
SCR_{10}	(4, 6.2, 6.8, 9)	(4, 6, 6.4, 9)	(0, 1.8, 2.2, 6)
Weight	(0.58, 0.68, 0.74, 0.82)	(0.64, 0.74, 0.80, 0.88)	(0.50, 0.60, 0.64, 0.74)

Table 5 Crisp values for decision matrix and weight of each risk parameter

Risk parameters	Supply chain risks										
	SCR_1	SCR_2	SCR_3	SCR_4	SCR_5	SCR_6	SCR_7	SCR_8	SCR_9	SCR_{10}	Weight
Probability	4.000	5.089	6.017	4.181	4.167	5.476	5.867	4.793	6.778	6.240	0.705
Impact	4.978	5.476	5.778	4.933	4.899	6.900	5.229	5.058	5.429	6.227	0.765
Mitigation	3.833	4.733	4.933	3.733	2.867	2.767	3.400	4.238	3.667	2.600	0.621

Table 6 The values of S, R and Q for all supply chain risks

Compromise value	Supply chain risks									
	SCR_1	SCR_2	SCR_3	SCR_4	SCR_5	SCR_6	SCR_7	SCR_8	SCR_9	SCR_{10}
By S	0.362	1.067	1.471	0.364	0.113	1.184	0.816	0.702	1.194	1.077
By R	0.328	0.568	0.621	0.302	0.071	0.765	0.474	0.436	0.705	0.568
By Q	0.277	0.709	0.896	0.259	0.000	0.894	0.549	0.480	0.855	0.713

of the scores of the supply chain risk and finally consolidation of the weights and scores into one single crisp value, which is the risk index. The addition of a main supplier is a major change in the supply chain, therefore the determination of the risk index should be carried out at regular intervals. Being notified of the risk status of the chain, the companies can decide on when risk management in supply chain needs more attention. This will allow them to free up available resources for the risk management team and thus can reduce the redundancy being built into the system.

Table 7 The ranking of the supply chain risks by S, R and Q values

Ranking	Supply chain risks									
	SCR_1	SCR_2	SCR_3	SCR_4	SCR_5	SCR_6	SCR_7	SCR_8	SCR_9	SCR_{10}
By S	9	5	1	8	10	3	6	7	2	4
By R	8	4	3	9	10	1	6	7	2	4
By Q	8	5	1	9	10	2	6	7	3	4

In this article, the integration of fuzzy linguistic VIKOR with the support of trapezoidal fuzzy set theory is proposed for the prioritization of measuring risks in a supply chain of aviation industry. Some steps of the extended fuzzy VIKOR method are discussed to show there are other possible extensions. It is an effective and simple tool to solve the imprecise, vague, intangible information for MCGDM problem. The verified example concerning the aviation supply chain risk shows that the proposed method is very useful for measuring of risks and also applicable to other management decision problem.

In the future, our research plans to develop new risk indexes by incorporating the new frameworks incorporating the various artificial intelligence modeling techniques, multi-agent, petri net, graph theory, gray theory, game theory and so on, and then comparing the performances of these risk indexes with the propose one.

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Research on Negative Effect of Controversial Slogans on Tourism Marketing

Xinzhu Wang, Yongge Niu and Wei Li

Abstract Controversial slogans in tourism marketing often exist, and they always lead to hot debate among consumers. This study conducted an experiment to explore the negative effect of controversial slogans on tourism marketing based on investigation of 197 consumers. The result shows that controversial slogans can lead to negative attitude towards advertising and lower travel intention. It implies that controversial slogans should be employed with prudence, because they go against consumers' values and morals. Tourism marketing should use inspiring slogans to enhance the persuasion of tourism advertising.

Keywords Controversial slogans · Advertising attitude · Travel intention

1 Introduction

Advertisers often employ salient slogans to help attract targeted segments, and good slogans actually can serve to enhance consumers' attitudes toward the advertising, which may carries over effect on the brand or product [1]. However, an advertisement should be very prominent to get consumers' attention before it is remembered, and advertisers therefore tend to employ every means to attain this end [2], for example, they often use controversial slogans to stand out from the advertising jungle.

Controversial slogans can also be encountered sometimes in tourism marketing in China, and they have got much pros and cons from commonplace people. The following table portrays two examples of such slogans.

These two slogans serve well as the epitome of controversial slogans. Firstly, they have led to much hot debate in the public successfully, being appraised as clever, also being criticized as breaching morals at the same time. Secondly, they have plain sex suggestions perse; take the first one as an example, "Wo kao ChongQing" in Chinese

Y. Niu (✉) · X. Wang · W. Li
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: niuyongge@gmail.com

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Table 1 Example of controversial slogans in recent years

Slogan[a]	Source	Features	Web pages in Baidu[b]
Wo kao Chongqing, Lichuan is yet so cool	Xinhua Net	Sex association, moral contradiction	237,000
Yichun, a City with the name of Jiao Chun	Xinhua Net	Sex association, moral contradiction	104,000

[a]These two slogans implies much sexual suggestions and vulgarity in Chinese
[b]The quantity of relevant web pages searched in Baidu with this slogan as the keyword (data of February 13, 2014)

means "I sit near the city of ChongQing" but at the same time the wording of "Wo kao" implies much vulgarity and sex suggestion (Table 1).

No doubt those slogans make the marketed destinations known, but can they really enhance the positive images of the destinations? Can they really produce effective marketing persuasion? This investigation is conducted to explore the negative effect of controversial slogans on tourism marketing.

This paper is constructed in six parts, i.e., introduction, literature review, experiment method, results, discussion and implication.

2 Literature Review

In this part extant literature is reviewed and controversial slogans are defined, and, hypotheses for this study are developed on the basis of other investigations' findings.

1. Controversial Slogans

Controversial slogans are also called provocative slogans, and are sometimes employed to make the advertising message more prominent or salient than many other competing advertisements [3]. Controversial slogans always produce much debate or complaint about their breach of morals, though they often can be known by the public. Vézina [4] proposed that controversial slogans carry two distinct chiropractors, on one hand, such slogans use inappropriate appeals including sex appeals or fear appeals, and on the other hand they often can acquire a plethora of pros and cons, which means that the public has very divergent opinions on them. Some controversial slogans, though not harmful plainly in short run, are publicized by advertisers with much endeavor, they have the potentiality of misleading persuasion in the long run, hence they can be protested against by some consumers [5].

Arrington [6] maintained that when advertising messages were in disagreement with societal tastes or customs, they would be in danger of being treated as provocative advertising, for example, some slogans in advertising described smoking as the behavior of peer hero, or praised female image of skeleton thin.

Congenial with the views of literature above mentioned, controversial slogans are defined as those that run counter to societal taste or even mores, such as conveying overt sex suggestions or fearful associations, and at the same time that can attract much attention of general audiences. In marketing practice such slogans may lead to (or have led to) audience complaints or even protests [7].

2. Slogans and Marketing Persuasion

Slogans in advertising constitute an important part of advertising messages, hence are relevant to marketing persuasion, specifically, slogans may have impact on the advertising attitude [3]. When receiving advertising messages targeted audience tend to conduct evaluations both in cognition and emotion, thus advertising attitude occurs. Effective marketing persuasion will be produced only when the advertising attitude is positive in valence, and advertising audience will vent out their anger and concerns via internet or other means of media when the advertising messages harm their morals or beliefs [8]. Advertising with controversial slogans usually go against established morals and lead to negative advertising attitude, hence may result in ineffective marketing persuasion [9].

Sengupta [10] documented that salient sex appeals in advertising slogans can result in negative emotion such as disgust or contempt in audiences, and be criticized by conventional groups, hence harm perceived quality of the brand by consumers.

Advertising slogans can convey messages of how the product or service can satisfy the need of consumers, also is an attempt to sell an image or lifestyle. Appropriate slogans always impress audiences deeply with both positive feelings and delightful imaginations and enhance their purchase intention. Successful advertising slogans, for example, often can inspire potential purchaser to look for more information of the product, including price, purchase place and so on [11].

Consumers are more willing to purchase a product or service advertised with interesting slogans, because interesting messages in advertising can bring delight or pleasure to consumers. Avraham [12] illustrated that when tourists saw brief and humor slogans (vs. provocative slogans) in marketing campaign for tourism destinations, they tended to have stronger travel intentions.

Wen [11] proposed that provocative advertising could be more eye-catching and be more accessible in audience memory, but it usually made detriments to the image of brand, and decrease the purchase intention as well, for provocative advertising oftentimes produced negative feelings in audience.

In tourism marketing delicate slogans can portray brief and key messages about the destinations and help tourists to remember the destinations and increase their interests in making a trip. On the contrary, unfit slogans in advertising can alienate tourists and harm the perceived images of the resorts. Avraham [13] conducted a survey and found that tourists were more interested in the destinations with beautiful slogans introduced in tourism handbook, and were more willing to pay more to have a sight of the places.

Glover observed [14] that the most popular tourism destinations usually employ prudently designed slogans to impress tourists and to make themselves different from their competitors.

Based on the review of extant literature, hypotheses are framed as follows:

Hypothesis 1. A controversial slogan (vs. a general slogan) tends to produce lower attitude toward advertising.

Hypothesis 2. A controversial slogan (vs. a general slogan) tends to produce lower tourism intention.

3 Method

In this part the experimental stimuli, relevant measurements, experiment process and subjects are introduced with detail.

1. Experiment Stimuli and Measurements

In the experiment a controversial slogan was designed as "Wo kao Chongqing, Lichuan is yet so cool" and a general slogan was designed to serves as a control which read as: "Wo lin Chongqing, Lichuan is yet so cool", in which "Wo lin" means that "I am near to".

When the experiment was conducted, subjects were asked to imagine that they were looking for a tourism destination and met with the advertisement with one of the slogans above mentioned.

Then three measurements were presented using a 7-point Likert scale, one measurement contained a single item to ensure the manipulation of slogans was to our end; one measurement that included three items was for advertising attitude (Cronbach's alpha was 0.89) and the last measurement which had a single item was for travel intention (See Table 2).

2. Subjects

Via internet survey service called "Wen Juan Xing", 197 subjects were enrolled, in which 80 including 45 males read the controversial slogan, and 117 including 67 males read the general slogan. The other demographics of subjects were presented in Table 3.

Table 2 Measurements used in the survey

Manipulation check item	It conveys no sex insinuation	1	2	3	4	5	6	7	It conveys much sex insinuation
Advertising attitude	This advertising is bad	1	2	3	4	5	6	7	This advertising is good
	This advertising is of bad taste	1	2	3	4	5	6	7	This advertising is of bad taste
	I don't like this advertising	1	2	3	4	5	6	7	I don't like this advertising
Travel Intention	I don't want to see this place	1	2	3	4	5	6	7	I want to see this place

Table 3 Sample demographics

Gender	48.7 % female and 51.3 % male
Age	Mean age is 31.45 with a standard deviation of 7.32, ranging from 18 to 69 year of age
Education	5.3 % senior high school or below
	17.4 % with junior college diploma
	71.1 % with Bachelor's degree
	6.3 % with master's or doctor's degree

4 Results

SPSS 18.0 was employed to process the data.

Firstly, statistical analysis was conducted to check the manipulation, and then compare the levels of advertising attitude and travel intention as well between the controversial slogan and the general slogan. Results are presented in Table 4.

There is a significant disparity in the level of sex suggestion ($M_{\text{contraversial}} = 5.11$, $SD_{\text{contraversial}} = 1.82$, $M_{\text{general}} = 3.78$, $SD_{\text{general}} = 2.25$, $t = 4.09$, $df = 97$, $p < 0.01$) between two types of slogans, which indicates that the experimental stimuli are to our end.

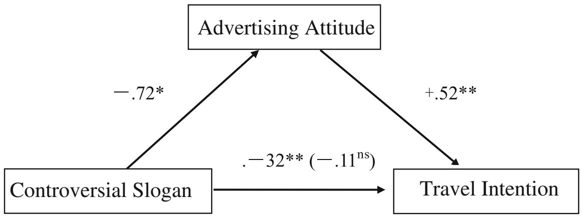
There is a significant disparity in the level of advertising attitude ($M_{\text{contraversial}} = 3.72$, $SD_{\text{contraversial}} = 1.98$, $M_{\text{general}} = 5.84$, $SD_{\text{general}} = 1.02$, $t = 9.66$, $df = 97$, $p < 0.01$) between two types of slogans.

There is a significant disparity in the level of travel intention ($M_{\text{contraversial}} = 3.36$, $SD_{\text{contraversial}} = 1.25$, $M_{\text{general}} = 5.41$, $SD_{\text{general}} = 1.08$, $t = 13.34$, $df = 97$, $p < 0.01$) between two types of slogans as well.

To examine whether advertising attitude mediated the effect of types of slogans on travel intention, we followed the procedure recommended by Muller [15]. Using level of travel intention as the dependent variable, we created a dummy variable for types of slogans, specifically, a controversial slogan is represented with $+1$, and the a general slogan is represented with -1 (Fig. 1).

Table 4 Results of statistical comparison

		M	SD	t	df	Sig.
Manipulation	Controversial slogan	5.11	1.82	4.09	97	0.000
Check item	General slogan	3.78	2.25			
Advertising	Controversial slogan	3.72	1.98	9.66	97	0.000
Attitude	General slogan	5.84	1.02			
Travel	Controversial slogan	3.36	1.25	13.34	97	0.000
Intention	General slogan	5.41	1.08			



Note. ** means that the parameters are significant at the .01 level; ns means no significant effect exists.

Fig. 1 Mediation of advertising attitude

A series of regressions showed that:

(1) A controversial slogan (vs. a general slogan) had a direct significant negative effect on the level of travel intention ($\beta = -0.32$, $t = -3.19$, $p < 0.01$);
(2) A controversial slogan (vs. a general slogan) had a direct significant negative effect on the level of advertising attitude ($\beta = -0.72$, $t = -7.43$, $p < 0.01$);
(3) When including the level of advertising attitude as a predictor, the negative effect of the controversial slogan became insignificant ($\beta = -0.11$, $t = -1.16$, $p > 0.05$), while the positive effect of advertising attitude was significant on the level of travel intention ($\beta = 0.52$, $t = 6.87$, $p < 0.01$).

Hence, the level of advertising attitude was found to explain fully why controversial slogans (vs. general slogans) lead to negative travel intention.

5 Discussion

Based on the statistical analysis results, this part offers deed discussion from two aspects, one focuses on attitudes toward advertising, and the other focuses on travel intention.

5.1 Controversial Slogans Lead to Lower Advertising Attitude

With the results of statistical analysis, we found that subjects under the condition of the controversial slogan (versus that of the general slogan) reported significant lower level of advertising attitude, which lends support to our first hypothesis. This result is congenial with many other empirical researches, for example, Izquierdo [16] found that consumers were inclined to dislike the advertising which offered messages against the context of their culture and ethics, for such messages often produce negative emotions. In mainland of China, the majority of people still cherish traditional and conservative mores though differing values and beliefs are beginning to change the established mores. In fact, advertisings serve as a means of public communication tool, and are expected to broadcast good taste in line with traditional mores. Therefore, when advertisings contain controversial slogans they can result in negative advertising attitude.

Apparently controversial slogans in advertising carry lots of messages that go against traditional mores, and therefore tend to produce negative cognitional association and negative feelings by some audience. Extant literature has documented that messages from advertising should conform to values and morals that targeted audience hold, or else the advertising may risk alienating the targeted segments or even lead to severe protest and anger from them [2]. In this investigation, the slogan “Wo kao” implies sexual suggestions and vulgarity in Chinese certainly it goes against traditional mores and lead to lower attitude toward advertising.

In fact, among many factors in advertisings which result in lower advertising attitude controversial slogans are a salient one, because languages are an important tool to convey opinions and thoughts [16]. In the process of marketing, well-designed slogans mean that the advertisings endeavor to communicate appropriate messages that consumers like to know, and on the contrary, unethical slogans may bring psychological harm to consumers.

5.2 Controversial Slogans Lead to Lower Travel Intention

The statistical analysis results show that controversial (vs. general) slogans led to lower tourism intention, which supports the second hypothesis. Advertising plays a major role in persuading consumers, and only when the messages it communicates cater to the consumers’ interests can effective persuasion ensues. Controversial slogans in advertising, however, infringe on consumers’ beliefs and values, hence lead to negative marketing persuasion.

With further mediation analysis of the effect of advertising attitude on travel intention, we found that advertising attitude can fully account the effect of controversial slogans on travel intention, which means that a controversial slogan can produce harm to advertising attitude, thus leads to lower travel intention.

Extant literature shows that tourists’ intention are driven partly by their internal needs, and partly by the external stimulus, and they are more likely to make a trip to the places when advertising messages are in line with their internal needs and good taste. Fullerton [17] found that coarse slogans in tourism advertising can make detriments to the perceived images of the destinations, and hence decrease tourists’ intention, for course slogans usually make tourists have negative associations about the marketed destination. Kyoungtae [18] proposed that strong controversial messages in advertising are more likely to inspire audiences’ negative emotions such as disgust, contempt or even fear, which will lower their willingness to purchase this brand.

Dual process model of persuasion proposed the idea that when consumers encounter an advertising, they are inclined to process the messages via tow routes, i.e., cognition path and emotional pathand then make evaluations of the advertising, and only when they have positive advertising attitude that will they have the high probability of making a purchase [16]. Obviously, advertisings with controversial slogans are disadvantaged in both routs: it leads to negative cognition association and destructive feelings in audiences. A plethora of researches have documented that good slogans lead to good persuasions, and vice versa [19].

6 Implications

In the process of tourism marketing, slogans constitute a major part of the promotion messages, and link with the image of the tourism resorts. Good slogans actually can impress the tourist positively and facilitate their decision making process. According with the results of this investigation, controversial slogans in tourism promotion can harm tourists' attitude toward the advertising, and lead to lower tourism intention as well. Hence when slogans are designed in tourism promotion, controversial messages should be used very carefully.

Extant findings maintain that advertising should convey the messages focusing on the strengths of the tourism resorts, such as distinct cultures, natural resorts and so on; few tourism promotions were successful to abstract floods of tourist with the eye catching provocative advertising, for it cannot at all communicate information to add to the image of the resorts.

Overall, controversial slogans in tourism advertising can lead to lower attitude toward advertising, and lower travel intention as well compared to well-designed slogans. When tourism destinations are marketed, controversial slogans should be avoided as much as possible.

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Research on the Formation Mechanism of Metro Emergency: A Case Study of Rear-End Accident on Shanghai Subway Line 10

Xiuquan Deng, Zhu Lu, Bing Bai and Dehua Gao

Abstract By exploring the formation mechanism of metro emergencies, theoretical support is offered for the prevention and management of emergencies. Using a case study of rear-end accident on Shanghai metro line 10, this paper introduces the Tropos goal risk framework to model the chain of risk transmission in the subway system. On the basis of the model, the emergencies' formation mechanism is researched by analysing the specific conditions and path of risks transmission and development into the emergency. Then the countermeasures to mitigate risks are proposed in order to prevent the risks from becoming the emergency. And theoretical support and methodological guidance are thereby provided for subway emergency management.

Keywords Subway · Emergency · Formation mechanism · Risk transmission

1 Introduction

In recent years, metro emergencies that frequently occurred have caused heavy loss of life and property and adversely affected city's public security and social stability. It exposes the weak points of metro emergency management. With the suddenness, uncertainty and complexity of emergencies, predicting and controlling metro emergencies faces difficulties. Merle Jacob and Tomas Hellstrom [8] have shown that the cognitive degree of emergencies' occurrence mechanism has a profound influence on the efficiency of handling and controlling emergencies. Therefore, it is worth finding the cause of occurrence as well as discovering the law of formation. And in order to minimize the damage, it is beneficial to develop reasonable and practicable

X. Deng (✉) · Z. Lu · D. Gao
School of Economics and Management, Beihang University,
Beijing 100191, People's Republic of China
e-mail: dengxiuquan@buaa.edu.cn

B. Bai
Department of Finance Management, Jiangsu Normal University,
Xuzhou 221116, People's Republic of China

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strategies based on the formation mechanism in an embryonic stage. Obviously the effective way of strengthening the subway's emergency management is exploring the formation mechanism of subway emergency.

But so far, there are few studies on formation mechanism of the metro emergency except for the issue about the evolution mechanism of public emergency that is brought into sharp focus. Public emergencies' evolution mechanism that covers the laws of occurrence, development, derivation and spread provides guidance for research on formation mechanism of the metro emergency. But the correlation between risks and emergencies is not considered in the research above. Risks caused by the uncertainty factors exist objectively in the subway system and will become an emergency when the damage approaches a certain level of severity owing to a lack of effective countermeasures dealing with the risks. Furthermore, the Metro, a system that consists of passengers, staffs, trains, tracks, subway stations as well as equipment and facilities and so on, is a socio-technical system. And in order to accomplish the common goals, the parts of the system are banded together closely. With the interdependence among the parts, risks existing in one part will impact others and even adversely affect the whole system. It is shown that risks can be transmitted and interact with each other in the system and may lead to the emergency. Thus, analysing the law that risks grow into the emergency is a way of exploring the formation mechanism of the metro emergency.

However, the studies on the emergencies which introduce the risk analysis are mainly found in the work about emergency management. The uncertainty of the emergency's outbreak is perceived [2, 7] and there exists some academic research considering the risk decision taken in the emergency management. For example, Korte [9] suggested that traditional risk analysis was of little use under complex and variable circumstances and proposed a risk decision analysis method to deal with emergencies. Liu et al. [10, 11] considered that emergency response was generally a risk decision-making problem with the uncertainty of decision information and dynamic evolvement of emergency scenarios. And two methods based on cumulative prospect theory (CPT) and Fault Tree Analysis (FTA) respectively have been presented for emergency response to support the risk decision-making. In summary, the process that risks evolve into emergencies is ignored and there is a lack of a detailed and systematic analysis for the formation mechanism of subway emergencies from the respective of risk transmission in the subway system.

Accordingly, our research introduces the Tropos Goal-Risk framework to model the network chain that represents the path of risk transmission in the subway system. Based on the model, the emergencies' formation mechanism is researched by discussing the specific conditions and ways of risks transmission and development into the emergencies. Under the guidance of the formation mechanism, the effective countermeasures are proposed for prevention and management of subway emergencies. As a result, method guidance and a supporting tool are provided to the emergency management of subway. In this paper, we simply explore the formation mechanism by using an example of rear-end collision on Shanghai subway line 10. And on the basis of this case study, the relevant theories will be concluded and the research findings will be further applied to practice in our future work.

2 Risk Transmission Chain Model Building for Rear-End Collision

The rear-end collision on Line 10 of the Shanghai subway occurred on Tuesday afternoon, September 27, 2011. On that day the trains had to be directed via phone by subway staff rather than by electric signals and run at slower speeds owing to a failure of the signal system. Then a subway train rear-ended another. That day was regarded as the darkest day in the history of Shanghai Metro. 275 passengers suffered minor injuries and 20 passengers were seriously injured in this accident. And it caused great harm to the citizens of Shanghai. According to the investigation, what directly caused the crash were the errors of manual operation. Actually, there are hidden dangers behind the crash.

According to the actual situation, this paper introduces the Tropos Goal-Risk framework to model the risk transmission in the subway system.

2.1 Tropos Goal-Risk Framework

Tropos Goal-Risk framework [4], which extended the Tropos goal modeling framework [5], is a goal-oriented framework for modeling and analysing risk in the requirements analysis phase of software development. It was proposed by the researchers from Department of Information Engineering and Computer Science in Italian University of TRENTO. Initially, the framework was developed for analysing the risks of single actors. Asnar et al. [3] later had extended it to model risks by considering the interdependency among the actors in organizational settings. As a social-technical system, the subway system's parts rely heavily on each other in order to fulfill their respective objectives and collaborate for reaching common goals [6]. And risks can be transmitted in the subway system along the dependencies among the parts. So it is suitable to adopt the Tropos Goal-Risk framework which able to describe risks also based on the relationships among the actors within the organization to model and analyse the subway system. Meanwhile, this framework is also a goal-oriented approach that state the why [1], besides what and how by clearly defining the dependencies. It helps study the mechanism of risk transmission.

Tropos Goal-Risk framework is composed of a set of nodes, dependency relations, impact relations and relationships among constructs. The nodes comprise actors, goals, tasks, resources and events. The relationships among constructs are partitioned into decomposition, means-end, contribution and alleviation relations [4]. The dependency between two actors denotes that one actor depends on another actor to attain goals, execute tasks, or furnish resources for some reason. This framework consists of three conceptual layers (i.e., asset, event, and treatment layer) [4]. In the asset layer, the actors and their interests can be identified and refined. And the relations of these elements are analyzed. Uncertain events defined as a potential circumstance that could cause harm or loss along their impacts to the asset layer can be identified and analyzed in the event layer. The countermeasures to be introduced in order to mitigate risks can be analyzed in the treatment layer. A detail description and analysis about the constructs of framework and the modeling phases will be illustrated according to the specific example of accident later in this paper.

2.2 Subway Social-Technical System Model

Risks, gathering and transmitted in the subway system, can finally become the emergency. According to the background of the case, this paper firstly models the subway system which gives rise to the accident by applying the Tropos Goal-Risk framework. In the subway system model, the parts and the dependencies among them as well as the risks are captured and described. And the subway system model involves the first two layers of the framework, namely asset layer and event layer.

Modeling the asset layer aims to identify the parts of system and model them as actors and presents the actors' intentions based on the concept of framework including goal, task and resource. And the dependencies among the actors can be modeled by adopting the constructs such as goal, task and resource dependency. In this case, the actors which are related to the collision in the subway system are operation organizations (i.e. , dispatching control center and station), vehicle system, signal system, power system as well as passenger. By analyzing the actors' goals and tasks, the analysis proceeds to identify the dependencies among actors: Actors may not be able to fully achieve their goals or execute the task by themselves for some reasons such as the lack of the resources, so they can either appoint other actors to fulfill them entirely or decompose themselves and assign part of them to other actors [4]. In particular, actor passenger takes the subway and is associated with two relevant goals prevention of loss of life and property (G3) as well as the timely arrival (G4). In order to fulfill these goals, other actors cooperate with each other in the system and it brings about a set of strategic dependencies among actors as described in Table 1. In Table 1, an actor (the depender) depends on another actor (the dependee) for goals to be achieved, tasks to be executed, and resources to be delivered (the dependum).

Once the asset layer has been modeled, the uncertainties that could cause harm or loss can be identified in the actor and denoted by events in the event layer. Then the events' impact on the asset layer is depicted. So the risk is modeled with two parts that are event and impact relation on the goals or tasks. For the actor station, in Fig. 1 the events obstruct the finish of task monitor and organize the train operation (T4). It affects the quality of work and even probably leads to the failure of task, thereby impacting the security of subway operation.

The events existing in the actors of this accident are described in Table 2. The model for the subway system where the collision happened is presented as the first two layers in Fig. 2. And based on the Tropos Goal-Risk framework presented in [4], the constructs that compose the model are specified in Table 3.

Table 1 Dependencies among the actors in the accident

Type of dependency	Depender	Dependum	Dependee	Explanation
Goal dependency	Passenger	Goal: prevention of loss of life and property; the timely arrival	Vehicle system	The vehicle system directly carries passengers, so it is important to ensure that the trains safely work
Task dependency	Vehicle system	Task: dispatch and control	Signal system	The traffic on Shanghai subway line 10 is automatically controlled by CBTC system (Communications Based Train Control System)
	Signal system	Task: supply electric power	Power system	The operation of the signal system needs electricity supply
Resource dependency	Dispatching control center	Information: location of trains	Vehicle system	To keep the running safe, the information of the trains' location needs to be offered
	Dispatching control center	Information: situation of block section	Station	Before giving the telephone block commands, dispatching control center needs to confirm that the block section is free
	Vehicle system	Information: traffic dispatching orders	Dispatching control center	The manual operation will be adopted in case of failures of signal system.

2.3 Risk Transmission Chain Model

As shown in Fig. 2, the actors cooperating with each other form the network chain structure to support the operation of the metro system. It is obvious that risks can be transmitted in the system due to the dependencies and the path of risk transmission is also the network chain. Accordingly, the risk transmission chain can be modeled by being extracted from the the network of the metro system.

Based on the system model, it is shown that the uncertain events existing in an actor may lead to the deviation from the objectives. It poses a risk to the actor. In order to identify and control the risk transmission effectively, this paper extracts the

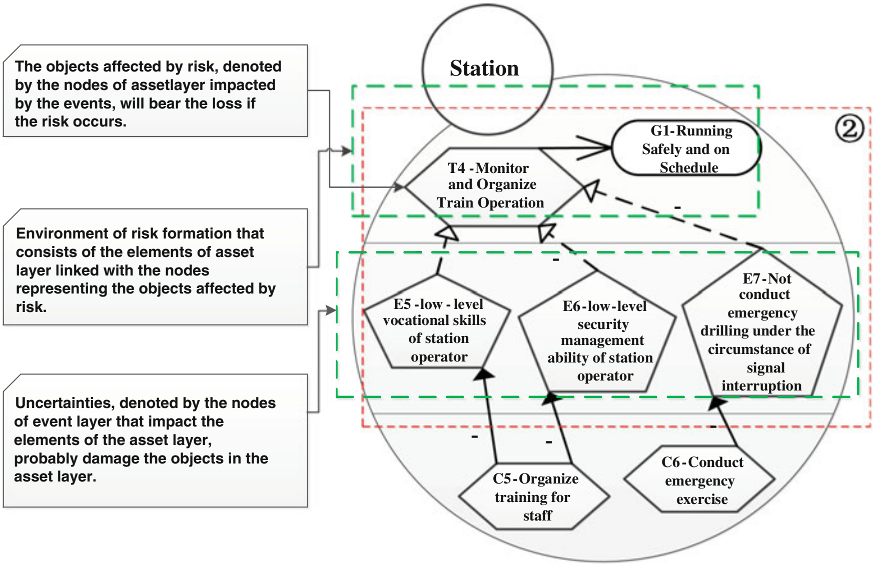


Fig. 1 Elements of the risk unit

Table 2 Uncertainties identified in the actors of this accident

Actor	Uncertainties
Dispatching control center	1. Not clearly define the requirements for check and monitor during the dispatching process
	2. Not add the related requirements for operation management such as telephone block working to the contingency plan
	3. Low-level vocational skills of dispatcher
	4. Low-level security management ability of dispatcher
Station	1. Low-level vocational skills of station operator
	2. Low-level security management ability of station operator
	3. Not conduct the emergency drilling under the circumstance of signal interruption
Power system	1. Not consider the hazards existing in the maintenance on the power supply facilities under the circumstance of subway operation
	2. Lack of the plan for the maintenance during the subway operation
	3. Not take precautions

relatively independent parts that probably cause risks within the actor, defining them as the risk unit. The components of the risk unit are illustrated by taking the actor station for example (Fig. 1). The risk, considered as a property of the unit, results from the interactions of the elements.

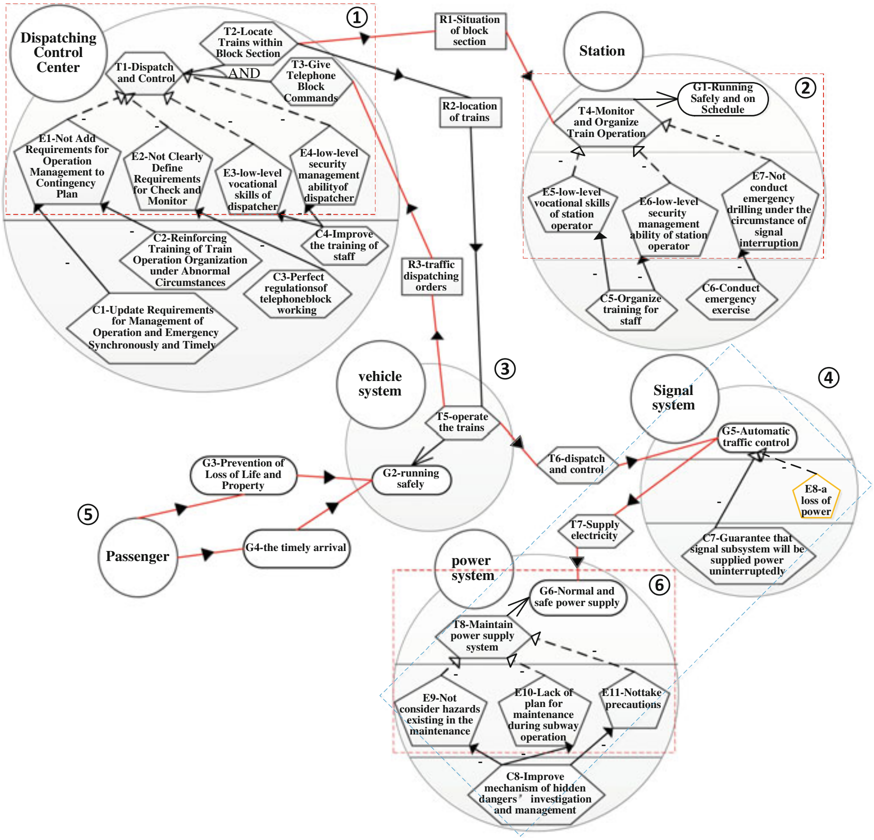
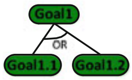
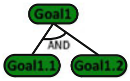
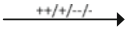
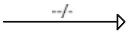
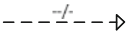


Fig. 2 Subway system and risk transmission chain model for rear-end accident including risk treatments. *Note* "-" simply presents that the event negatively affect the asset layer rather than accurately describes the degree of damage

The risk units are not always at risk. In this accident, there are uncertainties in the units within the actors of vehicle system, passengers and signal system, but these units are in the state of safety before affected by the impact of risk transmission because the uncertainties do not cause risks. With the limit of length, all the elements of the risk units that are safe are not presented in Fig. 2. And the risky units, bordered by the red dotted lines, form inside the actors involving dispatching control center, station and power system. We number all the risk units in Fig. 2.

On the basis of the proposed concept of the risk transmission from the researches on other fields, this paper defines the risk transmission as the process that the uncertainties or the results caused by risk are transferred from some risky units to other units (either risky or safety) through the carrier under the necessary conditions. According to the definition, it is seen that a basic process of risk transmission within

Table 3 Constructs of model

Type	Name	Icon	Description
Nodes	Actors		Parts of the subway system which have strategic goals and achieve them by performing tasks
	Goals		Objectives that actors intend to fulfill
	Tasks		Sequences of actions which are used to achieve goals in the asset layer or to treat events in the treatment layer
	Resources		A physical or an informational entity that can be used to perform the task or achieve the goal
	Events		Uncertain circumstances which can have a negative impact on the achievement of goals or execution of tasks in the asset layer
Dependency relations			Dependency relations represent relationships among actors
Relationships among constructs	OR decomposition		Alternatives for the satisfaction of goals, execution of tasks, or the occurrence of events can be modeled by OR decomposition
	AND decomposition		Objects (i.e., goals, tasks, and events) can be decomposed in subobjects by using AND decomposition
	Means-end relations		Means-end relations identify the tasks used to fulfill goals
	Contribution relations		Contribution relations denote the effects of a node (i.e., a goal, a task, and an event) on another. Contribution relations can be of 4 types: ++, +, –, and-, which respectively present the positive and negative influences
	Alleviation relations		Alleviation relations, which can be distinguished into: - and –, are used to model the reduction of the severity of events by adopting the treatments
Impact relations			Impact relations depict the severity of an event on the asset layer which can model opportunities or risks. In this paper, only the events with negative impacts (i.e., –,-) are considered

the subway system consists of the risky units serving as the transmitter, propellants for transmission (i.e. the necessary conditions) and the risk units as the receiver.

Then we extract the path of risk transmission from the subway system. The transmitters and receivers are identified firstly. For example, in Fig. 2 the risk unit ⑥ within the actor power system serves as the transmitter and the risk unit ④ of the actor signal system is the receiver. Next determine the propellants for transmission. The actors relying on each other in the subway system creates the ideal conditions for risk transmission. Therefore, the dependencies between the two actors are the propellants for transmission. The dependencies can be classified according to the dependum. In this case, there are three types, namely goal dependency, task dependency and resource dependency. The risk transmission between the risk units ④ and ⑥ bordered by the blue dotted lines in Fig. 2. And the specific process of risk transmission will be analysed in the following research on risk transmission's modes.

Propelled by the dependencies among actors, risks are exported from the risky unit and transmitted against the direction of the dependency relations. It forms the network chain structure namely the risk transmission chain of the collision. And the direction of dependency relations is indicated by the arrow and the path of risk transmission is denoted by the red lines in Fig. 2. And according to the Tropos Goal-Risk framework presented in [4], the constructs that compose the model are described in Table 3.

3 Research on the Formation Mechanism of Rear-End Collision

The subway emergency is the realization of risks. The emergencies' formation mechanism can be researched by exploring the condition and the path of risk developing into the emergencies from the respective of risk transmission. The law that risks are transmitted in the subway system can be studied by analysing the formation mechanism of risk transmission chain. Based on the model of the risk transmission, it is seen that the chain is actually a combination of various types of transmission relations among the risk units. Therefore, the formative modes of transmission between the risk units are analysed starting from the parts of the chain. Based on this, we discuss the mechanism of risk transmission and the process that risk became the accident through studying the path of risk transmission as a whole.

On the basis of the model for risk transmission chain, we analyse and summarize the transmission modes of risk in this case which include six types, namely risk transfer, overlap, control, mutation, many to one and one to one, as shown in Table 4.

1. Risk transfer

The way of risk transfer is that the objects affected by risk or the uncertainties are transferred from the transmitter to the receiver (e.g., from ① to ③). And the uncertainties are transferred via the objects affected by risk. For instance, the events (i.e., E1, E2, E3 and E4) of the risk unit ① obstruct the performance of the task

Table 4 Modes of risk transmission in this case

Mode of risk transmission	Transmitter	Receiver
Risk transfer	①	③
Risk overlap	②	①
Risk control	④	③
Risk mutation	⑥	④
	①	③
	③	⑤
Risk transmission from many to one	① and ④	③
Risk transmission from one to one	Including all the transmission modes except for the risk transmission from many to one	

dispatch and control (T1): the dispatcher gives false orders under the circumstance that all the trains in the block section are not accurately located. The vehicle system's demand for the information of dispatch pushes the objects affected by risk (i.e., wrong dispatching command) to transfer.

2. Risk overlap

The risks in the receiver overlap those from the transmitter (e.g., from ② to ①). For example, there are potential dangers existing in the risk unit ① of actor Dispatching control center. The risk adds to the unit ① through getting the inaccurate information about the situation of the fault section from the risk unit ② of actor station. It results in the actor dispatching control center making the wrong decisions. And these risks impact the finish of task dispatch and control (T1) jointly.

3. Risk control

The risks are controlled after moving to the other units (e.g., from ④ to ③). For instance, the event a loss of power (E8) which causes the failure of signal system obstructs the finish of the task dispatch and control (T6). But this risk does not impact the task operate the trains (T5) because the automatic control system can be insteaded by the manual operation.

4. Risk mutation

As the uncertainties and environment of risk formation change, a safety unit can be transformed into a risky unit and vice versa (e.g., from ⑥ to ④, from ① to ③ as well as from ③ to ⑤). For example, the failure of the task supply electricity (T7) caused by the events of the unit ⑥ affects the actor signal system along the task dependency between the actor signal system and power system. It adds the event a loss of power (E8) to the the unit ④ that changes its environment of risk formation and obstructs the goal automatic traffic control (G5). It converts the safe unit ④ into the riskty unit.

5. Risk transmission from many to one

The risks are transmitted from several units to one another (e.g., from ① and ④ to ③). The risks received by the units serving as receiver involve various types.

6. Risk transmission from one to one

The risks are transmitted from one unit to another. According to the analysis above, all the transmission modes belong to this type except for the risk transmission from many to one in this case.

The way of risk transmission is not out of order. The risks are transmitted along certain path with obvious directivity. During the process of transmission, risks are transmitted against the direction of dependency relations among the actors from the initial risky units to the last receivers. According to the categories of transmission modes and the direction of risk transmission in this case, the risk transmission network chain of this example is a hybird network. A sudden loss of power caused by the maintenance lead the signal system to fail, forcing the trains to be operated manually. And then the dispatching control center fail to follow relevant management rules, which led two trains to rear end. Its negative impact spread to a certain range and the risks finally became the actual emergency.

4 Countermeasure Analysis

Under the guidance of the formation mechanism of this subway trains rear-end accident, the countermeasures to mitigate risks are proposed based on the structure and features of risk transmission chain to model the treatment layer that is the third layer of the Tropos Goal-Risk framework. The treatment layer aims at blocking the path of risks becoming the emergency so as to prevent and control the emergency.

Transmitting risks successfully depends on some basic conditions. So the treatments can be elicited through controlling the basic elements constituting the process of risk transmission.

1. Controlling the risky units severing as transmitters

The transmitter may not be the risk source because its risk can come from other risk units. In this paper, we focus on the risk units that internally generate risk. Risks are caused by the uncertainties. Thus a treatment may impact on a risk in the way of reducing its likelihood which is modeled using a contribution relation to the event. For instance, in risk unit ②, the countermeasure organize training for staff (C5) negatively affects the event low-level vocational skills and security management ability of station operator (i.e., E5 and E6) in order to result in a less likely event.

2. Controlling the propellants for transmission

The dependencies between the two actors are the propellants for transmission. Therefore, this paper takes measures that can loosen the dependencies to forbid risks to proceed. For example, in case of a sudden loss of power, the signal system can continue to work by adopting alternatives such as using UPS (Uninterrupted Power Supply) which can provide the emergency power like a storage battery.

3. Controlling the risk units severing as receivers

If risks are received by the risk units, risks can be mitigated by reducing its severity. This type of countermeasure is modeled as the alleviation relation which can mitigate severity of an event to the asset layer. For instance in Fig. 2, the relation between the countermeasure guarantees that the signal system will be supplied power uninterruptedly (C7) to the impact relation between the event a loss of power (E8) and goal automatic traffic control (G5).

5 Conclusion

This paper uses a case of Shanghai subway trains rear-end collision to explore the formation mechanism of metro emergency through analysing the transmission of risk. With Tropos Goal-Risk framework, the subway system and risk transmission chain related to the accident are modeled. On the basis of the model, the law of risk transmission is researched and the countermeasures that prevent risk from becoming the emergencies are proposed. Our work not only provides the emergency management with theoretical analysis tool, but also has certain guiding significance in practice. But there is a lack of the combination of model and risk evaluation. Therefore, we will consider the assessment of the likelihood and severity of risk in our future study.

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An Allocation Strategy in Cooperative Game Based on Multiplayer Decision

Jianzhong Chen

Abstract Based on the importance analysis for the context of win-win cooperation in the knowledge economy era, several classic allocation strategy under conditions of multiplayer cooperation game is discussed, and an allocation strategy based multiplayer evaluation decision is proposed. It can effectively integrate the various interests in preference to choose the kinds of trade-offs, distinct ideas, simply computationally and strong economic sense. Finally an example presented to prove the feasibility of this method.

Keywords Cooperative game · Allocation strategy · Group decision-making

1 Introduction

"Profit maximization" is the best state in western economics to pursue. In a fully competitive market assumptions of classical economics, profit maximization in touch with rational economic man concept together, constitute the foundation of modern Western economics. Under this theoretical guidance enterprise used typical non-cooperative zero-sum game to maximize economic benefits as its own business objective. It becomes the only option of simply focusing on competitive strategy and the formation of a non-win-lose competition. Therefore achievement two win or multi-win game is theoretically possible in the actual social and economic reality [1, 2].

However, in the knowledge and information economy era, the traditional pattern of business decisions are being broken, the competitiveness of enterprises and other economic entities are increasingly intertwined reflecting the characteristics of competition and cooperation, in their existed principles the "exclusive" has been replaced by the "cooperation".

J. Chen (✉)
Information School, Guizhou University of Finance and Economics,
Guiyang 550004, People's Republic of China
e-mail: Chen_1154@aliyun.com

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Exclusive competition only considers themselves interests, which is only relied on their own resources, and will not only increase the cost of the competition, but also difficult to play to their strengths; otherwise cooperation between entities can bring union $1+1 > 2$ synthetic benefits and achieve optimal utilization of resources [3, 4].

The consistency of maximizing social benefit and individual interests in fully competitive market is Pareto optimal achieved by transacting through maximizing behavior of the parties. In the promise of classical assumption that a perfectly competitive market cannot be satisfied, inquiry and design various effective incentive-restraint mechanisms to translate the traditional zero-sum game competitive strategy into that of a non-zero sum and cooperative game to make the maximum the balance approaching the Pareto optimal is important research topic of modern management science [5].

In the game with incomplete information the two sides select the dominant strategy from the perspective of individual rationality will result in adverse selection, the two sides fall into Prisoner's Dilemma. The participants cannot form alliance and joint actions could lead to not being able to communicate, and there is a conflict of interest between them, or they could not reach a binding agreement. It showed that the key of cooperative games is forming the opportunity of binding agreements and eventually unifying individual and organization rationality, efficiency and fairness.

Therefore in the premise of the imperfectly competitive market realities and information asymmetry multi-aspect transaction, human emotions and moral constraints existed by using system constraints legal, moral and other limited personal opinion rational side of the game while providing more complete information, to optimize the benefits and win-win economic and social beneficial result is hotspot of cooperative game.

This article discusses how to achieve a reasonable distribution of co-operation, in the first part introduction distribution of a cooperative game in the individuals with individual rational, in the second part discussion three classical distribution method to analyze the process of cooperative games, in the three part for the stability of players' cooperation income distribution alliance, a method is proposed based on multiplayer decision-making to achieve Pareto optimal allocation and maximize and personal interests and in the fourth part an example presented to prove the feasibility of this method.

2 Distribution of a Cooperative Game

Game theory is involved in two or more acts of human decision-making process, where each person's behavior depends not only on the outcome of their actions, but also on the actions of other actors. Game involves players, game strategies, information, pay off, the outcome, equilibrium and other elements. A fundamental assumption is implied that the participants conducted a rational choice are to maximize the benefits of self-seekers and supporters.

In the game model, two type of division as cooperative game or non-cooperative can be determined by the player‘s behavior. The main difference between this two is that when the behavior of game player interaction, game parties can reach a binding agreement. If the game is cooperative (Cooperative Game), with a gain of more than interest of the members of each separate internal business, at the same time for a Pareto improvement within the Commonwealth should have the characteristics of the allocation rules. Compared with non-cooperative game that it stressed individuals rational and maximize income decision, the result is often inefficient. In cooperative game it is to emphasized that a organization rational sense, efficiency, impartiality, fairness, exclusive competition actually reflected in the "win-win" or "more win" strategy, finally achieve higher efficiency or effectiveness.

A classic research case discusses the A, B, C three companies facing operational issues of cooperation or independent. Income of cooperation or independent operating showed in Table 1 [6].

Table 1 shows that any two alliances will get additional income and caused the third reduction but the total operating revenue in excess of independence. When the same three coalition, total revenue will exceed separate operations revenue so that there is a joint net income. The rational decision of the three actions is cooperation to obtained Pareto optimal result. But whether format alliance and alliance stability mainly depends on that the distribution of alliance income is reasonable or accepted or not. With x, y, z represents income then a necessary conditions for the A, B, C three companies for the successful cooperation alliance should be met to: $x + y \geq 59,\ z \geq 5$; $x + z \geq 45,\ y \geq 22$; $y + z \geq 38, x \geq 30$; $x + y + z = 77$.

According to the solution set of the above conditions can be drawn as shown in Fig. 1.

And indicating that meet the above conditions are not the only solution, but also the need for further allocation.

Table 1 Income of different ways of operating three companies

Coalition way	Coalition order	Operating befits
Alone operation	A	32
	B	23
	C	6
Two coalition	AB, C	59, 5
	AC, B	45, 22
	BC, A	39, 30
Three coalition	ABC	77

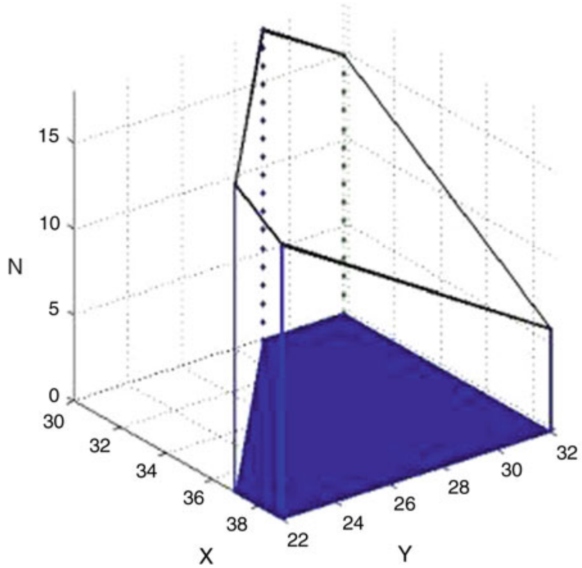

Fig. 1 Assigned Pareto optimal solution set

3 Cooperation Game Allocation Strategy

Let N the set of participants, S is a coalition $N(S \in N)$, $V(N)$ is defined function in a joint set, indicating regardless of how other people act, coalition members through cooperation in S the maximum income that can be achieved, if there is no net gain cooperative game cannot exist because of the lack of intrinsic motivation to form a coalition. Only the presence of

$$V(N) > \sum V(i)(i \in N) \text{ or } V(N) > \sum V(S)(S \in N),$$

in this cooperative game the case of the combined net income can exist alliance.

Cooperative game solution is essentially a rational allocation of each participant total receipts $V(N)$. An assignment of participants can be showed as $x = (x_1, x_2, \ldots, x_n)$, where x_i is the share of income of the ith player. A reasonable distribution should satisfy the following two conditions:

$$\text{Collective rationality: } \sum x_i \geq V(S), \forall S \in N. \tag{1}$$

$$\text{Overall rationality: } \sum x_i = V(N). \tag{2}$$

Satisfy Eqs. (1), (2) the allocation x collection called core, in most cases there is a cooperative game solution nucleus, it means set of non-dominated solutions to meet Pareto optimal [2, 7]. C is further set of n-person cooperative game core, the necessary and sufficient conditions are $x \in C$, for any $S \in I$, has $\sum x_i \geq C(S)$.

It means that in the stable distribution, any participant combinations have no willingness withdraw from the union, because the formation of a new coalition cannot obtain greater benefits. Since there may be multiple allocation scheme in cores, which need to meet the collective rationality and reasonableness of the overall condition of the solution set, according to some "fair" rule to coordinate among the participants in order to select a way to make everyone satisfied the allocation scheme.

For solving such cooperation game problems have the following classical methods.

Shapley proposed alliance is calculated according to the order of the members and then average earnings method, called Shapley value [2]:

$$x_i = \sum_{S \in N} \frac{(s-i)!(n-S)!}{n!} \left[V(S) - V(S-i) \right]. \tag{3}$$

It calculated benefits according to the order of the alliance members, the advantages that the proceeds be apportioned in accordance with all the marginal contribution, participants benefit equal to the corresponding average of the marginal contribution of each person involved in an alliance of his involvement.

Howard Raiffa according to earnings starting to join the alliance, and the subsequent formation of conduct in order to allocate the distribution alliance to work together for the benefit, taking into account both the upper and lower distribution, but also draws on Shapley thought, and it needs known Union case only $(n+1)$ species, low information collection difficult [2].

$$x_i = \frac{(n-1)}{n} x_j + \frac{1}{n} \left[\frac{x_j}{2} + \frac{1}{2(n-1)} \sum_{j \neq i} x_j \right]. \tag{4}$$

Nash-Hasanyi negotiation programming model for solving optimization model places:

$$\max \prod_{i=1}^{n} (x_i - c_i) \tag{5}$$
$$s.t.\ \ x_i \geq c_i, \quad i = 1, 2, \ldots, n, X \in R.$$

In this c_i is state of negotiator for the status, x_i is its consequences and R is the feasible region.

With these three classic example of cooperative game on the allocation of income for the program in Table 2.

These three methods can obtain the allocation result of Pareto optimal, but there are complex and difficult of collection information and decision-making criteria too simple to adapt various different situations of decision-making problems, especially not in line with the individual maximize the benefits, leading to the risk of an unstable coalition and not win final results.

Table 2 Income distribution of three classical methods

Allocations		Initial value	x	y	z	Total
①	Nash–Hasanyi	$C = (32, 23, 6)$	37.33	28.33	11.33	77
②		$C = (30, 22, 5)$	36.67	28.67	11.67	77
③	Shapley		36.83	28.33	11.67	77
④	Raiffa		36.58	27.92	12.5	77

4 Multiplayer Evaluation Decision Allocation Strategy

In a socio-economic issues complex decision-making, through cooperation and partly cooperation to process the problem of interest multi-conflict, and thus meet the precondition of ensuring the interests of others and their own interests, eventually achieving a win-win. It contains the essence concept of cooperative game on collective rationality and maximum the individual benefits. It can be provided as a new method of the distribution cooperative game interest.

Participates in the group evaluation decision-making methods can fully express their individual preferences, multiple participants select together to solve single decision maker information incompleteness and get the solution with more group satisfaction, which has a wide range of theoretical and applied value [6]. To solve the cooperative game with multiplayer allocation problem we have the following premise:

Decision-makers have individual part rational, so they have the ability and experience to judge the decision-making problems through comparing to select a different situation in the effective decision time;

The group composed by a limited number of decision-makers is cooperative, group preferences can be formed based on collection the basis of personal preference;

In the groups decision-making cooperative game process, information asymmetry of in participants decline and finally it can be reached effective groups decision-making result with certain group satisfaction.

Multiplayer decisions quintuple system can be expressed as: $GDS = \{M, O, W, S, C\}$. Among them,

M denotes the set of decision-making members, the player set in cooperative game, denoted by $N = (1, 2, \ldots, m)$, m participant's right weight $\alpha = (\alpha_1, \alpha_2, \ldots, \alpha_m)$, can be set according to marginal contribution of participants or other criteria;

S is the set of a finite number of solutions, when the number of parties involved in m increases, the number of possible different league to grow rapidly, we may assume that the actual effective alliance formation is limited, then the decision-making program number is possible effective alliances plus the full cooperation and uncooperative, denoted by n, a program set $x = (x_1, x_2, \ldots, x_n)$;

W represents the set of decision criteria, assumption decision-makers collecting all of possible net income as efficiency utility consequence of the decision-making, and the parties have agreed to participate in the criteria for revenue divided. The positive natural number sequence used as the level of decision-makers evaluate the effectiveness of scores, and the negative natural numbers used as loss assessment scores in the league outside, final evaluation and decision matrix A_{kn}, where a_{ij} represents the ith decision-making participants for jth effective program evaluation.

O represents the target set of decision problem, the participants are rational means that they will select overall revenue satisfaction program in a limited set to meet their preference, that is, Pareto optimal and individual benefits maximum balance.

So that multiplayer final evaluation and decision expressed as:

$$O = \alpha \times A = (\alpha_1, \alpha_2, \ldots, \alpha_k) \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{k1} & \cdots & a_{kn} \end{pmatrix} = (o_1, o_2, \ldots, o_n). \tag{6}$$

Finally, sorting o_i according to its synthetically value we can get the final solution order, that is, the Pareto optimal result.

5 Digital Cases

The above case expressed the issues there are three makers, five decision-making problems, allocation strategy is to maximize net income and average allocation in the league, decision-making criteria are allocated to maximize or satisfy their own interests, and the final distribution of earnings income is calculated as Table 3.

The table shows in the five programs, participant A got utility distribution for (32, 33.5, 35, 30, 37.33), B's utility is (23, 24, 5, 22, 27, 28.33), C's utility for (6, 5, 9, 10, 11.33); according to their utility maximization sorting, sorting A program is (4, 2, 3, 5, 1), the program is the sort of B (4, 3, 5, 2, 1), C is the sort program (4, 5, 3, 2, 1).

Table 3 Five benefits different distribution scheme

Scheme	Coalition way	Coalition order	Operating income	Net income	Income distribution	Actual income
X_1	Alone operation	A, B, C	32, 23, 6	0	0	32, 23, 6
X_2	Two coalition	AB, C	59, 5	3	1.5	33.5, 24.5, 5
X_3	Two coalition	AC, B	45, 22	6	3	35, 22, 9
X_4	Two coalition	BC, A	30, 39	8	4	30, 27, 10
X_5	Full coalition	ABC	77	16	5.33	37.33, 28.33, 11.33

Decision-makers take into account the weight to set fair competition within three separate companies, the weight set as the same of the $\alpha(1/3, 1/3, 1/3)$; evaluation value converted to a positive natural number sequence as a utility level of decision makers, a negative natural numbers in the league outside evaluation equal to the loss scores, the players A, B, C each evaluation of the program is (1, 2, 3, −1, 4), (1, 2, −1, 3, 4) and (1, −1, 2, 3, 4).

The final group evaluation value:

$$O = \alpha A = (1/3, 1/3, 1/3)\begin{pmatrix} 1 & 2 & 3 & -1 & 4 \\ 1 & 2 & -1 & 3 & 4 \\ 1 & -1 & 2 & 3 & 4 \end{pmatrix} = (1, 1, 1.33, 1.67, 4).$$

Sort by size evaluation value, t three decision-makers on the five program's set is priority as follow: $X_5 > X_4 > X_3 > X_1 = X_2$.

The group decision-making select the final program as X_5, namely tripartite cooperation program, this program can achieve Pareto optimal, the total maximum effectiveness, while also protect their own interests, can be compared with the operating method alone in tripartite negotiations with Nash allocation under negotiation results are consistent starting point, but with different starting negotiations Nash have different allocation schemes, Shapley and Raiffa allocation strategy also only some certain rationality.

6 Conclusion

In the knowledge economy era social and economic decision making issues are more and more transformed from traditional single exclusive mode to win-win cooperation, but only if cooperation is to generate new revenue and a reasonable distribution of constraints can be formed in participants. It can be said that the participants in the decision-making process is a measure of cooperation, some alliances and non-cooperation. So multiform allocation criteria should be provided for participants to choose their diversity in a satisfactory manner, which is the key to stability collaborative decision-making. In this paper we propose a different decision-making processes ideas and methods in conflict management and distribution of cooperative game, can effectively integrate the various interests in preference to choose the kinds of trade-offs, distinct ideas, simply computationally and strong economic sense, the classic case calculation is proved its feasibility and effectiveness, and can be used in the actual allocation and conflict cooperative game.

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Evaluation of New Media's Influences on College Students Based on Factor Analysis

Qisheng Chen, Haitao Liu, Lu Cao and Chan Han

Abstract This study applied the factor analysis method to evaluate new media's influences on college students. Firstly, it elaborated new media's influences on college students and highlighted the importance of new media in carrying out student works. Then, an evaluation index system was established to assess new media's influences specifically. The factor analysis method was applied to evaluate the influences of 5 types of currently-popular new media, and based on the research findings, countermeasures and recommendations were proposed with regard to the use of new media in propagation and student works.

Keywords New media's influences · College students · Factor analysis

1 Introduction

With the continuous advancement of digital technology and the escalating demand for network applications, new media has undergone considerable development in recent years. In the face of globalization and informatization, how to provide an objective and scientific evaluation on new media's influences has become not only a commercial but also a social issue [1]. With the popularization of mobile network and the progress of college informatization, new media has produced significant impacts on the daily life and learning activities of both teachers and students. There is a great significance to explore the propagation regularity of college new media, to investigate students' user behaviors and habits, and to evaluate new media's influences on college students. The research findings will be helpful for the college management to apply new media effectively in propagation and student works, to build a healthy campus network culture, and to promote the construction of campus informatization.

New media propagation has become a hot issue in recent years. Many scholars have carried out research to evaluate Internet and new media's influences.

Q. Chen (✉) · H. Liu · L. Gao · C. Han
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: chenqisheng@scu.edu.cn

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Christakou and Klimis [2] discussed the impact of blogs and social media on the reputation of banks and on their profitability. Bresinger et al. [3] gave the point that viewing news media online seems to increase one's feelings of having the ability to dissent. Juliana [4] analyzed innovative pedagogies and learning strategies in Massive Open Online Courses (MOOCS). Van Dusen [5] addressed how cost and affordability impact on universal access, noting that current virtual and distance education options will result in a digital divide. Yin [6] believed that people have stepped into an age called "MicroAge" and then bring some effective suggestions to the use of new media. Qiao [7] used AHP to evaluate the soft power of China media, which revealed that new media was developing rapidly, represented by SNS sites and microblogs, and its social influence had bypassed traditional print media and was almost comparable to the Internet. Yan [8] discussed the public's evaluation of networks and traditional media, through the data analysis of an urban and rural residents survey from China's 31 provinces, municipalities and autonomous regions in 2010.

This paper, on the basis of the influence perspective, proposed a concept to evaluate the influences of different types of new media on college students. Firstly, an evaluation index system was established, and 5 types of currently-popular new media were selected as the evaluation objects from the empirical point of view. A survey questionnaire was conducted in Sichuan University for data collection. Then, the factor analysis method was applied to rank the various new media in terms of the influence on college students. The results would provide important reference for the improvement of college student works, and the construction of informatization and campus culture. Meanwhile, pertinent recommendations were proposed with regard to the application of new media in network ideological and political education as well as in student works.

2 Establishment of the Evaluation Index System on New Media's Influences

2.1 Classification of New Media

Cao [9] suggested that, from the perspective of expression form, new media can be generally classified into three categories: instant messaging, forum, and exhibition. According to the college students' new media user behaviors, this paper classified new media into five categories: instant messaging (represented by QQ and Wechat), microblogging (represented by Sina and Tencent micro-blog), social media (represented by Renren and Kaixin), blog (represented by Sina blog), and post bar & forum (represented by Baidu Post Bar and Tianya forum). Based on the classification of new media, the influences of different types of new media could be objectively evaluated in order to analyze their commonness and uniqueness.

2.2 The Evaluation Index System on New Media's Influences

New media's influences refer to the force that dominates public ideas and behaviors through dissemination of information or other approaches. On one hand, media's influence means that media produces impacts or effects on audience's behaviors, beliefs, attitudes or knowledge structures. On the other hand, it also involves the impacts of mass media on the entire society and cultural system. This part of influences mainly refers to the influences of the media contents.

In this paper, the construction of the evaluation index system on different types of new media was mainly based on the relevant research of the following institutions and scholars: Qiu [10] proposed an evaluation index system for network information resources which consisted of 4 aspects, information contents, layout design, degree of user-friendliness and other indicators. Ren [11] suggested that the network media's influence is specifically expressed as the popularity index of the website and the loyalty and adhesion of the website users. Chen [12] proposed an evaluation system for new media's influences. Cyberstacks, a well-known new media evaluation service network, referenced to the traditional database evaluation method and established a new media evaluation index from 4 aspects, the authority, accuracy and clarity of the network information, the uniqueness and novelty of the contents, the relevant comments, and the community demand.

On the basis of above research and combining with empirical research and the Delphi method, this paper constructed an evaluation index system on new media's influences from four dimensions, Information Quality, Propagation, Layout & Design and Website Operation. The details are as follows:

(1) Information Quality (B_1): mainly including Relevance (C_1); Accuracy and Authority (C_2)—the accuracy and scientificity of the contents provided; Novelty (C_3)—the higher the ratio of original information in the total information, the higher the standard of this media is; Breadth of Information (C_4)—whether the information provided can meet the user demand; Depth of Information (C_5)—the degree of detail about a certain subject.
(2) Propagation (B_2): including Accessibility (C_6); Update rate of content (C_7)—good media should be featured with high update frequency, short update period and fast update speed; Interactivity (C_8)—the correlation between the information released and the media itself; Hyperlinks (C_9); Frequency of Usage (C_{10})—the higher the frequency of usage, the better the user stickiness is.
(3) Layout & Design (B_3): including User Interface (C_{11})—the interface design should make the operation simple, comfortable and free, and fully reflect the positioning and personality of the software application; Information Organization (C_{12})—whether the combination of texts, pictures and videos is reasonable and nice-looking.
(4) Website Operation (B_4): including Login Convenience (C_{13})—whether the website is adaptable to different mobile phone platforms and systems; Privacy (C_{14})—the degree of protection on user information; Update Frequency of applications (C_{15}); Free Resources (C_{16}).

3 Evaluation Analysis of New Media's Influences on College Students

New media's influences were evaluated following four steps: questionnaire design and distribution, reliability analysis, validity analysis, factor analysis and conclusions.

Students of Sichuan University were targeted as the survey subjects in this study. The questionnaire contained the basic information of survey subjects, questions on new media satisfaction, as well as open questions. Satisfaction was evaluated by the Likert Scale. Questionnaire data were collected from September to November 2013. A total of 450 copies of questionnaire were distributed through random sampling, and 427 valid questionnaires were returned. The effective recovery rate was 94.8 %.

The consistency reliability coefficient—Cronbach α reliability coefficient—was used in this study in order to ensure the reliability and validity of the questionnaire. The Cronbach α reliability coefficient was 0.785, and the Cronbach α reliability coefficient after standardized evaluation project adjustment was 0.810. The number of evaluation project was 15. As the reliability coefficient was between 0.80 and 0.90, the internal consistency of the questionnaire was relatively high.

Factor analysis was performed to examine the scale validity. The sample KMO value obtained from SPSS 17.0 was 0.855; the chi-square test value was 1338.27; the significance level was 0.000, which is less than 0.05, suggesting that the scale had a high validity and was suitable for factor analysis.

The questionnaire used in this study involved a total of 15 evaluation indexes, for which the R-type factor analysis was suitable. The mathematical model of R-type factor analysis was as follows:

Assuming there are P original variables, the mean of each variable (or after standardization processing) is 0 and the standard deviation is 1. Each of the original variables is expressed as the linear combination of $k(k < p)$ factors, i.e.:

$$
\begin{aligned}
x_1 &= a_{11} f_1 + a_{12} f_2 + \cdots + a_{1k} f_k + \varepsilon_1, \\
x_2 &= a_{21} f_1 + a_{22} f_2 + \cdots + a_{2k} f_k + \varepsilon_2, \\
&\vdots \\
x_n &= a_{n1} f_1 + a_{n2} f_2 + \cdots + a_{nk} f_k + \varepsilon_n.
\end{aligned}
$$

The basic procedure of factor analysis is as follows:
(1) Variance analysis;
(2) Construction of factor variables;
(3) Improving the interpretability of the factor variables using the rotation method;
(4) Calculating the scores of factor variables in all samples.
Next, factor analysis was performed following the four steps above.

Table 1 Outcomes of variance analysis

Component	Eigenvalue			Extraction of the square sum			Rotation of the square sum		
	Total	Var[a]	Accu[b]	Total	Var[a]	Accu[b]	Total	Var[a]	Accu[b]
1	8.935	59.569	59.569	8.935	59.569	59.569	8.051	53.671	53.671
2	4.065	27.098	86.667	4.065	27.098	86.667	3.584	23.896	77.568
3	1.498	9.988	96.656	1.498	9.988	96.656	2.863	19.088	96.656

[a]Variance %
[b]Accumulation %.

1. Variance analysis
SPSS 19.0 was used to perform factor analysis on the evaluation index system of new media's influences. Firstly, the outcomes of variance analysis were obtained as shown in Table 1.

The results showed that: the eigenvalues of the first three factor variables were greater than 1 (8.935, 4.065 and 1.498). With variance maximization rotation, their contribution rates to variance were 53.671, 23.89 and 19.088 % respectively, and the accumulated variance contribution reached 96.656 %, far greater than 85 %. It suggested that the first three factor variables contained sufficient information of the 15 evaluation indexes of the original data. Therefore, three public factors were selected.

2. Naming of factor variables
The principle component method was applied to calculate the factor loading matrix A, which could indicate the loading of each factor in all variables, i.e., the degree of influence. Since the coefficients of the initial factor loading matrix were not significant enough, variance maximization rotation was performed on the initial factor loading matrix to make the factor loading coefficients differentiate to 0–1 (Table 2). Then, the original indexes were classified according to the relative coefficients.

The first factor variable includes: Frequency of Usage X_1, Login Convenience X_2, Layout & Design X_3, Update rate of content X_6, Interactivity X_9, Relevance X_{10}, Information Organization X_{12}, Privacy X_{13}, Update Frequency of applications X_{14}. This factor mainly reflected the design and operation standard of new media, for which it was named as Design & Operation Factor.

The second factor variable includes: Accessibility X_{11} and Free Resources X_{15}. It mainly reflected the degree of convenience of information acquisition and the abundance of free resources, for which it was named as Free Resource Abundance & Accessibility Factor.

The third factor variable includes: Breath of Information X_4, Depth of Information X_5, Accuracy and Authority X_7 and Novelty X_8. It mainly reflected the quality of information, for which it was named as Information Quality Factor.

3. Calculation of factor scores
In order to understand the development of all types of new media and evaluate their influences comprehensively, the regression method was applied to calculate the factor score function. The SPSS19.0 output function coefficient matrix is shown in Table 3.

Table 2 Rotation of the component matrix

	Components		
	1	2	3
Frequency of Usage	0.976	0.090	−0.199
Login Convenience	0.987	0.158	−0.008
Layout & Design	0.965	0.085	0.235
Breath of Information	0.710	0.660	0.241
Depth of Information	−0.494	0.587	0.623
Update rate of content	0.760	0.596	0.254
Accuracy and Authority	0.110	0.102	0.932
Novelty	−0.357	0.473	0.805
Interactivity	0.997	0.034	−0.040
Relevance	0.986	0.048	−0.080
Accessibility	0.171	0.917	0.192
Information Organization	0.949	0.229	0.214
Privacy	0.421	0.029	0.769
Update Frequency of applications	0.788	0.569	0.236
Free Resource Abundance	0.184	0.976	0.051

Table 3 The component score coefficient matrix

	Components		
	1	2	3
Frequency of Usage	0.128	−0.002	−0.092
Login Convenience	0.127	−0.015	−0.018
Layout & Design	0.135	−0.096	0.110
Breath of Information	0.051	0.165	−0.016
Depth of Information	−0.108	0.153	0.153
Update rate of content	0.063	0.131	0.005
Accuracy and Authority	0.026	−0.167	0.413
Novelty	−0.075	0.055	0.265
Interactivity	0.139	−0.061	−0.006
Relevance	0.135	−0.046	−0.028
Accessibility	−0.049	0.328	−0.105
Information Organization	0.120	−0.030	0.069
Privacy	0.073	−0.189	0.359
Update Frequency of applications	0.069	0.121	0.003
Free Resource Abundance	−0.055	0.382	−0.183

Table 4 The comprehensive scores of new media's influences on college students

New media	Factor score			Comprehensive score
	F_1	F_2	F_3	
Instant messaging	1.43063	−0.74964	0.1748	0.68956
Microblogging	0.19243	1.40894	1.05096	0.622227
Social media	0.27066	−0.06139	−1.08743	0.037235
Blog	−1.10484	−1.09595	0.8454	−0.90084
Post bar & forum	−0.78888	0.49803	−0.98373	−0.44818

The coefficient matrix expressed the three factors as the linear combination of 15 indexes. The factor score functions are as follows:

$$F_1 = 0.128X_1 + 0.127X_2 + 0.135X_3 + 0.151X_4 + \cdots + 0.055X_{15}.$$

4. Calculation of the factor variable score in each sample
The factor scores of the 5 types of new media were calculated according to the factor score function. Meanwhile, on the basis of factor analysis, the 5 types of samples were evaluated comprehensively. The variance contribution rates of the 3 selected factor variables were taken as weights, and the comprehensive scores of new media's influences were calculated as follows (Table 4):

$$F = \frac{\lambda_1}{\lambda_1 + \lambda_2 + \lambda_3} f_1 + \frac{\lambda_2}{\lambda_1 + \lambda_2 + \lambda_3} f_2 + \frac{\lambda_3}{\lambda_1 + \lambda_2 + \lambda_3} f_3.$$

As shown in Table 4, the comprehensive scores of the 5 types of new media's influences on college students can be ranked in descending order as: instant messaging, microblogging, social media, blog and post bar & forum. The new media of instant messaging achieved the highest comprehensive factor score due to its excellent performance in the Design & Operation Factor. The influence of microblogging was second after instant messaging. Its scores in all three factors were greater than 0, and the Free Resource Abundance & Accessibility Factor achieved a particularly high score. Social media obtained a high score in the Design & Operation Factor, only after instant messaging. Blog achieved a good performance in the Information Quality Factor, while post bar & forum achieved a good performance in the Free Resource Abundance & Accessibility Factor.

4 Analysis and Recommendations

The influences of the 5 types of new media on college students can be ranked based on the evaluation scores as follows: instant messaging, microblogging, social media, forum and blog. Instant messaging, microblogging and social media are more in line with students' characteristics and user habits, as they fit the needs of utilizing fragmented time to obtain and disseminate information.

Based on the evaluation of new media's influences on students, college management should:

(1) Take the initiative to understand students' user behaviors and habits and capture the operation regularity of campus new media in order to apply new media in propagation and student works more effectively;
(2) Construct a multi-channel integrated new media platform to improve the pertinence, scientific and systematic of the propagation and student works; strengthen the construction of campus network culture and enhance the overall network media literacy of both teachers and students.

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Multiple Criteria Group Decision Making Problem Based on VIKOR Method Under Hesitant Fuzzy Environment

Jamil Ahmad, Muhammad Kashif Javed, Muhammad Nazam and Muhammad Nazim

Abstract All multiple criteria decision making (MCDM) methods are depends on an aggregation representing by closeness to the ideal which is generated by compromise methods. The VIKOR method of compromise ranking determines a compromise solution. It is an effective tool in multiple criteria decision making, especially in a situation where the decision makers are not able to express his or her preference. And the hesitant fuzzy set is also very useful tool to deal with uncertainty and hesitancy. It can be described in terms of the opinions of decision makers. In this paper we develop the traditional VIKOR method to solve the multiple criteria group decision making problem under hesitant fuzzy environment. Firstly, hesitant fuzzy set information and corresponding concepts are described, and the traditional VIKOR method is introduced. Then the problem of group decision making is described and also proposed the steps of extended VIKOR method. A numerical example of energy project selection is proposed as an application of VIKOR. In the end conclusion and discussions are made.

Keywords Multiple criteria group decision making · Hesitant fuzzy sets extension of VIKOR · Energy project selection

1 Introduction

Making decision and selection is an important part of everyday life; In decision making process the most of the decision issues have multiple, even incomputable criteria. So the multiple criteria decision making (MCDM) techniques are well known and well accepted method using to prioritize set of alternative [8]. Therefore, these

J. Ahmad (✉) · M.K. Javed · M. Nazam
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: jamil.ahmad040@gmail.com

M. Nazim
Institute of Business and Management, University of Engineering and Technology, Lahore 54890, Pakistan

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techniques or methods has been used to provide a better aspect to solve a practical problems in daily life. In general, the decision makers used different layout and descriptions to express their preferences or choices for each alternative in a group decision making problem [6, 12, 15].

In decision making process, many MCDM methods have been investigated, such as ELECTRE method [1], the VIKOR method [7], the TOPSIS method [4] and so on. But Opricovic and Tzeng [8] pointed out that the VIKOR method based on the distance of an alternatives to the ideal solution and also determines the compromise solution which is established by mutual concession. This method focused on ranking and selecting from a set of alternatives and determines a compromise solution for a problem with conflicting criteria. There exist a large amount of literature involving VIKOR theory and application. Ju and Wang [5] proposed an extension of VIKOR method for multi-criteria group decision making problem with linguistic information. Wan et al. [10] presented an extended VIKOR method for multiple attribute group decision making with triangular intuitionistic fuzzy numbers. Chang [2] integrated a fuzzy VIKOR method: A case study of the hospital service evaluation in Taiwan.

Dealing with uncertainty and hesitancy has been a long term research challenging that has originated from different methodologies and theories. A new extension of fuzzy set is called hesitant fuzzy sets and it has been introduced to deal with hesitant situation. In a short period of time, HFSs has attracted the attention of many researchers. It was first introduced by Torra and Narukawa [9], and they permit the membership degrees of an element to be a set of several possible values between zero and one. More and more multiple attribute group decision making theories and methods under hesitant fuzzy environment have been developed. In the past few years there are a lot of work had been published, Wang et al. [11], presented an interval-valued hesitant fuzzy linguistic sets and their applications in multiple criteria decision making problems. Farhadinia [3], proposed a series of score functions for hesitant fuzzy sets.

From the above analysis, we can observe that the HFS is a powerful tool to deal the hesitancy and uncertainty of decision makers decisions. many multiple criteria decision making theories and methods has been developed in hesitant fuzzy environment. In this paper, we extend the traditional VIKOR method with hesitant Euclidean distance in fuzzy environments to solve the multiple criteria group decision making problem. The rest of this paper is described as follows. Some preliminaries of hesitant fuzzy elements and corresponding concepts are given in Sect. 2. In Sect. 3, the traditional VIKOR method is introduced. The extension and principal of VIKOR methodology has given for MCGDM problem in Sect. 5. In Sect. 6, proposed a numerical illustration as an application of an extended VIKOR method. In the end some conclusion and discussion are made.

2 Preliminaries

In this step some preliminaries are given.

Hesitant fuzzy sets (HFS), which consent the membership of an element to a given set by different possible values between the interval [0, 1] and firstly it was introduce by Torra and Narukawa [9]. It is very powerful tool to obtain the membership degree especially when we have different values between 0 and 1.

Definition 127.1 ([9]) Let X be a fixed set, a HFS on X is in terms of a function that when applied to X returns a subset of the values between 0 and 1. For better understanding a mathematical form can be presented in the following terms:

$$E = \{< x, h_E(x) > | x \varepsilon X\}, \tag{1}$$

here, $h_{E(x)}$ denotes the set of some different values between 0 and 1 and it is also denoting the membership degree of elements $x \varepsilon X$ to the set E. For comfort we can say h is equal to $h_{E(x)}$ a hesitant fuzzy elements.

Let h, h_1 and h_2 be a three hesitant fuzzy elements then their some operations are defined as follows, here λ is a positive real number.

(1) Lower bound: $h^-(x) = \min h(x)$ or $\min\{\gamma | \gamma \varepsilon h\}$;
(2) Upper bound: $h^+(x) = \max h(x)$ or $\max\{\gamma | \gamma \varepsilon h\}$;
(3) Intersection : $\widetilde{h}_1 \bigcap \widetilde{h}_2 = \bigcup_{\gamma_1 \varepsilon \widetilde{h}_1, \gamma_2 \varepsilon \widetilde{h}_2} \min\{\gamma_1, \gamma_2\}$;
(4) Union : $\widetilde{h}_1 \bigcup \widetilde{h}_2 = \bigcup_{\gamma_1 \varepsilon \widetilde{h}_1, \gamma_2 \varepsilon \widetilde{h}_2} \max\{\gamma_1, \gamma_2\}$;
(5) $h^\lambda = \bigcup_{\gamma_1 \varepsilon h} \{\gamma^\lambda\}$;
(6) $\lambda h = \bigcup_{\gamma_1 \varepsilon h} \{1 - (1 - \gamma)^\lambda\}$;
(7) $h_1 \oplus h_2 = \bigcup_{\gamma_1 \varepsilon h_1, \gamma_2 \varepsilon h_2} \{\gamma_1 + \gamma_2 - \gamma_1 \gamma_2\}$;
(8) $h_1 \otimes h_2 = \bigcup_{\gamma_1 \varepsilon h_1, \gamma_2 \varepsilon h_2} \{\gamma_1 \gamma_2\}$.

Definition 127.2 ([14]) Let h_A and h_B be two hesitant fuzzy sets on the values $X = \{x_1, x_2, x_3, \ldots, x_n\}$, then the hesitant Euclidean distance of HFEs:

$$d(h_A, h_B) = \sqrt{\frac{1}{l} \sum_{j=1}^{l} |h_{A\sigma(j)} - h_{B\sigma(j)}|^2}, \tag{2}$$

here, l is a number of values in the HFEs of h while $h_A^{\sigma(j)}$ and $h_B^{\sigma(j)}$ are the j_{th} largest values in h_A and h_B. In many situation or cases, $l(h_A) \neq l(h_B)$ for better understanding we can write, let l = max $l(h_A), l(h_B)$. For obtaining the correct results we'll extend the shorter or greater element until all of them have same length. By adding any value we can extend shorter set, but the best way is to add the same value several time. The selection of these values depends on decision makers if the decision makers are optimistic then they will increase the greater value while if the decision makers are pessimistic then they will increase less value.

Example 127.1 Let h_A = (0.3, 0.4, 0.5) and h_B = (0.6, 0.7) be two HFs. Here, the length of both's sets are not equal so we can extend h_B set by increasing the shortest value and the new h_B = (0.6, 0.6, 0.7). The Euclidean distance of h_A and h_B are calculated as follows:

$$d(h_A, h_B) = \sqrt{\frac{|0.3 - 0.6|^2 + |0.4 - 0.6|^2 + |0.5 - 0.7|^2}{3}} = 0.23804.$$

3 VIKOR Method

A VIKOR method is a persuasive decision approach for solving a complex MCGDM problem. This technique is used to make the ranking list, give the weight and provide a compromise solution. A compromise solution is an agreement established by mutual adjustment. The compromise ranking is developed from the Lp-Metric used an aggregation function in a compromise programming method.

Let $D_t, (t = 1, 2, 3, \ldots, k)$ be the committee of various decision makers. The C_j $(j = 1, 2, 3, \ldots, n)$ and A_i $(i = 1, 2, 3, \ldots, m)$ represent the different criteria and alternatives respectively. The f_{ij} is a value of jth criteria function for the ith alternatives and n is the number of criteria. The VIKOR method is started with the following form of Lp-Metric.

$$L_{p,i} = \sum_{j=1}^{n}[\{w_j(f_j^* - f_{ij})/(f_j^* - f_j^-)\}^p]^{1/p}, \tag{3}$$

here, $1 \leq P \leq \infty$. The measure $L_{p,i}$ shows the distance between alternative A_i and the positive-ideal solution.

The traditional VIKOR method has following steps:

Step 1. In this step calculate the best values f_j^* and the worst values f_j^- for all criteria. When j is associated with benefit criteria, if follows that $f_j^* = \max x_{ij}$, $f_j^- = \min x_{ij}$.

When j is associated with cost criteria, if follows that $f_j^* = \min x_{ij}$, $f_j^- = \max x_{ij}$.

Step 2. Calculate the index S_i, which refers to the separation measure of ith alternative with the best value and also calculate the index R_i, which refers to the separation measure of ith alternative to the worst value. w_j is the weight of the jth criteria.

$$S_i = \sum_{j=1}^{n} w_j[(f_j^* - x_{ij})/f_j^* - f_j^-)], \tag{4}$$

$$R_i = \max_j[w_j(f_j^* - x_{ij})/f_j^* - f_j^-)]. \tag{5}$$

Note that from (3), S_i is $L_{1,i}$ and R_i is $L_{\infty,i}$. The solution obtained by R_i is with a minimum individual regret while the solution obtained by S_i is with a maximum group utility.

Step 3. Calculate the values Q_i, with the following equation.

$$Q_i = v\frac{S_i - S_{\min}}{S_{\max} - S_{\min}} + (1-v)\frac{R_i - R_{\min}}{R_{\max} - R_{\min}}, \tag{6}$$

where $S_{\max} = \max_i S_i$, $S_{\min} = \min_i S_i$, $R_{\max} = \max_i R_i$, $R_{\min} = \min_i R_i$, and v is a strategy weight of "maximum group utility"(or "The Majority of criteria") while $1 - v$ shows the weight of individual regret, here we suppose $v = 0.5$.

Step 4. Rank the alternatives sorting by the crisp values S, R and Q in ascending or descending order. The results are in three ranking lists $\{A\}_S$, $\{A\}_R$, $\{A\}_Q$. The index Q_i which implies the separation measures of the ith alternative A_i from the best alternative. The smallest value Q_i is the best alternative in the ranking list.

Step 5. Propose a compromise solution. The alternative denoted as $A^{(1)}$ which is the best ranked by the measure Q (minimum) is considered as a compromise solution if the following two conditions are satisfied:

Cond$_1$: Acceptable Advantage: $Adv \geq DQ$, $Adv = Q(A^{(2)}) - Q(A^{(1)}) \geq 1/(m-1)$, where Adv is the advantage of the alternative $A^{(1)}$ ranked first, $A^{(2)}$ is the alternative with the second position in $\{A\}_Q$ and $DQ = 1/(m-1)$ is the threshold.

Cond$_2$: Acceptable Stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by S or/and R.

If one of the two conditions is not satisfied, then a set of compromise solution is proposed, which consists of:

(1) Alternative $A^{(1)}$ and $A^{(2)}$ if only the condition Cond$_2$ is not satisfied;
(2) Alternative $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ if the condition Cond$_1$ is not satisfied.

$A^{(M)}$ is determined buy the relation $Q(A^{(M)}) - Q(A^{(1)}) < DQ$ for maximum M. This implies that the positions of these alternatives are "in closeness" and therefore $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ are the set of alternatives to be further considered.

4 Extended VIKOR Method for Group Decision Making Problem with a Hesitant Fuzzy Elements

In decision making process, some time it is very difficult or impossible for decision makers or experts to determine the exact values of the criteria because of uncertainty and hesitancy. In this situation the hesitant fuzzy sets are very powerful tool to deal the uncertainty and hesitancy. According to Torra and Narukawa [9], to avoiding such type of issues in which each criteria can be described as a hesitant fuzzy set in term of the opinion of experts and having a set of possible values to permit the membership function. So there is more appropriate to consider the values of the criteria as hesitant fuzzy element, where the hesitant fuzzy elements are the benefit criteria (Table 1).

Table 1 Decision making matrix

	C_1	C_2	$\cdots$	C_n
A_1	h_{11}	h_{12}	$\cdots$	h_{1n}
A_2	h_{21}	h_{21}	$\cdots$	h_{2n}
A_3	h_{31}	h_{32}	$\cdots$	h_{3n}
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
A_m	h_{m1}	h_{m2}	$\cdots$	h_{mn}

In our study we extend the VIKOR method in hesitant fuzzy environment to solve the MCGDM or MAGDM problem with the hesitant fuzzy set information.

Suppose that decision making matrix is shown in following form by the hesitant fuzzy elements.

Here, $A_1, A_2, A_3, \ldots, A_m$ and $C_1, C_2, C_3, \ldots, C_n$ are the possible alternatives and criteria of decision making respectively while, h_{ij} is the rating of alternatives A_i with respect to criteria C_j and it is exactly unknown. We only know the $h_{ij} = (h_{E(x)ij})$ and W_j is the weight of criteria.

The extended VIKOR method with Euclidean distance having a following steps:

Step 1. Arranging the committee of decision making group and defining a finite set of criteria and alternatives.

Step 2. Determine the best values f_j^* and the worst values f_j^- for all criteria. When j is associated with benefit criteria, it follows that :

$$f^* = \{h_1^*, h_2^*, \ldots, h_n^*\}, \tag{7}$$

where $h_j^* = \bigcup_{i=1}^m h_{ij} = \bigcup_{\gamma_{1j}\varepsilon h_{1j},\ldots,\gamma_{mj}\varepsilon h_{mj}} \max\{\gamma_{1j}, \gamma_{2j}, \ldots, \gamma_{mj}\}, \; j = 1, 2, \ldots, n.$

$$f^- = \{h_1^-, h_2^-, \ldots, h_n^-\}, \tag{8}$$

where

$$h_j^- = \bigcup_{i=1}^m h_{ij} = \bigcup_{\gamma_{1j}\varepsilon h_{1j},\ldots,\gamma_{mj}\varepsilon h_{mj}} \min\{\gamma_{1j}, \gamma_{2j}, \ldots, \gamma_{mj}\}, \; j = 1, 2, \ldots, n.$$

Step 3. Compute the normalized hesitant fuzzy difference $d_{ij}, i = 1, 2, \ldots, n, j = 1, 2, \ldots, m$. For benefit criteria d_{ij} is calculated from definition 2 as follows:

$$d_{ij} = \frac{\sqrt{|h_j^* - h_{ij}|^2}}{|h_j^* - h_j^-|}. \tag{9}$$

Step 4. Compute the index S_i and R_i over the benefit criteria as follows.

$$S_i = \sum_{j=1}^{n} \{w_j \times d_{ij}\},\ R_i = \max_j \{w_j \times d_{ij}\}. \tag{10}$$

The index S_i represent the hesitant fuzzy group utility measure and the index R_i represent the hesitant fuzzy individual regret measures.
Step 5. Calculate the values Q_i, with the following equation.

$$Q_i = v\frac{S_i - S^-}{S^* - S^-} + (1 - v)\frac{R_i - R^-}{R^* - R^-}, \tag{11}$$

where $S^* = \max_i S_i$, $S^- = \min_i S_i$, $R^* = \max_i R_i$, $R^- = \min_i R_i$, and v is a strategy weight of "maximum group utility"(or "The Majority of criteria") while $1 - v$ shows the weight of individual regret, here we suppose $v = 0.5$.
Step 6. Rank the alternatives sorting by the crisp values S, R and Q in ascending order. The results are in three ranking lists $\{A\}_S$, $\{A\}_R$, $\{A\}_Q$.
Step 7. Propose a compromise solution. The alternative denoted as $A^{(1)}$ which is the best ranked by the measure Q_i (minimum) is considered as a promise solution if the following two conditions are satisfied:

Cond$_1$: Acceptable Advantage: $Adv \geq DQ$, $Adv = Q(A^{(2)}) - Q(A^{(1)}) \geq 1/(m-1)$, where Adv is the advantage of the alternative $A^{(1)}$ ranked first, $A^{(2)}$ is the alternative with the second position in $\{A\}_Q$ and $DQ = 1/(m-1)$ is the threshold.

Cond$_2$: Acceptable Stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by S or/and R.

If one of the two conditions is not satisfied, then a set of compromise solution is proposed, which consists of:

(1) Alternative $A^{(1)}$ and $A^{(2)}$ if only the condition Cond$_2$ is not satisfied;
(2) Alternative $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ if the condition Cond$_1$ is not satisfied.

$A^{(M)}$ is determined by the relation $Q(A^{(M)}) - Q(A^{(1)}) < DQ$ for maximum M.

5 Application of the Proposed Method

Energy is an important factor for the social and economic development of any country or societies. The correct energy policy play an important role in economic development. The most appropriate energy policy selection is very important. Suppose that there are four energy projects $A_i = 1, 2, 3, 4$, and four project criteria, C_1 = Environmental, C_2 = socio-political, C_3 = Technological and C_4 = Economical. Several decision makers are invited to evaluate the performance of the four alternatives under these different criteria. All of the decision makers are provide their evaluation values

Table 2 Crisp values for decision matrix and weight of each criteria

	C_1	C_2	C_3	C_4
A_1	(0.2, 0.5, 0.7)	(0.1, 0.6, 0.8)	(0.2, 0.8, 0.9)	(0.3, 0.5, 0.6, 0.7, 0.8)
A_2	(0.2, 0.3, 0.6, 0.7)	(0.2, 0.3, 0.4, 0.6)	(0.3, 0.5, 0.6, 0.7, 0.9)	(0.4, 0.5, 0.8, 0.9)
A_3	(0.3, 0.5, 0.6, 0.7)	(0.2, 0.5, 0.7)	(0.2, 0.4, 0.7, 0.8)	(0.3, 0.5, 0.6, 0.7)
A_4	(0.3, 0.4, 0.6)	(0.3, 0.5)	(0.5, 0.6, 0.7)	(0.8, 0.9)

Table 3 Crisp values for decision matrix and weight of each criteria

	C_1	C_2	C_3	C_4
A_1	(0.2, 0.5, 0.7, 0.7, 0.7)	(0.1, 0.6, 0.8, 0.8, 0.8)	(0.2, 0.8, 0.9, 0.9, 0.9)	(0.3, 0.5, 0.6, 0.7, 0.8)
A_2	(0.2, 0.3, 0.6, 0.7, 0.7)	(0.2, 0.3, 0.4, 0.6, 0.6)	(0.3, 0.5, 0.6, 0.7, 0.9)	(0.4, 0.5, 0.8, 0.9, 0.9)
A_3	(0.3, 0.5, 0.6, 0.7, 0.7)	(0.2, 0.5, 0.7, 0.7, 0.7)	(0.2, 0.4, 0.7, 0.8, 0.8)	(0.3, 0.5, 0.6, 0.7, 0.7)
A_4	(0.3, 0.4, 0.6, 0.6, 0.6)	(0.3, 0.5, 0.5, 0.5, 0.5)	(0.5, 0.6, 0.7, 0.7, 0.7)	(0.8, 0.9, 0.9, 0.9, 0.9)

and some of theses values maybe repeated. However, a value repeated more times does not indicate that it has more importance than other values repeated less time.

The HFEs is just a tool to deal with such cases, and all possible evaluation for an alternative under the attributes can be considered as a HFEs. The results are evaluated by the decision makers contained in a hesitant fuzzy decision matrix shown in Table 2. For accurate results, calculate the distance between two hesitant fuzzy sets, we should extend the shorter one until both of them have the same length when we compare them. According to the regulations mentioned above, we consider that the decision makers are optimistic. The Table 3 represent the hesitant fuzzy data by adding the maximal value.

Step 1. Making a committee of decision makers and then describing a finite set of criteria and alternatives. In the specified selection problem, we have four criteria, $C_1, C_2, \ldots, C_4$ and four alternatives, $A_1, A_2, \ldots, A_4$ and three decision makers D_1, D_2, D_3.

Step 2. From Table 3, calculate the best value and the worst value of each criteria according to Eqs. (7) and (8). The results are shown as follows: $\{h_1^* = 0.7,\ h_2^* = 0.8,\ h_3^* = 0.9,\ h_4^* = 0.9\ h_1^- = 0.2,\ h_2^- = 0.1,\ h_3^- = 0.2,\ h_4^- = 0.3\}$.

Step 3. Compute the normalized hesitant fuzzy difference $d_{ij}, i = 1, 2, \ldots, n,\ j = 1, 2, \ldots, m$. For benefit criteria d_{11} is calculated from (9) as follows:

$$d_{11} = \frac{\sqrt{|0.7 - 0.2|^2 + |0.7 - 0.5|^2 + |0.7 - 0.7|^2}}{|0.7 - 0.2|} = 1.077.$$

Table 4 The values of S, R and Q for all alternatives

	A_1	A_2	A_3	A_4	The ranking order
S	0.7079	0.9195	0.9392	0.7677	$A_1 \succ A_4 \succ A_2 \succ A_3$
R	0.2506	0.3021	0.3360	0.2703	$A_1 \succ A_4 \succ A_2 \succ A_3$
$Q_{0.1}$	0	0.6342	1.000	0.2334	$A_1 \succ A_4 \succ A_2 \succ A_3$
$Q_{0.5}$	0	0.7589	1.000	0.2446	$A_1 \succ A_4 \succ A_2 \succ A_3$
$Q_{1.00}$	0	0.9148	1.000	0.2585	$A_1 \succ A_4 \succ A_2 \succ A_3$

Step 4. The values S_i and R_i are calculated respectively according to Eq. (10).

$$
\begin{aligned}
&S_1 = w_1 \times d_{11} + w_2 \times d_{12} + w_3 \times d_{13} + w_4 \times d_{14} = 0.7079,\\
&S_2 = 0.9195, \quad S_3 = 0.9392, \quad S_4 = 0.7677.\\
&R_1 = \max_4\{w_1 \times d_{11} + w_2 \times d_{12} + w_3 \times d_{13} + w_4 \times d_{14}\} = 0.2506,\\
&R_2 = 0.3021, \quad R_3 = 0.3360, \quad R_4 = 0.2703.
\end{aligned}
$$

Step 5. Compute the values Q_i for each alternative with Eq. (11), and the result are given in Table 4, $Q_1 = 0$, $Q_2 = 0.7589$, $Q_3 = 1.000$, $Q_4 = 0.2446$.
Step 6. According to Table 4, rank the alternatives sorting by the crisp values S, R and Q in ascending order and the the results are shown in Table 4.
Step 7. Since $Q(A^{(2)}) - Q(A^{(1)}) = 0.7589 \geq \frac{1}{4-1} = 0.333$, the Cond_1 is satisfied. And the alternative A_1 is also the best ranked by S or/and R and therefore A_1 meets the acceptable stability. Since both Cond_1 and Cond_2 are verified, it is suggested that the alternative A_1 has better performance rather than A_2, A_3, and A_4. From the ranking values of S_i, R_i and Q_i values, we can get the priorities of alternatives as the weight v changes which are shown in Fig. 1. From the Table 4 and Fig. 1, we can find that if the weight v increase then the value of Q_i also become increase. So the decision makers can choose the weight v according to their preference.

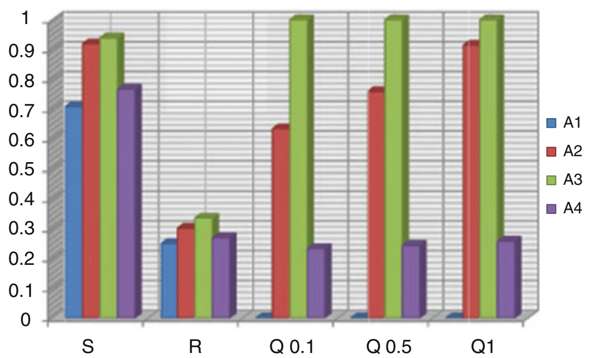

Fig. 1 The ranking graph of S_i, R_i and Q_i values

6 Conclusion

Hesitant fuzzy set is very useful tool to deal with hesitancy and uncertainty especially, when the membership degree of element are given. The main difficulty of establishing the membership degree is not because we have some possibility distribution on the possibility values or margin of errors because we have several possible values. From avoiding such type of issues each criteria can be describe as a hesitant fuzzy set defined in terms of the opinions of decision makers. Therefore, we extend the concept of traditional VIKOR method for solving MCGDM problems under hesitant fuzzy set information. A numerical illustration of extended VIKOR method are presented. From the illustrative example, we showed that the change trends of the results derived by the extended VIKOR method with the increase of the weight v. As a future scope, a consensus reaching process can be incorporated into the hesitant fuzzy VIKOR method under GDM setting to obtain a more robust version of VIKOR model.

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Creative Industries Incubator Knowledge Service Research Based on KIBS-Case of Tianjin Eco-City Animation Incubator

Wenjun Wu, Huiying Zhang and Dan Sun

Abstract With the rapid development of the cultural and creative industries, the cultural and creative industrial incubators-the aggregation of the companies-are also playing an increasingly important role. Based on the characteristics of the cultural and creative industries, the paper explores the composition of the content of knowledge service in the cultural and creative industrial incubators. Rooted in the Tianjin Eco-city animation incubator, and with the relevant personnel in Ecological city, incubator and incubated enterprises as subject, it establishes theoretical models from the perspectives of three groups of audience, namely the incubator, the incubated enterprises and the government, and uses ALTAS qualitative analysis software to explore the factors that may impact the knowledge service in the culture and creative industrial incubators. It concludes by pointing out the problems existing in the knowledge service in the eco-city animation incubator while putting forward its responding measures and suggestions, in order to provide a reference for the development of knowledge service in the culture and creative industrial incubators.

Keywords Cultural and creative industries · Incubator · Knowledge service

1 Introduction

In the context of blooming global economy, the cultural and creative industries have become pillar industries which stimulate the domestic economic demand and expand employment. At present, the global creative industry creates a wealth of tens of billions of dollars every day, especially in Western developed countries, for instance, the United-States-created video product export has exceeded the aerospace industry

H. Zhang · D. Sun (✉) · W. Wu
College of Management and Economics, Tianjin University, Tianjin 300072, People's Republic of China
e-mail: crystal8819@126.com

W. Wu
Tianjin Foreign Studies University, Tianjin 300204, People's Republic of China

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and become the largest export category, while in the UK, the cultural and creative industrial output value ranks the second in the major industries of its national economy [19]. During the decade since its inception, the added value of the Chinese cultural and creative industries has increased from 20.762 billion RMB Yuan in 1999 to 166.514 billion RMB Yuan in 2012, an increase of nearly 10 times, and the creative industry is becoming one of China's rapid-developing emerging industries [16]. Its clusters he creative industrial parks and incubators whose functions include incubating business , expanding employment, encouraging innovation and pooling of resources and others, are developing mushroomed.

As a "Flex" integrated system, creative industry incubators are different from the general technological business incubators, not only providing hardware services such as common venues and facilities, but also the professional knowledge services, including the software services needed in the development of creative companies, such as management support and resource network [5]. Laws of the cultural and creative industries in China is still under exploitation, various parks or incubators mainly provide hardware service for the industry, hence the knowledge service has a lot of room to improve.

2 A Literature Study and the Theoretical Framework

2.1 Summary of Study on Incubator Knowledge Service

There are quite some theoretical researches on incubators; relevant service researches are also not uncommon. Viewing domestic and international research, incubator services are summarized as supporting infrastructure and business services, as well as high-level professional advice and services [12], with its specific content demonstrated in 6 core services, namely the property services, agency services, project declaration or identification services, investment and financing services, information services, intermediary services and training services [18].

Most of the knowledge services are classified into soft information and consulting services. Researches on the incubator knowledge services in China and other countries are divided into three categories, ① content-perspective-based incubator Knowledge Service Research: Building of the system of incubator knowledge service [1, 7],incubators knowledge service evaluation [8, 11], incubators knowledge service innovation [15]. ② capability-perspective-based incubator Knowledge Service Research: capacity building and enhancement in incubator knowledge service [14], network construction and evolution in incubator knowledge service [17], incubator knowledge service evolution mechanism [13] and so on. ③ pattern-perspective-based incubator Knowledge Service Model: Incubator Knowledge Service business model [10, 13], incubators-incubation business interactive model in knowledge service [3].

The incubator knowledge service is considered to be a process of service to meet the knowledge need at different stages of the incubated company's growth and of different types, which relies on the external knowledge resources the incubators have to acquire, integrate knowledge or to provide sources of knowledge, and helps the incubated enterprises to accumulate knowledge and enhance capacity in an interactive way [4]. The knowledge involved mainly includes these aspects: company organization and management knowledge, policies and regulation knowledge, financial operation knowledge, technical expertise and marketing knowledge.

2.2 Commentary and Research Ideas

John Hawkins in the "creative economy-how people create money from the mind" points out from the perspective of intellectual property rights: the creative industry is the "intellectual property", and this knowledge industry, constituted by the intellectual capital while owning the nature of "intangible industry" often correspond to intangible value such as cultural and spiritual value, etc. [2]. The knowledge-based services are divided into three categories by Chinese scholars: technical services (hard knowledge services), advisory services (soft knowledge services), e-commerce services (mixed knowledge service) [9]. The knowledge-based services play an important role in the production and dissemination of knowledge [6]. In contrast with the previous reviews, the manage knowledge, technical expertise and marketing knowledge required by the nascent corporates in culture and creative industries must be different from those needed by the general manufacturing companies and high-tech research and development enterprises.

Therefore, the cultural and creative industrial incubator knowledge service has unique contents and patterns, which is worth sufficient attention and in-depth study. The creative industry itself is a new industry; the incubated companies urgently need high-intense and high-added-value professional knowledge service, which is just the feature expected in the creative industrial incubators in their knowledge service. Due to the lack of knowledge of the creative industries incubator knowledge service, such as what are the contents of knowledge service, how to achieve service objectives? This article uses the case study method. The new eco-city animation incubator is a well-known creative industrial incubator with its typicality and representativeness. Through the case study on the new eco-city animation incubator, an integrated model of incubator knowledge service is formed, which is of universal significance to the cognition of the creative industrial incubator knowledge services.

3 Case Selection and Data Encoding

3.1 Case Description

Seated in Tianjin Binhai New Area, the new eco-city animation incubator is a nation-level incubator, covering one square kilometer with a total construction area of about 770,000 square meters. There are more than 200 incubated companies here, including the excellent animation companies such as Green Tree Animation and CPT planet. With them, the number of registered companies now has exceed 900. With the basic industrial infrastructure such as the animation public technical service platform, the animation experience hall, the large-scale animation experience center, the animation museum and the product exhibition center, it is an important platform for the animation industrial cluster and development.

The animation incubator in cooperation with the National Supercomputing Center has established a "Super Render Center", which, relying on the "Milky Way One" super computing power, establishes the nation's largest and fastest rendering cluster system, greatly improves the production efficiency of animation and film, introduces the professional incubator management team and provides multiple services such as business start-up counseling, intermediary service, policy consulting, technological innovation support and project financing services so as to build an industrial chain service model, enhance the incubation capacity and gradually improve the industrial environment. It also builds up an industrial service system with a public technical service platform, an original project incubation platform, a training platform and a copyright trading center as the core. It provides full service for the tenant companies and creates a good business incubation environment.

3.2 Data Sources

In order to improve the validity of the conclusions of the case study, this paper uses "the triangulation method" that acquires first-hand information and second-hand information through a variety of ways, making the various data sources complement and cross-validate each other. The different data sources constitute a triangle and avoid the errors in the common method, which can help to verify the same facts and improve the structural validity of this case.

Due to the large number of the incubated companies, data is not easy to collect. Therefore, we collect data primarily through three channels: text data, field study visits, and interviews with important figures. For the data the author collected between 2013 and 2014, please see Table 1.

Table 1 Data sources of the case

Data sources	Practice and content
Text information	Internally-distributed publications "Eco-Way five exploration and practice in SSTEC", and so on, about 300,000 words
Fieldwork visit	Investigate SSTEC animation Park Tower for two days, and interview the employees in the incubated enterprises employees and refine the interview recording immediately after the interview to compile a 25,000-word report
Important interview	Interview the main persons in charge of multiple incubators such as the legal bureau of the Eco-City Administrative Committee and the Eco-City Bureau of Commerce, have a 4-h in-depth interview with the typical entrepreneurs, and refine the recordings immediately after the interviews to compile a 28,000-word report

4 Data Encoding

This paper uses the content encoding analysis, with the help of the qualitative analysis software ATLAS. Qualitative research has two main coding processes, one is the completely open coding process and the other is to set the encoding variables in strict accordance with existing theories. In this paper, the first encoding process is used. First, the four members of the research team read through all the case materials respectively to encode the data from different sources, following these encoding rules: (1) the entries are relevant to the case and unambiguous; (2) the expressions from the same source or of the same or similar meaning are treated as one entry; (3) consistent coding entries are adopted directly into the database while the inconsistent ones are adopted or deleted after the group discussion; (4) the same entry can subordinate to different categories; and (5) new problems discovered in the coding process should be corrected immediately. At the same time, the second-hand information can be used as verification evidence, to enhance the validity of the findings. Below is an example of the encoding process (Table 2).

Table 2 Encoding process example

First-hand information	Encoding process	
	① Audience category	② Encode
Entry one: "We (the incubated enterprises) hope incubators provide motion capture room, studio, review rooms, recording studios and other related aids and teach us using them"	Incubated enterprises	Technical expertise
Entry two: "We (incubators) can set up our own knowledge base website. If the companies encounter problems in the development process, they can check on the website themselves in order to get find the answers they need"	Incubators	Self-service

Using this analysis and the inductive method, the four members of the group give the first-hand information an initial coding, resulting in an entry library containing 225 entries, with some entries subordinate to two categories. Then they discuss over the results of the preliminary coding, excluding the 25 entries that have inconsistent comments or unclear meaning, and retaining 200 valid entries. Finally, according to the research framework, the subordinate dimension of individual entries is arranged.

4.1 Data Analysis and Case Studies

According to the results of coding, an in-depth analysis is conducted on the issue discussed in this study with the following findings obtained:

4.2 Audience One-Incubated Enterprises

Based on the coding result, the analysis from the perspective of incubated enterprises includes 90 factors that impact the creative industrial incubator knowledge, covering five dimensions. Sorted by the strength, the dimensions as well as the entries contained are as follow: technical expertise service (32), marketing knowledge service (22), organization and management knowledge service (16), financial operation knowledge service (12), policy and regulation knowledge service (8).

The technical expertise is the most notable feature of the eco-city animation incubator which is different from other typical creative industrial incubators. In the process of the incubated companies' product R&D, the incubators provide relevant technical supporting knowledge. Its content is mainly related to: incubators obtain the latest technical information of the animation industry; incubators' testing service for the late derivative items of the anime, animation, games and other products; hire excellent animation guru and animation experts who will provide critical technical and advisory services in the incubated enterprises to inspire their creativity; incubators create functional platforms such as public technical service platform, technical trade information and publishing platform, training platform, the original project incubation platform; incubators provide motion capture room, studio, review rooms, recording studios and other related supporting technologies (Table 3).

Marketing knowledge is the knowledge that helps the incubated enterprises' products or services better enter the market, playing an important role in the creative industrial incubator knowledge service. Only by entering and being accepted by the market can the products and services developed by the incubated companies help them achieve profits and development. According to the product features, its contents involve: providing services such as animation market development, product display and promotion animation industry market access and other services; animation materials and equipment suppliers (good authors, good animation equipment providers, etc.) incubated enterprises, animation product buyers (such as television

Table 3 Dimensions under each audience and typical entry

Audience category	Dimensions	The number of entries	Percent[a] (%)	Typical entries
Incubated enterprises	Service of company knowledge organization and management	16	17.80	We hope to cooperation establish and communication with other co-incubated enterprises
	Service of financial operation	12	13.30	Our companies hope the incubators or the government will help us apply for loans
	Service of policy and regulation knowledge	8	8.90	Our companies hope the government will apply the supporting policies on us at the first moment
	Technical expertise service	32	35.60	We (incubated enterprises) hope incubators provide motion capture room, studio, review rooms, recording studios and other related aids and teach us to use
	Marketing knowledge service	22	24.40	Our companies hope incubators or the government help us to recommend products to television or book publishers
Incubators	Smart service	22	33.30	Incubators take their initiative to provide guidance according to the condition of enterprise development
	Self service	14	21.20	We (incubators) have our own knowledge base site so that incubated enterprises can find answers in appropriate modules if they have any questions
	Expert consulting service	30	45.50	We (incubators) have our own team of consultants who talk with companies face to face on a regular basis
Government	Building of knowledge network	14	31.80	Government helps with the regular knowledge exchange and sharing between incubated enterprises, research institutes and universities
	Policy support	18	40.90	The Government will provide employees of incubated companies with preferential housing prices, with corresponding transport subsidies
	Talent building service	12	27.30	Government establishes cooperation with art colleges and universities which introduce the appropriate artistic talents every year

a: Percentage of dimensions in the category percent.

station, Internet, and publishers) to form a network; fully control the marketing of the derivative products (is peripheral products).

Business organization and management knowledge refers to the knowledge the eco-city animation companies use in carrying out their operation activities such as the organization of their management staff and their financial management. It mainly involves: the foundation of the basic knowledge of the animation business (such as business registration, tax registration); the organization of the animation team (such as managers and technical staff) and the training of professionals; structural and operative knowledge in the incubated companies, in particular, the project-oriented structure in the knowledge-intensive industry of animation; the incubators help the incubated companies know more about the professional services associated with the animation business, such as rendering centers; the establishment of cooperation and communication between the animation business.

As for financial operation knowledge, the growth and operation of companies cannot be achieved without the support of sufficient funding. The knowledge of financial operations mainly includes two aspects, namely finance and investment. The financial knowledge refers to the requirements, processes and document preparation of each financial source in the funding channel of the animation business (including loans, risk investment, etc.). The investment knowledge, whereas, Investment in knowledge is mainly used to help the incubated companies allocate and use the funding and develop their financial use plan.

The policy and regulation knowledge only relates to the policies and regulations pertaining to the organization and management of the animation business; the most important advantage for incubated companies is their policy advantage as well as the preferential policies which play an important promoting role in the companies' growth. Therefore, knowledge of policies and regulations is the most basic knowledge which mainly relates to the animation industrial regulations, such as those of supporting the originals and combating plagiarism and piracy; the preferential and supporting policies in the animation industry, such as the subsidiary policies launched by the cultural department to the animation and other creative industries.

4.3 Audience Two-Incubators

According to the encoding results, the analysis from the incubator perspective includes 66 factors that impact the creative industrial incubator knowledge service, covering 3 dimensions. Sorted by the strength, the dimensions and the number of entries contained are as follow: expert advisory service (30), smart service (22), and featured school-running model (14).

As for the expert advisory service, in order to meet the needs of the incubated enterprises, the incubators establish professional teams or consultant teams (business incubators counselor). From the requirement analysis in the incubated enterprises to the achievement of the requirements, both parties participate in the whole process and have face-to-face communication, or organize salons to help with the growth of the incubated companies. Parties have a high-level interaction, they give high attention to the process and results of service, and the service has a high cost.

In terms of smart services, the incubators classify and categorize the required knowledge at the different stages of the incubated companies ,according to the knowledge needs in business growth and the experience of providing knowledge service, so as to provide guidance for the incubated companies proactively and be informed of the companies' requirements and development. In this way, both parties interact with each other in an indirect and targeted manner; according to the feedback from the incubated companies, the incubators continuously improve their knowledge service and enrich the knowledge service.

The self-service mainly refers to the fact that the incubators offer a wide range and a large number of special knowledge and successfully set up their knowledge base website so that the companies can search the answer to the questions they encounter on the website or in the knowledge base. Though this approach is effective, both parties do not have a high-level interaction; the incubators do not know much about the incubated companies' requirements, hence they cannot obtain the timely feedback.

4.4 Audience Three-Government

According to the encoding results, the analysis from the government point of view includes 44 factors impacting the creative industrial incubator knowledge service over 3 dimensions. Sorted by the strength, the dimensions and the number of entries contained are as follow: policy support (18), the construction of knowledge network (14), personnel development (12).

The government's policy support is the most direct and effective service the incubated companies expect from the government, and the very service they concern the most. Incubated companies and projects enjoy the government's preferential policies, which mainly focus on financial support, project declaration, talent import, tax rebates and other aspects. The government has earmarked funding for the incubators and fund some incubated projects free of charge; its tax-related support to the incubated companies are demonstrated as the return of financial expenses. In addition, there are special policies available to include the incubated companies and projects in the local technical plan, project declaration and talent importation.

The knowledge network of the creative industrial incubators is based on information, capital, research and development, training, intermediary service and other resources, and effectively connect corporates, the government, universities, research institutes, intermediary institutions and other relevant entities. These elements synergize with each other, exchange and supply relevant knowledge and information, and form a network structure, which is a complete system integrating various incubation resources. The government helps to establish such knowledge networks between the incubators and incubated companies to form a good knowledge sharing and improve the utilization of knowledge service.

Human resources are the most important and scarce resource. Currently China's cultural and creative industries are in a good rise, either from the national perspective or on the local level, high-level innovative talents will always be the focus of competing by between local governments, incubators and the incubated enterprises. To introduce and cultivate high-level talents is undoubtedly one of the highlights of incubators, which play a key role in enhancing the competitiveness of the companies. Therefore, personnel development is the very concern of the government and the whole society. The government should strengthen the cooperation with s to attract talents, and strengthen the talent development inside the incubators as well.

5 Conclusions

The theory of the creative industrial incubator knowledge service herein selects the SSTEC creative industrial incubators as a typical carrier, uses the standardized case study approach, start from the incubated enterprises, incubators and the government audiences, analyze the contents of knowledge service respectively, put forward relevant suggestions to the SSTEC creative industrial incubators in a targeted manner, and broaden the application prospect of knowledge services. It provides important reference and guidance for the future development of the creative industrial incubator knowledge service. As for the limitations of this paper, first, the number of cases is limited, hence the findings can only be partial reference and guidance for other creative industrial incubators; Second, although this study quantifies the different dimensions of knowledge service, yet it has not until later.

6 Management Implications

6.1 The Disadvantages of the SSTEC Animation Incubator Knowledge Service

Currently, the new eco-city animation incubator Knowledge Service has the following disadvantages:

(1) The service is provided in accordance with the existing contents of the incubators which loose, and the systematicness and comprehensiveness need to be strengthened.
(2) Few incubated companies ask for service proactively; most of them receive service passively, hence they do not know well their real knowledge requirements.
(3) In the process of offering service for incubated companies, the incubator fails to achieve self-learning. With the continuous development of the incubators, they cannot effectively accumulate knowledge, thus the overall effect of the knowledge accumulation is not good enough.

6.2 Suggestions

Based on the above shortcomings, a number of recommendations is made:

(1) The incubators share knowledge internally and make the knowledge service more systematic and comprehensive. After acquiring certain knowledge, a company may improve the utilization of knowledge through the spread of knowledge sharing among companies. When common difficulties are discovered through the knowledge sharing among incubated enterprises, answers can be obtained from the incubators' knowledge sharing, which is also helpful for the knowledge accumulation of incubators and incubated companies.
(2) To provide proactive service, combine a variety of knowledge service approaches, turn passiveness into proactiveness, and proactively offer the knowledge service required at different stages of the companies.
(3) Strengthen the incubators' self-learning capacity and establish a successful graduation base. All companies that graduate successfully must experience common stages and important processes, hence in order to strengthen the incubators' self-learning capacity, it is necessary to establish and share a base of successful company cases, which should be used as a teaching material to develop new incubated companies and incubator managers.

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Stakeholders' Harmonious Integration of Construction Project Based on Game Theory

Yibin Ao, Yongxiang Wu, Yan Wang and Yuan Zhang

Abstract Construction project usually involves multitudinous stakeholders. How to balance the interest and reduce the conflicts among them to construct a more harmonious team has become a critical factor to reduce construction resources' waste. With the use of game theory, this paper established disintegrating disharmonious construction alliance model first and then further integrating harmonious construction alliance based on the first model. It concluded conditions and priorities of the two Unions and provided policy suggestions.

Keywords Construction project · Stakeholder · Harmonious integration · Game theory

1 Introduction

It needs many multitudinous stakeholders and passes through many different stages to complete a construction project. However, due to the finiteness of construction resources and the interest conflict among the stakeholders, they always don't cooperate with each other and their behaviors are not always consistent. Some stakeholders even damage others' interest or the whole project construction system's interest which

Y. Ao (✉)
College of Environment and Civil Engineering, Chengdu University of Technology,
Chengdu 610064, People's Republic of China
e-mail: 249016992@qq.com

Y. Wu
School of Management, Harbin Institute of Technology,
Harbin 150001, People's Republic of China

Y. Wang
Department of Engineering Management, Sichuan College of Architectural Technology,
Deyang 618000, People's Republic of China

Y. Zhang
State Grid Energy Research Institute, Beijing 100052, People's Republic of China

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finally affects the time, cost, quality and safety of the construction project [9]. So it becomes a serious and vexatious problem to create a harmonious built environment to minimize or avoid such risk.

Mitchell considers that Stakeholder Identification and Stakeholder Salience is the core of Stakeholder theory [8]. And Harmonious Management Theory is proposed, improved and enriched by the famous professor Xi You-min in China who has formed abundant research achievements [2, 6, 7, 10, 12]. In this paper "Stakeholders' Harmonious Integration of the Residential Construction System", the author has defined "stakeholders" and identified the path of harmonious integration. Furthermore, it conducted studies on stakeholders' harmonious integration with the use of game theory for example [3, 4, 11] and so on.

This paper had created disintegrating disharmonious construction alliance model and integrating harmonious construction alliance and concluded conditions and priorities of the two Unions. According to the study, it can easily find that all the stakeholders must integrate Harmoniously the construction will be completed better.

2 Harmonious Integration System Model

According to "A Study on Harmony Integration of Stakeholders of Residential Construction System Based on Game Theory" [1], there are harmonious and disharmonious status of residential Construction System. Accordingly, Residential Construction System also contains harmonious and disharmonious construction unions. The purpose of the stakeholders to integrate of harmonious residential construction system is collapsing disharmonious construction union while developing harmonious construction union. Relative authority draws up the construction laws and regulations and the rules of the game, whose purpose is restricting construction action of stakeholders to accord with harmonious construction requirements. However, there is no absolute or perfect harmony. There are inharmonious phenomena in the residential construction market. Therefore, the aim of the integration is seeking for transfer from disharmonious to harmonious system. It is widely accepted that stakeholders pursuit their own interests in the residential construction system. Development of certain regulations and laws will help standardize and guide the stakeholders' behavior and ultimately achieve harmonious system.

In the process of crumbling disharmonious construction union, one efficient way is to collapse the stakeholders with greatest behavior to restrict other stakeholders. As everyone knows, relative authorities are the initiator and guide for establishing rules of system game. They will automatically make their stand to stay away from the disharmonious union and propose a harmonious construction. Among the other stakeholders, the greatest binding is construction unit. If relative authorities want to collapse disharmonious construction union, their first priority should be construction unit, followed by supervision companies, contractors and material suppliers.

Similar as collapsing the disharmonious construction unit, one of the most efficient ways for the government departments to expand the harmonious construction unit, is to drag the most influential stakeholders into the system. Therefore, the priorities for the authorities to integrate the other stakeholders should be: Construction Company, Supervision Company, contractors and suppliers. Above all, Residential Construction System and Harmonious Integration Hierarchy Diagram are showed as following [1].

3 Developing a Harmonious Integration Game Model

1. Constructing Strategy Set and Payoff Matrix

This paper selects the relevant government departments, owners, supervisors, builders and suppliers as the game participants, in order to simplify, the five players will be recorded as 1, 2, 3, 4, 5 respectively [5].

In the project construction process, government is responsible for developing and implementing the related construction laws and regulations. Not only will it develops the regulations to constrain all the participants, the government also supervises the construction practical carried out under certain rules. Therefore, the relevant government departments play a critical role in the community construction system. It is also assumed that harmonious construction is the pursuit of those government departments. Based on the hypotheses that the community construction system contains two statuses, one is pursuing a harmonious system which means improvement of the regulations and standardize the rules, another is a disharmonious construction process. Thus all the stakeholders will have two strategic choices (harmonious and disharmonious construction). The players will have a corresponding payoff when they choose a strategy in the game process (Fig. 1).

In order to analyze clearly and simply, It simplified strategies as $S(S = 1, 2)$, and assumed 1 represented harmonious construction and 2 represented disharmonious construction, the stakeholders' strategy sets separately are $(A1, A2)$, $(B1, B2)$, $(C1, C2)$, $(D1, D2)$ and $(E1, E2)$. And the payoff of stakeholder denotes, where represents strategy, $(i = 1, 2, 3, 4, 5)$ represents the player. If one of the players

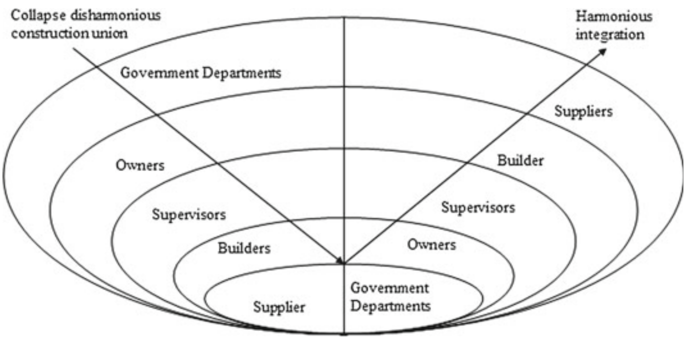

Fig. 1 Residential construction system and harmonious integration hierarchy diagram

chooses strategy 2 (disharmonious construction) will lead to a loss of all the players which result in time delays, quality problems cost increase and safety problems, etc. So it is assumed that i chooses strategy 2 will make the payoff reduce as f_{2i}, and $\sum_{i=1}^{5} f_{2i}$.

2. Solving the Characteristic Function

In the payoff matrix, I represents all players set, U represents alliance set, the players who are out of the alliance set are denoted as IU, V is characteristic function, MIN_i means the minimum value of each line and MAX_r represents the maximum value of each column. According to matrix maximum and minimum theory, the payoff matrix has a saddle point value which mean that the strategy has an optimal solution when MIN_i is equal to MAX_r. Otherwise the optimal strategy will be determined by Strategy priority relationship. And $i, j, k, l, m = 1, 2, 3, 4, 5$, when they appeared at the same time $i \neq j \neq k \neq l \neq m$, the subscript of i, j, k, l, m considers any three players have consensus to choose represent strategy choice. And represents the optimal strategy.

(1) Solving the Characteristic Function of Single Union

First, if all 5 players are independent, it is defined as Single Union, which means the game analysis between the individuals with no alliance. In this case, no matter the individual chooses harmonious or disharmonious construction; they don't have awareness of alliance. Each type of payoff matrix and optimal strategy for double Game composed of Single Union is shown as Table 1. The other four types of payoff matrix and optimal strategy for double Game composed of Single Union is similar as the one illustrated, so they will not be discussed here.

Through the above analysis, when payment of the stakeholders of the residential building system adopting the harmonious construction is greater than loss of adopting disharmonious construction, single union's optimal strategy is choosing the harmonious construction, while other stakeholders choose disharmonious construction. When payment of the alliance player adopting the harmonious construction is less than loss of adopting disharmonious construction, the players will choose disharmonious construction and so will the stakeholders out of the alliance. In this case, optimal strategy of the whole residential building system stakeholders is disharmonious construction, residential building system will maintain the current status. Above all, function specification and strategy selection for residential building system stakeholders of Single Union are as follows:

$$v(\{i\}) = \begin{cases} p_i^1 - \sum_{j=1}^{5} f_{2j}, & \text{if } p_i^1 - p_i^2 - f_{2j} \geq 0, \text{ OS: } (i_1 j_2 k_2 l_2 m_2), \\ p_i^2 - F, & \text{if } p_i^1 - p_i^2 - f_{2j} < 0, \text{ OS: } (i_2 j_2 k_2 l_2 m_2). \end{cases} \tag{1}$$

In the Eq. (1), p_i^1 means the net incomes that i get when they choose harmonious construction, and if i choose disharmonious construction, the net income they will win is $p_i^1 - p_i^2 + f_{2i}$.

Table 1 The payoff matrix and optimal strategy for double game composed of Single union (take government departments for example)

U	{2, 3, 4, 5}				
{1}	B1C1D1E1	B1C1D1E2	B1C1D2E1	B1C1D2E2	B1C2D1E1
{A1}	p_1^1	$p_1^1-f_{25}$	$p_1^1-f_{24}$	$p_1^1-f_{24}-f_{25}$	$p_1^1-f_{23}$
{A2}	$p_1^2-f_{21}$	$p_1^2-f_{21}-f_{25}$	$p_1^2-f_{21}-f_{24}$	$p_1^2-f_{21}-f_{24}-f_{25}$	$p_1^2-f_{21}-f_{23}$
MAX_r	If $p_1^1-p_1^2+f_{21}\geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1-p_{22}^1-p_{23}^1-f_{24}-f_{25}$				
	If $p_1^1-p_1^2+3f_{21}<0$, the maximum value is the first line and the minimum value of the first line is p_1^2-F				

{2, 3, 4, 5}			
B1C2D1E2	B1C2D2E1	B1C2D2E2	B2C1D1E1
$p_1^1-f_{23}-f_{25}$	$p_1^1-f_{23}-f_{24}$	$p_1^1-f_{23}-f_{24}-f_{25}$	$p_1^1-f_{22}$
$p_1^2-f_{21}-f_{23}-f_{25}$	$p_1^2-f_{21}-f_{23}-f_{24}$	$p_1^2-f_{21}-f_{23}-f_{24}-f_{25}$	$p_1^2-f_{21}-f_{22}$
If $p_1^1-p_1^2+f_{21}\geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1-p_{22}^1-p_{23}^1-f_{24}-f_{25}$			
If $p_1^1-p_1^2+3f_{21}<0$, the maximum value is the first line and the minimum value of the first line is p_1^2-F			

{2, 3, 4, 5}			
B2C1D1E2	B2C1D2E1	B2C1D2E2	B2C2D1E1
$p_1^1-f_{22}-f_{25}$	$p_1^1-f_{22}-f_{24}$	$p_1^1-f_{22}-f_{24}-f_{25}$	$p_1^1-f_{22}-f_{23}$
$p_1^2-f_{21}-f_{22}-f_{25}$	$p_1^2-f_{21}-f_{22}-f_{24}$	$p_1^2-f_{21}-f_{22}-f_{24}-f_{25}$	$p_1^2-f_{21}-f_{22}-f_{23}$
If $p_1^1-p_1^2+f_{21}\geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1-p_{22}^1-p_{23}^1-f_{24}-f_{25}$			
If $p_1^1-p_1^2+3f_{21}<0$, the maximum value is the first line and the minimum value of the first line is p_1^2-F			

{2, 3, 4, 5}			
B2C2D1E2	B2C2D2E1	B2C2D2E2	MIN_t
$p_1^1-f_{22}-f_{23}-f_{25}$	$p_1^1-f_{22}-f_{23}-f_{24}$	$p_1^1-f_{22}-f_{23}$ $-f_{24}-f_{25}$	$p_1^1-f_{22}-f_{23}$ $-f_{24}-f_{25}$
$p_1^2-f_{21}-f_{22}-f_{23}-f_{25}$	$p_1^2-f_{21}-f_{22}-f_{23}-f_{24}$	p_1^2-F	p_1^2-F
If $p_1^1-p_1^2+f_{21}\geq 0$, the maximum value is the second line and the minimum value of the second line is $p_1^1-p_{22}^1-p_{23}^1-f_{24}-f_{25}$			$V=p_1^1-f_{22}$ $-f_{23}-f_{24}-f_{25}$
If $p_1^1-p_1^2+3f_{21}<0$, the maximum value is the second line and the minimum value of the second line is p_1^2-F			$V=p_1^2-F$

(2) Solving the Characteristic Function of Duo Union

In the process of two players Union which we will call Duo Union, the perspective will be that any two players can cooperate and have consensus to choose harmonious or disharmonious construction. Therefore, if any of the two stakeholders choose the alliance, the decision of the alliance will be either harmonious or disharmonious. The other stakeholders out of the Duo Union can choose harmonious or disharmonious construction at random, ignoring the choice of the other parties. Then payoff matrix of any Duo Union can be presented in Table 2.

The game analysis of any other Duo Union is as the same as showed above, thus will not be discussed here.

Based on the above analysis, for any alliance, if for both players' individual interest and also for the alliance's total interest, the benefit from harmonious construction is larger than disharmonious construction, they will choose harmonious con-

Table 2 The payoff matrix and optimal strategy of double game of Duo union (take government departments, owners for example)

U	$\{3, 4, 5\}$			
{1,2}	C1D1E1	C1D1E2	C1D2E1	C1D2E2
A1B1	$p_1^1 + p_2^1$	$p_1^1 + p_2^1 - 2f_{25}$	$p_1^1 + p_2^1 - 2f_{24}$	$p_1^1 + p_2^1 - 2f_{24} - 2f_{25}$
A2B2	$p_1^2 + p_2^2 -2f_{21} - 2f_{22}$	$p_1^2 + p_2^2 - 2f_{21} -2f_{22} - 2f_{25}$	$p_1^2 + p_2^2 - 2f_{21} -2f_{22} - 2f_{24}$	$p_1^2 + p_2^2 - 2f_{21} - 2f_{22} -2f_{24} - 2f_{25}$
MAX_r	If $p_1^1 + p_2^1 - p_1^2 - p_2^2 + 2f_{21} + 2_f 22 \geq 0$, and $p_1^1 - p_1^2 + 2f_{21} \geq 0$, and $p_2^1 - p_2^2 + 2f_{22} \geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1 + p_2^1 + p_3^1 - 3f_{24} - 3f_{25}$			
	If $p_1^1 + p_2^1 - p_1^2 - p_2^2 + 2f_{21} + 2_f 22 < 0$, and $p_1^1 - p_1^2 + 2f_{21} < 0$, and $p_2^1 - p_2^2 + 2f_{22} < 0$, the maximum value is the second line and the minimum value of the second line is $p_1^2 + p_2^2 - 2F$			

$\{3, 4, 5\}$				MIN_t
C2D1E1	C2D1E2	C2D2E1	C2D2E2	
$p_1^1 + p_2^1 - 2f_{23}$	$p_1^1 + p_2^1 - 2f_{23} -2f_{25}$	$p_1^1 + p_2^1 - 2f_{23} -2f_{24}$	$p_1^1 + p_2^1 - 2f_{23} -2f_{24} - 2f_{25}$	$p_1^1 + p_2^1 - 2f_{23} -2f_{24} - 2f_{25}$
$p_1^2 + p_2^2 - 2f_{21} -2f_{22} - 2f_{23}$	$p_1^2 + p_2^2 - 2f_{21} -2f_{22} - 2f_{23} - 2f_{25}$	$p_1^2 + p_2^2 - 2f_{21} -2f_{22} - 2f_{23} - 2f_{24}$	$p_1^2 + p_2^2 - 2F$	$p_1^2 + p_2^2 - 2F$
If $p_1^1 + p_2^1 - p_1^2 - p_2^2 + 2f_{21} + 2f_{22} \geq 0$, and $p_1^1 - p_1^2 + 2f_{21} \geq 0$, and $p_3^1 - p_2^2 + 2f_{22} \geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1 + p_2^1 + p_3^1 - 3f_{24} - 3f_{25}$				$V = p_1^1 + p_2^1 -2f_{23} - 2f_{24} -2f_{25}$
If $p_1^1 + p_2^1 - p_1^2 - p_2^2 + 2f_{21} + 2_f 22 < 0$, and $p_1^1 - p_1^2 + 2f_{21} < 0$, and $p_3^1 - p_2^2 + 2f_{22} < 0$, the maximum value is the second line and the minimum value of the second line is $p_1^2 + p_2^2 - 2F$				$V = p_1^2 + p_2^2 -2F$

struction. Meanwhile, the stakeholders out of the alliance will choose disharmonious construction. If the benefit of harmonious construction is less than the loss, the alliance will choose disharmonious construction while the others will do the same choice. Then disharmonious construction will be the optimal strategy of the Residential Community Construction System. Therefore, payoff matrix for double Game composed of any Duo Union can be described as follows:

$$v(\{i,j\}) = \begin{cases} p_i^1 - p_j^1 - 2f_{2k} - 2f_{2l} - 2f_{2m}, & \text{if } p_i^1 - p_i^2 + 2f_{2i} \geq 0, \\ & \quad p_j^1 - p_j^2 + 2f_{2j} \geq 0, \\ & \quad \text{OS: } (i_1 j_1 k_2 l_2 m_2). \\ p_i^1 + p_j^1 - 2F, & \text{if } p_i^1 - p_i^2 - f_{2i} < 0, \\ & \quad p_j^1 - p_j^2 f_{2j} < 0, \\ & \text{OS: } (i_2 j_2 k_2 l_2 m_2). \end{cases} \tag{2}$$

In the Eq. (2), $p_{i(j)}^1$ means the net incomes that $i\,(j)$ get when they choose harmonious construction, and if $i\,(j)$ choose disharmonious construction, the net income they will win is $p_{i(j)}^2 - 3f_{2i(j)}$.

(3) Solving the Characteristic Function of Tri Union

Take the Tri Union government departments, owners and supervisors for example, it ignores the possibilities of any three stakeholder alliance first, and construction any three players have consensus to choose harmonious construction or disharmonious, the other players can choose any strategy arbitrarily. Then Double Game has constituted by any kind of Tri Union, and the payoff matrix is presented in Table 3.

The game analysis of any other three union is as the same as showed in the Table 3. The conclusion of the analysis is that any three-stakeholder union will choose harmonious construction if the union's gross earning of this choice is equal or greater than the earning of choosing disharmonious construction. And the other players outside the union will choose disharmonious construction. Otherwise the union will choose disharmonious construction which is the optimal strategy. Then the characteristic function of Tri Union Game can be described as follows:

$$v\left(\{i,j,k\}\right) = \begin{cases} p_i^1 + p_j^1 + p_k^1 - 3f_{2l} - 3f_{2m}, & \text{if } p_{i(j,k)}^1 - p_{i(j,k)}^2 + 3f_{2i(j,k)} \geq 0, \\ & \text{OS: } (i_1 j_1 k_1 l_2 m_2)\,. \\ p_i^2 + p_j^2 + p_k^2 - 3F, & \text{if } p_{i(j,k)}^1 - p_{i(j,k)}^2 + 3f_{2i(j,k)} < 0, \\ & \text{OS: } (i_2 j_2 k_2 l_2 m_2)\,. \end{cases} \tag{3}$$

Table 3 The payoff matrix and optimal strategy of double game of Tri union (take government departments, owners and supervisors for example)

U	{4, 5}				MIN_t
{1,2,3}	D1E1	D1E2	D2E1	D2E2	
A1B1C1	$p_1^1+p_2^1+p_3^1$	$p_1^1+p_2^1+p_3^1$ $-3f_{25}$	$p_1^1+p_2^1+p_3^1$ $-3f_{24}$	$p_1^1+p_2^1+p_3^1$ $-3f_{24}-3f_{25}$	$p_1^1+p_2^1+p_3^1$ $-3f_{24}-3f_{25}$
A2B2C2	$p_1^2+p_2^2+p_3^2$ $-3f_{21}-3f_{22}$ $-3f_{23}$	$p_1^2+p_2^2+p_3^2$ $-3f_{21}-3f_{22}$ $-3f_{23}-3f_{25}$	$p_1^2+p_2^2+p_3^2$ $-3f_{21}-3f_{22}$ $-3f_{23}-3f_{24}$	$p_1^2+p_2^2+p_3^2$ $-3F$	$p_1^2+p_2^2+p_3^2$ $-3F$
MAX_r	If $p_1^1-p_1^2+3f_{21}\geq 0$, and $p_2^1-p_2^2+3f_{22}\geq 0$, and $p_3^1-p_3^2+3f_{23}\geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1+p_2^1+p_3^1+p_4^1-3f_{24}-3f_{25}$				$V=p_1^1+p_2^1$ $+p_3^1-3f_{24}$ $-3f_{25}$
	If $p_1^1-p_1^2+3f_{21}<0$, and $p_2^1-p_2^2+3f_{22}<0$, and $p_3^1-p_3^2+3f_{23}<0$, the maximum value is the second line and the maximum value is the second line is $p_1^2+p_2^2+p_3^2-3F$				$V=p_1^2+p_2^2$ $+p_3^2-3F$

In the Eq. (3), $p_{i(j,k)}^1$ means the net incomes that $i(j,k)$ get when they choose harmonious construction, and if $i(j,k)$ choose disharmonious construction, the net income they will win is $p_{i(j,k)}^2-3f_{2i(j,k)}$.

(4) Solving the Characteristic Function of Quad Union

Quad Union of the residential community construction system is defined as that any four stakeholders can reach to agreement and have consensus to choose harmonious or disharmonious construction. The other stakeholders out of the alliance will choose either harmonious or disharmonious construction. This will establish "two-person zero-sum game" with the payoff matrix presented as Table 4.

The game analysis of any other Quad Union is as the same as showed above, thus will not be discussed here.

Based on the above analysis, for any Quad Union, if for all players' individual interest and also for the alliance's total interest, the benefit from harmonious construction is larger than disharmonious construction, they will choose harmonious construction. Meanwhile, the stakeholders out of the alliance will choose disharmonious construction. If the benefit of harmonious construction is less than the loss, the alliance will choose disharmonious construction while the others will do the same choice. Then disharmonious construction will be the optimal strategy of the Residential Community Construction System. Therefore, payoff matrix and optimal strategy of double game of any Quad Union will be:

Table 4 The payoff matrix and optimal strategy of double game of Quad union (take government departments, owners, supervisors and builder for example)

U	{5}		MIN_t
{1,2,3,4}	E1	E2	
A1B1C1D1	$p_1^1+p_2^1+p_3^1+p_4^1$	$p_1^1+p_2^1+p_3^1+p_4^1-4f_{25}$	$p_1^1+p_2^1+p_3^1+p_4^1-4f_{25}$
A2B2C2D2	$p_1^2+p_2^2+p_3^2+p_3^2-4f_{21}$ $-4f_{22}-4f_{23}-4f_{24}$	$p_1^2+p_2^2+p_3^2-4F_{21}$	$p_1^2+p_2^2+p_3^2-4F_{21}$
MAX_r	If $p_1^1-p_1^2+4f_{21}\geq 0$, and $p_2^1-p_2^2+4f_{22}\geq 0$, and $p_3^1-p_3^2+4f_{23}\geq 0$, the maximum value is the first line and the minimum value of the first line is $p_1^1+p_2^1+p_3^1+p_4^1-4f_{25}$		$V=p_1^1+p_2^1+p_3^1+p_4^1$ $-4f_{25}$
	If $p_1^1-p_1^2+4f_{21}<0$, and $p_2^1-p_2^2+4f_{22}<0$, and $p_3^1-p_3^2+4f_{23}<0$, and $p_4^1-p_4^2+4f_{24}<0$ the maximum value is the second line and the minimum value of the second line is $p_1^2+p_2^2+p_3^2+p_4^2-4F_{21}$		$V=p_1^2+p_2^2+p_3^2+p_4^2$ $-4F_{21}$

$$v(\{i,j,k,l\})=\begin{cases} p_i^1+p_j^1+p_k^1+p_l^1-4f_{2m}, \text{ if } & \begin{array}{l} p_i^1-p_i^2+4f_{2i}\geq 0,\\ p_j^1-p_j^2+4f_{2j}\geq 0,\\ p_k^1-p_k^2+4f_{2k}\geq 0,\\ p_l^1-p_l^2+4f_{2l}\geq 0,\end{array}\\ & \text{OS: } (i_1j_1k_1l_1m_2).\\ p_i^2+p_j^2+p_k^2-3F, \quad \text{if} & \begin{array}{l} p_i^1-p_i^2+4f_{2i}<0,\\ p_j^1-p_j^2+4f_{2j}<0,\\ p_k^1-p_k^2+4f_{2k}<0,\\ p_l^1-p_l^2+4f_{2l}<0,\end{array}\\ & \text{OS: } (i_2j_2k_2l_2m_2).\end{cases} \quad (4)$$

In the Eq. (4), $p_{i(j,k,l)}^1$ means the net incomes that $i(j,k,l)$ get when they choose harmonious construction, and if $i(j,k,l)$ choose disharmonious construction, the net income they will win is $p_{i(j,k,l)}^2-3f_{2i(j,k,l)}$.

(5) Solving the Characteristic Function of Five-Union

Solving the characteristic function of Five Union, the whole residential building system is viewed as an alliance. Then this alliance could choose either harmonious or disharmonious construction, and the payoff matrix and optimum strategy can be described in Table 5.

Based on the above analysis, for all players' individual interest, if the benefit from harmonious construction is larger than sum of the benefit and loss caused by

Table 5 The payoff matrix and optimal strategy of double game of five-union

$\{1, 2, 3, 4, 5\}$	$\{\phi\}$	MIN_t
A1B1C1D1E1 A2B2C2D2E2	$p_i^1 + p_j^1 + p_k^1 + p_l^1 + p_m^1$ $p_i^2 + p_j^2 + p_k^2 + p_l^2 + p_m^2 - 5F$	$p_i^1 + p_j^1 + p_k^1 + p_l^1 + p_m^1$ $p_i^2 + p_j^2 + p_k^2 + p_l^2 + p_m^2 - 5F$
MAX_r	If $p_1^1 - p_1^2 + 5f_{21} \geq 0$, and $p_2^1 - p_2^2 + 5f_{22} \geq 0$, $p_3^1 - p_3^2 + 5f_{23} \geq 0$, $p_4^1 - p_4^2 + 5f_{24} \geq 0$ and $p_5^1 - p_5^2 + 5f_{25} \geq 0$, the maximum value is the first line and the minimum value of the first line is $p_i^1 + p_j^1 + p_k^1 + p_l^1 + p_m^1$	$V = p_i^1 + p_j^1 + p_k^1 + p_l^1 + p_m^1$
	If $p_1^1 - p_1^2 + 5f_{21} < 0$, and $p_2^1 - p_2^2 + 5f_{22} < 0$, $p_3^1 - p_3^2 + 5f_{23} < 0$, $p_4^1 - p_4^2 + 5f_{24} < 0$ and $p_5^1 - p_5^2 + 5f_{25} < 0$, the maximum value is the second line and the minimum value of the second line is $p_i^2 + p_j^2 + p_k^2 + p_l^2 + p_m^2 - 5F$	$V = p_i^2 + p_j^2 + p_k^2 + p_l^2 + p_m^2 - 5F$

disharmonious construction, they will choose harmonious construction, vice versa. Therefore, payoff matrix and optimal strategy for Five Union will be: let $V(I) = v(\{i, j, k, l, m\})$

$$v(\{i, j, k, l, m\}) = \begin{cases} \sum_{i=1}^{5} p_i^1, & \text{if } \; p_i^1 - p_i^2 + 5f_{2i} \geq 0, \text{ OS: } (i_1 j_1 k_1 l_1 m_1), \\ \sum_{i=1}^{5} p2 - 5F, & \text{if } \; p_i^1 - p_i^2 + 5f_{2i} < 0, \text{ OS: } (i_2 j_2 k_2 l_2 m_2)\,. \end{cases} \tag{5}$$

In the Eq. (5), $p^1_{i(j,k,l,m)}$ means the net incomes that $i(j, k, l, m)$ get when they choose harmonious construction, and if $i(j, k, l, m)$ choose disharmonious construction, the net income they will win is $p^2_{i(j,k,l,m)} - 3f_{2i(j,k,l,m)}$.

Through the above analysis, we can see that either for One Union or Multiplayer Union, if $p_i^1 > p_i^2 - nf_{2i}$, they will choose harmonious construction, vice versa. p_i^1 means the benefit got from the choice of harmonious construction. p_i^2 means the benefit got from the choice of disharmonious construction, while nf_{2i} means the loss when choosing disharmonious construction.

The method of solving characteristic function of One Union, Duo Union, Quad Union and Five Union is showed as above, and the characteristic functions of any other unions are described as follows:

$$v(\{i\}) = \begin{cases} p_i^1 - \sum_{i=1}^{5} f_{2i}, & \text{if } p_i^1 - p_i^2 + f_{2i} \geq 0, \quad \text{OS: } (i_1 j_2 k_2 l_2 m_2), \\ p_i^2 - F, & \text{if } p_i^1 - p_i^2 + f_{2i} < 0, \quad \text{OS: } (i_2 j_2 k_2 l_2 m_2). \end{cases} \tag{6}$$

$$v(\{i, j\}) = \begin{cases} p_i^1 + p_j^1 - 2f_{2l} - 2f_{2m}, & \text{if } p_{i(j)}^1 - p_{i(j)}^2 + 2f_{2i(j)} \geq 0, \\ & \text{OS: } (i_1 j_1 k_2 l_2 m_2), \\ p_i^2 + p_j^2 - 2F, & \text{if } p_{i(j)}^1 - p_{i(j)}^2 + 2f_{2i(j)} < 0, \\ & \text{OS: } (i_2 j_2 k_2 l_2 m_2). \end{cases} \tag{7}$$

$$v(\{i, j, k, l\}) = \begin{cases} p_i^1 + p_j^1 + p_k^1 + p_l^1 - 4f_{2m}, & \text{if } p_{i(j,k,l)}^1 - p_{i(j,k,l)}^2 + 4f_{2i(j,k,l)} \geq 0, \\ & \text{OS: } (i_1 j_1 k_1 l_1 m_2), \\ p_i^2 + p_j^2 + p_k^2 + p_l^2 - 4F, & \text{if } p_{i(j,k,l)}^1 - p_{i(j,k,l)}^2 + 4f_{2i(j,k,l)} < 0, \\ & \text{OS: } (i_2 j_2 k_2 l_2 m_2). \end{cases} \tag{8}$$

$$v(\{i, j, k, l, m\}) = \begin{cases} \sum_{i=1}^{5} p_i^1, & \text{if } p_i^1 - p_i^2 + 5f_{2i(j,k,l)} \geq 0, \quad \text{OS: } (i_1 j_1 k_1 l_1 m_1), \\ \sum_{i=1}^{5} p_i^2 - 5F, & \text{if } p_i^1 - p_i^2 + 5f_{2i} < 0, \quad \text{OS: } (i_2 j_2 k_2 l_2 m_2). \end{cases} \tag{9}$$

From all analysis above, it is easy to understand that the union will choose harmonious construction if the net income benefit from this choice is equal or greater than their gross earnings of choosing disharmonious construction. Otherwise, the union will choose disharmonious construction.

The characteristic function of the whole construction system can be calculated according to the previous analysis, and the construction system characteristic function value can be described as follows:

$$\sum_{i=1}^{5} v(\{i\}) = \begin{cases} \sum_{i=1}^{5} p_i^1 - 4F, \ \forall p_i^1 - p_i^2 + 2f_{2i} \geq 0, \\ \sum_{i=1}^{5} p_i^2 - 5F, \ \forall p_i^1 - p_i^2 + 2f_{2i} < 0. \end{cases} \tag{10}$$

$$\sum_{i,j=1}^{5} v(\{i, j\}) = \begin{cases} 4\sum_{i=1}^{5} p_i^1 - 12F, \ \forall p_{i(j)}^1 - p_{i(j)}^2 + 2f_{2i(j)} \geq 0, \\ 4\sum_{i=1}^{5} p_i^2 - 20F, \ \forall p_{i(j)}^1 - p_{i(j)}^2 + 2f_{2i(j)} < 0. \end{cases} \tag{11}$$

$$\sum_{i,j,k=1}^{5} v(\{i,j,k\}) = \begin{cases} 6\sum_{i=1}^{5} p_i^1 - 12F, \ \forall p_{i(j,k)}^1 - p_{i(j,k)}^2 + 3f_{2i(j,k)} \geq 0, \\ 6\sum_{i=1}^{5} p_i^2 - 30F, \ \forall p_{i(j,k)}^1 - p_{i(j,k)}^2 + 3f_{2i(j,k)} < 0. \end{cases} \tag{12}$$

$$\sum_{i,j,k,l=1}^{5} v(\{i,j,k,l\}) = \begin{cases} 4\sum_{i=1}^{5} p_i^1 - 4F, \ \forall p_{i(j,k,l)}^1 - p_{i(j,k,l)}^2 + 3f_{2i(j,k,l)} \geq 0, \\ 4\sum_{i=1}^{5} p_i^2 - 20F, \ \forall p_{i(j,k,l)}^1 - p_{i(j,k,l)}^2 + 3f_{2i(j,k,l)} < 0. \end{cases} \tag{13}$$

Oder:

$V(I) = \sum_{i=1}^{5} v(\{i\}),\ V(II) = \sum_{i,j=1}^{5} v(\{i,j\}),\ V(III) = \sum_{i,j,k=1}^{5} v(\{i,j,k\}),$

$V(IV) = \sum_{i,j,k,l=1}^{5} v(\{i,j,k,l\}),\ V(V) = \sum_{i,j,k,l,m=1}^{5} v(\{i,j,k,l,m\}),$

$P_1 = \sum_{i=1}^{5} p_i^1,\ P_2 = \sum_{i=1}^{5} p_i^2.$

According to the assumptions and the calculation above, the order of the construction system characteristic function value can be concluded as follows:

$$\begin{cases} V(\text{III}) \geq V(\text{IV}) \geq V(\text{II}) \geq V(\text{V}) \geq V(\text{I}),\ \forall P_2 > 5F, \\ V(\text{V}) \geq V(\text{I}) \geq V(\text{IV}) \geq V(\text{II}) \geq V(\text{III}),\ \forall P_2 \leq 5F. \end{cases} \tag{14}$$

$$\begin{cases} V(\text{III}) \geq V(\text{IV}) \geq V(\text{II}) \geq V(\text{V}) \geq V(\text{I}),\ \forall P_1 > 4F, \\ V(\text{IV}) \geq V(\text{III}) \geq V(\text{V}) \geq V(\text{II}) \geq V(\text{I}),\ \forall P_1 \leq 4F < {}^3\!/_2 P_1, \\ V(\text{IV}) \geq V(\text{III}) \geq V(\text{V}) \geq V(\text{I}) \geq V(\text{II}),\ \forall {}^3\!/_2 P_1 \leq 4F < {}^5\!/_3 P_1, \\ V(\text{IV}) \geq V(\text{V}) \geq V(\text{III}) \geq V(\text{I}) \geq V(\text{II}),\ \forall {}^5\!/_3 P_1 \leq 4F < {}^5\!/_2 P, \\ V(\text{V}) \geq V(\text{IV}) \geq V(\text{I}) \geq V(\text{III}) \geq V(\text{II}),\ \forall P_1 \leq 4F. \end{cases} \tag{15}$$

4 The Result of Game Analysis and Policy

The conditions of establishing harmonious construction union, the order of integrating it and disintegrating disharmonious construction union are not difficult to generate from the results of game analysis above. And several basic conclusions can be drawn. The responsibility of construction relevant departments is to regulate the construction market and improve the construction rule. And establishing and maintaining a harmonious construction environment are the final goal of government department. Based on this reality, the government department must disintegrate disharmonious construction union first.

Based on the above analysis, the conditions of establishing harmonious construction union, the order of integrating it and disintegrating disharmonious construction union can be summarized. Firstly, the responsible construction related authorized departments are regulating the construction market and trying to improve the construction rule. Secondly, establishing and maintaining a harmonious construction environment are the ultimate goal of government department. We can see that the most important issue for this is the role and impact of government department. Therefore, the government department has to disintegrate disharmonious construction union first.

4.1 The Formation of Harmonious Construction Alliance

Based on Eqs. (1)–(5), we can conclude that, when the net income benefit of harmonious construction is greater than the average net income benefit of disharmonious construction which is the current status, the union, whether it is single, Duo Union, Tri union, Quad union or five union, will intend to choose harmonious construction strategy.

The smaller the average net income benefit of maintaining the current status of disharmony construction, the greater the net income benefit of harmonious construction, and the easier it is to form the harmonious construction union, vice versa.

So the relevant government departments that intend to construct harmonious construction system should focus on improving the net income benefit p_i^1, and reduce the net income benefit $p_i^2 - f_{2i}$ resulted from disharmonious residential construction system.

Without taking other factors into consideration, in order to improve the net income benefit of harmonious construction, the relevant government departments should coordinate various stakeholders' construction behavior, regulate construction interests objectives of each stakeholder, reduce the loss of conflict, and at the same time increase the penalties of disharmonious builder and reduce its net income benefit from disharmonious construction.

4.2 Disintegrating Disharmonious Construction Union

Construction project always goes along under a certain level of laws, regulations and game rules. Some conclusion can be summarized according to the disharmonious construction characteristic value order of Eqs. (3)–(10) and the integration path in the paper of "Stakeholders' Harmonious Integration of the Residential Construction System":

(1) The order of disharmonious construction union is Five Union, One Union, Four Union, Two Union and Three Union, if the interests are less than the loss of choosing disharmonious construction. In this situation, the Five Union will collapse of itself if government department strengthens the position of harmonious construction. Then project construction system will achieve the best status of collapsing disharmonious construction.

(2) The order of disharmonious construction union is Five Union, One Union, Three Union, Four Union, Two Union, and if the interests are equal or greater than the loss of choosing disharmonious construction. The government department must increase punishment of disharmonious construction to collapse the union psychology of choosing disharmonious construction.

4.3 Integrating Harmonious Construction Union

What we need to do is to make the process of construction projects turn to harmonious point from disharmonious point for there is no absolute harmony in the process of project construction process, only relative harmony exists. In the process of project construction turning to harmony, the gross loss of all the players will increase and this is caused by any player who chooses disharmonious construction. And the F is greater; the construction market is more harmonious.

(1) The best harmonious integration union is Five Union in which all the players will choose the strategy of harmonious construction. And if $3p_1 \leq 4F$, the Five Union will be formed easily. So the government department needs to distribute well between the earnings and losses and try to make $\frac{p_1}{F} \leq \frac{4}{3}$.

(2) If $p_1 \leq F \leq 3p_1$, the most harmonious construction union is Four Union. The government department should integrate the owners, the supervisors, the builders, and the suppliers will be controlled easily for the sanction of the other four stakeholders.

(3) If $p_1 > 4F$, the most harmonious construction union is Three Union. The owners and the supervisors should be brought into the harmonious union. The government department should make use of the duties of the stakeholders in the union to constrain other stakeholders' behaviors.

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The Allocation of Carbon Emission Allowances for Power Plants with Gini Coefficient

Xin Yang and Lurong Fan

Abstract The "cap-and-trade" mechanism, an effective way to control emissions, is a market-based approach focused on the efficient allocation of initial emissions allowances. The equality principle is established to make most allocating objects be satisfied with the allocation, which could promote emission reduction. This paper employs the Gini coefficient, a measurement of inequality in economics, to implement the equality principle, and build relative mathematical model for the allocation problem. Two indicators, output and investment, are chosen to calculate the Gini coefficient, because the output stated for its contribution to the society, while the investment implied its scale and attitude towards the environment. Finally, an example in Guangdong ETS was taken to demonstrate the efficiency of the method proposed in this paper.

Keywords Carbon emission allowance allocation · Power plants · Equality · Gini coefficient

1 Introduction

The climate is changing across our planet [7]. For example, global mean surface air temperatures over land and oceans have increased over the last 100 years, the extreme weather and climate events have an increasing trend. Many changes can be explained by the natural variability of the climate system. Human activities, however, also affect the climate by changing the emissions and resulting atmospheric concentrations of greenhouse gases (GHGs) and aerosols and by changing land surface properties [7, 14]. Specially, carbon emission (short for GHGs emission) is regarded as one of the largest contributors to long-term climate change [10]. Due to the harmful impact of excessive carbon emission brings, various methods were proposed to control carbon emission. The Emission Trading Scheme (ETS), a market-based approach by

X. Yang (✉) · L. Fan
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: sweat_girl@163.com

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providing carbon allowances as economic incentives, was put forward for the first time in Kyoto Protocol in 1997 [2, 3, 5, 12, 13]. One of the most controversial issues in the ETS is how to allocate the allowances.

Research on carbon emission allowances allocation problem has attracted plenty of attentions in the last few decades. Some are focus on allocations between nation and nation, some are in a nation, and the others are among entities. A key for this problem is to ensure the equity of the allocation [8]. Especially allocation for the power plant, on the biggest emitters. An inequitable may not only fail to encourage plants to reduce emissions but also cause electricity shortage. There have been a variety of acceptable ways proposed based on equity principles, such as "grandfathering" (allowances based on historical emissions), "benchmarking" (allowances based on energy input or product output) and some others like per capital allocation and land area-based allocation [1, 16, 17]. Several researchers have proposed a series of more comprehensive and complicated allocation methods. For instance, Groenenberg et al. [4] extended the Triptych approach presented by Phlipsen et al. [11] to the global differentiation of emission reduction, which is a kind of allocation among countries, emphasizing the mitigation of contradictions between developed and developing countries. Wang et al. [15] applied data envelopment analysis (DEA) to reginal allocation of carbon emission allowance over provinces in China by 2020 for realizing China's national mitigation targets. Park [9] described a new method using Boltzmann distribution, which is available to allocate among any entities. Aimed to develop a decision support model for establishing benchmarks as a tool for free allocation in the construction industry. Taehoon et al. [6] developed a decision support model for establishing benchmarks as a tool for free allocation in the construction industry. In this paper, we introduce the Gini coefficient so as to ensure the equity of allocation. In economics, the Gini coefficient is a measure of statistical dispersion intended to represent the income distribution of a nation's residents. It was developed by the Italian statistician and sociologist Corrado Gini and published in his 1912 paper "Variability and Mutability". Now it has been widely used in many fields such as sociology, health science, ecology and engineering, not only in economics. One of the factor we select to calculate the Gini coefficient is the cost of emission reduction. An entity with high cost implies it already has advanced equipments or technologies, leading to little reduction space. In this case, allowances the entity got may be a bit more in a suitable range. On the contrary, the entity with low cost ought to get relatively few allowances so that it is promoted to make efforts on emission reduction.

This research put an eye on the carbon emission allowance allocation for the power plants, and try to make it to be as fair as possible so as to be helpful for the emission mitigation while guarantee the electricity supply. The remainder of this paper is organized as follows. Section 2 is the methodology part, focusing on employing the Gini coefficient in the allowance allocation and then constructing mathematical model. In Sect. 3, an application in Guangdong ETS is presented to explore useful results and prove the validity of the model proposed in Sect. 2. Finally, Sect. 4 gives our conclusions and future research.

2 Method

In this section, a model for the allocation problem through Gini coefficient is constructed. The mathematical description of the problem is given as follows.

1. Notations

In order to facilitate the description of the problem, the following notions are introduced.

i	: index of the coal-fired power plants, $i = 1, 2, \cdots, I$
emi_i	: the historical emission of the ith plant
to_qut	: the total allowances for allocation
out_i	: the annual electricity output of the ith plant
inv	: the historical investment of the ith plant
ω_1	: the weight of the output-index for the Gini coefficient
ω_2	: the weight of the investment-index for the Gini coefficient
y_i^0	: the initial carbon emission allowances allocated to power plant i
Δy_i	: adjustment coefficient of plant i's allowances
y_i	: the carbon emission allowances power plant i obtained

2. Allocation Model with Gini Coefficient

The key issue for local government is how to allocation the carbon emission allowances. Since electricity is one of basic energies, its production is crucial to the development of the whole society. If the power plants produce negatively duo to the few allowances, it is bound to cause a series of social problems. Oppositely, if the allowances are too many, it would not reach the purpose of emission reduction. To balance the two questions above, a multi-objective model is established in this paper to supply policy for the local government. What we take into account are the emission reduction target and the electricity supply, besides the equality and efficiency of the allocation. The mathematical description in detail is shown below.

Firstly, we choose emission-based allocation approach named "grandfathering" to allocate the initial allowances. The emission-based allocation is to take the previous years emission proportion as the standard used for setting emission allowances in the following year, which is the current allowance allocation mechanism in the EU ETS. Power plant i's initial allowance, y_i^0, can be calculated by Eq. (1).

$$y_i^0 = \frac{emi_i}{\sum_{i=1}^{n} emi_i} \times to\_qut. \tag{1}$$

Under this free allocation method of grandfathering, most allowances are assigned to the entities that have emitted most. In this regard, grandfathering is potentially problematic [17]. To make the allocation more faire and effective, we take reduction investment and production output called "benchmarking" into consideration to make some adjustments on the initial allowance.

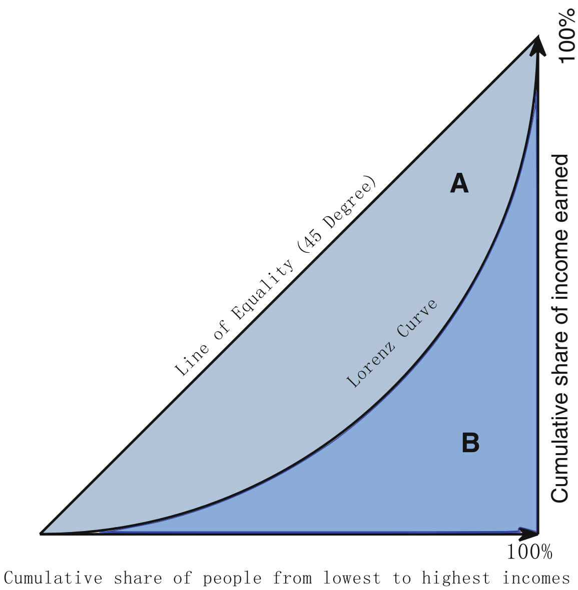
To guarantee the balanced development of the power plants and satisfy the electricity demand, the local government needs to consider the equity of the allocation. In economics, there is a measure of statistical dispersion intended to represent the income distribution of a nation's residents, known as the Gini coefficient. Here, we introduce it to measure the equity of the carbon emission allowances allocation.

We take the Gini coefficient of income as an example to present it. The Gini coefficient is defined mathematically based on Lorenz curve, which plots the proportion of the total income of the population (y axis) that cumulatively earned by the bottom x% of the population (see Fig. 1). The line at 45 degrees thus represents perfect equality of incomes. GI can be thought of as the ratio of the area that lies between the line of equality and the Lorenz curve (marked A in Fig. 1) over the total area under the line of equality (marked A and B in Fig. 1); i.e., $G = A/(A + B)$. It can theoretically range from 0 to 1. The lower it is the more equal the distribution is, with 0 corresponding to complete equality and 1 corresponding to complete inequality.

Choosing the evaluation index, like income, is a very important link, when applying the Gini coefficient to measure the fairness. There are various factors needed to be considered in the carbon emission allowances allocation, such as the power plants size, its contribution to public and its influence on environment. Considering the indexes need to be quantifiable, two representative factors, the annual output and the investment on carbon reduction, are selected to calculate the corresponding Gini coefficient for measuring the equality of the allocation.

How to calculate the coefficient is another important issue. The main problem is to compute the area A or B shown in Fig. 1. In practice, the mathematical expression of the Lorenz curve is not known. As a result, area B and A cannot be computed.

Fig. 1 The Gini coefficient based on the Lorenz curve



Only the discrete values at certain intervals on the abscissa are given. In this case, the Gini coefficient could be approximated by using various techniques for interpolating the missing values of the Lorenz curve. One of them is to approximate area B with trapezoids. The formula is as follows:

$$\text{Gini} = 1 - \sum_{m=1}^{M} (U_m - U_{m-1})(V_m + V_{m-1}), \tag{2}$$

where U_m means the cumulative percentage of the evaluation index, and V_m indicates the cumulative percentage of the carbon emission allowance. And when $m = 1$, (U_{m-1}, V_{m-1}) is regarded as $(0, 0)$.

(1) Output-based: For a power plant, its output reflects its contribution to society. Allocating the plant with higher output more allowances can help maintain the total electricity supply. Meanwhile, output-based allocation also satisfy the principle that more pay for more work. The output-based Gini coefficient is defined as:

$$G_1 = 1 - \sum_i (out\,p_{\pi_i} - out\,p_{\pi_{i-1}})(yp_{\pi_i} + yp_{\pi_{i-1}}), \tag{3}$$

where $out\,p_{\pi_i}$ and yp_{π_i} stand for the cumulative percentages of output and allowances of the first π_i plants, respectively. Thy are calculated by Eq. (4):

$$out\,p_{\pi_i} = out\,p_{\pi_{i-1}} + \frac{out_{\pi_i}}{\sum_i out_{\pi_i}},\ \ yp_{\pi_i} = yp_{\pi_{i-1}} + \frac{y_{\pi_i}}{\sum_i y_{\pi_i}},\ \text{ and } out\,p_{\pi_0} = yp_{\pi_0} = 0. \tag{4}$$

Here π indicates a sorting order in output/allocation, and satisfies the following formula:

$$\frac{y_{\pi_1}}{out_{\pi_1}} \leq \frac{y_{\pi_2}}{out_{\pi_2}} \leq \cdots \leq \frac{y_{\pi_{I-1}}}{x_{\pi_{I-1}}} \leq \frac{y_{\pi_I}}{x_{\pi_I}}.$$

(2) Investment-based: The investment on carbon reduction of a power plant reflects its concern degree on environment. The more the investment is, the more attention it pays on environment. The more carbon allowances should be allocated as encouragement. Moreover, this investment can also indirectly reflect the cost of continuing reduction. The more the investment is, the more the cost of going on reduction will be. The more carbon allowances should be got as a reward. Besides, it can also stimulate plants with little attention on environment to make investment on emission reduction, that reflects the efficiency of the allocation. Then the investment-based Gini coefficient is defined as Eq. (5):

$$G_2 = 1 - \sum_i (invp_{\tau_i} - invp_{\tau_{i-1}})(yp_{\tau_i} + yp_{\tau_{i-1}}), \tag{5}$$

where $invp_{\tau_i}$ and yp_{τ_i} means the cumulative percentages of investment and allowance of the first τ_i plants, respectively. They are shown as Eq. (6):

$$invp_{\tau_i} = invp_{\tau_{i-1}} + \frac{inv_{\tau_i}}{\sum_i inv_{\tau_i}},\ yp_{\tau_i} = yp_{\tau_{i-1}} + \frac{y_{\tau_i}}{\sum_i y_{\tau_i}},\ \text{and } invp_{\tau_0} = yp_{\tau_0} = 0. \quad (6)$$

Here τ indicates a sorting order in investment/allocation, satisfying the following formula:

$$\frac{y_{\tau_1}}{inv_{\tau_1}} \leq \frac{y_{\tau_2}}{inv_{\tau_2}} \leq \cdots \leq \frac{y_{\tau_{I-1}}}{inv_{\tau_{I-1}}} \leq \frac{y_{\tau_I}}{inv_{\tau_I}}.$$

To assess the equity of the allocation, the comprehensive Gini coefficient, a composite reflection of output and investment, is taken into consideration as the objective function. It is defined by weight-sum approach as below:

$$CG(y_i) = \omega_1 G_1 + \omega_2 G_2, \quad \text{where} \quad \omega_1 + \omega_2 = 1.$$

Objective: According to the regulations of the United Nations organizations, 0.4 is usually regarded as the “cordon” of the Gini coefficient. The lower, the better. Here, considering many other influences on the allocation, we cannot promise the coefficient to stay below 0.4. What we can do is to minimize it, that is:

$$\min \quad CG(y_i).$$

Constraints: The final allowance allocated to each power plant is the sum of the initial allowance and the adjustment. Additionally, to make sure total amount of the allowances allocated to be the same, the sum of the adjustments equals to zero. What' more, In order to make every plant to reduce emission, the allowance it get can not exceed its emission in previous year. At last, no matter the initial allowance or the final one every plant got are positive.

$$y_i = y_i^0 + \Delta y_i, \quad \sum_i \Delta y_i = 0, \quad y_i^0 > 0, \quad \text{and} \quad 0 < y_i \leq emi_i. \qquad (7)$$

2.1 Global Model

To control the emission of carbon, the government has to allocate the carbon emission allowances to the enterprises participated in emission reduction action. As one of the major emitters, the coal-fired power plants are included with no doubt. In this paper, the government takes the “cap-trade” mechanism and allocates the allowances freely to the plants first. When allocating, the government should consider the equity and efficiency of the allocation. The Gini coefficient, a measure of income inequality in economics, is applied to make the allocation as equitable as possible, and the detailed mathematical expression for this two models are show below.

$$\begin{cases} \min_{y_i} \ \omega_1 G_1 + \omega_2 G_2 \\ s.t. \begin{cases} y_i = y_i^0 + \Delta y_i \\ y_i^0 = \frac{emi_i}{\sum\limits_{i=1}^{I} emi_i} \times to\_qut \\ \sum_{i=1}^{I} \Delta y_i = 0 \\ 0 < y_i \le emi_i, i = 1, 2, \cdots, I. \end{cases} \end{cases}$$

3 Application

In this section, the carbon reduction planning of Guangdong province in China is used as a practical application example for the proposed optimization method.

1. Background

Up to now, China has been the second largest greenhouse gas emitter throughout the world, with enormous pressures in the international negotiation on carbon emissions control and climate change mitigation. At the Copenhagen climate conference in 2009, China government pledged that China would cut down carbon emission intensity (i.e. carbon emissions per unit GDP) by 40–45 % based on 2005 level by 2020. To achieve this target, China still employs CET mechanism adopted by many other countries. In 2013, Guangdong as well as Beijing, Tianjin, Shanghai, and Shenzhen has set up carbon emission trading center.

Guangdong province locates on the bank of the South China Sea, bordering on Hongkong, Macao, Guangxi, Hunan, Jiangxi and Fujian. It is one of the most developed provinces in China. On 19th December of 2013, carbon emission trading launched in Guangdong, and 7 deals accomplished on the first day with 120,029 ton of carbon trading volume. In its carbon emission management system, there are 3 participants as well as 4 systems, with the relationship between them is shown in Fig. 2. At present, hundreds of enterprises with annual carbon emission 20,000 ton and above are taken as the targets, relating to 9 kinds of industry. There's no doubt that most coal fired and LNG fired power plants are included. The detailed information about the parameters involved in the proposed model in shown in Table 1.

2. Results

To verify the practicality and efficiency of the model with Gini coefficient for the allowance allocation problem for the power plants in this paper, the example in Guangdong ETS is applied. Here the weights are chosen as $\omega_1 = 0.6$ and $\omega_2 = 0.4$. The final optimal results are shown in Fig. 3. It can be seen that under this allocation plan, the "output-allowance" curve almost coincides with the curve of absolute equality, which makes the output-Gini coefficient (i.e. G_1) very low at 0.0125. The situation for the investment-Gini coefficient is the same as $G_2 = 0.0187$. It indicates this allocation plan could reach equality to some extent on these two dimensions. This result demonstrates the efficiency of the method proposed in this paper.

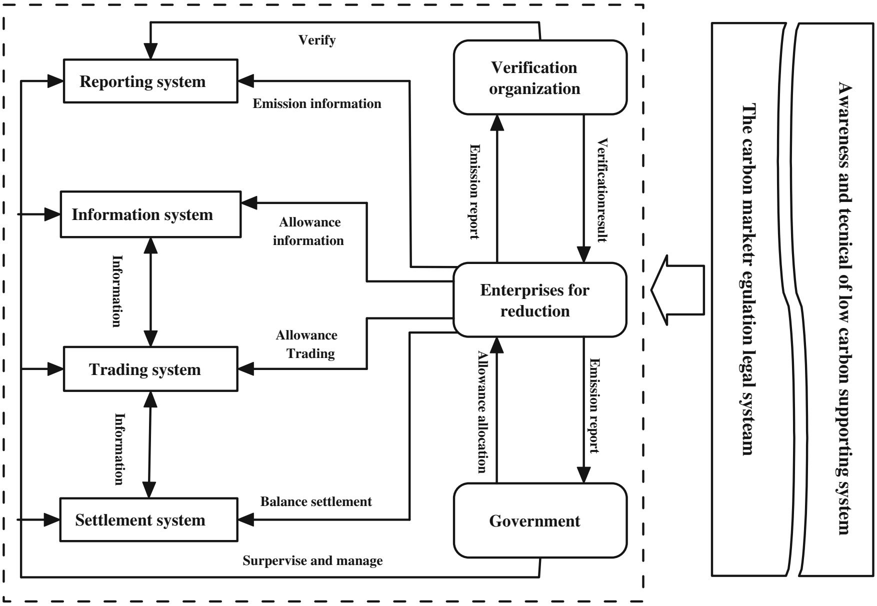


Fig. 2 The carbon emission management system

Table 1 The basic information for power plants involved

Index	Fuel type	Unit type	Emissions-base (104 Tonne)	Output-base (109 KWh)	Investment (109 CNY)
$i = 1$	Coal-fired	2*1000 Ultra supercritical	1109.6190	134.81	82.81
$i = 2$	Coal-fired	2*600 Ultra supercritical	684.3463	80.37	50.42
$i = 3$	Coal-fired	2*600 Supercritical	680.2186	78.49	46.79
$i = 4$	Coal-fired	2*300 Subcritical	340.8804	37.67	23.42
$i = 5$	Coal-fired	2*200 CFB	240.0019	24.31	15.28
$i = 6$	LNG-fired	2*190 S209E	58.6186	13.35	10.83
$i = 7$	LNG-fired	2*390 S209F	167.0058	42.95	22.51
$i = 8$	LNG-fired	2*260 S209E	111.2421	26.73	17.14

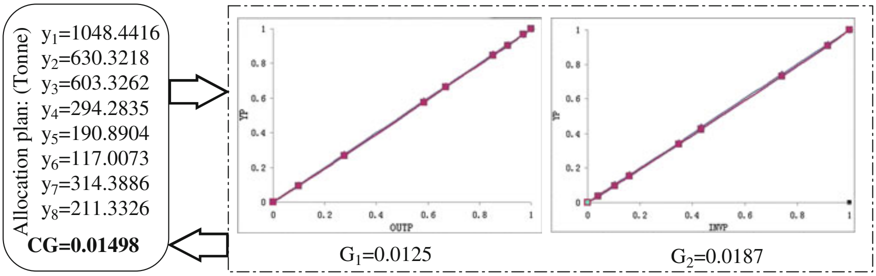


Fig. 3 The allocation plan and results

4 Conclusions and Future Research

This paper studied the carbon emission allowance allocation problem for the power plants. Our focus is on how to make the allocation achieve a certain degree of fairness. So we employed the Gini coefficient, a measurement of inequality in economics, to build mathematical model for the allocation problem. Further, two indicators, output and investment, were chosen to calculate the Gini coefficient, because the output stated for its contribution to the society, while the investment implied its scale and attitude towards the environment. Finally, an example with background in Guangdong ETS was taken to demonstrate the efficiency of the method proposed in this paper, and the results indicated that the idea of employing Gini coefficent could indeed make the equality principle of allocation come true. Since the allocation activity can also be regarded as an interaction between the regional authority and the entity. In the future research, we may take the reactions of the entity for the allocation into consideration when make allocation plans and construct a multi-level model. It might yield substantially different results.

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Dynamic Group Decision Making Approach Based On Aggregating Intuitionistic Fuzzy Cross Entropy and Lattice Order Preference

Chunxiang Guo, Yaqin Ling and Junjie Chang

Abstract We propose a dynamic group decision approach with intuitionistic fuzzy entropy and lattice order preference, where preference relations' possibility with respect to decision makers is represented by intuitionistic fuzzy number. Firstly, the preference characterization of decision makers is extended from four variety relations to seven variety preference relations. Then, considering the dynamic weight of decision-makers, the comprehensive intuitionistic fuzzy decision matrix is built by aggregating intuitionistic fuzzy preference matrix of decision makers at each time. Further, combined with the concept and property of intuitionistic fuzzy entropy and cross entropy, the ER nonlinear optimization model to reflect the nearness between personal preferences and group preferences based on preference entropy is constructed, and the individual preferences are aggregated by solving the model, gives the specific steps of the decision making. Feasibility and effectiveness of the proposed method are illustrated using a numerical example.

Keywords Dynamic decision-making · Lattice order preference · Intuitionistic fuzzy number · Preference entropy · Nonlinear optimization

1 Introduction

Group decision making (GDM) is used to obtain the best solution(s) for a problem according to the information provided by some decision makers. Group decision-making has been extensively applied in fields such as society, economy, management, industry and engineering system in recent years. In GDM problems, the decision maker should provide decision objectives and preference information of alterna-

C. Guo (✉) · Y. Ling
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: gchx1@163.com

J. Chang
Physics School of Beijing Institute of Technology,
Beijing 100081, People's Republic of China

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tives based on different decision-making environment. The preference information provided by decision makers can be expressed in multiple formats, such as weight model, paired comparison, sequence table, order relation, utility value, fuzzy preference relation, multiplicative preference relation, interval number and mixed mode, they are determined by decision-making environment and ability. Research results have been achieved based on GDM problems of the above preference information at home and abroad. Chiclana [4] presented a novel visual information feedback mechanism for GDM problems with TFCPRs; Guo [5] developed an approach to solve the random lattice order group decision-making problem, where the preference information on alternatives pair provided by experts is in the form of uncertain binary preference relations; Through a combination of multigranulation rough sets with intuitionistic fuzzy rough sets, Huang and Guo [12] developed a new multigranulation rough set model, called an intuitionistic fuzzy multigranulation rough set (IFMGRS); Yager and Alajlan [20] investigated the role of stochastic dominance as tool for comparing uncertain payoff alternatives; Fan [8] developed an approach to solving group decision-making problems, where the preference information on alternatives provided by experts is in the form of uncertain preference ordinals.

Studies had shown that when decision makers expressed their preference for alternatives, the simplest and most direct methods was pairwise comparison of alternatives, comparison results are presented using binary preference relations, such as González-Pachón et al. [9], Fan [8], Kou et al. [15] and Greco et al. [10]. In the pairwise comparison of alternatives, decision makers utilized binary preference relations to express comparison results [5, 11, 13]. Xu [18] presented a comprehensive survey of preference relations, point out that Mathematical concepts and language on binary relations were widely used in decision maker preference model of decision theory. For example, in criterion importance theory, the multi-criteria decision support was based on binary relations [16]. Scholars believed that binary preference relations included superior, inferior, and no difference, or four kinds of relations-superior, inferior, incomparability and indifference. Namely, preference of decision makers had the property of total or partial order [1, 14].

In fact, decision makers may not compare some decision alternatives for some reason. But in most major decisions, the supremum and infimum of alternatives pairs can be derived through data mining. Therefore, describing decision maker preference only in the form of ordinal number is vague and general. Lattice structure is more realistic to describe preferences of decision makers. In uncertain decision making problems, random preference relation of decision makers should be better described and expressed to make decision-making consequences clear. So it is necessary to extend preference description from four kinds of preference relations (superior, inferior, no difference and incomparability) to seven kinds of relations-superior, inferior, indifference, incomparability, as well as incomparability due to supremum, infimum and both of them.

In addition, due to the lack of information, decision-making environment, knowledge background and ability of decision makers, they are often difficult to give a clear preference relation. At this point, experts usually indicate their estimation of the alternatives pair with uncertainty preference relations. They think that the occurrence membership or probability of binary relation between alternatives pairs is uncertain. Therefore, uncertain binary preference of decision problems is particularly important.

More importantly, most of the previous studies focused on static decisions, which did not consider the natural state, decision-making objectives and the time sequence of decision makers' preference. In fact, static decision problem is few in real life, because most situations of decision making are dynamic. In many areas of decision making, such as multi-period investment decision, medical diagnostics, personal dynamic evaluation and military system efficiency dynamic evaluation, original decision-making information is usually collected at different periods. Therefore, ways to develop and address these problems are very necessary.

In dynamic intuitionistic fuzzy environment, this work combined with intuitionistic fuzzy set theory and preference theory, studying dynamic group decision-making problems with lattice order preference based on cross entropy. In the problems, a number of experts will give the possibility of binary relations between alternatives pairs at different times. And they describe the possibility of binary relations between alternatives pairs in the form of intuitionistic fuzzy numbers. Generally, there may be different decision makers or experts during the decision making process in each period. Based on the former's researches, this work assumed that at each period, decision-makers or experts independently obtain their own assessment results.

2 Preliminary Knowledge

This section includes a brief review of intuitionistic fuzzy sets and binary relation.

2.1 Intuitionistic Fuzzy Set (IFS)

Fuzzy set theory, proposed in 1965 by Zadeh, has been widely used among the fuzzy decision problems. To deal with uncertain information, Atanassov [2, 3] proposed the concept of intuitionistic fuzzy sets in 1983, and studied its operations and properties.

An intuitionistic fuzzy set (IFS) A in X is defined as:

$$A = (x, u_A(x), \nu_A(x))|x \in X,$$

where $u_A : X \to [0, 1]$ and $\nu_A : X \to [0, 1]$, with the condition $0 \leq u_A(x) + \nu_A(x) \leq 1, \forall x \in X$.

The numbers u_A and ν_A denote the degree of membership and non-membership of $x \in X$ in A, respectively. For each IFS A in X, the number $\pi_A(x) = 1-u_A(x)-\nu_A(x)$ denotes a hesitancy degree of $x \in X$ in A. Obviously, for $0 \leq \pi_A(x) \leq 1$ each $x \in X$.

In this work, $IFS(X)$ indicates that all intuitionistic fuzzy sets related to X. For every A_1 and $A_2 \in IFS(X)$, the following operations are defined:

(1) $A_1 \in A_2$ if and only if $\forall x \in X, u_{A_1}(x) \leq u_{A_2}(x)$ and $\nu_{A_1}(x) \geq \nu_{A_2}(x)$;

(2) $A_1 = A_2$ and only if $\forall \mathrm{x} \in \mathrm{X}, \mu_{A1}(\mathrm{x}) = \mu_{A_2}(\mathrm{x})$ and $\nu_{\mathrm{A}_1}(\mathrm{x}) = \nu_{A_2}(\mathrm{x})$;

(3) $A_1 + A_2 = \{\langle x, \mu_{A_1}(x) + \mu_{A_2}(x), \nu_{\mathrm{A}_1}(\mathrm{x}) + \nu_{\mathrm{A}_2}(\mathrm{x})\rangle | x \in X\}$;

(4) $A_1 \times A_2 = \{\langle x, \mu_{A_1}(x)\mu_{A_2}(x), \nu_{\mathrm{A}_1}(\mathrm{x}) + \nu_{\mathrm{A}_2}(\mathrm{x})$ - $\nu_{A_1}(x) \times \nu_{A_2}(x)\rangle | x \in X\}$.

2.2 Preference Relations

Definition 1 ([5]) A (non-strict) partial order is a binary relation in set P, the binary relation "$\succeq$" is anti-symmetric, transitive and non-reflexive. I.e., $\forall a, b, c$ in set P has following properties: $a \succeq a$ (reflexivity);
If $a \succeq b$ and $b \succeq a$, then $a \approx b$ (anti-symmetric);
If there is $a \succeq b$ and $b \succeq c$, then $a \succeq c$ (transitive).
$\succ, \approx$ represents the "superior" and "indifference" relation of alternatives in set A. Correspondingly, there are "$\succeq$" = "$\succ$" $\smile$ "$\approx$".

Definition 2 ([5]) Partial-order set L is a lattice. For any alternatives pairs x and y has a minimum upper bound $x \vee y$ (and operation), and a maximum lower bound $x \wedge y$ (intersection operation). That is, $z \succeq x \vee y \Longleftrightarrow z \succeq x$ and $z \succeq y$; $x \wedge y \succeq z \Longleftrightarrow x \succeq z$ and $y \succeq z$.

As mentioned above, in an uncertain decision-making environment, only four relations-superior ($\succ$), inferior ($\prec$), indifference ($\approx$) and incomparability ($||$) are not enough to describe the preference situation of decision-makers. In order to better express random preference relation of decision-makers and make the decision consequences clear, preference description of decision makers needs to be broadened. The four preference relations are changed into seven relations.

For example, a manufacturer plans to choose green technology for a green product and there are five types of candidate green technology ($A1$, $A2$, $A3$, $A4$, and $A5$). The decision maker considered that $A1$ is superior to $A2$ (denoted as $A1 \succ A2$); $A2$ is incomparable to $A3$, $A2$ and $A3$ have an $l.u.b.$ (denoted as $A2 \overset{\vee}{\|} A3$); $A3$ is incomparable to $A1$, $A3$ and $A1$ have a $g.l.b.$ (denoted as $A3 \underset{\wedge}{\|} A1$); $A4$ is incomparable to $A5$, $A4$ and $A5$ not only have an $l.u.b.$, but also a $g.l.b.$ (denoted as $A4 \overset{\vee}{\underset{\wedge}{\|}} A5$); $A2$ is incomparable to $A4$ (denoted as $A2||A4$); and the decision maker is indifferent between $A1$ and $A5$ (denoted as $A1 \approx A5$).

Binary relations “ $\overset{\vee}{\|}$, $\underset{\wedge}{\|}$ and $\overset{\vee}{\underset{\wedge}{\|}}$” are added into preference relations, providing reasonable borders and analysis basis for decision-makers. Decision-makers think the binary relation between alternatives pairs A_i and A_j $(A_i, A_j \in X)$ may be $\succ$, $||$, $\overset{\vee}{\|}$, $\underset{\wedge}{\|}$, $\overset{\vee}{\underset{\wedge}{\|}}$, $\approx$ or $\prec$, denoted as $H = \{r_g | g = 1, \ldots, 7\} = \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$. These seven kinds of binary relations are completely and mutually independent, constituting the set that is the recognition framework. About each alternatives pairs A_i, A_j, preference values of decision-makers $D_l (l = 1, 2, \ldots, m)$ are represented by intuitionistic fuzzy sets. IFS mode is defined as $D_l(A_i, A_j) = \{\langle r_g, \mu_{ij}^{r_g}(l), \nu_{ij}^{r_g}(l), \pi_{ij}^{r_g}(l)\rangle | r_g \in H\}$.

${\mu^{r_g}}_{ij}(l)$ and ${v^{r_g}}_{ij}(l)$ denote membership and non-membership degree of $A_i r_g A_j$, respectively. Accordingly, $0 \leq {\mu^{r_g}}_{ij}(l), {v^{r_g}}_{ij}(l) \leq 1\sqrt{b^2 - 4ac}$, $0 \leq \mu_{ij}^{r_g}(l) + \nu_{ij}^{r_g}(l) \leq 1, \pi_{ij}^{r_g}(l) = 1 - \mu_{ij}^{r_g}(l) - \nu_{ij}^{r_g}(l)$. Example 1: (A_i, A_k) is an alternatives pairs. Assume that there are three modes expressed by IFS as follows:

$$\begin{aligned}
D_l(A_i, B_k) =&\{\langle(\succ, 0.1, 0.1), (||, 0.5, 0.2), (\overset{\vee}{||}, 0.1, 0.9), (\underset{\wedge}{||}, 0.5, 0.5), (\overset{\vee}{\underset{\wedge}{||}}, 0.7, 0.1), \\
&(\approx, 0.3, 0.1), (\prec, 0.2, 0.5)\rangle\}, \\
D_2(A_i, B_k) =&\{\langle(\succ, 0.1, 0.3), (||, 0.4, 0.2), (\overset{\vee}{||}, 0.6, 0.1), (\underset{\wedge}{||}, 0.5, 0.3), (\overset{\vee}{\underset{\wedge}{||}}, 0.4, 0.3), \\
&(\approx, 0.3, 0.4), (\prec, 0.2, 0.5)\rangle\}, \\
D_3(A_i, B_k) =&\{\langle(\succ, 0.7, 0.1), (||, 0.5, 0.4), (\overset{\vee}{||}, 0.1, 0.4), (\underset{\wedge}{||}, 0.5, 0.5), (\overset{\vee}{\underset{\wedge}{||}}, 0.4, 0.2), \\
&(\approx, 0.5, 0.1), (\prec, 0.5, 0.4)\rangle\}.
\end{aligned}$$

3 Interaction Method of Dynamic Lattice Order Group Decision Making Problem with Intuitionistic Fuzzy Number

3.1 *Entropy of Intuitionistic Fuzzy Decision Preference System*

Besides IFS, there are two important concepts, entropy and cross entropy. These two concepts are widely used in mode recognition, medical diagnosis, image segmentation, etc.

Entropy of fuzzy sets, originally proposed by Zadeh, is an effective tool for measuring the information fuzziness. Szmidt and Kacprzyk [17] expanded the axiom of De Luca and Termini, eventually forming the following definition of $IFS(X)$ entropy measurement.

Definition 3 ([6]) The entropy of IFS (X) is a real-valued function H: $IFS(X) \to [0, 1]$, which meets the following several axioms:

(1) $H(\alpha) = 0$, if and only if $\alpha = (0, 1)$ or $\alpha = (1, 0)$;

(2) $H(\alpha) = 1$, if and only if $\mu_\alpha = \nu_\alpha$;

(3) $H(\alpha) \leq H(\beta)$, if $\mu_\alpha \geq \mu_\beta \geq \nu_\beta \geq \nu_\alpha$ or $\mu_\alpha \leq \mu_\beta \leq \nu_\beta \leq \nu_\alpha$

(4) $H(\alpha) = \mathrm{H}(\bar{\alpha})$, where $\alpha = (\mu_\alpha, \nu_\alpha)$ and $\beta = (\mu_\beta, \nu_\beta) \in V$, $\overline{\alpha}$ is a complement of set α.

Cross entropy is used to measure the difference of information. Based on the inequality principle proposed by Shannon, Vlachos and Sergiadis defined the intuitionistic fuzzy cross entropy.

Definition 4 ([17]) For two intuitionistic fuzzy sets α and β, if the following conditions are satisfied, $H(\alpha, \beta)$ is the cross entropy of α and β:

(1) $H(\alpha, \beta) \geq 0$

(2) $H(\alpha, \beta) = 0$ if and only if $\alpha = \beta$.

Above measurements can describe entropy and cross entropy of intuitionistic fuzzy sets.

Definition 5 ([7]) For two intuitionistic fuzzy sets α and β, $\alpha = (\mu_\alpha, \nu_\alpha)$ and $\beta = (\mu_\beta, \nu_\beta)$. Setting

$$H(\alpha, \beta) = \mu_\alpha \ln\frac{2\mu_\alpha}{\mu_\alpha + 2\mu_\beta} + \nu_\alpha \ln\frac{2\nu_\alpha}{\nu_\alpha + 2\nu_\beta},$$

$H(\alpha, \beta)$ is the intuitionistic fuzzy cross entropy between α and β.

In terms of parameters, is asymmetric. Therefore, symmetry measurement is defined as follows.

Definition 6 ([7]) For two intuitionistic fuzzy sets α and β, let $I(\alpha, \beta) = H(\alpha, \beta) + H(\beta, \alpha)$, where $I(\alpha,\beta)$ is symmetrical identifying information of intuition fuzzy sets.

It's easy to prove that $I(\alpha, \beta) \geq 0$; $I(\alpha, \beta) = 0$ if and only if $\alpha = \beta$.

According to the above properties, the cross entropy of α and β can be used to measure their conformity. When α has the same preferences with β, the cross entropy is minimum. Therefore, the cross entropy can measure the conformity of decision-makers' preferences in group decision.

Definition 7 Decision preference system $S = (H, D)$, $H = \{r_g | g = 1, \ldots, 7\} = \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$ is the identification framework. For alternatives pairs (A_i, B_j), $D_l(A_i, B_j)$ is an intuitionistic fuzzy set mode in H,

$$D_l(A_i, A_j) = \{r_g, \langle \mu^{r_g}{}_{ij}(l), v^{r_g}{}_{ij}(l), \pi^{r_g}{}_{ij}(l) \rangle | r_g \in H\}$$

denoted as, $(r_g \in H = \succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\})$, where $0 \leq \mu^{r_g}{}_{ij}(l) + v^{r_g}{}_{ij}(l) \leq 1$.

Definition 8 In decision preference system $S = (H, D)$, $H = \{r_g | g = 1, \ldots, 7\} = \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$ is the identification framework. For any alternatives pairs (A_i, B_j), $D_l(A_i, A_j)$ and $D_{l'}(A_i, A_j)$ are two intuitionistic fuzzy modes in H:

$$D_l(A_i, A_j) = \{r_g, \langle \mu^{r_g}{}_{ij}(l), v^{r_g}{}_{ij}(l), \pi^{r_g}{}_{ij}(l) \rangle | r_g \in H\},$$

$$D_{l'}(A_i, A_j) = \{r_g, \langle \mu^{r_g}{}_{ij}(l'), v^{r_g}{}_{ij}(l'), \pi^{r_g}{}_{ij}(l') \rangle | r_g \in H\}.$$

$H(D_l, D_{l'})$ is the intuitionistic fuzzy cross entropy between D_l and $D_{l'}$:

$$H(D_l, D_{l'}) = \sum_{r_g \in \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}} \left[\mu^{r_g}_{A_i,A_j}(l) \ln \frac{2\mu^{r_g}_{A_i,A_j}(l)}{\mu^{r_g}_{A_i,A_j}(l) + 2\mu^{r_g}_{A_i,A_j}(l')} + \nu^{r_g}_{A_i,A_j}(l) \ln \frac{2\nu^{r_g}_{A_i,A_j}(l)}{\nu^{r_g}_{A_i,A_j}(l) + 2\nu^{r_g}_{A_i,A_j}(l')} \right]. \tag{1}$$

$H(D_l, D_{l'})$ indicates the difference between D_l and $D_{l'}$, also called as IFS difference information. According to Shannon Inequality Principle, it is easy to prove $H(D_l, D_{l'}) \geq 0$, and $H(D_l, D_{l'}) = 0$ if and only if $A = B$.

Besides $H(D_l, D_{l'}) = H(D_l^c, D_{l'}^c)$ Where D_l^c, $D_{l'}^c$ are the complement of set D_l and $D_{l'}$, then

$$D_l^c(A_i, A_j) = \{r_g, \langle v^{r_g}{}_{ij}(l), \mu^{r_g}{}_{ij}(l), \pi^{r_g}{}_{ij}(l)\rangle | r_g \in H\},$$

$$D_{l'}^c(A_i, A_j) = \{r_g, \langle v^{r_g}{}_{ij}(l'), \mu^{r_g}{}_{ij}(l'), \pi^{r_g}{}_{ij}(l')\rangle | r_g \in H\}.$$

Therefore, intuitionistic fuzzy cross entropy can be defined by Eq. (1) as follows. Entropy $H(S)$ of System S is defined as: $H(D_l) = -(2\ln 2)^{-1} I(D_l, D_l^c) + 1$. That is

$$H(D_l) = -(\ln 2)^{-1} \sum_{r_g \in \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}} \left(\mu^{r_g} \ln \frac{2\mu^{r_g}}{\mu^{r_g} + 2v^{r_g}} + v^{r_g} \ln \frac{2v^{r_g}}{v^{r_g} + 2\mu^{r_g}}\right) + 1. \quad (2)$$

It is a measurement of intuitionistic fuzzy entropy, and meets the definition of Szmidt and Kacpraczyk [17]. Functions $\mu^{r_g}{}_{ij}(l)$ and $v^{r_g}{}_{ij}(l)$ indicate membership and non-membership degree of $A_i r_g A_k$. $H(D_l)$ is the preference entropy of intuitionistic fuzzy preference vector D_lAi, A_k). $H(D)$ reflects the granularity of decision classification and the impact of the decision-making classification on uncertainties. Finer classification of decisions means the smaller granularity and greater uncertainty in decision making.

3.2 Decision Making Method

In group decision making problem with dynamic intuitionistic fuzzy lattice order characteristics, preference values of all the decision makers (DMs) are expressed in the form of intuitionistic fuzzy numbers (IFNs) during different periods.

Firstly, a detailed description is given on DIFGDM problem:

(1) $X = \{a_1, a_2, \ldots, a_i, \ldots, a_j \ldots, a_m\}$ is a discrete set of feasible alternatives.

(2) $H = \{r_g | g = 1, \ldots, 7\} = \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$ is a finite set of seven kinds of binary relations.

(3) $D = \{D_1, \ldots, D_l, \ldots, D_q\}$: at each moment $t_k (k = 1, 2, \ldots, p)$, weight vector of the same q decision makers (DMs) is $w(t_k) = (w_1(t_k), \ldots, w_l(t_k), \ldots, w_q(t_k))$, where $w_l(t_k) \geq 0$; $l = 1, 2, \ldots, q$ and $\sum_{l=1}^{q} w_l(t_k) = 1$.

A decision maker cannot have sufficient expertise to evaluate all aspects of the problem. For them, to make the evaluation part of the problem is permissible. Therefore, different decision-makers should be allocated with different weights, particularly when the decision problem involves changes of policies, guidelines and environment.

In the past few decades, people have developed a number of methods to determine the weights of decision-makers. Generally, the weights should be determined according to their knowledge, skills and experience.

(4) For the periods $t_k(k = 1, 2, \ldots, p)$, the weight vector of t_k is $w(t) = ((w(t_1), w(t_2), \ldots, w(t_p))$, where $w(t_k) > 0, k = 1, 2, \ldots, p$; $\sum_{k=1}^{p} w(t_k) = 1$.

(5) At time $t_k(k = 1, 2, \ldots, p)$, decision makers $D_l(l = 1, 2, \ldots, q)$ provide preference values between alternatives pair (a_i, a_j), and construct intuitionistic fuzzy decision matrix $V(t_k^l) = (\upsilon_{ij}^{r_g}(t_k^l))_{C_m^2\times 7}$.

Accordingly, any alternatives pair has an intuitionistic fuzzy number about binary relation r_g provided by the decision makers, expressing as: $\upsilon^{r_g}{}_{ij}(t_k^l) = (\mu^{r_g}{}_{ij}(t_k^l), v^{r_g}{}_{ij}(t_k^l), \pi^{r_g}{}_{ij}(t_k^l))$, the decision maker considers that the possibility of $a_i r_g a_j$ is an intuitionistic fuzzy number. Where $\mu^{r_g}{}_{ij}(t_k^{(l)})$ indicates the membership degree of $a_i r_g a_j$ by decision-maker Dl ; $v^{r_g}{}_{ij}(t_k^l)$ indicates the non-membership degree of $a_i r_g a_j$ by decision-maker d_l; $\pi^{r}{}_{ij}(t_k^{(l)})$ indicates the uncertainty degree of $a_i r_g a_j$ by decision-maker d_l.

Where, $\mu^{r_g}{}_{ij}(t_k^{(l)}) \in [01], v^{r_g}{}_{ij}(t_k^l) \in [0, 1], \pi^{r_g}{}_{ij}(t_k^l) \in [0, 1], u^{r_g}{}_{ij}(t_k^{(l)}) + v^{r_g}{}_{ij}(t_k^{(l)}) \leq 1, \pi^{r_g}{}_{ij}(t_k^{(l)}) = 1 - \mu^{r_g}{}_{ij}(t_k^{(l)}) - v^{r_g}{}_{ij}(t_k^{(l)})$.

(6) Weight vector of decision makers $D_l(l = 1, 2, \ldots, q)$ at different time $t_k(k = 1, 2, \ldots, p)$ is: $w_l(t_k) = (w_l(t_1), w_l(t_2), \ldots, w_l(t_p))$. The evaluation of expert D_l at time t_k is $D_l^{t_k}(a_i, a_j) = \{(r_g, \langle\mu_{ij_{ij}}^{r_g}(t_k^l), \nu_{ij}^{r_g}(t_k^l), \pi_{ij}^{r_g}(t_k^l))\rangle |\, r_g \in H\}$, an intuitionistic fuzzy preference vector.

Based on the above decision-making information, the dynamic intuition fuzzy weighted average operator (DIFWA) is utilized to establish the optimal model, in order to achieve optimal group preference. Then satisfactory binary relationship between alternatives pair can be determined.

Step 1. We introduce DIFWA operator related to IFNs [19].

$$\begin{aligned}
\upsilon_{ij}^{r_g}(l) &= (\mu_{ij}^{r_g}(l), \nu_{ij}^{r_g}(l), \pi_{ij}^{r_g}(l)) \\
&= \mathrm{DIFWA}_w(t_k)(\upsilon_{ij}^{r_g}(t_1^l), \upsilon_{ij}^{r_g}(t_2^l), \ldots, \upsilon_{ij}^{r_g}(t_p^l)) \\
&= w(t_1)\upsilon_{ij}^{r_g}(t_1^l) \oplus w(t_2)\upsilon_{ij}^{r_g}(t_2^l) \oplus \cdots \oplus w(t_p)\upsilon_{ij}^{r_g}(t_p^l) \\
&= (1 - \prod_{k=1}^{p}(1 - \mu_{ij}^{r_g}(t_k^l))^{w(t_k)}, \prod_{k=1}^{p} \upsilon_{ij}^{r_g}(t_k^l))^{w(t_k)}, \prod_{k=1}^{p}(1 - \mu_{ij}^{r_g}(t_k^l))^{w(t_k)} \\
&\quad - \prod_{k=1}^{p}(\upsilon_{ij}^{r_g}(t_k^l))^{w(t_k)}).
\end{aligned} \tag{3}$$

Individual's intuitionistic fuzzy matrices at $t_k (k = 1, 2, \ldots, p)$ are gathered to form integrated intuitionistic fuzzy decision matrix for each decision maker $D_l (l = 1, 2, \ldots, q)$, where $w(t_k) > 0, k = 1, 2, \ldots, p$; $\sum_{k=1}^{p} w(t_k) = 1$.

Step 2. Using DWA operator [19] obtain decision makers' combined weights.

$$w_l = DWA_{w(t_k)}(w_l(t_1), w_l(t_2), \ldots, w_l(t_p)) = \sum_{k=1}^{p} w(t_k) w_l(t_k). \tag{4}$$

Decision makers' weights $w(t_k)$ are gathered during p different periods $(k = 1, 2, \ldots, p)$ to form their combined weight $w_l (l = 1, 2, \ldots, q)$.

Step 3. The relative closeness degree between individual preference and group preference is calculated for each alternatives pair.

According to the properties of cross entropy, the cross entropy of group preference to individual preference should be the minimum to maximize consistency of decision-making group preference, establishing the following optimization problems:

$$\min \sum_{l=1}^{q} w_l H(D, D_l) = \min \sum_{l=1}^{q} w_l \Bigg(\sum_{r_g \in \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx \prec\}} u_{ij}^l(r_g) \ln \frac{2u_{ij}^l(r_g)}{u_{ij}^l(r_g) + 2u_{ij}(r_g)} + \upsilon_{ij}^l(r_g) \ln \frac{2\nu_{ij}^l(r_g)}{\nu_{ij}^l(r_g) + 2\nu_{ij}(r_g)} \Bigg)$$

$$s.t. \begin{cases} 0 \le \mu_{ij}^l(r_g) + \upsilon_{ij}^l(r_g) \le 1 \\ 0 \le \mu_{ij}^l(r_g) \le 1 \\ 0 \le \upsilon_{ij}^l(r_g) \le 1 \\ 0 \le \mu_{ij}(r_g) + \nu_{ij}(r_g) \le 1 \\ 0 \le \mu_{ij}(r_g) \le 1 \\ 0 \le \nu_{ij}(r_g) \le 1 \\ 0 \le \nu_{ij}(r_g) \le 1 \\ \sum_{l=1}^{q} w_l = 1 \text{ and } 1 \ge w_l \ge 0. \end{cases} \tag{5}$$

Constraints in the model are linear and bounded, so they have their feasible solution sets, as bounded convex set; the objective function is continuously differentiable function, namely, the model have the optimal solution. In addition, the objective function is strictly concave function, so the solution exists and is unique. The optimization problem can be solved by direct calculation with Lingo8.0 software. Evidence D is the group preference. Preference vector for group distribution follow as that can be obtained with Lingo8.0 software.

$$D(A_i, B_j) = \{(r_g, \langle \mu_{ij}(r_g), \nu_{ij}(r_g), \pi_{ij}(r_g)\rangle)|r_g \in H\}.$$

Step 4. Determining the groups' preference for the alternatives pair.

Setting $0 < \sigma < 1$, the binary relationship between the alternatives pair is determined, the steps as follows.

Assume that the group preference on alternatives pair (a_{i}, a_j) is:

$$r_g, r_{g'} \in \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\},$$

where $\upsilon_{ij}(r_g) = (\mu_{ij}(r_g), \nu_{ij}(r_g), \pi_{ij}(r_g))$, $\upsilon_{ij}(r_{g'}) = (\mu_{ij}(r_{g'}), \nu_{ij}(r_{g'}), \pi_{ij}(r_{g'}))$ and the binary relation set of the group preference about alternative pair (a_{i}, a_j) is denoted as $\mathrm{R}^*(a_{\mathrm{i}}, a_j)$:

(1) About r_g, if $\forall r_{g'} \in \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$, then $|\upsilon(r_g) - \upsilon(r_{g'})| \geq \delta$ satisfied, so $r_g \in R * (a_{\mathrm{i}}, a_j)$, or to the next step;

(2) About r_g, $r_{g'}$, if $\forall r_{g'} \in \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$, (where, g $\neq$ g" $\neq$ g') there are $|\upsilon(r_{g''}) - \upsilon(r_{g'})| \geq \delta$ and $|\upsilon(r_{g''}) - \upsilon(r_g)| \geq \delta$, moreover $|\upsilon(r_{g'}) - \upsilon(r_g)| \leq \delta$, then $r_g, r_{g'} \in R * (a_{\mathrm{i}}, a_j)$.

4 Examples

The 21st century is highly information-oriented era, the network has gradually become the main channel for people to obtain information, become an indispensable part of Daily life, and the online shopping has also been integrated into the ordinary people's life. With the advent of 4G era, the competition in e-commerce markets is becoming more and more intense. In this case, the merchant by the consumer's shopping experience, online surveys to understand the consumer's dynamic preference, providing consumers with satisfactory products is particularly important.

A group of customers $D = \{D_1, D_2, D_3\}$ is organized to estimate a batch of similar online products $X = \{A_1, A_2, A_3, A_4, A_5\}$ by Amazon, the online products with different brands. It is necessary to comprehensively consider the brand, quality, cost, and other factors. The estimation is divided into three stages, and the information of customer group is collected in these stages.

Without loss of generality, the weight vector at time $t_k (k = 1, 2, 3)$ is assumed as $w(t) = ((w(t_1), w(t_2), \ldots, w(t_p))^T = (0.2, 0.3, 0.5)^T$, weight vector of decision makers $D_l (l = 1, 2, 3)$ at period $t_k (k = 1, 2, 3)$ are $w_1(t_k) = (0.5, 0.3, 0.2)$, $w_2(t_k) = (0.20, 0.35, 0.45)$, $w_3(t_k) = (0.25, 0.30, 0.45)$, respectively. Considering the influence of different decision-making environments and customers' abilities and range of knowledge, preference of the customer to product has partial order structure. Recognition frame of customers is denoted as $H = \{r_{\mathrm{g}} | \mathrm{g} = 1, \ldots, 7\} = \{\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx, \prec\}$, H is the set of limited binary relation.

Experts give their preferences for the product at different times, preferences in the form of intuitionistic fuzzy distribution preference vector. Their degree of support for the product is shown in the appendix (Table 1). For example, the data in the second row and rank of Table 1 are: Expert D1 thinks membership degree of A1 A2 $A_1 \succ A_2$ is 0.25 at the moment of $T = 1$; non-membership degree is 0.74; hesitation degree is 0.01. Because of space, experts' other preferences are not shown.

Considering the views of each customer, selling products were selected from five candidate products. Solving process is as follows.

Step 1. Based on Eq. (3), integrated intuitionistic fuzzy decision matrix of decision makers $D_l (l = 1, 2, 3)$ at $t_k (k = 1, 2, 3)$ by using DIFWA operator [20], forming the comprehensive intuitionistic fuzzy matrix $V(l) = [\upsilon^{r_g}{}_{ij}(l)]_{\mathrm{C}_{\mathrm{m}}^2 \times 7}$. The expert D1's comprehensive intuitionistic fuzzy matrix is shown in Table 2. Because of space, the comprehensive intuitionistic fuzzy matrix of expert D2 and D3 are not shown.

Step 2. Based on Eq. (4), a combined decision maker weight $w_l (l = 1, 2, 3)$ was formed using DWA operator [19] and decision-makers' weights $(k = 1, 2, 3)$ of at p different periods. $w_1 = 0.29$; $w_2 = 0.37$; $w_3 = 0.365$.

Step 3. Based on Eq. (5), the relative proximity between preferences of individuals and groups was calculated for each alternatives pair (A_i, A_j). And group distribution preference vector was $D\mathrm{A_i}, A_\mathrm{j}) = \{\mathrm{r_g}, \langle \mu_{ij}(\mathrm{r_g}), \nu_{ij}(\mathrm{r_g}) \rangle | \mathrm{r_g} \in \mathrm{H}\}$ (See Table 3).

Step 4. Determining the group preference for the alternatives pair. $\sigma = 0.01$ Setting, the binary relation between alternatives pair was determined:

$$A_1 || A_2,\ A_1 \approx A_2;\ A_1 \overset{\vee}{||} A_3;\ A_1 \succ A_4,\ A_1 \prec A_4;\ A_1 \overset{\vee}{\underset{\wedge}{||}} A_5,\ A_1 \prec A_5;\ A_2 \overset{\vee}{\underset{\wedge}{||}} A_3;$$

$$A_2 \overset{\vee}{\underset{\wedge}{||}} A_4,\ A_2 \approx A_5;\ A_3 || A_4,\ A_3 \overset{\vee}{||} A_4;\ A_3 \succ A_5;\ A_4 \overset{\vee}{\underset{\wedge}{||}} A_5.$$

If there is one element in set R*, namely there exist the only collective preference relation so that the sum of conflict degrees between group and individual suggestions reaches minimum. Then the preference relation is the preference of groups [5]. If group preference relation R* is more than one element, then the preference relations are determined in accordance with the gathering principle or priority principle [5]. For example, if $A_1 \succ A_4, A_1 \prec A_4$, then the binary relation of A_1, A_4 will be determined by the gathering principle, as $A_1 \overset{\vee}{\underset{\wedge}{||}} A_4$. And if $A_1 || A_2, A_1 \approx A_2$, the binary relation is determined with principle of priority, as $A_1 \approx A_2$.

Finally, the preferences of decision-making group for the product were obtained as follows:

$$A_1 \approx A_2;\quad A_1 \overset{\vee}{||} A_3;\quad A_1 \overset{\vee}{\underset{\wedge}{||}} A_4;\ A_1 \prec A_5;\ A_2 \overset{\vee}{\underset{\wedge}{||}} A_3;\ A_2 \overset{\vee}{\underset{\wedge}{||}} A_4;$$

$$A_2 \approx A_5;\ A_3 \overset{\vee}{||} A_4;\ A_3 \succ A_5;\ A_4 \overset{\vee}{\underset{\wedge}{||}} A_5.$$

5 Conclusions

With the development of modern society, actual group decision making process has become increasingly complex and uncertain. At different times of group decision-making environment, decision-makers can express their different preferences. Dynamic group decision making can be utilized in many fields, including military, medical, management, sports and emergency situations.

For dynamic uncertain lattice order group decision-making problem in view of the intuitionistic fuzzy dynamic uncertain environment, this paper proposes a dynamic intuition lattice ordered group decision making interaction method based on preference entropy .

At this point, decision-makers' preferences had the feature of uncertain lattice order. Besides, a number of experts provided the possibility of binary relation between pair-programs at different times, which was described in the form of intuitionistic fuzzy number (IFNs).

To achieve this goal, the types of binary relations were extended. The binary relationship between A_i and $A_j \in X$ was assumed as $\succ, ||, \overset{\vee}{||}, \underset{\wedge}{||}, \overset{\vee}{\underset{\wedge}{||}}, \approx$ *or* $\prec$; based on preference features of lattice order, the concept of entropy and cross entropy of intuitionistic fuzzy set modes was defined; DIFWA operator [19] was also utilized to determine the preferences and weight indicators of decision makers. Then each decision maker's intuitionistic fuzzy decision matrix at different periods was integrated into combined intuitionistic fuzzy decision matrix. Based on intuitionistic fuzzy mixing entropy, optimization model was established to reflect differences between the preferences of individuals and group, determining the group preference. Results showed that preferences of decision-making groups had characteristic of lattice order, which can more truly reflect the preferences of decision makers.

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Appendix

Table 1 The intuitionistic fuzzy distribution preference vector under expert D1 ($T = 1$)

D1	$\succ$	$\|\|$	$\overset{\vee}{\|\|}$	$\underset{\wedge}{\|\|}$
$(A1, A2)$	(0.25, 0.74, 0.01)	(0.74, 0.26, 0)	(0.41, 0.58, 0.02)	(0.65, 0.30, 0.05)
$(A1, A3)$	(0.5, 0.4, 0.1)	(0.5, 0.3, 0.2)	(0.4, 0.4, 0.2)	(0.4, 0.4, 0.2)
$(A1, A4)$	(0.6, 0.3, 0.1)	(0.7, 0.3, 0.0)	(0.6, 0.2, 0.2)	(0.6, 0.2, 0.2)
$(A1, A5)$	(0.5, 0.4, 0.1)	(0.4, 0.5, 0.1)	(0.5, 0.3, 0.2)	(0.3, 0.4, 0.3)
$(A2, A3)$	(0.6, 0.2, 0.2)	(0.7, 0.2, 0.1)	(0.4, 0.2, 0.4)	(0.5, 0.2, 0.3)
$(A2, A4)$	(0.5, 0.3, 0.2)	(0.6, 0.2, 0.2)	(0.5, 0.1, 0.3)	(0.6, 0.4, 0.0)
$(A2, A5)$	(0.5, 0.5, 0.0)	(0.6, 0.2, 0.2)	(0.5, 0.4, 0.1)	(0.5, 0.3, 0.2)
$(A3, A4)$	(0.5, 0.4, 0.1)	(0.6, 0.2, 0.2)	(0.6, 0.3, 0.1)	(0.7, 0.3, 0.0)
$(A3, A5)$	(0.5, 0.5, 0.0)	(0.3, 0.5, 0.1)	(0.4, 0.4, 0.2)	(0.2, 0.5, 0.3)
$(A4, A5)$	(0.6, 0.3, 0.1)	(0.7, 0.2, 0.1)	(0.4, 0.2, 0.4)	(0.7, 0.2, 0.1)

D1	$\overset{\vee}{\underset{\wedge}{\|\|}}$	$\sim$	$\prec$	
$(A1, A2)$	(0.4, 0.54, 0.06)	(0.33, 0.62, 0.05)	(0.7, 0.23, 0.07)	
$(A1, A3)$	(0.6, 0.3, 0.1)	(0.5, 0.5, 0.0)	(0.8, 0.1, 0.1)	
$(A1, A4)$	(0.5, 0.4, 0.1)	(0.6, 0.2, 0.2)	(0.4, 0.4, 0.2)	
$(A1, A5)$	(0.7, 0.2, 0.1)	(0.6, 0.3, 0.1)	(0.8, 0.1, 0.1)	
$(A2, A3)$	(0.6, 0.4, 0.0)	(0.5, 0.4, 0.1)	(0.7, 0.1, 0.2)	
$(A2, A4)$	(0.5, 0.5, 0.0)	(0.5, 0.3, 0.2)	(0.6, 0.2, 0.2)	
$(A2, A5)$	(0.7, 0.2, 0.1)	(0.6, 0.3, 0.1)	(0.7, 0.3, 0.0)	
$(A3, A4)$	(0.6, 0.4, 0.0)	(0.5, 0.4, 0.1)	(0.5, 0.4, 0.1)	
$(A3, A5)$	(0.6, 0.3, 0.1)	(0.8, 0.1, 0.1)	(0.6, 0.3, 0.1)	
$(A4, A5)$	(0.7, 0.2, 0.1)	(0.4, 0.4, 0.2)	(0.7, 0.3, 0.0)	

Table 2 The comprehensive intuitionistic fuzzy matrix under expert D1

D1	$\succ$	$=$	$\geq$	$\leq$
$(A1, A2)$	(0.48, 0.387, 0.133)	(0.716, 0.199, 0.085)	(0.361, 0.519, 0.121)	(0.595, 0.134, 0.272)
$(A1, A3)$	(0.614, 0.153, 0.232)	(0.818, 0.052, 0.13)	(0.612, 0.054, 0.334)	(0.431, 0.333, 0.237)
$(A1, A4)$	(1, 0, 0)	(0.548,0.429,0.024)	(0.596,0.294,0.109)	(0.76,0.146,0.094)
$(A1, A5)$	(0.678, 0.089, 0.233)	(0.463, 0.235, 0.302)	(0.467, 0.226, 0.307)	(0.685, 0.077, 0.238)
$(A2, A3)$	(0.516, 0.073, 0.412)	(0.655, 0.262, 0.084)	(0.648, 0.193, 0.159)	(0.708, 0.077, 0.214)
$(A2, A4)$	(0.505, 0.268, 0.227)	(0.755, 0.063, 0.182)	(0.448, 0.241, 0.311)	(0.557, 0.219, 0.224)
$(A2, A5)$	(0.547, 0.245, 0.208)	(0.615, 0.134, 0.251)	(0.485, 0.39, 0.125)	(0.542, 0.205, 0.253)
$(A3, A4)$	(0.515, 0.228, 0.257)	(0.642, 0.214, 0.143)	(0.553, 0.095, 0.352)	(0.576, 0.383, 0.041)
$(A3, A5)$	(0.565, 0.211, 0.224)	(0.438, 0.247, 0.315)	(0.755, 0.063, 0.182)	(0.252, 0.524, 0.224)
$(A4, A5)$	(0.557, 0.129, 0.315)	(0.599, 0.118, 0.283)	(0.669, 0.127, 0.204)	(0.729, 0.083, 0.188)
D1	$\gtreqless$	$\approx$	$\prec$	
$(A1, A2)$	(0.714, 0.204, 0.082)	(0.381, 0.266, 0.352)	(0.679, 0.207, 0.114)	
$(A1, A3)$	(0.648, 0.317, 0.035)	(0.563, 0.269, 0.167)	(0.695, 0, 0.305)	
$(A1, A4)$	(0.728, 0.241, 0.031)	(0.743, 0.09, 0.167)	(0.938, 0.054, 0.008)	
$(A1, A5)$	(0.748,0.146, 0.106)	(0.67, 0.257, 0.073)	(0.913, 0.067, 0.02)	
$(A2, A3)$	(0.6, 0.303, 0.097)	(0.392, 0.438, 0.17)	(0.633, 0.176, 0.191)	
$(A2, A4)$	(0.654, 0.122, 0.224)	(0.582, 0.19, 0.229)	(0.531, 0.179, 0.29)	
$(A2, A5)$	(0.641, 0.228, 0.131)	(0.631, 0.155, 0.214)	(0.645, 0.226, 0.129)	
$(A3, A4)$	(0.6, 0.155, 0.245)	(0.676, 0.089, 0.235)	(0.485, 0.228, 0.287)	
$(A3, A5)$	(0.568, 0.175, 0.28)	(0.759, 0.084, 0.17)	(0.535, 0.212, 0.253)	
$(A4, A5)$	(0.535, 0.261, 0.204)	(0.468, 0.299, 0.233)	(0.599, 0.117, 0.284)	

Table 3 The group distribution preference vector

D	$\succ$	$\|\|$	$\overset{\vee}{\|\|}$	$\underset{\wedge}{\|\|}$
$(A1, A2)$	(0.607, 0.393)	(0.813, 0.187)	(0.555, 0.455)	(0.677, 0.323)
$(A1, A3)$	(0.733, 0.267)	(0.775, 0.225)	(0.796, 0.204)	(0.716, 0.284)
$(A1, A4)$	(0.766, 0.234)	(0.597, 0.403)	(0.758, 0.242)	(0.759, 0.241)
$(A1, A5)$	(0.731, 0.269)	(0.745, 0.255)	(0.592, 0.408)	(0.762, 0.238)
$(A2, A3)$	(0.718, 0.282)	(0.748, 0.252)	(0.627, 0.373)	(0.758, 0.242)
$(A2, A4)$	(0.633, 0.367)	(0.759, 0.241)	(0.496, 0.504)	(0.629, 0.371)
$(A2, A5)$	(0.649, 0.351)	(0.735, 0.265)	(0.639, 0.361)	(0.741, 0.259
$(A3, A4)$	(0.615, 0.385)	(0.773, 0.227)	(0.774, 0.226)	(0.619, 0.381)
$(A3, A5)$	(0.863, 0.137)	(0.752, 0.248)	(0.758, 0.242)	(0.598, 0.402)
$(A4, A5)$	(0.725, 0.275)	(0.771, 0.229)	(0.633, 0. 367)	(0.741, 0.259)
D	$\overset{\vee}{\underset{\wedge}{\|\|}}$	$\approx$	$\prec$	
$(A1, A2)$	(0.725, 0.275)	(0.797, 0.203)	(0.655, 0.334)	
$(A1, A3)$	(0.568, 0.432)	(0.678, 0.322)	(0.756, 0.244)	
$(A1, A4)$	(0.694, 0.306)	(0.725, 0.275)	(0.771, 0.229)	
$(A1, A5)$	(0.876, 0.124)	(0.506, 0.494)	(0.869, 0.131)	
$(A2, A3)$	(0.782, 0.218)	(0.52, 0.48)	(0.694, 0.306)	
$(A2, A4)$	(0.809, 0.191)	(0.499, 0.501)	(0.662, 0.338)	
$(A2, A5)$	(0.593, 0407)	(0.824, 0.176)	(0.752, 0.248)	
$(A3, A4)$	(0.675, 0.325)	(0.589, 0.411)	(0.711, 0.289)	
$(A3, A5)$	(0.703, 0.297)	(0.535, 0.465)	(0.761, 0.239)	
$(A4, A5)$	(0.784, 0.216)	(0.673, 0.327)	(0.692, 0.308)	

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Work-Family Conflict and Decision Making Styles: Study of Higher Education Sector of Pakistan

Rana Rashid Rehman, Komal Mushtaq and Ajmal Waheed

Abstract This study examines the impact of work-family conflict on decision making styles of faculty members in higher education sector of Pakistan. Study also highlights the moderating role of decisional intelligence (a part of emotional intelligence) in predicting the relationship among work-family conflict and decision making styles. Two hypotheses are generated for the present research work including; (i) work-family conflict has significant impact on the decision making styles of faculty members; and, (ii) decisional intelligence moderates the relationship between work-family conflict and decision making styles of faculty members. Questionnaire method is utilized to collect data from the sample of 352 faculty members employed in federal chartered universities of Pakistan. Results for H_1 suggest that work-family conflict negatively predicts rational and intuitive decision making; and, positively predicts avoidant and spontaneous decision making styles while no association is found with dependent decision making style. Results for H_2 suggest that decisional intelligence moderates the relationship among work-family conflict, rational, intuitive and dependent decision making styles. This research work describes both academic and professional issues and its findings can be comprehensively utilized for the betterment of higher education sector of Pakistan.

Keywords Work-family conflict · Decision making styles · Emotional intelligence · Higher education institutions

1 Introduction

Getting education has become the necessity for endurance in the present era while higher education institutions play the role of leadership in this regard. However, the rapid economic development during last few years has led the organizations towards several challenges. Change in work setups is one of these challenges. It lead the

R.R. Rehman (✉) · K. Mushtaq · A. Waheed
School of Management Sciences, Quaid-i-Azam University, Islamabad 45320, Pakistan
e-mail: rashidrehman29@gmail.com

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employees towards complex jobs requiring more involvement as compared to last decades. The demanding jobs, long working hours, struggling job tasks, work pressure and use of rapidly changing technology makes it difficult for working individuals to maintain a balance between work and family life. Creating a balance with family and job responsibilities is a dilemma for the employees and almost impossible due to tempestuous work environment. This state of affairs leads towards a greatest challenge i.e., work-family conflict (WFC) for human resource management. Work-family conflict can be defined as incompatibility between work and family life or as push and pull between family and work responsibilities.

In the span of life, a working individual perform dual type of role which include role from family as being father/mother, sibling, friend, spouse etc.; and, role from work such as being employer, worker etc. In performing these roles, individuals have to take many routine decisions as well as strategic decisions which have long lasting impacts on their role performances. However, a quality decision making by an individual leads him/her towards satisfied life while poor decision making in performing work or non-work roles may result in certain incompatibilities such as work-family conflict. Therefore, this research work mainly focuses on examining the impact of work-family conflict on different decision making styles along with the role of decisional intelligence in faculty members of Pakistan.

2 Literature Review

During the last few years, a great pact of attention according to Carlson and Perrewe [1] had been given to study work-family conflict and its sway on various outcomes. Work-family conflict is reflected as a potential source of stress that has negative impact on behavior and well-being [2]. A cross sectional study by Kinnunen and Mauno [3] identified that work-family conflict is associated with various negative work and stress related outcomes. Researchers such as Amstad et al. [4]; Bellavia and Frone [5] categorized the consequences of work-family conflict in three ways i.e., (a) family related; (b) work related; and (c) domain unspecific outcomes. Both directions i.e., WIF and FIW of work-family conflict are linked with family related outcomes such as family satisfaction [6], family related stress [7], decrease in family well-being [8], marital satisfaction [9]. Work related outcomes such as job satisfaction [8, 10], organization commitment [11], absenteeism [12], intention to quit [13], turnover [8, 10] work-related strain [37], occupational burnout [10, 14] and organizational citizenship behavior [38]. Lastly, domain unspecific outcomes of work-family conflict are also found to be related with both directions of work-family conflict such as psychological strain [15], life satisfaction [10, 16], depression [17], somatic complaints and abuse [18]. However, little attention has been given to study work-family conflict in relation to individual or group level decision making for comprehensive understanding that is; how work-family conflicts can affect individual/group decision making behaviors.

It is argued that individuals and couples often develop habits for how they will respond to work-family conflict that arises in everyday life [19]. However, not every decision to settle work-family conflict is covered by these routine decisions. When an individual establish an ongoing and complex nature of work-family conflict related decision making and the influence of these decisions [19, 20], researchers may provide value to explore these decisions made by individual on that particular incidents of work-family conflict. Past researchers such as Greenhaus and Powell [21] have focused on the phenomenon of ongoing work-family conflict and the decision processes through which people manage work-family conflict incidents [22] while slight attention has been given to study consequent effects of work-family conflict on individual decision making processes.

Further to this, Nelissen and Zeelenberg [23] found that emotional state of an individual acts as motivational factor in decision making where as according to Bechara et al. [24]; Bechara et al. [25], emotional instability results in poor quality decisions. Abraham [26] found that an emotionally intelligent individuals have high organization commitment, high success rate [27], and use positive emotions to enhance their decision making capability. From this, it is clear that emotional intelligence is a crucial factor for effective decision making and emotionally intelligent individual is a better decision maker than his counterpart.In relation to work-family conflict, minor attention has been given to study this variable with emotional intelligence. Lenaghan et al. [28] found that emotional intelligence and work-family conflict are negatively associated variables while Panorama and Jdaitawi [29] established no significant relationship between work-family conflict and emotional intelligence due to which, more comprehensive studies are needed to understand the association between these constructs.

In the past studies, researchers such as Medved [20] and Shumate and Fulk [21], argued that work-family conflict of an individual influence their decision making and emotional intelligence of a person associated with enhanced decision making capabilities [30] and helps him/her in effective conflict management. Though, little consideration has been given to quantify the relationships among work-family conflict, decision making and emotional intelligence. Due to which, there is lack of proper framework and present literature is slightly unable to effectively manage the problem associated with these factors such as the teaching quality is decreasing gradually in higher education institutions of Pakistan [31].

In order to further highlight this issue, a small survey is conducted to access the decision quality of faculty members (through quality of decision making scale) [32] and to magnify the significance of work and family related conflicts and the intelligence of an individual. Forty-three faculty members participated in the survey which are from the public sector universities including Quaid-i-Azam University, Islamabad and COMSATS Institute of Information Technology, Islamabad; and, from the private sector such as Riphah International University, Islamabad, Pakistan.

Results of the survey supplement the research problem. It is found that decision making quality of faculty members in Higher Education Institution is not up to the mark. Item wise responses regarding the quality of decision making are depicted in Table 1. In nutshell, results of the survey conclude that quality of decision making

Table 1 Items wise responses of the survey

Items	NAT (%)	NT (%)	ST (%)	VT(%)
1. I took into account the full range of goals I want and what's important to me	–	39.5	32.6	27.9
2. I carefully weighed the points for and against each option	–	7	74	18
3. I thought very carefully about any new information and what experts said	–	41.9	23.3	34.9
4. I took a second careful look at all of my options, even those I had earlier thrown out, and focused on the points for and against them one more time before making my final choice	–	46.5	30.2	23.3
5. I made detailed plans for carrying out my choice, with special attention to backup plans that might be needed	–	53.5	7.9	18.6
6. Intelligence of an individual helps him in making effective decision making and in resolving conflicts	–	2.3	32.6	65.1
7. Rank the following factors from high to low that affect your decision making. Family related conflicts (66.6 %); Conflicts with supervisor (23.3 %); Conflicts with peers (2.6 %); Conflicts with subordinates (7.5 %)				

NAT = Not at all true; *NT* = Not true; *ST* = Somewhat true; *VT* = Very true; Sample size = 43

of faculty members is not satisfactory and work and family related conflicts are important factors that affect their decision making behavior while intelligence of an individual helps him/her in making better decisions and in resolving conflicts.

Based on the above literature, initial survey findings and in-depth analysis of the stated problem, this study will determine the impact of work-family conflicts on decision making styles of faculty members. Role of emotional intelligence (most particularly decisional intelligence) will also be quantified in this regard so that comprehensive framework can be developed regarding the effective management of the identified problems.

Hypothesis 1. (H_1) Work-family conflict has significant impact on the decision making styles of faculty members.
Hypothesis 2. (H_2) Decisional intelligence (a part of emotional intelligence) moderates the relationship between work-family conflict and decision making styles of faculty members.

3 Measurements

Validated scales are used to measure the study variables, however, scales are adapted to little extent according to the need of the present research work.
1. Work-Family Conflict

Work-family conflict for the present study is defined as a form of conflict that develops through stress, time constraint and changes in individual behavior, causing an imbalance between work and family life [33]. It is measured through 18 items scale developed by Carlson et al. [33]. Each item is measured on 5 point Likert rating scale with 1 representing strongly disagree to 5 representing strongly agree. Results of the Cronbach's alpha reliability tests show that work-family conflict scale have alpha reliability of 0.770 including 0.642 for WIF and 0.653 for FIW.

2. Decision Making Styles

Individual decision making styles is defined as how an individual acts in decision making scenarios or individual characteristic mode during which he/she observe decision making situations and respond accordingly. It is further elaborated by identifying the individual decision styles. Normally, an individual responds towards such decision tasks by utilizing any of the five styles that are rational, intuitive, dependant, avoidant and spontaneous styles [34]. A 25 items adapted scale originally developed by Scott and Bruce is utilized to measures the individual decision making styles. Five decision making styles including rational, intuitive, dependent, avoidant and spontaneous decision making styles are quantified by using this scale. Five items are utilized to measure each decision style that are rational, intuitive, dependent, avoidant and spontaneous decision making styles. All the responses are measured using 5 point Likert scale with 1 representing strongly disagree to 5 denoting strongly agree with the given item. Decision making styles scale have alpha reliability of 0.595 for rational decision making style; 0.619 for intuitive decision making style; 0.574 for dependent decision making style; 0.611 for avoidant decision making style and 0.610 for spontaneous decision making style.

3. Decisional Intelligence (A Part of Emotional Intelligence)

Based on the findings of Panorama and Jdaitawi [35] and Biggart et al. [36], it can be stated that emotional intelligence is not fully correlated with work-family conflict and by considering the perspective of utilization of emotional intelligence in conflict and decision making processes, it can be defined as individual emotional mental control in the process of decision making, awareness and control of emotional perspective of self and others, and employing these identified emotional information in the process of decision making. Decisional intelligence is measured through 8 items scale extracted from short GENOS emotional intelligence inventory which measure three adapted facets including emotional awareness and control, emotional mental control and emotional reasoning. All the items responses are rated on 5 point scale representing 1 for "almost never" and 5 representing "almost always" with 0.597 alpha reliability for the entire.

4 Sample

Population for the present study consists of the permanent faculty members of Higher Education Institutions (HEIs) chartered by the Government of Pakistan and mainly located in two cities i.e.; Islamabad and Rawalpindi, Pakistan. A total of 4378 permanent faculty members are employed in these HEIs as per the latest survey conducted in 2008 by Higher Education Commission, Pakistan. Base on this, a statistically justified sample size of 352 faculty members has been taken as calculated by utilizing the method proposed by Bartlett et al. [36]. Information regarding participants denotes that seventy-two (72.2 %) percent of the respondents are male while rest i.e., 27.8 % are the female faculty members. Reason being, in Pakistan, men is considered as bread earner therefore less female contribute in workforce. Similarly, sample consists of 47.4 % single, 50.9 % married and 1.7 % of others (divorced, widows and separated faculty members). All of these faculty members have job position ranges from lecturer to Professor. Comparatively, a smaller amount of participants from the private sector universities ($N = 82$) are due to less number of private sector universities chartered by federal government in Pakistan.

5 Results

5.1 Testing of H_1: WFC and Decision Making Styles

To study the impact of work-family conflict on decision making styles of the faculty members, simple linear regression model is utilized. The results of the regression analysis are depicted in Table 2.

Regression Eq. (1) is calculated by taking work-family conflict as predictor variable and rational decision making style as criterion variable. Results of the regression analysis suggest that 4.2 % variance in rational decision making style is explained by work-family conflict as $R^2 = 0.042$, $F(1351) = 16.048$. It is determined that work-family conflict has negative impact on rational decision making style of an individual. The regression equation for this relationship suggest that the rational

Table 2 Regression analysis of work-family conflict and decision making styles

Model	B	SE	B	T	F	R^2	P
Constant	19.353	1.214		15.937	16.408	0.042	0
Rational	−0.082	0.02	−0.212	−4.051			
Constant	14.018	1.04		13.475	7.948	0.019	0.005
Intuitive	−0.049	0.017	−0.149	−2.819			
Constant	8.886	0.754		11.791	0.241	−0.002	0.624
Dependent	−0.006	0.013	−0.026	−0.491			
Constant	8.775	1.066		8.232	64.101	0.152	0
Avoidant	0.142	0.018	0.393	8.006			
Constant	11.825	1.137		10.404	41.153	0.103	0
Spontaneous	0.121	0.019	0.324	6.415			

Significance level is at 0.05, Sample size = 352 decision making style will decrease by 0.082 with per unit increment in WFC.

$$\text{Rational DMS} = 19.353 - 0.082\text{WFC}. \tag{1}$$

Similarly, results of the regression analysis calculated by taking work-family conflict as predictor and intuitive decision making style as criterion variable suggest that work-family conflict negatively predicts intuitive decision making style as $\beta = -0.049$, $t(351)$, $p = 0.005$. Results of the analysis further reflects that WFC caused significant variance of 1.9 % in dependent decision making style as $R^2 = 0.019$, $F(1351) = 9.148$, $p = 0.005$ and regression equation for intuitive decision making style are depicted in Eq. (2). While, results of the regression analysis indicates that work-family conflict has no influence on dependent decision making style as $\beta = -0.006$, $t(351)$, $p = 0.624$.

$$\text{Intuitive DMS} = 14.018 - 0.049\text{WFC}. \tag{2}$$

Equation (3) entails that work-family conflict significantly and positively predicts avoidant decision making style such as one unit increase in WFC caused 14.2 % increase in avoidant decision making style as $\beta = 0.142$, $t(351)$, $p = 0.000$. Statistical data for the regression analysis further reflects that a total of 14.4 % variance in avoidant decision making style is explained by WIF as $R^2 = 0.152$, $F(1351) = 64.101$, $p = 0.000$.

$$\text{Avoidant DMS} = 8.775 + 0.142\text{WFC}. \tag{3}$$

It is determined that work-family conflict also positively predicts spontaneous decision making style. Regression equation for this decision making style is given in Eq. (4).

$$\text{Spontaneous DMS} = 11.825 + 0.121\text{WFC}. \tag{4}$$

Based on the above results, it is determined that work-family conflict significantly predicts rational, intuitive, avoidant and spontaneous decision making styles and do not predicts dependent decision making style which shows that hypothesis H_1 is partially supported.

5.2 Testing of H_2: Decisional Intelligence, Work-Family Conflict and Decision Making Styles

Multiple hierarchal regression analysis is utilized to measure the moderating effect of decisional intelligence on the relationship among work-family conflict and decision making styles as depicted in Table 3. Regression equation as provided in Eq. (5)

Table 3 Moderation analysis of decisional intelligence on the relationship among work-family conflict and decision making styles

Model	B	SE	B	T	F	R^2	ΔR^2	P
Rational DMS								
Constant	−6.145	7.274		−0.845				
WFC	0.335	0.121	0.867	2.78	9.846	0.045	0.045	0.006
DI	0.919	0.259	1.121	3.554		0.046	0.001	0
WFC × DI	−0.015	0.004	−1.539	−3.506		0.078	0.033	0.001
*Intuitive DMS**								
Constant	0.257	6.292		0.041				
WFC	0.191	0.104	0.584	1.833	4.587	0.022	0.022	0.068
DI	0.495	0.224	0.713	2.214		0.023	0.001	0.027
WFC × DI	−0.009	0.004	−1.047	−2.333		0.038	0.015	0.02
Dependent DMS								
Constant	−4.591	4.531		−1.013				
WFC	0.225	0.075	0.96	2.996	3.384	0.001	0.001	0.003
DI	0.485	0.161	0.975	3.012		0.001	0.001	0.003
WFC × DI	−0.008	0.003	−1.407	−3.121		0.028	0.028	0.002
Avoidant DMS								
Constant	18.139	6.478		2.8				
WFC	−0.018	0.107	−0.05	−0.169	22.156	0.155	0.155	0.866
DI	−0.337	0.23	−0.441	−1.464		0.155	0	0.144
WFC × DI	0.006	0.004	0.633	1.511		0.16	0.006	0.132
Spontaneous DMS								
Constant	12.632	6.929		1.823				
WFC	0.102	0.115	0.273	0.889	13.684	0.105	0.105	0.374
DI	−0.029	0.246	−0.036	−0.117		0.105	0	0.907
WFC × DI	0.001	0.004	0.073	0.169		0.106	0	0.866

WFC Work-family conflict, *DI* Decisional intelligence, *DMS* Decision making style, Significance level is at 0.05, *Significance level is at 0.10, Sample size = 352 is computed by taking work-family conflict as predictor variable, rational decision making style as criterion variable while decisional intelligence serves as moderating variable. To analyze the moderation effect, a product term of work-family conflict and decisional intelligence is introduced as an interaction term. Results of the regression model summarizes that decisional intelligence moderates the relationship between rational decision making styles and work-family conflict as $\beta = -0.015$, $t(348)$, $p = 0.001$ for the interaction term. The values of ΔR^2 for rational decision making style as given in Table 3 also define the change in the model variance with the introduction of interaction term.

$$\text{Rational DMS} = -6.145 + 0.335\text{WFC} + 0.919\ \text{DI} - 0.015\text{WFC} \times \text{DI}. \tag{5}$$

Hierarchal regression model is calculated by utilizing decision intelligence as a moderator on the relationship between work-family conflict and intuitive decision making style. The results of the analysis indicates that decisional intelligence moderates the relationship between the work-family conflict and decisional intelligence as $\beta = -0.009$, $t(348)$, $p = 0.020$ for the interaction term as shown in Table 3. To further analyze this moderation effect, regression equation is computed as shown in Eq. (6).

$$\text{Intuitive DMS} = 0.254 + 0.191\text{WFC} + 0.495\ \text{DI} - 0.009\text{WFC} \times \text{DI}. \tag{6}$$

In the same, regression equation as shown in Eq. (7) is computed to study the moderating effect of decisional intelligence on the relationship between dependent decision making styles and work-family conflict. Analysis shows that decisional intelligence moderates the relationship and causes reduction in the work-family conflict. The values of ΔR^2 for dependent decision making style as depicted in Table 3 also defines the significant change in the model variance with the introduction of interaction term. By following the same, hierarchal regression analysis is computed by considering avoidant and spontaneous decision making styles as predictors, work-family conflict as criterion and decisional intelligence act as moderating variable. Results of the analysis suggest that decisional intelligence not moderates the relationship among dependent decision making style ($p > 0.05$) and spontaneous decision making styles ($p > 0.05$) as given in Table 3.

$$\text{Dependent DMS} = -4.591 + 0.225\text{WFC} + 0.485\ \text{DI} - 0.008\text{WFC} \times \text{DI}. \tag{7}$$

Based on the moderation analyses, it is found that decisional intelligence moderates the relationships among work-family conflict, rational, intuitive and dependent decision making style while not moderates the relationships among work-family conflict, avoidant and spontaneous decision making styles. The hypothesis H_2 is partially supported.

6 Discussion and Conclusion

In relation to the influence of work-family conflict on decision making styles, it is examined that work-family conflict negatively predicts rational and intuitive decision making style and has no effect on dependent decision making style. Results show that work-family conflict directly influences rationality and intuition of an individual during the process of decision making. Usually, individuals during the phase of work-family conflict take avoidant and spontaneous decision. It is also supported by the results of H_1. Findings of the present research complement the findings of Medved [20] and Shumate and Fulk [21]. They highlighted that work family conflict affects the decision making process of an individual.

In the present study, decisional intelligence serves as a moderator to study its role in predicting the relationship among work-family conflict ad decision making styles. Hierarchal multiple regression with the insertion of interaction term is utilized to examine the moderating effect of decisional intelligence. It is found that decisional intelligence moderates the relationships among work-family conflict as predictor and rational, intuitive and dependent decision making style as criterion variables. It is concluded that decisional intelligence has same kind of moderating effect on all of these relationship among predictor and criterion variables. It is clear from the analysis of moderation effect, that if an individual has high level of decisional intelligence than this will decrease the intensity of work-family conflict and individuals can make better rational, intuitive and dependent decisions during the phase of decision making. Findings of the present study on decisional intelligence by complemented by results of Nelissen and Zeelenberg [26], Bechara et al. [28], Bechara et al. [29] and Abraham [30]. They argued that emotional intelligence acts as motivational factor for an individual and enhances his/her decision making capability. With respect to work-family conflict and decisional intelligence, this study findings are also supported by Lenaghan et al. [33] who argued that work-family conflict is negatively associated with emotional intelligence of an individual due to which decisional intelligence decreases the intensity of work-family conflict during moderation analysis. In the same pattern, moderation effects of decisional intelligence are analyzed on the relationship among work-family conflict, avoidant and spontaneous decision making styles. The findings of the current study indicate that decisional intelligence has no impact on the relationship among work-family conflict, avoidant and spontaneous decision making style. During the occurrence of work-family conflict, if an individual make spontaneous decisions or avoid decision making process at all, there is no need of decisional intelligence as the individual deny involving in the process of decision making.

7 Recommendations

Certain improvements in higher education sector of Pakistan can be made, based on the findings of this study. At first, there may be proper capacity building programs for faculty members employed in higher education of Pakistan related to conflict management, decision management and emotional intelligence. These programs can be initialized in these higher education institutions with the coordination of psychology and management faculties along with financial contribution from higher education commission, Pakistan. In addition to these long term programs, trainings, work-shops and seminars can be conducted to signify the importance of conflict and emotions management in predicting positive contribution towards decision making. These short-term trainings programs can be started in these HEIs with the coordination of private sector organizations. The assistance in financial terms can also be obtained from professional organizations in exchange of providing training opportunities to their human resource in the same programs. Finally, university administration need to consider the constraints faced by faculty members and make suitable adjustments in the policies so that employee satisfaction is enhanced. These policies can be defined/amended with the consent of boards of faculty members and employee societies in these HEIs.

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