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Edgardo Bucciarelli
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Juan M. Corchado *Editors*

Decision Economics

In the Tradition of Herbert A. Simon's Heritage

Distributed Computing and Artificial Intelligence, 14th International Conference

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Preface

To Vela and Nicola,

our continuous source of learning, knowledge, inspiration, creativity, wisdom, and understanding; our strength, refuge, and support throughout these years; on your wings only have we soared; without you both, many things would not be as they are.

(Edgardo Bucciarelli and Shu-Heng Chen)

Decision Economics, in the Tradition of Herbert A. Simon's Heritage

This book is dedicated to our mentors—Kumaraswamy Vela Velupillai and Nicola Mattoscio—who, more than anyone else, have led us to a deep understanding of Herbert A. Simon's immense body of work. Among their countless teachings, indeed, Vela and Nicola have had the merit to convey to us their great passion for Simon's lifelong research program on computational complexity theory, as classical behavioural economics, that has brought so many positive changes and challenges to the progress of economic studies. In remembering Herbert A. Simon, a pioneering scholar in the interlinked development of economics, cognitive psychology, and computer science, this book presents a collection of selected peer-reviewed papers presented at the special session on "Decision Economics" (DECON), a scientific forum held annually which works to share ideas, projects, research results, models, and experiences associated with the complexity of behavioural decision processes and socio-economic phenomena. DECON 2017 took place at the Polytechnic of Porto, ISEP, Portugal, as part of the 14th International Conference on Distributed Computing and Artificial Intelligence.

This year, in continuing to celebrate the centennial of Herbert A. Simon's birth, the Editors of this book decided to emphasize his quintessential vision and substance in framing decision problems to be solved by bounded rational agents, satisficing in the face of computationally complex search spaces. This vision and substance, as well as his thoughts, have endured through time and have proved to be seminal for generations of scholars. Not only that, but they also acquire new vitality in every age proving always to be relative and effective. Herbert Simon advanced great and beautiful ideas and was a genius of innovation who broke down the barriers between disciplines and opened up insights into seemingly distant fields: economics, psychology, epistemology, computer science, and business organization. What point do these disciplines have in common? The presence of human beings who, with their baggage of limited, imperfect, and incomplete cognitive ability, openly reject neoclassical economic theory. It is mainly in "The Sciences of the Artificial" (1969) that Simon gives us his broad and genial view of the future, a thoughtful synthesis of his conception of complexity and processes through which innovation is attained. A teaching that is a polar star for anyone who aims to engage in science and innovation.

In an effort to be in line with this teaching, the precepts that inform several of the peer-reviewed contributions selected in this book are based on notions of algorithms invoked by Simon. More specifically, each contribution has gradually moved away from the idea of being able to develop a general theory of decision-making, thus leaving open the question to see the extent to which the results achieved analytically can then be translated, given the different forms of rationality, into real progress in understanding complex phenomena. Therefore, this book discusses decision economics from a wide spectrum of methodological issues and applications. The content of each chapter is described briefly below.

Chapter 1. *"The Bayesian cost-effectiveness decision problem"* by Elías Moreno, Francisco-José Vázquez-Polo, Miguel A. Negrín, and María Martel-Escobar. In this chapter, the authors provide a decision theory approach for medical treatment comparison based on cost-effectiveness reasoning and illustrate the optimal decisions for two utility functions. The first utility function yields the optimal criterion of choosing the treatment having the maximum expected net benefit; the second one is motivated by the health objective of choosing the treatment having, in probability, the highest net benefit. In revising this decision problem, the authors assume Bayesian models for the cost and effectiveness of treatments. In order to briefly illustrate the performance of the two utility functions, an example with simulated data is presented. The authors' simulation study shows that the optimal Bayesian decision with respect to the second utility function beats the first one in the sense of choosing the optimal treatment more often, so minimizing the proportion of wrong decisions.

Chapter 2. *"Evaluation of scientific production without using bibliometric indicators: decision-making on a priori criteria"* by Carmen Pagliari and Nicola Mattoscio. In this chapter, the authors provide insights into the process of assigning analytical scores to the scientific production of researchers who challenge in an open competitive exam for a socio-economic scientific sector. The authors describe the preliminary decisions made by the evaluation board subdividing them into six decision steps. The role of decision-making about a priori criteria is pointed out in relation both to the respect of researchers' identity and the evolution of science. In this contribution, moreover, an example of application is proposed, and some algebraic implications are highlighted. In particular, it is suggested to reflect on the usefulness of the rules of Boole's algebra for the calculation of total scores deriving from the simultaneous application of criteria having different logical characteristics. Although this contribution does not address behavioural issues, these are at the base of distorting and obsessive consequences on researchers' nature and may represent an original starting point for addressing future research lines in this emerging field as intended by the authors.

Chapter 3. *"Information aggregation in Big Data: Wisdom of crowds or stupidity of herds"* by Tongkui Yu, Shu-Heng Chen, and Connie Houning Wang. In this chapter, the authors explore the information aggregation behaviours of an interconnected population using an agent-based model and study how the connectedness among agents influences the checks and balances between the *"wisdom of crowds"* and the *"stupidity of herds"*, as well as the decision quality of the agents. The authors find that in a population of interconnected agents with limited fact-checking capacity, a quasi-equilibrium with a small portion of agents making decisions based on fact checking and a large portion of agents following the majority can be achieved in the process of reinforcement learning. The effects of agents' fact-checking capacity and search scope on herding behaviour, decision quality, and the possibility of systemic failure are also investigated. This contribution is interesting not only because it addresses big data and the effect of the information convenience on the quality of our decision-making, but mostly because the authors find that the decision accuracy first increases and then decreases as the agents' search scope goes up if the agents have a limited fact-checking capacity. This finding implies that a partially connected rather than a fully connected network is preferred from the viewpoint of information aggregation efficiency.

Chapter 4. *"Designing and programming a graphical interface to evaluate treatments in economics experiments"* by Edgardo Bucciarelli and Assia Liberatore. In this chapter, the authors develop a graphical interface that allows to calculate the efficacy of one or more *treatments* before adopting an experimental economics design. The graphical interface is built with Java according to a model-based *treatment* design. The originality of the contribution is twofold. The authors are first concerned with designing *treatments* in order to increase their efficacy, evaluating how experimental factors can affect the *treatment* process design. Second, they are interested in enhancing the internal and external validity of experiments to be run. Therefore, this research contributes to the economic literature focusing on the experimental economics design and providing a Graphical

Experimenter Interface (GEI) capable to support economists when deciding which experimental *treatment* design to adopt and, thus, which factors to include.

Chapter 5. *"A decision framework for understanding data-aware business process models"* by Raffaele Dell'Aversana. In this chapter, the author investigates the role played by data in Business Process Management as a discipline that enables organizations to analyse, design, and deploy business processes, providing tools to investigate the processes from an organizational point of view and transforming the design into a working software implementation. Based on Herbert A. Simon's intuitions, the Business Process Modeling and Notation (BPMN) is the most widely adopted modelling language for designing and re-engineering business processes. As a matter of fact, one of best feature is that BPMN provides a graphical representation that is not only easy to understand by business people without technical expertise but also machine processable, with tasks assigned to software or human agents based on the workflow and rules defined within the process. The originality of this contribution, therefore, lies in the approach enabling the verification of the conformance to the business rules combining logic and mathematical expressions. Moreover, the new framework gives the possibility of separating the business requirements from the implementation, giving hints to the process designer and to the programmer.

Chapter 6. *"Cluster analysis as a decision-making tool: A methodological review"* by Giulia Caruso, Stefano Antonio Gattone, Francesca Fortuna, and Tonio Di Battista. In this chapter, the authors provide emphasis on cluster analysis as an important tool in a broad variety of research fields, such as psychology, biology, computer sciences, and economics. It has established as a precious tool for marketing and business areas, thanks to its capability to support decision-making processes. Traditionally, clustering approaches concentrate on purely numerical or categorical data. A significant application of cluster analysis addresses the role of mixed data, composed by both numerical and categorical attributes. Clustering mixed data is not simple, because there is a strong gap between the similarity metrics for these two kind of data. In their review, the authors present some technical details about the kind of distances that could be used with mixed-data types. Finally, they stress the importance of cluster analysis in many practical applications focusing either on numeric or categorical variables, lessening the effectiveness of the method as a tool of decision-making.

Chapter 7. *"Similar patterns of cultural and creative industries. A preliminary analysis based on Self-Organized-Map to the Italian case"* by Donatella Furia, Alessandro Crociata, Fabiano Compagnucci, Vittorio Carlei. In this chapter, the authors deal with cultural and creative industries (CCI) with the aim to establish a better understanding of relevant industry relevance (RIR) of geographic samples with a relevant similarity in terms of industrial patterns. In this sense, the authors move from a methodological approach, based on Self-Organizing Maps (SOM) by comparing patterns of local employment. The Italian case provides an interesting case study to analyse industrial patterns by offering new insights of occupational dynamics. This contribution represents a first explorative attempt to extend the previous literature to seize the overall productive structure of the local creative economy.

Chapter 8. *"Understanding Bruno de Finetti's decision theory: A basic algorithm to support decision-making behaviour"* by Edgardo Bucciarelli, Nicola Mattoscio, and Valentina Erasmo. In this chapter, the authors present an algorithm inspired to Bruno de Finetti's decision theory, limited to the version proposed in the 1965 essay *"La probabilità: guida nel pensare e nell'agire"*. Therefore, this contribution is focused on decision theory within the subjective theory of probability conceived by de Finetti. It opens with a brief overview of his theory of probability, followed by a methodological analysis functional to introduce the renowned de Finetti's example model given for the solution of decision problems. Starting from this example, the authors present a mathematical generalization of the decision algorithm. Afterwards, a real decisional algorithm written in mathematical-style pseudo code is developed: this novel algorithm represents the main aim and originality of this contribution.

Chapter 9. *"FOREX trading strategy optimization"* by Svitlana Galeshchuk and Sumitra Mukherjee. In this chapter, the authors address the challenge to stimulate the development of robust trading rules for forex trading. The idea behind this contribution is to employ a genetic algorithm to evolve a diverse set of profitable trading rules based on weighted moving average method. In this regard, the authors use the daily closing rates between four pairs of currencies—EUR/USD, GBP/USD, USD/JPY, and USD/CHF—in order to develop and evaluate their own method. Results are presented for all four currency pairs over sixteen years, from 2000 to 2015. The rules obtained using the genetic algorithm proposed by the authors result in significantly higher returns than those produced by rules identified through exhaustive search.

Chapter 10. *"Looking for regional convergence: evidence from the Italian case with multivariate adaptive regression splines"* by Iacopo Odoardi, Fabrizio Muratore, Edgardo Bucciarelli, and Shu-heng Chen. In this chapter, the authors propose a multivariate adaptive regression splines (MARS) analysis to investigate regional income difference in Italy and in order to help to detect relationships between variables that may not be very visible or even appear invisible to traditional econometric techniques. In Italy, as known for decades, the presence of a still unresolved North–South divide lends itself to being studied by multiple analytical perspectives. Recent studies prove that strong differences exist also in the regional human capital. Thus, the authors search for the causes of the local differences, also considering the entrepreneurial vitality and the international trade leverage. In searching among several variables, MARS is useful in showing the actual determinants on which to intervene. This is possible by comparing regions grouped into clusters using huge amount of data. MARS results are used by the authors for providing policy suggestions as a contribution aiming at filling the income gap.

Chapter 11. *"Information manipulation and web credibility"* by Te-Cheng Lu, Tongkui Yu, and Shu-Heng Chen. In this chapter, the authors deal with fake information, news, and reviews in the era of big data, using an agent-based model to simulate social interaction between information producers and consumers. Whether the information producers manipulate true or fake information depends on individual consumers attitude to truth or presentation of information. Consumers adapt themselves to accept or reject information and may evolve or learn socially from the others. Honest and dishonest producers select production strategies and also evolve from the same type of producers. The authors unexpectedly find that dishonest producers may produce true information because consumers co-evolve with producers by raising their standard on truth of information. To prevent fake information diffusion, the authors let consumers take social responsibility by raising standard on truth of information improving social welfare and web credibility in the era of information overload.

Chapter 12. *"A data mining analysis of the Chinese inland-coastal inequality"* by Shu-Heng Chen, Hung-Wen Lin, Edgardo Bucciarelli, Fabrizio Muratore, and Iacopo Odoardi. In this chapter, the authors study the inland/coastal income inequality differences in China which is a different phenomenon than the well-known Chinese rural/urban inequality. As in many countries, even the Chinese socio-economic changes have affected income inequality in recent decades. The various economic opportunities have led to different paths of development causing severe disparities in GDP per capita level. Among the many known causes of inequality, the authors aim to discover the actual determinants of the local GDP and, therefore, of income in a period that includes the international economic crisis started in 2007. With this aim, the authors use different variables to obtain clusters of the Chinese provinces in the period 2004–2015 and, subsequently, they investigate the determinants of income with a multivariate adaptive regression splines (MARS). There is an extensive economic literature on the Chinese case: MARS allows the authors to integrate this literature enabling them to find which GDP determinants are the most relevant in the certain areas of China.

Chapter 13. *"The cognitive determinants of social capital. Does culture matter?"* by Alessandro Crociata, Donatella Furia, and Massimiliano Agovino. In this chapter, the authors address the relationship between social capital and cultural access. In doing that, the authors provide a conceptual framework by moving from a cultural economics standpoint and by applying a simultaneous equation model (SEM). Some linkages and relationships emerge through the analysis of cultural participation as a proxy of cultural capital and the accumulation of two selected dimensions of social capital. More specifically, anchoring this contribution within the literature of cultural economics, the output of the analysis is as follows: *(i)* the share capital and the capital generated by informal volunteering stimulate each other and are thus connected by a virtuous circular process; *(ii)* the capital generated from volunteering is positively stimulated by more introspective and niche cultural consumption; *(iii)* the informal social capital is stimulated by cultural consumption related to recreation and the stimulation of relationships whose goal is entertainment and fun.

Chapter 14. *"A unified framework for multicriteria evaluation of intangible capital assets inside organizations"* by Raffaele Dell'Aversana. In this chapter, the author addresses the importance of the capability concerning the internal metrics used to evaluate intangible assets within modern organizations. The author presents a novel unified framework to measure, assess, and develop intangible capital assets within organizations giving the possibility of enhancing decision-making within the operational and strategic governance. Once identified the assets under investigation, the author's idea is to focus on a method based on a data model approach, giving directions for open research challenges in order to develop more efficient and effective organizations.

Chapter 15. *"Processing and analysing experimental data using a tensor-based method: evidence from an ultimatum game study"* by Edgardo Bucciarelli and Tony E. Persico. In this chapter, the authors address a multidimensional approach proposing a tensor-based method to analyse the experimental data obtained through an ultimatum game conducted by them in the context of an extra-laboratory-based experiment in 2015. The authors find a significant role both for different structures of preferences and meta-ranking. More specifically, the authors prove that subjects do not behave as standard game theory would predict, but rather they basically prefer fair divisions of gains. This evidence confirms significant implications for theories addressing the evolution of, and the mechanisms underpinning, human group behaviour in economics, cognitive, and organizational studies.

Chapter 16. *"The mediating effect of the absorptive capacity in the international entrepreneurial orientation of family firms"* by Felipe Hernández-Perlines. In this chapter, the author analyses the mediating effect of absorptive capacities on the impact of international entrepreneurial orientation on the international performance of family firms. The author focuses on family businesses using a structural equation model PLS-SEM. The main conclusion of this contribution is that the international performance of family firms can be explained both by the influence of the international entrepreneurial orientation and the absorptive capacity having a mediating role in previous relationships.

Last but not least, this year's Special Session on Decision Economics would not have been possible without the enthusiastic help of its Program Committee. Special thanks are due to Sara Rodríguez González, Fernando De la Pietra, Jeyashree Kumar, and Renzo D'Agnillo for their support, encouragement, and advice. The

Program Committee members and English language mentors have helped ensure the quality of the contributions with their extensive and continuous feedback to most of the authors.

Edgardo Bucciarelli
Shu-Heng Chen
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The Editors

Edgardo Bucciarelli is an Italian economist who holds the position of affiliate professor of Economics at University of Chieti-Pescara (Italy), where he earned his PhD in Economics (cv SECS/P01). His main research interests lie in the area of complexity and market dynamics; experimental, behavioural, and cognitive economics; and economic methodology. His main scientific articles appeared, among others, in the Journal of Economic Behavior and Organization, Journal of Post Keynesian Economics, Metroeconomica, Applied Economics, Rivista di Politica Economica, and other international journals. Several key contributions appeared in chapters of book in Physica-Verlag, and Springer Lecture Notes in Economics and Mathematical Systems. At present, he teaches Experimental Economics, Behavioural Economics and Finance, and Economic Methodology at University of Chieti-Pescara. He is one of the Directors of the Research Centre for Evaluation and Socio-Economic Development and the co-founder of the academic spin-off company "Economics Education Services". He is the co-founder, organizing chair, program committee chair in a number of international conferences.

Shu-Heng Chen is a Taiwanese economist. He earned his PhD in Economics at the University of California (UCLA, Los Angeles, United States) in 1992. Currently, he is a distinguished professor of Economics at the Department of Economics and also the Dean of the Office of International Cooperation at the National Chengchi University (Taipei, Taiwan). Furthermore, he is the founder and director of the AI-ECON Research Center at the College of Social Sciences of the National Chengchi University and the coordinator of the Laboratory of Experimental Economics in the same University. He is unanimously considered one of the most influential and pioneer scholars in the world in the field of applied research known as Computational Economics. His scientific contributions were directed to the affirmation of the computational approach aimed to the interpretation of the theoretical issues and applied economic problems still today unresolved, from a perspective more connected to reality and therefore different from the dominant neoclassical paradigm. In particular, his most decisive contributions are aimed to the approach based on models with heterogeneous agents and the genetic programming in the socio-economic studies. His work as a scholar is interdisciplinary and focused since the beginning on methodologies related to the bounded rationality and Herbert A. Simon's contributions. Shu-Heng Chen holds the position of Editor of prestigious international economic journals and is author of more than 150 publications including scientific articles, monographs, and book chapters.

Juan Manuel Corchado is the Vice President for Research and Technology Transfer at University of Salamanca (Spain) where he holds the position of full-time professor of Computer Science and AI. He is the Director of the Science Park and Director of the Doctoral School of University of Salamanca, in which he has been elected twice as Dean of the Faculty of Science. In addition to a PhD in Computer Science earned at University of Salamanca, he holds a PhD in Artificial Intelligence from University of the West of Scotland. Juan Manuel Corchado is Visiting Professor at Osaka Institute of Technology since January 2015, Visiting Professor at University Teknologi Malaysia since January 2017, and a Member of the Advisory group on Online Terrorist Propaganda of the European Counter Terrorism Centre (EUROPOL). Juan Manuel Corchado is the Director of BISITE Research Group (Bioinformatics, Intelligent Systems and Educational Technology) created by him in 2000. He is also editor and Editor-in-chief of specialized journals such as Advances in Distributed Computing and Artificial Intelligence Journal, International Journal of Digital Contents and Applications, and Oriental Journal of Computer Science and Technology.

The Bayesian Cost–Effectiveness Decision Problem

Elías Moreno[1(✉)], Francisco-José Vázquez–Polo[2], Miguel A. Negrín[2], and María Martel–Escobar[2]

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Abstract. Cost–effectiveness analysis of medical treatments is a statistical decision problem whose aim is to choose an optimal treatment among a finite set of alternative treatments. It is assumed that the treatment selection is to be based on their cost and effectiveness.

In this paper we revise this statistical decision problem, discuss two utility functions, and assume Bayesian models for the cost and the effectiveness. For illustrating the performance of the utility functions an example with simulated data is presented.

1 Introduction

Cost–effectiveness analysis of medical treatments is a statistical decision problem in which there is a finite number of alternative treatments for a given disease and the problem is that of selecting an optimal treatment based on their cost and effectiveness. Although this is a relatively new problem, there is an extensive literature on it, and some references include Claxton et al. (2000); Drummond et al. (2005); Willan and Briggs (2006) and Moreno et al. (2010), among others.

In this paper we discuss two utility functions of the reward of the treatments and present an example with simulated data to compare the optimal decisions. The utility functions are defined in two steps. In a first step the bidimensional deterministic reward (c, e) is reduced to a one–dimensional reward in the real line using the notion of *net benefit* of the pair (c, e). This step is briefly described in Sect. 2. In a second step two utility functions of the net benefit are presented in Sects. 3 and 4. Section 5 presents an example with simulated data, and in Sect. 6 a discussion is given.

1.1 Notation

We denote as $\mathcal{D} = \{d_1, ..., d_k\}$ the decision space, where d_i denotes the decision of choosing treatment T_i for $i = 1, ..., k$. It is assumed that the deterministic reward r of a generic decision d is a bidimensional vector $r = (c, e) \in \mathbb{R}^+ \times \mathcal{E}$, where

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$c \in \mathbb{R}^+$ is the cost for the administration of the generic treatment T, and $e \in \mathcal{E}$ the effectiveness. Further, the reward of a specific decision d_i is not deterministic but a probability distribution $P_i(c,e)$ on the space $\mathbb{R}^+ \times \mathcal{E}$ for $i = 1, ..., k$. If we assume the existence of a utility function $U(c,e)$, and also that the expectation of $U(c,e)$ with respect to any of the distributions $\{P_i(c,e),\ i = 1, ..., k\}$ is finite, it follows that $U(c,e)$ induces an order of preference $\preceq^*$ among these distributions. The order is given by $P_i(c,e) \preceq^* P_j(c,e) \iff E_{P_i}(U) \leq E_{P_j}(U)$, and d_j is an optimal decision if $E_{P_j}(U) = \max_{i=1,\ldots,k} E_{P_i}(U)$.

2 The Net Benefit of a Treatment

For a generic treatment T with cost and effectiveness (c,e), the net benefit of this reward, conditional on a nonnegative parameter R, is defined by $z(c,e|R) = R \times e - c$, where $R \geq 0$ represents the amount of money the decision maker (health provider) is willing to pay for the unit of effectiveness. For simplicity in the notation, we will simply write

$$z = R \times e - c. \tag{1}$$

The main implication of the net benefit is that for any value of the parameter R, the reward $P_i(c,e)$ is transformed into $P_i(z|R)$ by doing the simple change of variables from (c,e) to (z,w) given by $z = R \times e - c$ and $w = e$ whose Jacobian is 1. Then, the distribution $P_i(c,e)$ yields $P_i(Re - z, e)$, and the distribution of z is obtained as

$$P_i(z|R) = \int_{\mathcal{E}} P_i(Re - z, e)\, de. \tag{2}$$

If $\mathcal{E}$ is a discrete space, $P_i(z|R)$ becomes the sum

$$P_i(z|R) = \sum_{e \in \mathcal{E}} P_i(Re - z, e). \tag{3}$$

The net benefit notion was introduced by Stinnett and Mullahy (1998) and Willan and Lin (2001).

3 The Utility Function $U_1(z|R)$

The commonly used utility function of the net benefit z, conditional on R, is the linear function

$$U_1(z|R) = z. \tag{4}$$

The optimal decision, conditional on R, is treatment T_j if the equality $E_{P_j}(z|R) = \max_{i=1,\ldots,k} E_{P_i}(z|R)$ holds. It is convenient to present to the health provider the set of points R for which a given decision is the optimal one. The set of points R for which treatment T_j is the optimal treatment under U_1 is given by

$$\mathfrak{R}_j^{U_1}(R) = \Big\{ R \,:\, E_{P_j}(z|R) = \max_{i=1,\ldots,k} E_{P_i}(z|R) \Big\}.$$

Clearly we have that $\mathbb{R}^+ = \bigcup_{j=1}^{k} \mathfrak{R}_j^{U_1}(R)$, and some of the sets $\mathfrak{R}_j^{U_1}(R)$, $j = 1, ..., k$, might be empty.

3.1 Criticism to U_1

An interpretation of the expected utility $E_{P_j}(z|R)$ of the net benefit of treatment T_j follows from the following approximation. For a fixed value of R, let $(z_{j_1}, ..., z_{j_n})$ be a sample of the net benefit of n patients under treatment T_j. From the Law of Large Numbers it follows that for large n we have

$$\frac{1}{n}\sum_{i=1}^{n} z_{ji} = R\frac{1}{n}\sum_{i=1}^{n} e_{ji} - \frac{1}{n}\sum_{i=1}^{n} c_{ji} \approx E_{P_j}(z|R).$$

Thus, for a fixed R, the optimal decision under the utility function $U_1(z|R)$ depends on the accumulated patient effectiveness $\sum_{i=1}^{n} e_{ji}$ and cost $\sum_{i=1}^{n} c_{ji}$. This means that individual effectiveness and costs compensate in the sum, and while compensation of individual cost is acceptable, compensation of individual effectiveness might not be acceptable (Vanness and Mullahy 2006). This criticism to the utility function $U_1(z|R)$ suggests considering another utility function $U_2(z|R)$ that does not involve transference of health among patients.

3.2 The Utility Function $U_2(z|R)$

For simplicity in the presentation let us first consider the case of comparing two treatments T_1 and T_2 with probabilistic rewards $P_1(z_1|R)$ and $P_2(z_2|R)$. We also assume that the equality $P_1(z_1|z_2, R) = P_1(z_1|R)$ holds, so that the net benefit of treatment T_1 and T_2 are, conditional on R, independent random variables.

Let us first introduce the conditional utility function

$$U_2(z_1|z_2, R) = 1_{(z_1 \geq z_2)}(z_1|z_2, R),$$

that is the utility of z_1, the net benefit of T_1, conditional on the net benefit of T_2 and R, is 1 if $z_1 \geq z_2$ and 0 otherwise.

Similarly, we consider $U_2(z_2|z_1, R) = 1_{(z_2 \geq z_1)}(z_2|z_1, R)$. Then, the expectation of $U_2(z_i|R)$ with respect to $P_i(z_i|R)$ for $i = 1, 2$, are

$$E_{P_1}U_2(z_1|R) = \Pr(z_1 \geq z_2|R) \text{ and } E_{P_2}U_2(z_2|R) = \Pr(z_2 \geq z_1|R). \quad (5)$$

From (5) it follows that treatment T_1 is preferred to treatment T_2, conditional on R, if and only if $\Pr(z_1 \geq z_2|R) \geq \Pr(z_2 \geq z_1|R)$.

Therefore, the set of points R for which treatment T_1 is optimal is given by

$$\mathfrak{R}_1^{U_2}(R) = \Big\{R : \Pr(z_1 \geq z_2|R) \geq \Pr(z_2 \geq z_1|R)\Big\},$$

and T_2 is optimal for any R in the set $\mathfrak{R}_2^{U_2}(R) = \mathbb{R}^+ - \mathfrak{R}_1^{U_2}(R)$. We note that either $\mathfrak{R}_1^{U_2}(R)$ or $\mathfrak{R}_2^{U_2}(R)$, might be empty.

A simpler expression of the sets $\mathfrak{R}_j^{U_2}(R)$, $j = 1, 2$, are given in the next Lemma.

Lemma 1. *The sets* $\mathfrak{R}_j^{U_2}(R)$. $j = 1, 2$, *can be written as*

$$\mathfrak{R}_1^{U_2}(R) = \Big\{ R \, : \, \Pr(z_1 \geq z_2 | R) \geq 1/2 \Big\},$$

and $\mathfrak{R}_2^{U_2}(R) = \mathbb{R}^+ - \mathfrak{R}_1^{U_2}(R)$.

Proof. From

$$\int_{z_1 \geq z_2} dP_1(z_1|R) dP_2(z_2|R) = 1 - \int_{z_2 \geq z_1} dP_1(z_1|R) dP_2(z_2|R),$$

we have that $\Pr(z_1 \geq z_2|R) \geq \Pr(z_2 \geq z_1|R) \iff \Pr(z_1 \geq z_2|R) \geq 1/2$. This proves the assertion. ▽

The interpretation of the expectation of $U_2(z_i|R)$ comes from the following argument. For a given R, let $z_{i1}, ..., z_{in_i}$ be a sample of net benefit of patients under treatment T_i for $i = 1, 2$. Then, for large sample sizes n_1 and n_2 we have that

$$\frac{1}{n_1 + n_2} \sum_{i=1}^{n_1} \sum_{j=1}^{n_2} 1_{(z_{1i} \geq z_{2j})} \approx \Pr(z_1 \geq z_2|R).$$

Hence, treatment T_1 is optimal for a given R, if for large sample sizes n_1 and n_2 the counter $\sum_{i=1}^{n_1} \sum_{j=1}^{n_2} 1_{(z_{1i} \geq z_{2j})}$ is greater than $\sum_{i=1}^{n_1} \sum_{j=1}^{n_2} 1_{(z_{2i} \geq z_{1j})}$. Therefore, the optimal treatment under U_2 takes into account the number of patients with the largest net benefit. We recall that the utility function U_1 takes into the account the total amount of the net benefit. Interestingly, for symmetric distributions the optimal treatment under U_1 and U_2 coincides (Moreno et al. 2010).

3.3 Extension of U_2

The extension of U_2 to the case of $k \geq 3$ medical treatments is straightforward. The conditional utility function $U_2(z_i| \; z_{-i}, R)$, where $z_{-i} = (z_1, ..., z_{i-1}, z_{i+1}, ..., z_k)$ is defined as

$$U_2(z_i|z_{-i}, R) = 1_{(z_i \geq \max z_{-i})}(z_i|z_{-i}, R), \; i = 1, ..., k,$$

where

$$\max z_{-i} = \max \{z_1, ..., z_{i-1}, z_{i+1}, ..., z_k\}.$$

Then, it is immediate to see that the set of points R for which the optimal treatment is T_j is given by

$$\mathfrak{R}_j^{U_2}(R) = \Big\{ R \, : \, \Pr(z_j \geq \max z_{-j}|R) \geq \max_{i \neq j} \Pr(z_i \geq \max z_{-i}|R) \Big\}$$

for $j = 1, ..., k$. We have that $\mathbb{R}^+ = \bigcup_{j=1}^{k} \mathfrak{R}_j^{U_2}(R)$, and that some of the sets $\mathfrak{R}_j^{U_2}(R)$, $j = 1, ..., k$, might be empty.

4 Bayesian Approach to Cost–effectiveness

In the preceding sections we have assumed that the distribution $P_i(z_i|R)$ of the net benefit of treatment T_i, conditional on R, is fully determined for any value of R and any $i = 1, ..., k$. However, the cost–effectiveness analysis starts proposing a parametric class of distributions for the cost and effectiveness of the treatment $\{P_i(c, e|\theta_i), \theta_i \in \Theta\}$, and hence distribution of the cost c and the effectiveness e of treatment T_i depends on an unknown parameter $\theta_i \in \Theta$. This implies that the net benefit distribution of treatment T_i is given by

$$P_i(z_i|\theta_i, R) = \int_{\mathcal{E}} P_i(Re - z_i, e|\theta_i)\, de,$$

which is determined up to the unknown parameter θ_i.

This difficulty is solved using the Bayesian approach which integrates θ_i out from the probabilistic reward $P_i(z_i|\theta_i, R)$, or equivalently from $P_i(c, e|\theta_i)$. This integration is with respect to the posterior distribution on θ_i conditional on the sample information on the cost and effectiveness of treatment T_i. Further, this integration accommodates the net benefit the distribution of to the specific problem. We note that R is treated as a known parameter, and the decision making is conditional on R.

For the Bayesian approach the existence of the unknown parameter θ_i in the distribution $P_i(c, e|\theta_i)$ implies the need of eliciting a prior distribution $\pi_i(\theta_i)$ to complete the original sampling model $P_i(c, e|\theta_i)$ model. The Bayesian model is then given as $\{P_i(c, e|\theta_i), \pi_i(\theta_i)\}$.

Let $\mathbf{c}_i = (c_{i1}, ..., c_{in_i})$ and $\mathbf{e}_i = (e_{i1}, ..., e_{in_i})$ be random samples on the cost and effectiveness of treatment T_i. The likelihood of the unknown parameter θ_i for $\mathbf{c}_i$ and $\mathbf{e}_i$ is then given by

$$\ell_{\mathbf{c}_i,\mathbf{e}_i}(\theta_i) = \prod_{j=1}^{n_i} P_i(c_{ij}, e_{ij}|\theta_i).$$

Using this likelihood, we can update the prior $\pi_i(\theta_i)$ to the posterior distribution $\pi_i(\theta_i|\mathbf{c}_i, \mathbf{e}_i)$ which is obtained as

$$\pi_i(\theta_i|\mathbf{c}_i, \mathbf{e}_i) = \frac{\ell_{\mathbf{c}_i,\mathbf{e}_i}(\theta_i)\pi_i(\theta_i)}{m(\mathbf{c}_i, \mathbf{e}_i)},$$

where $m(\mathbf{c}_i, \mathbf{e}_i) = \int_\Theta \ell_{\mathbf{c}_i,\mathbf{e}_i}(\theta_i)\pi_i(\theta_i)d\theta_i$ is the marginal distribution of the data $(\mathbf{c}_i, \mathbf{e}_i)$. Using this posterior distribution, we can now compute the distribution $P_i(z_i|\mathbf{c}_i, \mathbf{e}_i, R)$ of the net benefit z_i, conditional on the samples $\mathbf{c}_i, \mathbf{e}_i$ and R, as

$$P_i^{\pi_i}(z_i|\mathbf{c}_i, \mathbf{e}_i, R) = \int_\Theta P_i(z_i|\theta_i, R)\pi_i(\theta_i|\mathbf{c}_i, \mathbf{e}_i)\, d\theta_i.$$

We note that $P_i^{\pi_i}(z_i|\mathbf{c}_i, \mathbf{e}_i, R)$, the probabilistic reward of treatment T_i, is nothing else but the predictive distribution of the net benefit of treatment T_i.

Then, for a generic utility function $U(z_i)$, the expectation of $U(z_i)$ with respect to $P_i(z_i|\mathbf{c}_i, \mathbf{e}_i, R)$ is given by

$$E_{P_i}U(z_i|\mathbf{c}_i, \mathbf{e}_i, R) = \int_{\mathcal{R}} U(z_i) dP_i^{\pi_i}(z_i|\mathbf{c}_i, \mathbf{e}_i, R)\, dz_i,$$

which depends on the samples $\mathbf{c}_i, \mathbf{e}_i$, the prior π_i and R, and the optimal treatment for the samples $\mathbf{c}_i, \mathbf{e}_i$ and prior π_i, conditional on R, is the one having the maximum expected utility. Consequently, for the samples $\mathbf{c}_i, \mathbf{e}_i$ and prior π_i, the set of points R for which the optimal treatment is T_j is given by

$$\mathfrak{R}_j^U(R|\mathbf{c}_j, \mathbf{e}_j) = \left\{R \;:\; E_{P_j}^{\pi_j} U(z_j|\mathbf{c}_i, \mathbf{e}_i, R) \geq \max_{i=1,\ldots,k} E_{P_i}^{\pi_i} U(z_i|\mathbf{c}_i, \mathbf{e}_i, R)\right\}.$$

It is clear that $\mathbb{R}^+ = \bigcup_{j=1}^{k} \mathfrak{R}_j^U(R|\mathbf{c}_j, \mathbf{e}_j)$, and for $R \in \mathfrak{R}_j^U(R|\mathbf{c}_j, \mathbf{e}_j)$ it follows that the optimal treatment is T_j. It is also clear that some of the sets $\mathfrak{R}_j^U(R|\mathbf{c}_j, \mathbf{e}_j)$, $j = 1, ..., k$, might be empty.

5 A Simulated Example

To illustrate the Bayesian decision approach to the cost–effectiveness analysis we simulated data for the cost and effectiveness for two treatments. Also, we are interested in the comparison with the frequentist procedure to cost–effectiveness.

The frequentist optimal decisions under the utility function U_1 is given as

$$d_1 \text{ is optimal } \iff E(z_1|R, \hat{\theta}_1) - E(z_2|R, \hat{\theta}_2) \geq 0, \tag{6}$$

and d_2 otherwise, where $\hat{\theta}_1$ and $\hat{\theta}_2$ are the maximum likelihood estimators. Similarly, under U_2,

$$d_1 \text{ is optimal } \iff \Pr(z_1|R, \hat{\theta}_1) - \Pr(z_2|R, \hat{\theta}_2) \geq 0, \tag{7}$$

and d_2 otherwise.

We consider the following two statistical models for the cost and the effectiveness: $P_1(c_1, e_1) = \text{Gamma}(c_1|1.45, 0.004) \times \text{Normal}(e_1|0.7, 0.2^2)$ and $P_2(c_2, e_2) = \text{Gamma}(c_2|1.5, 0.004) \times \text{Normal}(e_2|0.6, 0.2^2)$. It is clear that treatment 1 is more effective and less costly than treatment 2. We simulate samples of size n of the cost and effectiveness from each of the models. The size of the samples are given in Table 1 and corresponds to three scenarios of small, medium and large sample sizes. Note that intentionally we select sampling models not too different, thus making the selection of the optimal treatment difficult, specially for small sample sizes.

We repeat the simulation 10,000 times and compute the proportion of times treatment T_1 is chosen by the Bayesian and the frequentist approaches. For the Bayesian approach we use the parametric sampling models with the standard reference prior for the parameters of the two treatments (Berger and Bernardo 1992).

Table 1. Rate of success (in %) of the optimal decision rule for different values of R and sample size scenarios: small ($n = 20$), medium ($n = 50$) and large ($n = 100$). Gamma cost and Normal effectiveness.

Utility function U_1			Utility function U_2		
R	Frequentist rule	Bayesian rule	R	Frequentist rule	Bayesian rule
Small sample size					
0	55.7	55.7	0	55.8	55.8
100	60.1	60.0	100	61.9	61.9
400	70.7	70.3	400	75.0	75.0
700	78.4	78.2	700	82.3	82.5
Medium sample size					
0	58.6	58.5	0	58.5	58.5
100	65.2	65.2	100	68.0	68.2
400	80.3	80.0	400	85.6	85.6
700	89.3	89.1	700	92.5	92.5
Large sample size					
0	66.0	66.1	0	65.7	66.0
100	76.7	76.9	100	80.6	80.8
400	94.8	95.0	400	97.9	97.9
700	99.3	99.2	700	99.8	99.7

Although results under all rules are very similar, the optimal Bayesian posterior decisions under U_2 choose the more effective and less costly treatment in a larger proportion of times than the optimal decisions under U_1. Also, as sample size increases, the rate of success both rules select the right treatment tends to 1.

6 Discussion

We have considered a decision theory approach for treatment comparison based on the cost–effectiveness of treatments, and we illustrated the optimal decisions for two utility functions. We started with the commonly used utility U_1, which yields the optimal criterion of choosing the treatment having the maximum expected net benefit. A second utility function U_2 motivated by the health objective of choosing the treatment having, in probability, the highest net benefit, has also been considered, and their optimal frequentist and Bayesian decisions are compared with the optimal frequentist and Bayesian decisions associated to U_1.

While the U_1 utility function might be appropriate when the health provider assigns small values to R, in which case the cost of the treatment is the main component of the net benefit and transfers of wealth among individuals might be appropriate, the utility function U_2 seems to be the appropriate one when large values of R are being considered, and then the effectiveness becomes the more important component of the net benefit. This latter argument also applies when the treatments under consideration have similar costs.

Our simulation study shows that the optimal Bayesian decision with respect to U_2 beats U_1 in the sense of choosing the optimal treatment more often, so minimizing the proportion of wrong decisions. This fact should have a monetary consequence on the formulation of the utility, although how to implement it is a quite elusive task.

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Evaluation of Scientific Production Without Using Bibliometric Indicators: Decision-Making on *a Priori* Criteria

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Abstract. The present contribution contains the formalisation of a method (not based on bibliometric indicators) for assigning analytical scores to the scientific production of researchers who challenge in an open competitive exam in a Socio-economic Scientific Sector. The preliminary decisions of the evaluation board are described subdividing them into six decision steps. The role of decision-making about *a priori* criteria is pointed out in relation to the respect of the researcher's identity and of the spontaneous evolution of science. In this work, also an example of application is proposed to the evaluation board. Some algebraic implications are highlighted and it is suggested to reflect on the usefulness of the rules of Boole's Algebra for the calculation of total scores deriving from the simultaneous application of criteria having different logical characteristics.

Keywords: Scientific evaluation · Non-bibliometric scientific sectors · Scientific productivity · *A priori* criteria decisions

1 Introduction

Recently, interesting scientific contributions have focused on new questions about the appropriateness of the bibliometric indicators in the evaluation of scientific production within the Social Sciences and Humanities [9]. A very significant conclusion of these studies is the individuation of the negative consequences that may originate from the implementation of the evaluation model based on bibliometric indicators in the areas of the Social Sciences and Humanities. In fact these areas are led to change their way of publishing in order to achieve the objectives proposed by the bibliometric indicators (for alternative approaches and criticism to the use of bibliometric indicators see, among others, [1–3, 5–8, 12]). This change is not good for the development of research, because it comes from the application of a model which is exogenous and unnatural for the evaluation of scientific productivity in the Social Sciences and Humanities.

In the recent past, many studies contributed to define methods for the evaluation of research performance, mainly in relation to bibliometric indicators (see, among others, [4, 11, 13, 14]).

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The present contribution shows how, without using bibliometric indicators, it is possible to formalise a rigorous method for assigning analytical scores to the scientific production of researchers who challenge in an open competitive exam in a Socioeconomic Scientific Sector.

In Sect. 2 definitions, symbolism, quantitative conditions and parameters are formalised in an essential way to simplify the tasks of the evaluation board. In Sect. 3 two types of *a priori* criteria are defined in relation to the degree of necessity of the conditions required. Analytical consequences of these definitions into the evaluation formula are highlighted and an example of application is synthetically expressed by a calculation table. In Sect. 4 the preliminary decisions of the evaluation board are described, subdividing them into six decision steps. The conclusions essentially focus on the negative consequences, for the natural development of research in the Social Sciences and Humanities, of the use of the evaluation model based on bibliometric indicators, highlighting the necessity of creating instruments, models and objective criteria suitable to support an evaluation system that respects the researcher's identity and the spontaneous evolution of science.

2 Definitions, Symbolism, Quantitative Conditions and Parameters

The objects under evaluation, named by the symbol i ($i = 1,\ldots,N$), are the N scientific publications of each competing researcher. The set of *a priori* criteria for the evaluation of each publication is $\{c_h\}$, $h = 1,\ldots,H$. The set of *a priori* criteria for the evaluation of the scientific production as a whole (*e.g.* scientific productivity respect to time) is $\{g_k\}$, $k = 1,\ldots,K$.

The highest total score assignable to the scientific production of each researcher is S. The weights of the total scores coming from the application of the two sets of the above mentioned criteria are α_c and α_g. In particular, α_c is the weight of the total score deriving from the application of the set of the criteria $\{c_h\}$ and α_g is that of the total score coming from the application of the set of criteria $\{g_k\}$, under the conditions: $0 < \alpha_c < 1$, $0 < \alpha_g < 1$, $\left(\alpha_c + \alpha_g\right) = 1$, so that $\left(\alpha_c S + \alpha_g S\right) = S$.

Consequently, the highest analytical score assignable to each publication is equal to $\left(\alpha_c S\right)/N$.

The score assigned to publication i on the base of each criterion c_h is s_{ih} and it must verify the following conditions: $0 \leq s_{ih} \leq S_h$, for all $i = 1,\ldots,N$.

Moreover, the score assigned to the scientific production as a whole on the base of each criterion g_k is s_k and it must verify the following conditions: $0 \leq s_k \leq S_k$.

The parameter S usually is institutionally predetermined.

The weights α_c and α_g and the scores S_h, S_k, ($h = 1,\ldots,H$ and $k = 1,\ldots,K$) are the $(H + K + 2)$ quantitative parameters of the model, which are to be established by the evaluation board.

3 Two Different Types of Criteria and the Implications for the Evaluation Formula

The verification of certain criteria of the sets $\{c_h\}$ and $\{g_k\}$ may be considered by the evaluating board a necessary condition for the assignment of a non-zero score. Therefore, the evaluation criteria can be distinguished, by the evaluation board, into two types: those implying necessary conditions and those not implying necessary conditions.

The criteria of the first type are marked by the symbols c_k^* and g_k^*; similarly the relative assigned scores are s_{ih}^* and s_k^*.

In relation to this type of criteria, the analytical formalisation of the model requires that the highest scores assignable to each publication or to the scientific production as a whole, S_h^* and S_k^*, must be equal to 1 and, consequently, that $0 \leq s_{ih}^* \leq 1$ and $0 \leq s_k^* \leq 1$. In particular, there are the following equivalences:

- the equalities $s_{ih}^* = 0$ and $s_k^* = 0$ are equivalent to the non-verification of the corresponding criteria;
- the inequalities $0 < s_{ih}^* < 1$ and $0 < s_k^* < 1$ are equivalent to a partial verification of the corresponding criteria;
- the equalities $s_{ih}^* = 1$ and $s_k^* = 1$ are equivalent to the verification of the corresponding criteria.

The criteria $\{c_h\}$ are ordered in the following way: $\left\{c_1, c_2, c_3, \ldots, c_\varphi, c_{\varphi+1}^*, c_{\varphi+2}^*, \ldots, c_H^*\right\}$, where $(H - \varphi)$ is the number of the criteria implying necessary conditions; the criteria $\{g_k\}$ are ordered in a similar way $\{g_1, g_2, g_3, \ldots, g_\tau, g_{\tau+1}^*, g_{\tau+2}^*, \ldots, g_K^*\}$ and, in this set, $(K - \tau)$ are the criteria implying necessary conditions.

In this model, the assigned scores s_{ih}^* and s_k^* are used as factors in the analytical formula for the calculation of the total score of the scientific production of each competing researcher. Moreover, the assigned scores s_{ih} and s_k (related to the criteria that do not imply necessary conditions) are used as addends.

The formula of the total score (TS) of the scientific production of each competing researcher is the following:

$$TS = \sum_{i=1}^{N} \left[\left(\sum_{h=1}^{\varphi} s_{ih} \right) \prod_{h=\varphi+1}^{H} s_{ih}^* \right] + \left(\sum_{k=1}^{\tau} s_k \right) \prod_{k=\tau+1}^{K} s_k^* \tag{1}$$

It is useful to observe that, in relation to the criteria of the set $\{c_h\}$ that do not imply necessary conditions, the following equality must be verified:

$$\sum_{h=1}^{\varphi} S_h = \left(\alpha_c S\right)/N.$$

Similarly, in relation to the criteria of the set $\{g_k\}$ that do not imply necessary conditions, the following equality must be verified:

$$\sum_{k=1}^{\tau} S_k = \alpha_g S.$$

In Table 1, an example of application of the evaluation formula (1) is schematized on the base of some criteria expressed by Italian Ministry of Education, University and Research [10].

Table 1. Example

PUBLICA-TION NUMBER	c_1 **criterion score** (referred to originality, innovativeness, methodological accuracy and relevance of each scientific publication)	c_2 **criterion score** (referred to scientific relevance of each publication's publishing house and its diffusion among the scientific community)	c_3 **criterion score** (referred to analytical evaluation of the candidate's contribution in the case of works in cooperation)	c_4^* **criterion score** (referred to congruence of each publication with the scientific area of the competitive exam)	c_5^* **criterion score** (referred to congruence of each publication with the required scientific profile, defined by indication of one or more scientific sectors)	c_6^* **criterion score** (referred to congruence of each publication with issues related to the required scientific commitment)	**TOTAL SCORES**
1	s_{11}	s_{12}	s_{13}	s_{14}^*	s_{15}^*	s_{16}^*	$\sigma_1 = (s_{11}+ s_{12}+ s_{13})\, s_{14}^* s_{15}^* s_{16}^*$
2	s_{21}	s_{22}	s_{23}	s_{24}^*	s_{25}^*	s_{26}^*	$\sigma_2 = (s_{21}+ s_{22}+ s_{23})\, s_{24}^* s_{25}^* s_{26}^*$
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
N	s_{N1}	s_{N2}	s_{N3}	s_{N4}^*	s_{N5}^*	s_{N6}^*	$\sigma_N = (s_{N1}+ s_{N2}+ s_{N3})\, s_{N4}^* s_{N5}^* s_{N6}^*$
Total score of the *N* publications (T_1)							$T_1 = \sigma_1 + \sigma_2 + \ldots + \sigma_N$
g_1 **criterion** (Consistency of the scientific production as a whole)							s_1
g_2 **criterion** (Intensity over time of the scientific production as a whole)							s_2
g_3 **criterion** (Continuity over time of the scientific production as a whole)							s_3
Total score of the scientific productivity respect to time (T_2)							$T_2 = s_1 + s_2 + s_3$
TOTAL SCORE							$T_1 + T_2$

4 The Six Decision Steps of the Evaluation Board

By the application of the formula expressed in the previous section, the evaluation board has to carry out a simplified work in order to perform the responsibility of assign an analytical score to the scientific production of each researcher.

In this section the preliminary decisions of the evaluation board are described subdividing them into six decision steps.

The number N of publications under evaluation and the maximum total score S to be assigned to the scientific production of each competing researcher are institutionally predetermined in the announcement of the selection.

The first decision step of the evaluation board is to establish α_c and α_g, *i.e.* the weights, respect to S, of the two maximum scores respectively assignable to the set of the scientific publications (examined one by one) and to the scientific production as a whole (*e.g.* the scientific productivity respect to time); these two scores must result reciprocally complementary respect to the maximum total score S.

The second decision step for the evaluation board is to establish the two sets of *a priori* criteria $\{c_h\}$ and $\{g_k\}$, which are mainly defined by the existing institutional guidelines and can be completed by other appropriate criteria.

The third step is to establish which *a priori* criteria must be considered equivalent to necessary conditions among the set $\{c_h\}$ and the set $\{g_k\}$.

The fourth step for the evaluation board is to decide the maximum score related to each *a priori* criterion. In particular, the maximum scores S_h (related to each of the φ criteria that do not imply necessary conditions) are to be established controlling that the sum of these φ numbers is equal to: $(\alpha_c S)/N$. The maximum scores related to each of the $(H - \varphi)$ criteria of the set $\{c_h\}$ that imply necessary conditions must be equal to 1. Similarly, the maximum scores S_k (related to each of the τ criteria that do not imply necessary conditions) are to be established controlling that the sum of these τ numbers is equal to: $(\alpha_g S)$. The maximum scores related to each of the $(K - \tau)$ criteria of the set $\{g_k\}$ that imply necessary conditions must be equal to 1.

The fifth decision step and the sixth one (respectively regarding the set of criteria $\{c_h\}$ and the set of criteria $\{g_k\}$) are referred both to methodological and quantitative aspects.

Expressly, in the fifth step the evaluation board, in relation to each criterion of the set $\{c_h\}$, has to decide how to assign a score s_{ih} (not exceeding the established maximum score S_h) to each publication i. For this purpose, the evaluation board can establish to use instruments and parameters conventionally shared in the related scientific community, *e.g.* classifications of scientific journals (for the criterion referred to originality, innovativeness, methodological accuracy and relevance of each scientific publication); presence of an international editorial board in the publishing house (for the criterion referred to relevance of each publication's editorial house and its diffusion among the scientific community); number of co-authors and order of co-authors in the sequence of authors (for the criterion referred to the analytical evaluation of the candidate's contribution to works in cooperation). Moreover, for the congruence of the publication with the scientific area of the competitive exam, with the required scientific profile and with issues related to the required scientific commitment, the evaluation board can use the information emerging from the journal classifications and from objective elements of the publication. The score s_{ih} can be adequately graduated in relation to the adopted instrument and parameter, provided that it does not exceed the established maximum S_h. Similarly each score s^*_{ih} (related to the criteria equivalent to necessary conditions) can be adequately graduated in relation to the adopted instrument and parameter, provided that it does not exceed 1.

In the sixth step the evaluation board, in relation to each criterion of the set $\{g_k\}$, has to decide how to assign a score s_k (not exceeding the established maximum score S_k) to the researcher's scientific production as a whole. For this scope, the evaluation board can establish to refer the scores to quantitative aspects whose computation is objective and certain, *e.g.* the number of publications of high classification, the number of publications in publishing houses with international editorial board, the average number of publications in a year, the number of years without publications. The score s_k can be adequately graduated in relation to the adopted quantitative indicator, provided that it does not exceed the established maximum S_k. Similarly each score s_k^* (related to the criteria equivalent to necessary conditions) can be adequately graduated in relation to the adopted indicator, provided that it does not exceed 1.

The calculation of the total score assigned to the scientific production of each competing researcher can easily be made using the support of the format represented in Table 1, in which the application of the evaluation formula (1) is subdivided in two phases in relation to the different sets of criteria. In the calculation, the scores related to the criteria that imply necessary conditions are factors and this algebraic aspect has the following practical implications: if, for a publication i, the score of only one criterion (among those which are equivalent to necessary conditions) is zero (*i.e.* if only one of the necessary conditions is not verified), the total score to be assigned to the publication is zero (because it results multiplied for a factor equal to zero); moreover, to the publication i it will be wholly assigned the score deriving from the sum of the partial scores s_{ih} if, and only if, all the scores related to the criteria that are equivalent to necessary conditions are equal to 1 (*i.e.* if, and only if, all the necessary conditions are verified); a halfway non-zero score, related to a criterion that is equivalent to necessary conditions (*i.e.* the presence of a necessary condition which is partially verified), implies the reduction of the total score to be assigned to the publication.

It is likewise possible to explain the algebraic implications referred to the similar calculation of the score corresponding to the evaluation of the scientific production as a whole.

5 Conclusions

The principal aim of this work is to alert the scientific community of evaluation specialists about the negative consequences of the use of evaluation models based on bibliometric indicators for the natural development of research in the Social Sciences and Humanities. The evaluation method proposed in this contribution is an example useful to observe that it is possible to achieve an effective evaluation of scientific production without bibliometrics. It is also important to highlight that, for this scope, it is necessary to create instruments, models and objective criteria suitable to support an evaluation system that should respect the researcher's identity and the spontaneous evolution of science. Particularly, the observations inspired by the method presented in this contribution lead to note the usefulness of Boole's Algebra for the calculation of total scores deriving from the simultaneous application of criteria having a different logical nature.

This paper is not focused on the aspects that are fundamental for the analysis of researchers' behaviour. Many of these aspects are at the base of distorting and obsessive consequences on the researcher's nature. However, these conclusions represent a starting point for addressing future research lines in this field.

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Information Aggregation in Big Data: Wisdom of Crowds or Stupidity of Herds

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Abstract. We are entering an age of big data in which our everyday lives depend on tremendous amounts of data and at the same time generate new data. However, the effect of this information convenience on the quality of our decision-making is still not clear. On the one hand, more information is expected to help people make better decisions by serving as the "wisdom of crowds". On the other hand, imitation among interconnected agents may lead to the "stupidity of herds" with the result that most people will make worse choices. Using agent-based modeling, we explore the information aggregation behaviors of an interconnected population and study how the connectedness among agents influences the checks and balances between the "wisdom of crowds" and the "stupidity of herds", as well as the decision quality of the agents. We find that in a population of interconnected agents with limited fact-checking capacity, a quasi-equilibrium with a small portion of agents making decisions based on fact checking and a large portion of agents following the majority can be achieved in the process of reinforcement learning. The effects of agents' fact-checking capacity and search scope on herding behavior, decision quality, and the possibility of systemic failure are also investigated. It is interesting to find that the decision accuracy first increases and then decreases as the agents' search scope goes up if the agents have a limited fact-checking capacity. This finding implies that a partially connected rather than a fully connected network is preferred from the viewpoint of information aggregation efficiency.

Keywords: Information aggregation · Wisdom of crowds · Stupidity of herds · Reinforcement learning

1 Introduction

Information aggregation mechanisms in a population with dispersed information are an interesting and fundamental topic of economic research [8]. In the

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era of big data, it is expected that more information shared in the interconnected world helps people make more accurate predictions and better decisions, which is referred to as the "wisdom of crowds" [2,6,7,9]. However, due to the time and capacity limitation, people may simply follow others' choices. When imitators are imitated by others, a cascading failure may occur [1,3], which is referred to as the "stupidity of herds" [5]. What we are concerned about is whether the Internet and big data can enlarge the wisdom of crowds and diminish the stupidity of herds. To address this issue, a model that can generate aggregate patterns bottom up from individuals behaviors is needed, and agent-based modeling is exactly this kind of model [4].

One of the pioneering agent-based models to study information aggregation is Vriend's model [10]. Vriend considered a society in which a finite number of consumers are repeatedly offered a binary choice. To make a choice between two items with unknown stochastic utilities, agents will observe the behaviors and choices of a limited number of other randomly sampled agents. Agents will also adapt to choose a strategy from the strategy pool through a reinforcement learning process. The society will reach a quasi-equilibrium at which there is a statistically stable percentage of agents making correct decisions after the learning process. Vriend found that at the quasi-equilibrium, the percentage of agents who choose the superior item is higher. However, the probability that the majority of the population will make wrong choices is also higher. This result can be interpreted as the simultaneous existence of the wisdom of crowds and the stupidity of herds.

In this paper, we extend Vriend's model to study the information aggregation mechanism in an interconnected population of individuals with different observation capacity and search scope as in an environment of big data. We first introduce Vriend's model and highlight its main results in Sect. 2. In Sect. 3 we probe deeper to understand the underlying mechanism from the individual's strategic choices to the overall information aggregation efficiency. We then extend Vriend's model to investigate the influence of the agents' fact-checking capacity and connectedness in the population on the information aggregation efficiency in Sect. 4. Conclusions are provided in Sect. 5.

2 Vriend's Model and the Main Results

2.1 Basic Choice Situation

The model has a population of 100 individuals who face the same choice problem in each period for 25000 periods. In every period, two new items that are completely independent of earlier items arrive, and all agents sequentially face a choice between them, with the order of the agents being determined at random in every single period. Each new item, i, is characterized by the expected value of the utility it can provide EV_i, which is randomly generated from a uniform distribution $U(0.25, 0.75)$. These expected values are unknown to the individual agents. Given an expected value, EV_i, the utility that a specific agent will actually experience from consuming the item will be a random draw from the uniform distribution $U(EV_i+0.25, EV_i+0.25)$. Every 500th period, the expected values of the two items are identical (0.50) and serve as useful benchmarks to see how much information contagion has emerged.

Since an agent has no experience with these two specific new items, when making a decision, he is given an opportunity to draw 6 random observations from the people that have already made a decision before him. For each element in his sample, he can observe the item chosen and the utility actually experienced from the item by the consuming agent. Before the first agent in the sequence makes his decision in a given period, six dummy agents are added with three of them choosing one item and the other three choosing the other item (this 50-50 seeding prevents any bias at the start of a period). Given the sample information, an agent makes his choice, and then the next agent in the randomly generated order does the same thing until everyone makes his decision and another period starts.

2.2 Individual's Decision Making and Learning

In general, the information gleaned from the limited number of observations is far from conclusive when it comes to determining which of the two items has the greater expected value. For example, a utility level of 0.70 experienced by a specific agent in a sample could have been generated by an item with an expected value of 0.45 or by an item with an expected value of 0.95. Obviously, this uncertainty matters in an agent's decision making.

To make a decision from limited uncertain information, each agent manages a pool of strategies, which contains a set of strategies or action rules. Each strategy consists of a condition part ('if ... '), and an action part ('then ... '). Table 1 summarizes the set of strategies to be used in the model.

Each strategy is assigned a score s which measures the goodness of the strategy, and the higher the score, the more likely a strategy is to be used. Each agent maintains the strategy scores separately by himself and may assign a different score to the same strategy in a different period. When making a choice, an agent will check all the strategies in the pool and select the applicable ones whose 'if ... ' condition is satisfied by his sample. Among the applicable strategies, the one with the highest score (plus a white noise $s + \epsilon$) will be chosen as the strategy to be applied.

The strategy score that has been used in one period will be updated according to the utility (or reward) it brings as follows:

$$s_t = s_{t-1} + c(r_{t-1} - s_{t-1}) \quad (1)$$

Here, s_t and s_{t-1} are the scores for a strategy in periods t and $t-1$, r_{t-1} is the reward gained by this strategy in period $t-1$, and $0 < c < 1$ is the learning rate that can be used to adjust the speed at which a strategy is updated. Hence, as long as the reward generated by the strategy in period $t-1$ is greater than its score in period $t-1$, its score will increase.

Table 1. Strategy pool (Adapted from Appendix Al in Vriend's paper [10])

No	Name	Description
1	Highest average	If both items are present in the sample of observations, then choose the item that has the highest average performance in the sample. If the condition is not satisfied, the rule is not eligible and will be neglected.
2	Highest average(2)	Same as No. 1, with one more requirement that the item with the highest average performance must occur at least twice in the sample.
3	Highest average(3)	Same as No. 1, with one more requirement that the item with the highest average performance must occur at least three times.
4	Highest minimum	If both items are present in the sample of observations, then choose the item that has the highest minimum performance in the sample. Otherwise, neglect this rule.
5	Highest minimum(2)	Same as No. 4, with one more requirement that the item with the highest average performance must occur at least twice in the sample.
6	Highest minimum(3)	Same as No. 4, with one more requirement that the item with the highest average performance must occur at least three times.
7	Highest maximum	If both items are present in the sample of observations, then choose the item that has the highest maximum performance in the sample. Otherwise, neglect this rule.
8	Highest maximum(2)	Same as No. 7, with one more requirement that the item with the highest average performance must occur at least twice in the sample.
9	Highest maximum(3)	Same as No. 7, with one more requirement that the item with the highest average performance must occur at least three times.
10	Majority	If a strict majority in the sample chooses one item, then follow the majority. Otherwise, neglect this rule.
11	Majority (3)	Same as No. 10, with one more requirement that the majority is at least three observations greater than the minority.
12	Majority (5)	Same as No. 10, with one more requirement that the majority is at least five observations greater than the minority.
13	Follow last	This rule chooses the same item as in the last observation sampled.
14	Follow last (2)	If the last two observations sampled choose the same item, then choose that item as well. Otherwise, neglect this rule.
15	Follow last (3)	If the last three observations sampled choose the same item, then choose that item as well. Otherwise, neglect this rule.
16	Random	Randomly select one of the items, each with equal probability.
17–31	Opposite of rules 1–15	These rules operate just as Rules 1 to 15. However, when the corresponding Rules 1 to 15 determines to choose Item 1, then the current rule selects Item 2, and vice versa

2.3 Main Results

We replicate Vriend's model and re-generate the main results as shown in Fig. 1, which is the same as Fig. 8 in Vriend's paper [10]. The horizontal axes of both panels are time. The left panel is for the first 5000 periods (from 1 to 5000), and the right panel is for the last 5000 periods (from 20001 to 25000). The vertical axis is the success frequency, which is the percentage of those agents who choose the superior item in the total population.

It is interesting to note that while the success frequency goes up as the learning process continues, the spread of the success frequency increases as well. At the beginning for about 1000 periods, about 50% of the agents choose the correct item and the frequency located in a narrow range never exceeds the 35 to 70% band. As time goes on to about the 2000th period, the success frequency goes up to 60%, but periods in which only about 30% of the agents pick the superior item occur occasionally. Later on there are periods with just 15% choosing correctly, and eventually (after about 5000 periods) it even happens that almost nobody makes the correct choice, which can be interpreted as the stupidity of herds. All the time, however, the success frequency exhibits an upward trend, which can be interpreted as the wisdom of crowds.

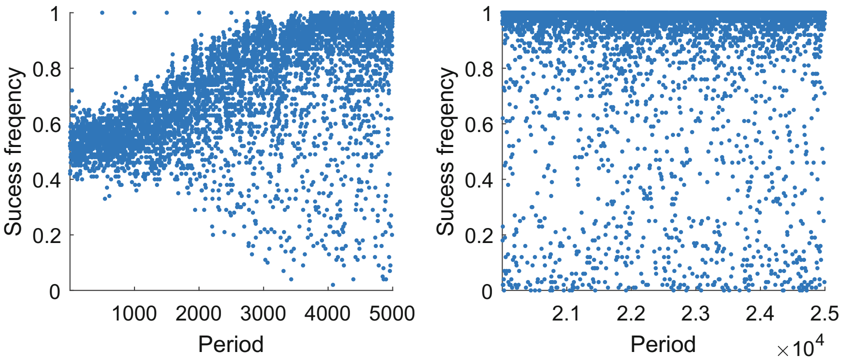

Fig. 1. The main result of Vriend's model.

3 Additional Insights into Vriend's Model

It is a great contribution for Vriend to provide a framework that generates a co-existence of the wisdom of crowds and stupidity of herds. However, it is still not clear how individuals' strategic learning gives rise to the overall information aggregation. To obtain a deeper understanding of the driving forces behind the wisdom of crowds and stupidity of herds, we categorize the strategies into two types. Strategies No. 1 to No. 9 (see Table 1) are utility-based strategies. An agent who adopts this type of strategy checks both the items that the sampled agents choose and the utilities provided by these items to those sampled agents. Strategies No. 10 to No. 15 are majority-based strategies. An agent who adopts this type of strategy does not check how much utility an item can provide, and his decision only relies on what choices the sampled agents make. We do not consider the random strategy (No. 16) and the abnormal strategies (No.17–31) because they are less profitable and abandoned by agents before the quasi-equilibrium is reached.

Figure 2 illustrates that the frequency of the majority-based strategy adopters is the main driving force behind information aggregation and the underlying reason for the wisdom of crowds and the stupidity of herds. The horizontal axis is time, and the vertical axis is the frequency of agents who adopt the majority-based strategies among all 100 agents. The frequency goes up during the first 3000 periods and gradually reaches a quasi-equilibrium after about 5000 periods. Compared with Fig. 1, the switches in structures in both figures coincide with each other.

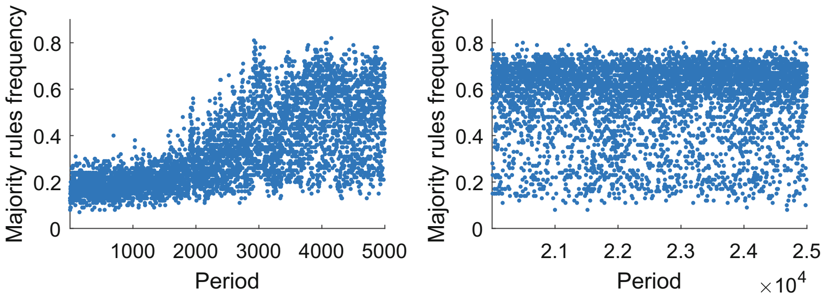

Fig. 2. The evolution of the frequency of the majority-based strategies.

It is important to note that the profitability of the majority-based strategies depends on the proportion of the adopters of the utility-based strategies. If there are many adopters of the utility-based strategies (to be extreme, all other agents use utility-based strategies), the majority-based strategy is very effective because the agent who uses this strategy makes use of 6×6 observations of the chosen items and the corresponding utilities. In the other extreme situation, if all other agents use the majority-based strategy, then the agent adopting a majority-based strategy obtains no information about the utilities provided by the items. We should also notice that in reinforcement learning, if one strategy provides higher utility, its score will increase, and it will be adopted more often. On the other hand, a strategy providing less utility will gradually be abandoned.

Therefore, when there are few majority-based strategy adopters, a majority-based strategy is very profitable, and more and more agents will learn to choose this type of strategy. With the increase in the adoption of the majority-based strategy, its profitability will decrease. Once the frequency of agents adopting a majority-based strategy goes down to such a level that both types of strategies bring the same utility, the society reaches a quasi-equilibrium with a roughly fixed portion of agents using the majority-based strategies and the other agents using utility-based strategies. As shown in Fig. 3, the horizontal axis is time, and the vertical axis is the utilities (a moving average with a time window of 2000 periods) that the two types of strategies provide. We can see that in the first 3000 periods, the utilities of the majority-based strategies are significantly larger than those of the utility-based strategies. After the 3000th period, the utilities of both types of strategies greatly coincide with each other. It is only by this balance that quasi-equilibrium can be achieved. We believe that this profitability difference (or equality) is the driving force behind the strategy switching and the underlying reason for the wisdom of crowds and the stupidity of herds.

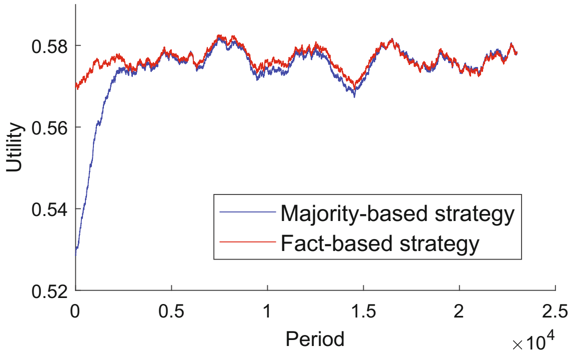

Fig. 3. The profitabilities of the two types of strategies.

4 Extended Model and Results

4.1 The Effect of Observation Capacity

In Vriend's model, each agent can only observe up to 6 other agents' choices and resulting utilities. The Internet and big data provide us with the ability to observe a larger sample. How will the information aggregation change as the observation capacity changes?

We extend Vriend's model to allow the observation capacity, that is, how many other agents an agent can observe before he makes his decision, to range from 6 to 30 and perform the simulation for 10 runs. Figure 4 shows the effect of observation capacity on information aggregation. The horizontal axis of the four panels is the observation capacity. The vertical axis in the top-left panel is the mean of the success frequencies after the society reaches the quasi-equilibrium. The society reaches the quasi-equilibrium after about the 5000th period. We choose the last 5000 (20000 to 25000) periods to calculate the average success frequency in each run and then calculate the mean in 10 runs. It is a measure for the wisdom of crowds; the higher the mean of the success frequencies, the greater the wisdom of crowds. The vertical axis in the top-right panel is the standard deviation of the success frequencies after the society reaches the quasi-equilibrium. It is a measure

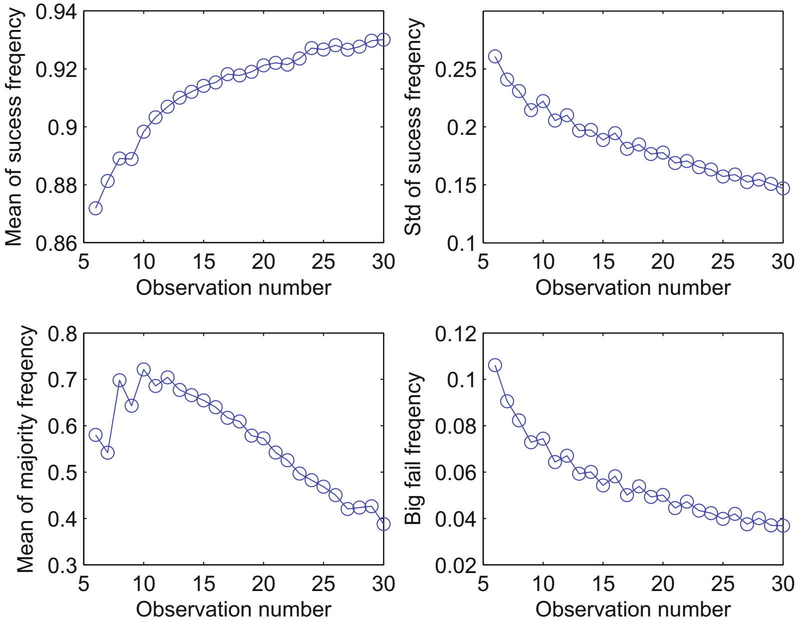

Fig. 4. The effect of observation capacity on information aggregation.

for the stupidity of herds; the higher the standard deviation of the success frequencies, the greater the stupidity of herds. We can see that as the observation capacity increases, the wisdom of crowds becomes higher and higher, and the stupidity of herds lower and lower. This result can also be verified by the left-bottom panel of Fig. 4, whose vertical axis is the frequency of big failure, which is defined as the ratio of the periods in which more than 50% of the agents choose an inferior item in the last 5000 periods of the 10 runs.

The above finding suggests that increasing the observation capacity is an effective and fundamental way of improving the information aggregation in an interconnected population. To some extent, if the technological innovation and big data can provide us with an opportunity to observe more facts in the world, the wisdom of crowds can be enhanced, and the stupidity of herds diminished.

One may be concerned that, even if individuals can access more information, the learning process or utility-maximization incentive may drive them to imitate others' behavior, instead of checking the facts, and lead them to the more severe stupidity of herds. The bottom-left panel of Fig. 4, however, tells us that this is not the case. The vertical axis depicts the proportion of the majority-based strategy adopters in the total population after the society reaches the quasi-equilibrium state. We can see that as the observation capacity increases from 6 to 10, the frequency of the majority-based strategy adopters in the quasi-equilibrium by and large goes up. The reason for this is that when fewer agents use the majority-based strategies, a majority-based strategy can gather more information from those being observed. Hence, the marginal utility of the increment in observation capacity for the majority-based strategies is larger than that for the utility-based strategies. When the observation capacity is larger than 10, there are at least three reasons that make the majority-based strategies less attractive than the utility-based strategies. Firstly, the possibility of observing other majority-based strategy adopters who provide no information is higher, which reduces the effectiveness of the majority-based strategies. Secondly, the increase in the observation capacity leads to an increase in obtaining duplicate samples under a majority-based strategy. A majority-based strategy adopter follows the majority of the observations in his sample (the sample size is the observation capacity, n). Because the sampled agents' decisions are based on the information they observed, the size of the working sample from which a majority-strategy adopter can gather information is the observation capacity (n) times the observation capacity (n). In our simulation, when the observation capacity is larger than 10, the size of the working sample for a majority-based strategy adopter is more than 10×10. Since there are only 100 agents in total, duplicate observations are expected. Thirdly, the utility-based strategies become more effective as the observation capacity increases because larger sample provides more information based on which an agent can make a decision. Overall, due to the decrease in the effectiveness of the majority-based strategies and the increase in the effectiveness of the utility-based strategies, the proportion of the majority-based strategy adopters in the total population at the quasi-equilibrium state becomes smaller when the observation capacity increases from 10 to 30 or even more.

4.2 The Effect of Search Scope

One may not be too optimistic regarding the effectiveness of the observation capacity in improving the efficiency of information aggregation. Although technological innovation may help us enlarge our observation capacity to some extent, there is an upper bound due to our limited time and cognitive capacity. Nevertheless, even though we can only observe a limited number of other people's behavior and results, the scope in which we can choose these samples can be extended easily with the help of the Internet and big data technology. In Vriend's model, the search scope is assumed to be global, that is, an agent can choose his samples from all other agents. In this section, we vary the search scope to investigate how the search scope influences the information aggregation.

To study the effect of individuals' search scope on the information aggregation, we assume that each agent has a fixed observation capacity, that is, he can only access 6 other agents' choices and the resulting utilities. In our model, we use a simple network structure, the ring or circle structure, instead of a complex network, because the simple network structure is enough for us to see how the search scope influences the overall information aggregation efficiency. Agent 1 is connected to Agent 100 and 2; Agent 2 is connected to Agent 1 and Agent 3;...; Agent 99 is connected to Agent 98 and Agent 100; and Agent 100 is connected to Agent 99 and Agent 1. The search scope is defined as how far the agents can access the information. For example, if the search scope is 3, Agent 1 can only access the information from Agents 98, 99, and 100 and Agents 2, 3, and 4.

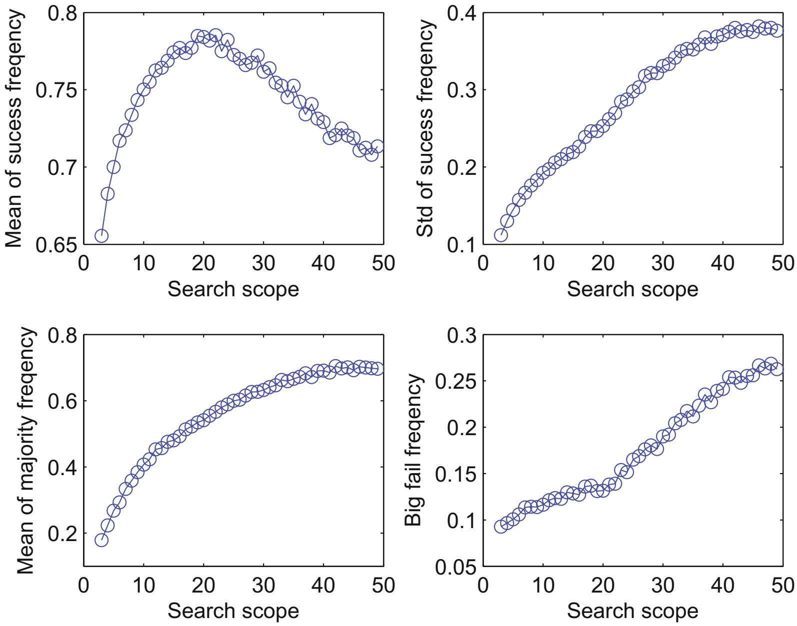

Fig. 5. The effect of search scope on information aggregation.

By simulating with the search scope from 3 to 49, we obtain the results illustrated in Fig. 5. The horizontal axis of the four panels is the search scope. We define the search scope as a one-sided scope in the ring structure, which means that an agent with a scope of 3 can see 6 (left 3 and right 3) other agents' choices and utilities, and an agent with a scope of 49 can see almost all (98 in 99) other agents. The vertical axis of the top-left panel is the mean success frequency after the society reaches the quasi-equilibrium (the last 5000 periods). The vertical axis of the top-right panel is the standard deviation of the success frequency in the last 5000 periods of the 10 runs. The bottom-left panel's vertical axis is the mean frequency of the majority-based strategies adopted in the last 5000 periods of the 10 runs. The last panel's vertical axis is the frequency of big failure, which is an indicator of how severe the stupidity of herds is.

As shown in the bottom-left panel, as the search scope increases, more agents will learn to adopt the majority-based strategies at the quasi-equilibrium state. The intuitive reason is that the wider the scope where one agent can choose a fixed number of other agents to observe, the fewer the opportunities to obtain duplicate samples, the more effective the majority-based strategies are. Also intuitively, with more majority-based strategy adopters, the stupidity of herds is more severe (top-right panel), and the big failure is more frequent (bottom-right panel).

It is surprising and interesting to see that the mean success frequency has a nonlinear relationship with the search scope (as shown in the top-left panel). When the search scope is small, the early-acting agents' chances of observing others' behavior are few in each period because these agents can only access a small range of neighbors and many of them have not made choices. Therefore, the early-acting agents have little information to use for making decisions, resulting in an overall lower frequency of success. As the search scope increases, the chances of lacking information reduce, and thus the mean success frequency becomes larger. However, when the search scope increases beyond some threshold (24 in our simulation), the mean success frequency reverses and begins to decrease steadily. The reason is that although the information shortage is no longer a big problem, the proportion of the majority-based strategy adopters increases, resulting in the stupidity of herds.

Now we consider the top-left and top-right panels together. Before the threshold of the search scope, both the wisdom of crowds and the stupidity of herds are increasing. After the threshold, the wisdom of crowds decreases and the stupidity of herds increases. Therefore, the society is worse off if the search scope continues to rise. Because the search scope roughly reflects how far the agents can be connected, this phenomenon suggests that a moderate connectedness rather than a complete connectedness is preferred in a population with a fixed and limited information processing capacity.

5 Conclusion

The Internet and big data change our information processing dramatically by providing a convenient interconnection and huge volume of data. However, it is still not clear whether these techniques advance or impair the quality of information aggregation and to what extent they can improve collective decisions. By extending Vriend's model [10], we study the formation of the wisdom of crowds and the stupidity of herds and investigate the factors influencing the collective decision efficiency.

Several insights are obtained as follows. Firstly, the wisdom of crowds and the stupidity of herds can co-exist in an interconnected population of individuals with limited observation capacity. Secondly, the fundamental reason for the co-existence of the wisdom of crowds and the stupidity of herds is the individuals' strategy learning driven by their utility-maximization incentives. Thirdly, increasing the individuals' observation capacity is an effective way of improving information aggregation efficiency. However, due to the time and cognitive limitations of human beings, the potential for observation capacity to increase is very limited. Fourthly, a moderately connected rather than completely connected network is preferred from the viewpoint of information aggregation efficiency under the condition that the observation capacity is limited.

There is plenty of room for future work. Firstly, more complex network structures instead of simple ring structure can be employed to explore the effect of network properties on information aggregation. Secondly, an agent may adopt a different strategy in the situation where he is placed in the front of the queue when he has little information to refer to from the situation where he is placed at the back of the queue when he has much information to refer to.

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Designing and Programming a Graphical Interface to Evaluate *Treatments* in Economics Experiments

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Abstract. In this paper, we develop a graphical interface that allows to calculate the efficacy of one or more *treatments* before adopting an experimental economics design. The graphical interface is built with Java according to a model-based *treatment* design. The aim is twofold. We are first interested in designing *treatments* in order to increase their efficacy, evaluating how experimental factors can affect the *treatment* process design. The second aim is to enhance the internal and external validity of the experiment to be run. The general idea behind this research is to implement a Graphical Experimenter Interface (GEI) capable to support economists when deciding which experimental *treatment* design to adopt and thus which factors to include.

Keywords: Experimental economics · Model-based *treatment* design · Computational economics

JEL classification: C90 · C91 · C93 · C99

1 Introduction

In the context of economics experiments, a *treatment* is generally an artificial variation applied to randomly selected subset of experimental subjects having a causal effect on some outcome, and this subset compared to a randomly selected control group. Experimental research, indeed, enables economists to go beyond descriptive and predictive analytics, and attempts to determine what caused effects, providing information on cause-and-effect relationships between variables[1]. Among the aims of an experimental design is to ensure that the experiment is capable of detecting the *treatment* effects

[1] A large body of scientific literature is concerned with modelling the effects of a *treatment* on an outcome of interest [see 1–3]. In economics experiments, therefore, the experimenter selects variables which may affect the dependent variable and, thus, she considers them treatment variables (independent variables). The experimenter observes the effect on the dependent variable generated by one or more variations or manipulations of independent variables, ruling out any competing explanation.

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considered [4]. Regarding the effects in the experiments, we can define an effect as a notion of the counterfactual. A possible effect of a *treatment* or *treatment* effect may be the difference between what did happen when the *treatment* was introduced and what would have happened had it not been introduced. Nevertheless, we focus on experimental designs *"[…] based on the random assignment of a purposeful "treatment" or manipulation. We include studies where treatment is deterministically assigned in a way that can be viewed as equivalent to random, such as assigning every second name in a list, or choosing a permutation of potential subjects that optimizes the balance between treatment and control groups."* Card *et al*. [5] pp. 40–41. In search of greater relevance, therefore, we argue that there is still much to learn from designing *treatments* increasingly turning to the experimental method in the field of economics. In line with this aim, we develop a "material" model[2] to predict the potential outcomes of *treatment*. This model provides potential outcomes that allow experimenters to predict efficacy of *treatments*. Indeed, *"the goal of any evaluation method for "treatment effects" is to construct the proper counterfactual, and economists have spent years examining approaches to this problem."* Harrison G.W. and List J.A. [7] p. 1014. Following [7], more specifically, a *treatment* is a process relying on the modifications of the baseline conditions in the experimental factors. As yet, the existing literature on experimental economics has principally converged on the effects that *treatments* yield in terms of experimental results (*treatment* effect) [8]. Nevertheless, a *treatment* is always endogenously generated by experimenters in economics before yielding results (*treatment* design) [9]. In particular, we investigate the role of *treatment* as a possible combination of one or more constitutive factors to design an economic experiment and in order to validate its outcome. The broad objective of our research project is to involve, and to draw preliminary conclusions about, two interrelated research themes. The first regards the preliminary evaluation of the *treatment* design in terms of efficacy [9, 10]; the second concerns the internal and external validity of an experimental study in terms of baseline and non-baseline characteristics of the experimental factors [11, 12]. On the one hand, we analyse the first theme by formulating a model which consists of two sub-models based on experimental factors included into the three experimental design contexts [13]. Drawing upon the model formulated, on the other hand, we consider the second theme by means of an evaluation index that relates the experimental factors to control and *treatment* groups within the design to be implemented. We devote most of our space to modelling experimental factors in *treatment* design because we feel it is otherwise under-emphasized both in economics and its applications [4]. In doing so, we present a model to evaluate *treatments* in economics experiments that allows experimenters to identify the preliminary efficacy of a *treatment* design. We initially describe a setting in which one *treatment* group is considered with one control group. We then extend this setting for examining the relationship between the modes of experimental factors and all possible experimental

[2] In fact, "*a "material" model is a model of flesh and blood, the exogenous variables of which are controlled by the experimental design in order to see how the endogenous variables react to changes in the treatment variables*." Schmidt J. [6] p. 15. Although the model is general and can be applied to several experimental contexts, we introduce it in the context of designing economics experiments.

group. The idea is to measure the potential outcomes of *treatment* and control groups that are randomized for different subject pools (students and no students). To support this idea, we develop a graphical interface using Java code as a tool that facilitates experimenters to design a variety of *treatments* before adopting an experimental economics design. We named this tool *Graphical Experimenter Interface* (GEI). The layout of the paper is as follows. In Sect. 2, we present the model-based *treatment* design consisting in two sub-models. Section 3, presents relevant work in designing and programming a graphical interface in order to put the proposed model into context. Finally, in Sect. 4 we draw some conclusions and outline directions for future research and developments.

2 The Model

In this section, we develop a model for designing *treatment* in economics experiments according to well-defined validation criteria [7–12, 14]. The purpose of the model is to test the preliminary efficacy of an experimental *treatment*, in other words we aim to determine whether or not the *treatment* actually works under certain conditions established by the experimenter. Card *et al.* [5] claim for the use of between-group designs including at least one *treatment* group and one control group. However, the potential outcome framework allows to incorporate more than two groups. In a binary *treatment* setting causal effects are assessments of pairs of potential outcomes for the same experimental group, where a given group can only be assigned to one level of *treatment*. In a multiple *treatment* setting, causal effects are ultimately based on assessments of different units with different levels of *treatment*. Typically, experimenters in economics divide experimental subjects into one or more *treatment* group and a control group, manipulating one or more experimental factors. Factors that are manipulated represent the independent variable, whereas the outcome of the experiment corresponds to the dependent variable [14, 15]. The experimenter can then compare the *treatment* group to the control group in order to understand whether the manipulation of the independent variable affects the dependent variable. In our research project, we aim to determine whether the manipulation of the independent variable (hereafter *treatment*) can show its efficacy or whether one *treatment* is more effective than another. This is the novelty of our research and, therefore, we formulate and develop a multi-factor model, *Design of Treatment* (DOT), which describes and synthesizes the process of *treatment* in the experimental economics framework. To this aim, we organise the model into two parts: the first is made up of a non-parametric *Fractional Factor* (FF) sub-model; the second is formed by a parametric *Multi-Treatment* (MT) sub-model. Both these parts work before the experiment is carried out (*treatment* design phase) and, thus, during the experimental design process [16]. More specifically, by considering all possible combinations of experimental factors, we use FF sub-model to construct all possible experimental groups (control and *treatment* groups)[3], then we generalize FF in MT model in order to allow the experimenter to select the *treatment* groups from the set of possible combinations of all possible *treatments*, evaluating their potential efficacy afterwards.

2.1 The Fractional Factor Model

Basing upon the experimental factors, we use FF sub-model to explore the preliminary efficacy of *treatment* in various types of experimental design. In FF sub-model, therefore, we first describe, and then evaluate, all possible control and *treatment* groups by using experimental factors which are manipulated by the experimenter[4]. These factors are used to construct several experimental vectors which identify all possible control and *treatment* groups. In line with [7], each vector consists of four experimental factors: x_1 indicates the experimental design context[5] (three categories: lab, field, extra-lab designs); x_2 refers to the nature of *commodity* (artificial or physical goods); x_3 indicates the nature of the *task* (baseline task or varied task); x_4 refers to the nature of the *stake* (null, fixed, random, or variable stakes). In addition to these factors, let us denote control and *treatment* groups with T_j. This term identifies the type of the experimental group, control or *treatment*, to which the experimental subjects are assigned. Bearing in mind the theory-testing view of science (for good discussions of theory-testing approach and

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[3] For *treatment group* we intend the group of experimental subjects to which the experimenter applies a *treatment*. For *treatment* we intend the change of one (single *treatment*) or more experimental factors (multiple *treatment*) compared to the value of those same factors tested in the control group or baseline group (group of basic experimental subjects).

[4] According to Shadish *et al.* [17], a *treatment* should not be applied to nonmanipulable experimental variables. For example, the authors suggest not to consider gender to be a cause in an experiment because it cannot be manipulated due to the presence of so many co-variates based on life experience. A stronger inference is possible if experimenters are able to manipulate independent variables such as the dosage in medical investigations or the word choice in media messages.

[5] This first factor (x_1) summarizes three factors originally considered by [7]: (i) subject pool, (ii) information, and (iii) environment. Indeed, among the original six factors taken into account in [7], only the three aforementioned factors can determine the experimental design context. If we do not summarize them, moreover, we obtain some vectors non-representative of the possible control and *treatment* groups. The opportunity to summarize these three factors enables us to exclude non-representative vectors and, at the same time, to overcome related problems of redundancy with experimental factors.

its relevance for experimental economics, among others see [9–19][6], in FF model we focus on a between-subject design [5] following two main steps. First, we set up an evaluation index (EVI) by using a threefold validation criteria [11, 12, 14] for the three categories of the experimental design context[7]. Based on these criteria, we assess (i) how the variations of experimental factors may affect the preliminary efficacy of the experimental groups (values of EVI); and (ii) the difference between a *treatment* group and a control group in terms of effect size (this difference is approximated with a constant c). Since this is a non-parametric sub-model, the experimenter cannot modify the scale of values of EVI. Second, we consider the values of EVI in order to estimate $\hat{y}$ outcomes that are determined through a multiple linear regression model. We assume a linear model in which we exclude that there is interference between the variables x_1, x_2, x_3, x_4:

$$y_j = \sum_{k=0}^{4} (\beta_k x_{j,k}) + cT_j + \varepsilon_j = (\beta_0 + \beta_1 x_{j,1} + \ldots + \beta_4 x_{j,4}) + cT_j + \varepsilon_j \quad (1)$$

where y_j is the preliminary efficacy of the experimental group considered, with j = 1, 2, …, 36; c is a constant term equal to 0.10; T_j is coded as a dummy that takes value 1 in a *treatment* group and 0 in a control group; ε_j is the random error. In other words:

$$y_j = \hat{y}_{CG} \text{ with } T_j = 0 \text{ (control group)}$$

$$\text{and } y_j = \hat{y}_{CG} + cT_j \text{ with } T_j = 1 \text{ (\textit{treatment} group) and } \varepsilon_j \sim 0$$

In a matrix form, the proof (1) becomes:

$$Y = XB + cT + E \quad (2)$$

We estimate the parameters of FF sub-model to minimize the squared errors of prediction. For FF sub-model, the predictions are:

$$y = 0.26 + 0.08\,x_1 + 0.31\,x_2 + 0.09\,x_3 + 0.23\,x_4 + 0.10\,T \quad (3)$$

[6] The connection between economics experiments and economic theories is very close. In this regard, there is a broad consensus among economists on the fact that economics experiments can be run to test economic theories [20–22]. According to [13, 23], when testing theories, experimenters can design laboratory, extra-lab and field contexts which, in a certain way, remind the economic theories – only for what is needed in regard to a particular knowledge of the world insofar as the economic theory itself does – while, in other ways, it represents the world in a different way, by replacing unrealistic assumptions with experimental subjects' actual behavior.

[7] We aim to represent the complementarity of lab and field designs, also including the extra-lab environment in order to represent the mechanism of *treatment* according to internal and external validity criteria [7–9, 12]. The matrices include no. 12 vectors that is to say no. 12 possible *control groups* and no. 24 *treatment groups* that is to say no. 24 possible *treatment groups*. Therefore, we have no. 36 possible experimental groups.

In Fig. 1, we illustrate the generalisation given by the theoretical matrix which provides a formulation of the multiple regression model shown in (2).

$$\begin{bmatrix} y_1 \\ \vdots \\ y_{36} \end{bmatrix} = \begin{bmatrix} 1 & x_{1,1} & x_{1,2} & x_{1,3} & x_{1,4} \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ 1 & x_{36,1} & x_{36,2} & x_{36,3} & x_{36,4} \end{bmatrix} \cdot \begin{bmatrix} \beta_0 \\ \vdots \\ \beta_4 \end{bmatrix} + c \begin{bmatrix} T_1 \\ \vdots \\ T_{36} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_{36} \end{bmatrix}$$

$$\begin{bmatrix} 0.15 \\ \vdots \\ 1.00 \end{bmatrix} = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \cdot \begin{bmatrix} 0.26 \\ \vdots \\ 0.23 \end{bmatrix} + 0.10 \begin{bmatrix} 0 \\ \vdots \\ 1 \end{bmatrix} + \begin{bmatrix} -0.03 \\ \vdots \\ -0.07 \end{bmatrix}$$

Fig. 1. Generalization: the theoretical matrix of the model.

Results of the statistical analysis performed confirm a goodness of R square (0.8361).

2.2 The Multiple Treatment Model

In the case of two or more *treatments*, we use MT sub-model which considers only *treatment* groups. The aim of MT is to study the combinations of *treatment* groups and to select which and how many *treatment* groups should be designed in order to evaluate the preliminary efficacy of multiple *treatment* combinations. The evaluation of the effects of multiple *treatment* combinations is done according to a linear combination of the various experimental factors that have been manipulated. Therefore, each *treatment* is represented by a vector:

$$f_i(x_1, x_2, x_3, x_4, y) \tag{4a}$$

Variables x_1, x_2, x_3, x_4 and (1) are linked by a linear relation and together they can be considered as coordinates of a point identified by a radius-vector:

$$f_i\left(x_j, y\right) \tag{4b}$$

Each linear combination of (4b) produces a new vector (radius-vector):

$$f\left(x_j, y\right) = p_1 f_1\left(x_j, y_1\right) + p_2 f_2\left(x_j, y_z\right) \text{ with } \text{j} = 1, 2, 3, 4 \tag{5}$$

or more generally:

$$f_i\left(x_j, y\right) = \sum\nolimits_k p_k f_k\left(x_j, y_k\right) \tag{6}$$

Consequently, the coefficients of the linear combinations p_k can be determined using the same weight for each *treatment* group, so that $\sum_{k=1}^{n} p_k = 1$. The result of the average of *treatments* is given by:

$$f\left(x_j, y\right) = \frac{1}{n}\left[\sum\nolimits_{j=1}^{n} f_i\left(x_j, y_k\right)\right] \tag{7}$$

As we preliminary evaluate the efficacy of multiple *treatment* combinations, the evaluation of the efficacy of a multiple-*treatment* is as follows:

$$\hat{y} = \frac{1}{n}\left[\sum\nolimits_{j=1}^{n} \hat{y}_i\right] \tag{8}$$

Finally, all possible multiple-*treatment* combinations are given by n combinations in class $\boldsymbol{k}$: $\binom{n}{k} = \frac{n!}{k!(n-k)!}$.

3 Putting the Model into Context: A Software Application

At this stage of the work, we make the model accessible to experimental economists through the development of a graphical Java interface. Basing upon DOT model, in this section we address the creation of a software application named GEI which is designed to engage experimenters to preliminary evaluate the efficacy of their *treatment* designs. Using GEI is straightforward consistent with the prediction of the model presented in Sect. 2. The experimenter has many components in GEI that allow flexibility in designing input screens. The experimenter specifies one or more *treatment* design to develop and which factors to include in order to preliminary detect the efficacy of the design. The experimenter can also decide to include a control design and GEI estimates the efficacy of the total design. In Fig. 2, we present the general algorithm according to which GEI is made, so as to represent every process related to GEI by focusing on a *top-down* technique. At the beginning, the experimenter selects the type of group of interest. Both in the *control group* and the *treatment group*, the experimenter can select the modes of the factors (see Sect. 2.1): in the case of *control*, she can set up the modes of factors *environment*, *commodity* and *stake*; in the case of *treatment*, she has to decide the number of *treatments* and then the modes of factors *environment*, *commodity*, *task* and *stake*.

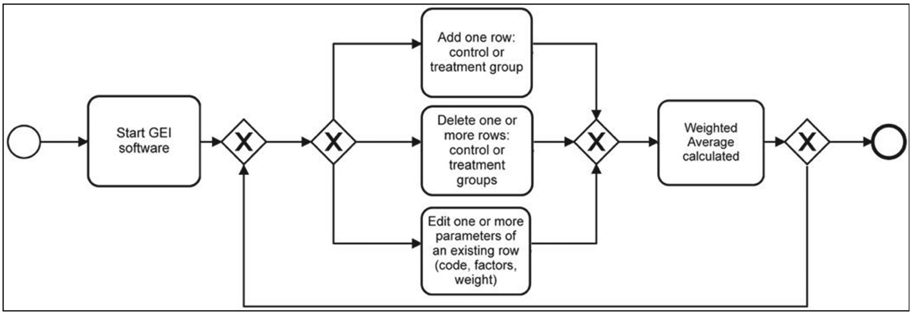


Fig. 2. The flowchart of the general algorithm at the base of GEI

As we show in Figs. 3 and 4, each row of GEI includes a possible experimental group (control or *treatment* group). We can consider two main phases in GEI: during the first, the experimenter launches the software and then decides whether to add a row (control or *treatment* group), delete one or more rows (control or *treatment* groups), or edit one or more parameters of an existing row. These parameters consist of (i) experimental factor(s) (see sub-Sect. 2.1), (ii) weight (one for each group), and more generally (iii) code (one for each group). During the second phase, GEI calculates the weighted average efficacy of *treatment* groups. The cycle of GEI repeats itself or terminates if the experimenter does not need to continue.

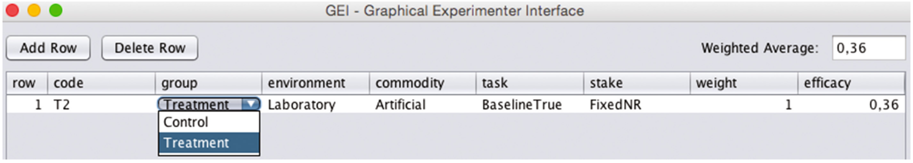


Fig. 3. Experimenter's decision between *treatment* group or control group

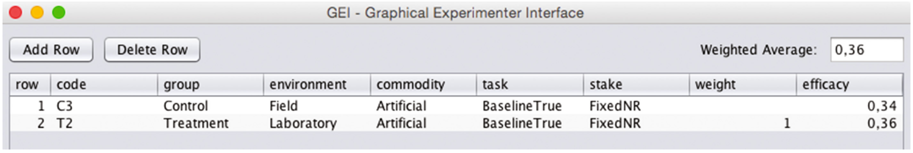


Fig. 4. Experimenter's decision: a single *treatment* with a control group

In Fig. 3, we present an example of the first row or the initializing line which corresponds to the choice that the experiment makes in the decision between *treatment* group or control group. In Fig. 4, we illustrate the case of a single *treatment* and a control group associated to it. When the *treatment* group is only one, the output provided by GEI corresponds to what is shown in Fig. 4. When the *treatment* group is more than one, the experimenter has to decide how many *treatment* groups to include and their *weights*. In this last case, indeed, the experimenter can use MT sub-model in two ways: in the first (see Fig. 5), the experimenter considers each *treatment* group giving the same *weight* to each of them, thus GEI automatically gives the same weight equal to 1 (weight = 1) to all *treatment* groups; in the second (see Fig. 6), the experimenter assigns a subjective *weight* to each *treatment* group on the basis of other elements related to the design but unrelated to the experimental factors (*e.g.*, the number of the experimental subjects *assigned to the treatment group* or the work activity carried out by the same subjects).

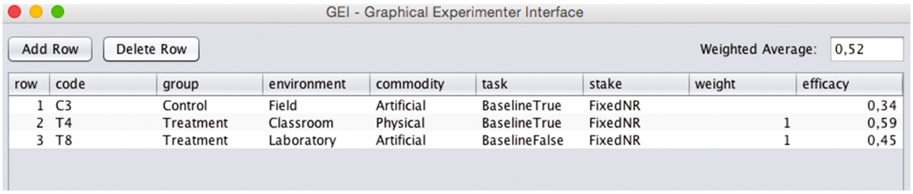
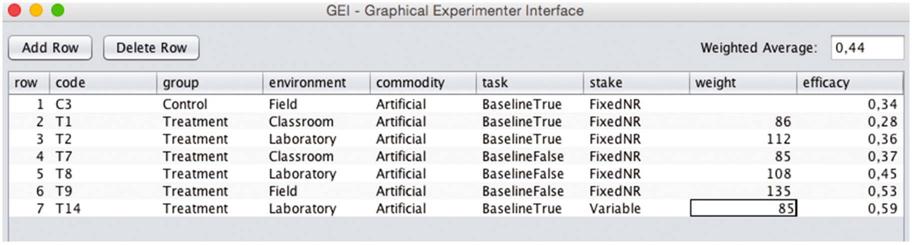


Fig. 5. Experimenter's decision: a double *treatment* with a control group


GEI - Graphical Experimenter Interface

Add Row | Delete Row | Weighted Average: 0,44

row	code	group	environment	commodity	task	stake	weight	efficacy
1	C3	Control	Field	Artificial	BaselineTrue	FixedNR		0,34
2	T1	Treatment	Classroom	Artificial	BaselineTrue	FixedNR	86	0,28
3	T2	Treatment	Laboratory	Artificial	BaselineTrue	FixedNR	112	0,36
4	T7	Treatment	Classroom	Artificial	BaselineFalse	FixedNR	85	0,37
5	T8	Treatment	Laboratory	Artificial	BaselineFalse	FixedNR	108	0,45
6	T9	Treatment	Field	Artificial	BaselineFalse	FixedNR	135	0,53
7	T14	Treatment	Laboratory	Artificial	BaselineTrue	Variable	85	0,59

Fig. 6. Experimenter's decision: a multiple *treatment* with a control group (with weighted average *treatments* based on the number of experimental subjects involved)

4 Conclusions and Future Research

In the course of this paper, we present a software application designed and developed for experimental economists in order to optimize their design of *treatment* before running an experiment. More in detail, we introduce a graphical interface that may be useful for experimenters interested in estimating the efficacy of *treatment* (potential *treatment* effects) in economics experiments. At this stage, the software is configured based on a model for designing *treatment*; we adapt the software to the needs of experimental economists when they organize *ex ante* one or more *treatments* of interest concerning theory-testing and between-subject designs [16, 24]. The model is based on the trade-off between internal validity, which concerns the question whether the experimenters are drawing the right inferences within the experiment, and external validity, which concerns the question whether the experimenters are drawing the right conclusions from the experiment about the real-life world [6]. As future work, we intend to scale up the model in order to handle any possible experimental designs in economics. On the one hand, we aim to further develop *extra-lab* designs for analysing both *classroom* and *internet* experiments [25, 26]. On the other hand, we seek to include in the model a *within subject* design by which to apply a *treatment* to the same subject pool in a deferred mode [27]. To achieve this end, we suggest the implementation of values of EVI required by the model. More specifically, we promote the idea that there is often more than one scale of values of EVI that can vary according to the type of economic experiments to be performed [28]. We consider this to be a promising starting point for developing our model and for future research.

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A Decision Framework for Understanding Data-Aware Business Process Models

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Abstract. Business Process Management is a discipline that enables organizations to analyze, design and deploy business processes, providing tools to investigate the processes from an organizational point of view and transforming the design into a working software implementation.

The Business Process Modeling and Notation (BPMN [1]) is the most widely adopted modeling language for designing and re-engineering business processes. One of best feature is that it provides a graphical representation that is not only easy to understand by business people without technical expertise but also machine processable, with tasks assigned to software or human agents based on the workflow and rules defined within the process.

This paper extends the framework presented by the author in [2] adding the possibility of verifying more properties of data-aware business processes using a novel approach. This approach enables the verification of the conformance to the business rules combining logic and mathematical expressions. Moreover, the new framework gives the possibility of separating the business requirements from the implementation, giving hints to the process designer and to the programmer. Finally, it gives directions for open research challenges.

Keywords: Decision framework · Model checking · Business processes

JEL codes: D80, M10

1 Introduction

The implementation of Business Process Management (BPM) solutions within industrial and business organizations is quite common due to its capability to support executives and managers to take decisions, enabling the possibility to measure and manage the organizations' resources, improving their governance.

Usually the implementation of BPM starts by analyzing the existing business processes within an organization and then re-engineering them mainly to improve productivity and reduce the inefficiencies. The processes are composed of *tasks*, control flow logic and event management logic, where the tasks are assigned to roles and each role is covered by people or software agents.

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The verification of properties and correctness of a Business Process (BP) is a challenging activity: when re-engineering a BP, it would be desirable to be able to guarantee that the modified BP preserves the properties of the original process and continues to meet its goals. Furthermore, it is quite common to have an existing process that is not functioning properly and we might need to modify it and be sure that the new one meets the design and business objectives.

The work presented in this paper extends the framework introduced in [2] providing new tools useful and usable both to verify the conformance of business processes to the design requirements and to and to ascertain if a modified process preserves the original properties, enhancing the ability of the business processes to meet the business goals.

2 Verification of Business Processes

There are many approaches to business process analysis that are focused exclusively on the analysis of the workflow, able to check properties such as the termination or *soundness*, abstracting away the underlying data layer and focusing only on the operations (*tasks*) and their order of execution (e.g. [3–5]).

The introduction of a data model into verification is a quite challenging task, because it leads to the analysis of infinite-state systems [6], but enables the verification of more complex properties and requirements. Several new methodologies have been proposed that take into account both the workflow and the underlying data layer (for a survey, see [7]). These methodologies define an abstraction of the data layer and identify techniques to study properties of BPs using these enhanced models, sometimes introducing limitations to find a compromise between expressive power and decidability [8–14].

In [2] the author presented a framework that gives the possibility to analyze BPs enriched with a data model by transforming them into a *logic program* that can be analyzed using logic queries. The tool was developed in Prolog with Constraint Logic Programming over Finite Domains (CLP-FD [15,16]) and the algorithm was inspired by *Event Calculus* [17].

3 The Framework for Properties Verification

BPMN uses a standard XML format to describe the business processes [1]; to give the possibility of working with any BPMN tool, as in [2] the author adopted the *Text Annotation Artifact* to define the data model and express properties about each task, event, gateway or flow arc. In such way, the designer is able to specify variables and conditions using *logic predicates* without the need to extend the tool of choice.

With respect to the previous work [2], the author adds new predicates to better reason about flows and decisions. The new predicates are:

- *ensure*(C): this predicate ensures the validity of the condition C on the variables declared. For tasks the condition is checked after the task completion (it is a post-condition), while for gateways and events is checked before their evaluation. The condition is checked against the entire state of the computation, for all possible states. In other words, the framework tells us if the condition is verifiable or not; if it fails, the framework provides a counter-example.
- *require*(C): this predicate restricts the input, imposing a condition C before the execution of the task or event. The predicate *require* defines a contract that must be respected.
- *assume*(C): this predicate can be used to assert a condition C that we know it must be true. It is a non-deterministic predicate inspired by Hilbert's epsilon calculus. This predicate can be used to specify the output of a computation without specifying how it is carried on. You can use *assume* when you only know the *interface* of some function.

The example in Fig. 1 shows a simple but non-trivial e-commerce process where a customer buys some items from a seller. In the example we assume that a customer puts some items into the shopping cart, pays for the items, then in parallel the payment is processed by the seller while the parcel is prepared for shipping; finally the items are shipped to the customer and the process ends. We can see how the annotations can be used to reason about the process. In the start event S we define four variables:

- *shipped*: indicates if items have been shipped, initialized to false;
- *total*: the total value of the shopping cart, initialized to zero;
- *paid*: the amount paid by the customer, initialized to zero;
- *recv*: the total money received for the items, initialized to zero.

We consider now the only two outcomes we expect when the process ends:

1. Items sold: the customer bought some items and paid for them; we want to be sure that we successfully shipped the items and received all the money.
2. Items not sold: the payment was not completed (not received or only partial) or we were not able to ship: in this case we want to be sure that we gave back all the money to the customer without shipping the items.

We can model this situation using the following formula:

$$\mathit{ensure}((\mathit{shipped} \wedge \mathit{recv} = \mathit{total}) \vee (\neg \mathit{shipped} \wedge \mathit{recv} = 0))$$

We might know nothing about the implementation of the tasks, or simply we still do not have an implementation, so instead of using *ensure* to verify the output of the task (that is, to use the framework to verify the function implemented) we can use *assume* to assert what we expect from the output of the task. Therefore, the first task assumes that, after adding items to the shopping cart, the customer cart has a total value greater than zero: $\mathit{assume}(\mathit{total} > 0)$.

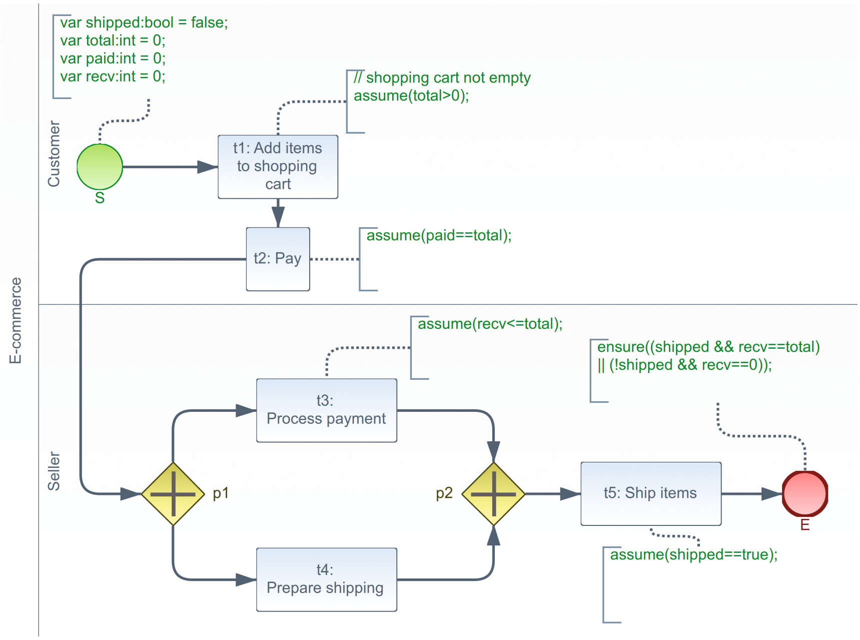

Fig. 1. BPM e-commerce diagram

We also assume that, in the *Pay* task, the amount paid is equal to the total in the shopping cart: $assume(paid = total)$. We have to consider that we do not know anything about how the payment is made, so we simply assume that the customer paid and informed the seller that she sent the money.

The task *Process payment* is related to the verification, by an hypothetical accounting office, of the amount of money received for the order, therefore we can assume that the amount received is less than, or equal to, the total amount of the shopping cart: $assume(recv \leq total)$.

For the shipping we assume that the we are always able to ship, so the *shipped* variable takes the *true* value.

We can ask the automatic reasoner to check if the final condition is true under the assumptions and, if it's false, change the assumptions or the process design until we have the final condition true.

If we feed the example in Fig. 1 to the automatic reasoner, we discover that the final condition is not true. We call S, T, P, R the four variables that represent respectively the *shipped, total*, *paid* and *recv* variables involved into the process. If we run the reasoner we have a counter-example that shows, as a formula, that there is an output that *does not satisfy* the conditions imposed on the end state E. Here is the output of the automatic reasoner:

$$S = 1 \wedge T = P \wedge P \in [1, \infty[\wedge R \neq P \wedge P \geq R \tag{1}$$

In other words:

- $S = 1$: shipped is true
- $T = P$: total amount is equal to paid amount
- $P \in [1, \infty[$: paid amount is positive
- $R \neq P \wedge P \geq R$: received amount is strictly lower than paid amount

This is clearly not what we expect from the process. Continuing with the example, we can imagine that the designer will change the process or the assumptions to be sure that the process conforms to the semantics intended: we will change the assertions related to the *Ship items* task as follows: $assume(shipped = true \vee shipped = false)$ in order to specify that it is possible to ship or not to ship. Even with this change the final *ensure* still fails, because it becomes possible that we receive the full payment ($recv = total$) but we are not able to ship ($shipped = false$). To solve the situation we have to modify the process more deeply: for example, we can give back the money if we are not able to ship or if the customer has not paid all the amount.

The modified process and conditions is shown in Fig. 2 (the figure shows only the seller part, because the customer part was unchanged). The output of the software verification for the modified process tells us that there is no counter-example that can falsify the final *ensure* so the process behaves as specified.

The following listing is the logic program with CLP produced by the framework for the process in Fig. 1:

$$
\begin{aligned}
verify(E) &\leftarrow start(S, E) \wedge E = [Shipped, Total, Paid, Recv] \\
&\quad \wedge \neg((Shipped \wedge Recv = Total) \vee (\neg Shipped \wedge Recv = 0)) \\
start(S, E) &\leftarrow S = [Shipped, Total, Paid, Recv] \\
&\quad \wedge Shipped = false \wedge Total = 0 \wedge Paid = 0 \wedge Recv = 0 \\
&\quad \wedge t1(S, E) \\
t1(S; E) &\leftarrow S = [Shipped, Total, Paid, Recv] \wedge Total_1 > 0 \\
&\quad \wedge S_1 = [Shipped, Total_1, Paid, Recv] \wedge t2(S_1, E) \\
t2(S, E) &\leftarrow S = [Shipped, Total, Paid, Recv] \wedge Paid_1 = Total \\
&\quad \wedge S_1 = [Shipped, Total, Paid_1, Recv] \wedge p1(S_1, E) \\
p1(S, E) &\leftarrow t3(S, E) \\
t3(S, E) &\leftarrow S = [Shipped, Total, Paid, Recv] \wedge Recv_1 \leq Total \\
&\quad \wedge S_1 = [Shipped, Total, Paid, Recv_1] \wedge t4(S_1, E) \\
t4(S, E) &\leftarrow p2(S, E) \\
p2(S, E) &\leftarrow t5(S, E) \\
t5(S, E) &\leftarrow S = [Shipped, Total, Paid, Recv] \wedge Shipped_1 = 1 \\
&\quad \wedge S_1 = [Shipped_1, Total, Paid, Recv] \wedge end(S_1, E) \\
end(S, S)&.
\end{aligned}
$$

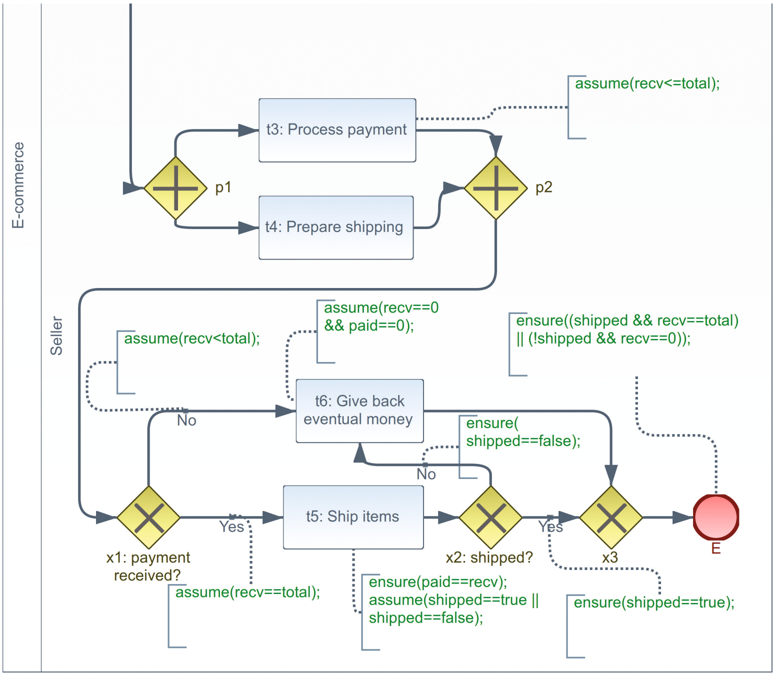

Fig. 2. Modified BPM e-commerce diagram (only Seller's side) that satisfies the final condition given by the state E

It is worth noting that the main predicate, *verify*, checks for the negation of the final condition to find a counter-example: the predicate will be *false* if the final conditions are always true, otherwise will return one or more counter-examples. In this case, a counter-example exists as shown in Eq. (1).

4 Logic Model and Prolog Implementation

Processes described in BPMN are composed of four main items:

- *Task*, represented with a rectangle, it indicates activities executed by a role;
- *Event*, represented with a circle, it indicates something that happen and can have an impact on the process;
- *Gateway*, represented with a diamond, it indicates flow control points where the activities can advance according to conditions and rules;
- *Sequence flow*, represented with an arrow, used to interconnect flow elements.

In this paper, we implemented a series of program transformations from the BPMN to CLP logic formulas, to be able to evaluate the properties of a process. The syntax used to specify the data values and the conditions is Java-like and very easy to extend. The framework transforms the BPMN XML file into a set of

Prolog *formulas* with *CLP* that can be run to verify the properties. The parser software is written using the Java language for the Graphical User Interface and the Scala language [18] for the parser and transformation code.

As in [2], the logic model is inspired by Event Calculus with *reified fluents*. The new approach is oriented to producing a CLP logic program that can be run, instead of producing a set of predicates that can be queried using the framework.

Using this new approach, each element of the BP (task, event, gateway) is translated into a logic predicate and the sequence flow governs the transition between predicates. The most important transformations regards the three predicates *require*, *assume* and *ensure:*

- *assume* replaces the current conditions on variables with new conditions, as we can see in the formula for the task $t2$ of the listing in previous paragraph, where the current state S is replaced by a new state S_1 where the variable $Paid$ (and all its constraints) is replaced by the new variable $Paid_1$and the new constraint $Paid_1 < Total$.
- *require* and *ensure* both checks for the validity of a condition in the current state S, with the semantics described before. If we consider the task $t5$ in Fig. 2 the formula produced by the transformation shows that is introduced a new variable $Shipped_1$ that can assume two different states and is added a new constraint $Paid = Recv$ on the variables already present into the state S; a new state S_1 is produced and passed to the next computation step $x2$:

$$\begin{aligned} t5(S, E) \leftarrow\ & S = [Shipped, Total, Paid, Recv] \\ & \wedge (Shipped_1 = true \vee Shipped_1 = false) \\ & \wedge Paid = Recv \\ & \wedge S_1 = [Shipped_1, Total, Paid, Recv] \\ & \wedge x2(S_1, E) \end{aligned}$$

5 Conclusion and Future Work

Today is common practice to reason about business organizations as a system where business processes interact in complex ways. The decision framework presented in this paper has been developed with the objective of meeting the utility and usability needs of BP designers, enabling the possibility of verifying the requirements of a business process, check the preservation of properties when changing the process and give hints to developers about the pre- and post-conditions that tasks and gateways must meet in the concrete implementation.

The possible future lines of research may regard the extension of this framework in order to add the possibility of showing not only a counter-example for the properties but also the intermediate states that lead to the counter-example, starting from the input through all the workflow, giving more knowledge to the process designer. Another possibility is to integrate Satisfiability Modulo Theories (SMT) solvers and try them as an alternative to, or mixed with, CLP. This will give the possibility of verifying more complex properties that may not be verifiable using only the CLP solver.

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Cluster Analysis as a Decision-Making Tool: A Methodological Review

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Abstract. Cluster analysis has long played an important role in a broad variety of areas, such as psychology, biology, computer sciences. It has established as a precious tool for marketing and business areas, thanks to its capability to help in decision-making processes. Traditionally, clustering approaches concentrate on purely numerical or categorical data only. An important area of cluster analysis deals with mixed data, composed by both numerical and categorical attributes. Clustering mixed data is not simple, because there is a strong gap between the similarity metrics for these two kind of data. In this review we provide some technical details about the kind of distances that could be used with mixed-data types. Finally, we emphasize as in most applications of cluster analysis practitioners focus either on numeric or categorical variables, lessening the effectiveness of the method as a tool of decision-making.

Keywords: Clusters analysis · Mixed data · Decision-making

1 Introduction

Clustering (unsupervised learning) means dividing data into meaningful groups [1] and classification (supervised learning) aims to assign particular objects to these groups [14,29]. The difference is that, while in supervised learning the classes are defined and the information are used to classify future observations, in unsupervised learning there is not a pre-assigned classification system, which could indicate the allocation of one observation to a specific class [16].

The aim of clustering is to group together objects which are similar among them and which differ from the objects in other groups [15]. Cluster analysis techniques have been widely applied to a variety of scientific fields, such as computer science, bioinformatics, pattern recognition, data analysis, image processing and in particular in the area of market segmentation, to identify relevant groups which can be very helpful in making decisions.

Similarity is the basis of the definition of a cluster. There are a lot of possible choices to quantify it, depending on the nature of the variables under study and on the final objectives. Clustering algorithms are classified in hierarchic methods and non-hierarchic methods.

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Hierarchic methods develop a tree-structure for clustering observations; the tree-leaves correspond to the observations and the knots to subsets of observations. There is a hierarchy in the subsets associated to the branches of the tree. There are two wide families of hierarchical methods. Agglomerative methods start from an initial situation of n groups, where each observation represents a group. Then, groups with low dissimilarity are merged until $k = 1$, that is, when all the observations belong to the same group. Divisive methods, instead, start with one single group and then groups are recursively split until one has n groups. Both procedures take as input a dissimilarity matrix. The main characteristic of this kind of methods is that once two groups are merged, they can no longer be separated and, similarly, once two groups are separated they can no longer be part of the same cluster. Furthermore, applying this kind of algorithm, the same tree is used for all k values, referring each time to a different level of the tree. It is a rigid structure.

Non-hierarchic methods are characterized by the identification of aggregation points, named centroids, around which groups are created. Each observation of the data-set is assigned to the group with the nearest centroid. Unlike hierarchic methods, they build one partition per time, so it is necessary to repeat the algorithm for each value of k. The identification of the optimal partition would need the preliminary examination of all the possible configurations of the data set in k groups. The algorithm progresses iteratively, grouping the observations around centroids (they are subjected to updating too), up to a convergence point. The convergence is guaranteed, but it is not said that it corresponds to an absolute minimum of the objective function. The best-known non-hierarchic method, only suitable for numeric variables, is the k-means method [19]. The objective function of this algorithm is numerically defined, so it is not applicable to the data sets with categorical attributes, unless one finds a unified similarity metric for categorical and numerical, such that the gap between them can be eliminated [6]. Several works have been presented on this issue, trying to find a unified similarity metric for categorical and numerical attributes [26,27], but a computational efficient similarity measure remains to be developed [18]. An alternative approach could be to transform the categorical values into numerical ones, and only then apply the numerical-value based clustering methods. However, this approach causes a loss of knowledge, ignoring the similarity information contained in the categorical attributes [1]. In this work we review some of the proposals for clustering mixed data existing in the literature and provide some technical details about the kind of distances that could be used with mixed-data types. Finally, a list of potential applications that would benefit from considering mixed data types is presented.

2 Related Works on Data Clustering with Categorical and Numerical Data

A lot of works have been published on data clustering with categorical and numerical data. The methods rely on the concept of similarity metric, graph partitioning or information entropy. The algorithms are essentially created for purely categorical attribute, although they have been applied also to mixed data after a transformation of the numerical attributes to categorical ones (discretization).

For example, ROCK (Robust Clustering using link) is an agglomerative hierarchic algorithm for market basket databases [12]. It is based on the proximity concept (neighbours) to define the number of links between two points. A pair of objects are neighbours if their similarity exceeds a certain limit, and the desired cluster structure is obtained by gradually merging the clusters which share a pre-assigned number of neighbours. From an empiric point of view, ROCK has shown to be better than traditional hierarchical algorithms, but it is quite time-consuming [4] and its performance is influenced by the setting of a similarity threshold.

By contrast, the CLICKS (CLusterIng Categorical data via maximal K-partite cliques) algorithm [35] computes the clusters encoding a data set into a weighted graph structure, where each weighted vertex represents an attribute value and two nodes are coupled if there is a sample in which the related attribute values co-occur. CLICKS is more efficient than ROCK algorithm and scales better than other algorithms in case of high-dimensional data sets. However, its performance is also influenced by a set of parameters whose tuning is not straightforward in real applications.

COOLCAT is an entropy-based algorithm [3] for categorical attributes. It uses the concept of entropy in place of that of distance. Clusters with "similar" points have a lower entropy level than those with dissimilar points. Clusters found by this algorithm reveal to be rather stable when parameters change.

Finally, LIMBO (scalable InforMation Bottleneck clustering) is a scalable algorithm for categorical data clustering [2]. It is based on the Information Bottleneck (IB) framework [30] and aims to cluster data with the minimum information loss. In general, all of the algorithms mentioned above can be applied to mixed data through a discretization process, which may, nevertheless, produce a loss of important information.

3 Measuring Data Similarity and Dissimilarity

Objects are characterized by multiple attributes. Let's suppose to have n objects (e.g., persons, firms...) described by p attributes (e.g., weight, age...). The objects are $x_1 = (x_{11}, x_{12}, ..., x_{1p})$, $x_2 = (x_{21}, x_{22}, ..., x_{2p})$, and so on, where x_{ij} is the value of the j-th attribute for object i. To synthesize, we refer to object x_i as object i. The objects may be tuples in a relational database. Cluster analysis operates on either the data matrix or on the dissimilarity matrix. A data matrix stores the n data objects in a table or n-by-p matrix (n objects $\times$ p attributes), where each row represents an object.

Similarity and dissimilarity are measures of proximity. A dissimilarity matrix stores a collection of proximities available for all pairs of n objects. Usually, it is represented by an n-by-n table, as follows:

$$\begin{bmatrix} 0 & & & & \\ d(2,1) & 0 & & & \\ d(3,1) & d(3,2) & 0 & & \\ ... & ... & ... & 0 & \\ d(n,1) & d(n,2) & ... & ... & 0 \end{bmatrix}. \quad (1)$$

The dissimilarity between objects i and j is represented by $d(i,j)$ and is a non-negative number. When i and j are very similar, it is close to 0, whether when they differ, it grows. The dissimilarity between an object and itself is 0. Moreover, the matrix is symmetric.

3.1 Proximity Measures for Nominal Attributes

A nominal attribute may take more than one state (i.e., colors). The dissimilarity between two objects i and j can be computed as follows:

$$d(i,j) = \frac{p-m}{p}, \quad (2)$$

where m is the number of matches (i.e., the number of attributes for which i and j are in the same state) and p is the total number of objects attributes. It is possible to give more weight to those matches in attributes characterized by a higher number of states.

3.2 Proximity Measures for Ordinal Attributes

Ordinal attributes have a meaningful order. They can also be obtained through the discretization of numeric attributes, by dividing the value range into a finite number of categories, which are organized into ranks. Ordinal attributes are handled very similarly to numeric attributes when calculating dissimilarity between objects. Suppose that the attribute j has M_j ordered categories. We can represent these categories with ranks from 1 to M_j. Replace each x_{ij} by its corresponding rank, $r_{ij} \in \{1, ..., M_j\}$. Since each ordinal attribute can have a different number of categories, it is often necessary to map the range of each attribute onto $[0,1]$, by replacing the rank r_{ij} of the i-th object in the j-th attribute by

$$z_{ij} = \frac{r_{ij}-1}{M_j-1}. \quad (3)$$

Dissimilarity can then be computed using any of the distance measures described in the next subsection for numeric attributes, using z_{ij} to represent the j-th value of the i-th object.

3.3 Dissimilarity of Numeric Data

The most used distance measures to compute the dissimilarity of objects described by numeric attributes are the Euclidean and the Manhattan distances. Sometimes, before to apply distance calculations, data are normalized, in order to give an equal weight to all attributes. Let $i = (x_{i1}, x_{i2}, ..., x_{ip})$ and $j = (x_{j1}, x_{j2}, ..., x_{jp})$ be two objects described by numeric attributes, the Euclidean distance is defined as:

$$d(i,j) = \sqrt{(x_{i1} - x_{j1})^2 + (x_{i2} - x_{j2})^2 + ... + (x_{ip} - x_{jp})^2}. \tag{4}$$

The Manhattan distance (so-called because it is the distance in blocks between any two points in a city) is defined as:

$$d(i,j) = |x_{i1} - x_{j1}| + |x_{i2} - x_{j2}| + ... + |x_{ip} - x_{jp}|. \tag{5}$$

4 Dissimilarity for Attributes of Mixed Types

There are several approaches to calculate dissimilarity between objects of mixed attribute type. One approach consists in dichotomizing all variables, then using a similarity measure for nominal (binary) data. Another possibility, if the categorical variables are ordinal, would be to consider the ranks instead of the variable values and use a similarity measure for continuous data [33]. A better approach is to process all attribute types together, carrying out a single analysis. To this purpose, one has to combine the different attributes into a single dissimilarity matrix, bringing all the meaningful attributes into a common scale. Assuming that the data set contains p attributes of mixed type, the dissimilarity $d(i,j)$ between objects i and j is defined as [13]

$$d(i,j) = \frac{\sum_{k=1}^{p} I_k(i,j) d_k(i,j)}{\sum_{k=1}^{p} I_k(i,j)}, \tag{6}$$

where $I_k(i,j) = 0$ if either object i or j is missing or both x_{ik} and x_{jk} are equal to zero and the k-th attribute is asymmetric binary, otherwise, $I_k(i,j) = 1$. The dissimilarity $d_k(i,j)$ depends on the type of attribute. For example, it might be defined as follows:

- if the k-th attribute is numeric, then $d_k(i,j) = \frac{|x_{ik} - x_{jk}|}{\max x_k - \min x_k}$
- if the k-th attribute is nominal, then $d_k(i,j) = 0$ if $x_{ik} = x_{jk}$, otherwise $d_k(i,j) = 1$
- if the k-th attribute is ordinal, compute the rank r_{ij} and normalize to z_{ij} and use z_{ij} as numeric.

The use of (6) allows to compute the dissimilarity between objects of mixed types which also belongs to the interval $[0, 1]$. With such a measure of dissimilarity, both hierarchical and non-hierarchical clustering algorithms could be suitably adopted to cluster data with mixed numerical and nominal values.

5 Applications of Clustering

In this section we shed light on the different fields of applications where cluster analysis has been used, such as computer science, bioinformatics, pattern recognition, data analysis, image processing and market segmentation [32].

In marketing, clustering can help to identify different customers groups on the basis of their purchases, helping marketing managers to identify different segments within customer database, and to use this knowledge to develop targeted campaigns [20,25,31].

In biology, it can be used to identify taxonomies (hierarchical clustering) of plants and animals, to categorize genes which have similar functionalities and to analyze the features of different populations [8].

In urban studies, clustering analysis can also help to identify geographical areas with a similar use within a spatial database, through the analysis of a database of observations on the territory [5,7,23].

In the insurance sector, the segmentation of customers portfolio can be used to support targeted marketing activities, to identify groups of car insurers characterized by the same policy, to classify policy holders on the basis of their perceived risk, modelling the claim costs within each risk group accordingly [34].

In seismic studies, clustering earthquake epicenters is used to recognize precursory events more precisely [10].

In astronomy, it is used to analyze sky images and the explosion of gamma rays, to identify galaxies and to see whether they belong to one morphology type or another [11,17].

In the world wide web, clustering can also help to classify documents on the Internet and to analyze weblog data, so to identify groups characterized by profiles with common access and navigation [28].

In the anti-crime field, clustering analysis is useful in the search of credit card fraud or in monitoring criminal activities in electronic commerce. Exceptional cases in credit card transactions, for example very expensive and/or frequent purchases, could indicate fraudulent activities [22,24].

In climate studies, finding patterns in the areas of the ocean and in the atmospheric pressure is very useful to understand global climate [21].

In the educational field, clustering algorithms can be used to identify specific common patterns among test items [9].

In Medicine and Psychology, cluster analysis can be used to identify specific subcategories of illnesses from medical diagnosis data [29].

6 Conclusions and Future Research

In conclusion, we have seen how cluster analysis techniques have been widely applied to a variety of scientific fields. We emphasize that all the above examples analyze variables of the same type, rather than mixed ones, reducing the effectiveness of the method as a decision making tool. Thus, our future research interest will be focused on the development of new clustering analysis techniques, specific for mixed data, and on the consequent creation of dedicated software packages, with the aim of widening the number of potential users of this method.

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Similar Patterns of Cultural and Creative Industries. A Preliminary Analysis Based on Self-Organized-Map to the Italian Case

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Abstract. In recent years, there has been a widely belief that creativity, going hand in hand with innovation and knowledge creation, readily translates into regional competitiveness. In the same time, cultural and creative industries (CCI) industrial pattern have been attracting a growing interest from a wide range of academic research and policy interventions. The aim of this article is to establish a better understanding of relevant industry relevance (RIR) of geographic samples with a relevant similarity in terms of industrial patterns and not of industry concentration. In this sense, we move from a methodological approach, based on Self-Organizing Maps (SOM) by comparing patterns of local employment. The Italian case provides an interesting case study to analyze industrial patterns by offering new insights of occupational dynamics. We conclude that this paper represents a firs explorative attempt to extend the previous literature to seize the overall productive structure of the local creative economy.

Keywords: Cultural and creative industries · Self-Organizing Maps · Pattern recognition

1 Introduction

The cultural and creative industries (CCI) have become increasingly the most dynamic component of the European economy. These industries are experiencing a growing role in the post-fordist economy and facing the challenge of strong international competition [3]. According to the European Commission, the CCI in Europe account for 3.3% of GDP and employ 6.7 million people (3% of total employment). Furthermore, employment in the CCI over the last five years has proved more resilient than in the EU economy and includes a higher percentage of youth employment than the rest of the economy [10]. CCI and their occupational features have received a huge amount of interest both theoretically and empirically as new driver of economic performances at both national and regional level. Although there is an increasing recognition of the positive role that CCI play in innovation and growth, there is little evidence on the dimension of this impact [16]. This paper tries to explain the industrial patterns of CCI in terms of local supply of creative

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workers, measured by similar patterns of labour factor employed within an industry that is engaged in creative occupations providing three main contributions to the literature. It provides a taxonomy by moving from the recent and well-documented KEA model [13] applying this framework to specific Italian context. It develops a methodology based on Self-Organizing Maps (SOM) overcoming the traditional metrics in defining the CCI spatial patterns. According to Carlei and Nuccio [5], this methodology can be suitable in the analysis of different sizes of economic regions, of different industries and at different levels of industry classification, but to our knowledge have never been applied in creative economics literature. The paper is organized as follows. Section 2 delineates the literature background of the study. Section 3 describes the methodology. Section 4 develops some empirical results. Section 5 concludes.

2 Literature Background

The issue of culture and creative-led development has become increasingly relevant in the regional science, sparking a growing literature based on the main assumption that the cultural and creative industries (CCI) pave the way for shaping a knowledge-based economy, and that CCI are conducive to sustainable regional growth [4, 8, 17, 19]. Contributions in the literature reveal some important considerations. The operational definition of CCI is not without controversy and the consequent taxonomy is suffering from a lack of methodological convergence. In the early (and most cited) taxonomy developed by DCMS [9] was not clear what were the underlying threads linking this seemingly heterogeneous set of industry subsectors [11]. As a matter of fact, the structural system of interdependencies that governs the cultural and creative sectors is much more complex than it might seem [18] and the contribution of culture to development processes, is not mechanic, and is subject to complex nonlinear effects [7] which are often elusive and difficult to evaluate. In the first place, each form of production borrows processes, content and skills typical of other forms: the making of film needs of photography, the costumes, the script, the soundtrack, the design of interior. Moreover, contemporary capitalism is characterized by flexible production, the commodification of culture and the injection of symbolic ‘content’ into all commodity production [1, 14]. In this way, cultural and creative production interacts deeper with the multiple supply chains products and services. These new forms of production with a strong symbolic therefore require a continuous process exchange and cross-fertilization with the cultural and creative sphere. In a such industrial configuration, firms could benefit from sharing skilled staff and services, gaining the opportunity to capture valuable knowledge spillovers [6]. Since CCI provide a direct input to the wider economy, its innovation capacity depends from a high degree of diversity/variety and the subsequent processes of inter-sectoral cross-fertilisation [2]. In that sense a recently work of Lazzaretti et al. [15] try to evaluate the co-evolution of firms by moving from the evolutionary economic geography (EEG), adopting the recently established approach based on related variety [12].

3 Method and Data

To define the Italian creative economy, we adopted the industry-based approach, similarly as Bertacchini and Borrione [3] do. The model has been introduced in the Report "The Economy of Culture in Europe" by KEA [13].

The KEA Survey has distinguished the cultural and creative sectors; the cultural sector comprises traditional arts fields and cultural industries, whose outputs are exclusively "cultural". The following fields of activities are included: visual arts (crafts, paintings, sculpture, photography, etc.), performing arts (theatre, dance, circus, festivals, etc.), heritage (museums, libraries, archaeological sites, archives, etc.), film and video, television and radio, video games, music (recorded music performances, revenues of collecting societies in the music sector), books and press (book publishing, magazine and press publishing). In this paper, we move from the 5-digit taxonomy identifying a specification necessary to catch the peculiarities of the Italian production system, where culture, creativity and production activities are particularly interrelated. The main advantage of this 5-digit classification is that it potentially allows capturing relationships among different economic activities. This is especially true in the Italian case, where there is a large component of the sector manufacturing often founded on a tradition of craftsmanship of small, and micro-enterprise, there a large "grey area" in which the boundary between the creative industries and traditional manufacturing becomes blurred and particularly elusive. We feel that an approach based around the analysis of occupational data offers greater insight. Such accumulation of creative skills is imperative to a region's success in the knowledge economy as the value creation in many sectors rests, increasingly, on non-tangible. By moving from a methodological approach, based on Self-Organizing Maps algorithm [5] we focus on the strongest regularities, in terms of occupational patterns, emerging from the model. SOMs are among the most important and widely used neural network architectures. They were developed by Kohonen [5]. The key element of a SOM network is the Kohonen Layer (KL), which is made up of spatially ordered Processing Elements (PEs) or neurons. The global state of the layer evolves during the learning process, identifying each PE as a representative pattern of the input data with an unsupervised learning technique. A vector is associated with the generic PE in the KL, whose elements are the weights relative to the patterns identified. The weight vector associated with the generic PEs in the KL is indicated by:

$$W_r = (w_{r,1}, w_{r,2}, \ldots, w_{r,p}, w_{r,p+1}, \ldots, w_{r,N-1}, w_{r,N}).$$

At the end of the training process of the matrix Y, we obtain the $RIR_{r,p}$ index 235 for a given industry p defined as the value of the weight $w_{r,p}$ in the vector W_r associated with the respective PEs. Therefore, the RIR represents the convergence value of W, by which the SOM algorithm has reconstructed the relationships between the given industry and all the others through examination of observed data and the consequent training process. Contrary to the results of spatial analysis based on the concentration of a single industry, high values of the RIR define spatial agglomerations of geographic samples with a relevant similarity in terms of industrial patterns. With RIR we achieved three main results:

1. a new measure of relevance for a given industry p on a given P Er: high values of $RIR_{r,p}$ suggest that a given industry has a relatively greater weight than the others;
2. a new relation between high levels of RIR_p and similarities of the geographic samples in terms of industrial patterns (the neighborhood of PEs on the KL).

The overwhelming presence of a specific economic sector can be identified through the RIR (Relative Industrial Relevance) indicator for each creative industry. In other words, the proposed methodology allows us to understand whether an industry is important in relative (rather than in absolute) terms and how it contributes to the formation of observed industrial patterns for understanding the development and adaptive transformation of the economic landscape. Data supporting the analysis are drawn from the 2011 Census of Industry and Services. They concern the number of employees in the local productive units which are recorded by place of work on the basis of the 8.092 Italian municipalities, being the most updated ones at this territorial level. Employment data refer to the private sector, as the final version of those regarding public institutions has not yet been released, while non-profit ones have been recorded on a four-digit base. Data have been extracted with a five-digit detail according with the ATECO 2007 classification of economic activities, the Italian version of the NACE Rev. 2 nomenclature.

4 Results and Discussion

The output made by the SOM algorithm is about 10 creative industries as described by the following picture. The results put in evidence three major results:

1. The RIR value is high (red) only in a few exagons on the map for all the creative industries, except for “creative goods and services”: patterns of creative industries for a defined industry are with low variance and are good representations of relationships among the analyzed industry and the other creative sectors.
2. Some creative industries like “Design”, “Branding and Communication” and “Motion Picture, Video, TV and Radio” have two spots with high values in terms of RIR: those sectors have multiple patterns, different among themselves but coherent with the industry with;
3. Some creative industries present same or very near patterns with high values in terms of RIR: same patterns with high RIR’s values represent a good proxy to highlight linkage in terms of skills and cognitive capacity (Fig. 1).

In general the analysis of the map can give a good representation of the related skills which find place in productive architectures that have similar patterns for creative industries. In fact what can emerges from the output is a good regularity for people employed in the creative industries ad also some relationship in terms of higher RIR values for some of them.

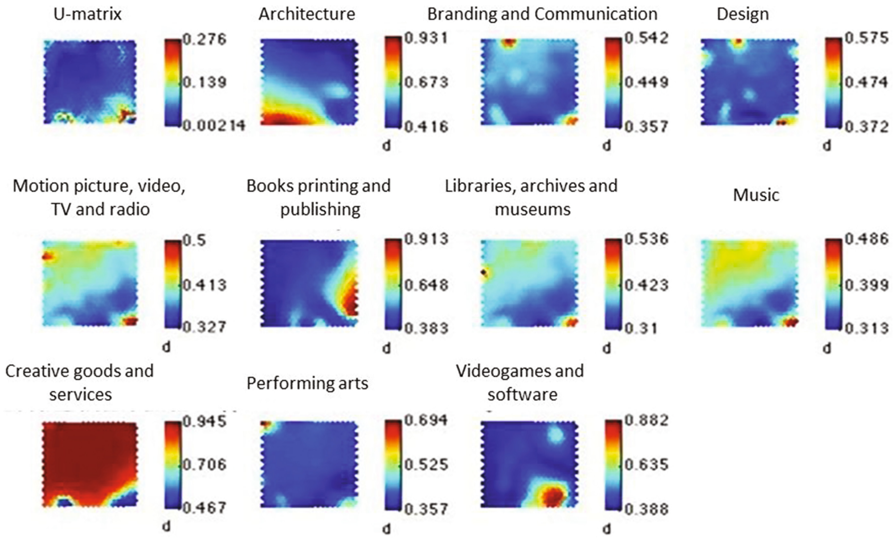

Fig. 1. Kohonen Layer for the creative clusters

5 Conclusions

The present work has studied organizational pattern of CCI via cultural and creative workers, considering their intrinsic socio-economic complexity of local development paths, which often are unique. To put in evidence the multidimensionality of this phenomena and its simultaneous similarities and differences, the authors have chosen artificial neural network Self Organising Map (SOM) as tool of work. This approach allowed the representation of industrial pattern of the CCI in Italy and a characterization of them not based on specialization but built on similarity in resources allocation.

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Understanding Bruno de Finetti's Decision Theory: A Basic Algorithm to Support Decision-Making Behaviour

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Abstract. The aim of this work is to present an algorithm inspired to Bruno de Finetti's decision theory, limited to the version proposed by him in the essay *"La probabilità: guida nel pensare e nell'agire"* released in 1965. This work is focused on decision theory within the subjective theory of probability conceived by de Finetti. It opens with a brief overview of his theory of probability, followed by a methodological analysis functional to introduce the renowned de Finetti's example model given for the solution of decision problems. Starting from this example, this work presents a mathematical generalization of the decision algorithm. Afterwards, a real decisional algorithm written in mathematical-style pseudo code is developed. Finally, some conclusive remarks are discussed along with possible future developments.

Keywords: Decision theory · Information · Earnings · Mathematical expectation · Probabilities · Uncertainty · Mathematical algorithm

JEL Classification: C44 · D81

1 Introduction

It is needless to say how great has been the fortune of the deFinettian consensus [1, 2], so it results a rather difficult task to mark out an exhaustive map of the thousands of works which are linked to de Finetti's wide scientific production embracing issues of mathematics, statistics, economics, and philosophy.

Among others, however, Kao's and Velupillai's reflections on de Finetti seem of quite sufficient weight and importance to merit a particular attention [3]. The two authors, indeed, argue that the subjective theory of probability devised by de Finetti has furnished an essential contribution to the modern behavioral economics, especially in its origins. In the wake of the deFinettian tradition, one of the leading exponents of behavioral economics, Ward Edwards [4, 5], drew from Leonard J. Savage [6] the

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notion of expected subjective utility. In this regard, the expected subjective utility has gradually replaced the expected utility of von Neumann-Morgenstern [7], surpassing the fundamental limits of the latter. These limits concern the extreme weakness of the behavioural axioms of the expected utility theory and, therefore, the general incapability to formalize realistic axioms regarding human decision-making under uncertainty. The possibility of exceeding this limit became possible thanks to de Finetti's contributions to the theory and the foundations of probability.

In support of the deFinettian reflection, in this work we intend to highlight the renowned example model given for the solution of decision problems and shown in the essay released in 1965, *La probabilità: guida nel pensare e nell'agire* [8] (*Probability: A guide to think and act*, authors' translation). This example effectively represents the decision problem under uncertainty, with the purpose of identifying the optimal decision, that is capable of maximizing the expected earnings of economic agents. The example considers the possibility of using any more information, evaluating *ex ante* whether it is appropriate or not to decide to make use of further information, both in terms of cost to be incurred and of benefits in decision-making. The example described by de Finetti lends itself well to generalization and to the definition of an algorithm capable of supporting the action of rational economic agents. In this work, we have therefore generalized the example of de Finetti in mathematical terms and developed a decision-making algorithm. The algorithm, called *Wish* by us and based on the decision theory of de Finetti, aims (i) to show the manner in which the decisions made by economic agents may vary, especially in the presence of additional information with respect to the probability of occurrence of an event, as well as (ii) to show if further information can improve the expected earnings of economic agents. Indeed, further information is useful in a decision-making process only if it allows to maximize the mathematical expectation placed in the earnings or utility associated with a given event by an economic agent. Instead, if the information confirm the original decision, that the economic agent would have made in the absence of it, the information represents just a cost. The algorithm provides as output both the best decision to be made in the absence of more information and the best decision in case the further information increases the mathematical expectation of earnings, as well as the earnings (in terms of mathematical expectation) for each decision, both in the presence and in the absence of further information. The methodology adopted in this work is explained in more detail in the next section: first and foremost, we choose to consider and analyze the second example shown by de Finetti in [8], in order to deepen the role of information within the decision-making process under uncertainty.

This work is composed of five sections: this first section is intended as an introductory contribution to the following sections. Section 2 offers a brief methodological note preparatory for the subsequent sections. The third section includes an extensive analysis of the process used by de Finetti to make the optimal decision in the presence of multiple alternatives decisions (six) with respect to three different events, with the possibility to use more information. Section 4 contains the mathematical generalization of the problem and the definition of the algorithm *Wish* presented in mathematical-style pseudo code. Finally, the most significant findings achieved in this work are discussed.

2 A Methodological Note

The route followed in this work is the same adopted by de Finetti [8] in order to address the decision problem under uncertainty. This type of decisions do not aim at utility maximization, but rather to the maximization of mathematical expectation of earnings associated to a given event in monetary terms. We consider only the second of the two examples shown by de Finetti in [8], as the first example is restricted to addressing the decision relating to or not to proceed in performing a certain action.

The second example is different from the first one as it includes the opportunity to make use of additional information before choosing the optimal decision. The optimality of the decision is given by the maximum of the mathematical expectation calculated starting from the earnings corresponding to the decision D which in turn corresponds to the single events E.

With regard to the additional role of information in decision-making, it should be noted that it can be extremely useful if it allows to obtain different probabilities associated with events respect to those already known, thus modifying also the mathematical expectation to earn in each decision. Consequently, the optimal decision to be made will be different, as compared to that taken in the absence of information. If the information confirms the previous decision, it can only represent a cost.

3 A Method for Decision-Making Under Uncertainty

Bruno de Finetti seeks to reduce the uncertainty problem using known probabilities with respect to the occurrence of an event E, as well as with respect to any information H which can modify the choices that economic agents would have made in absence of H.

Here, we bring back up the second example addressed by de Finetti in [8], in order to establish a possible method to address decisions under uncertainty.

The example addressed by de Finetti concerns six decisions associated with three different events $E = \{E_1,\ E_2,\ E_3\}$, to which probabilities $\boldsymbol{p} = [p_1, p_2, p_3]$ are associated respectively, whereas there are six possible decisions that can be made $D = \{D_1, \ldots, D_6\}$. The matrix of earnings is also introduced $\boldsymbol{A} = [[a_{11}, \ldots, a_{16}], \ldots, [a_{31}, \ldots, a_{36}]]$ where each element represents the consequent earnings related to a certain decision D with respect to the probability p of a certain event E. The author calculates the mathematical expectations to earn associated to each decision in average values (for instance, for the decision D_1 we have the mathematical expectation $a_1 = p_1 a_{11} + p_2 a_{21} + p_3 a_{31}$).

In doing so, the mathematical expectations obtained $a_1, \ldots, a_6$ corresponding to each of the six possible decisions, of which the greater one corresponds to the best decision in the absence of additional information.

De Finetti also suggests the possibility of acquiring additional information, which we denote by H and they may have three possible outcomes $H^{'}$, $H^{''}$, $H^{'''}$, each of which may change the probabilities of the three events E_1, E_2, E_3: therefore, we may have for $H^{'}$ the new probabilities $p_1^{'}$, $p_2^{'}$, $p_3^{'}$ and so on. Furthermore, the three possible outcomes will each have their own probability of occurrence, respectively $c^{'}$, $c^{''}$, $c^{'''}$ (see Table 1).

By means of the example model just rebuilt, de Finetti points out how it is possible to decide *ex ante* whether or not to use the additional information, calculating the mathematical expectations of earnings for each of the three possible outcomes of H and verifying if the mathematical expectation in the presence of H is greater than the mathematical expectation in the absence of more information.

Table 1. Bruno de Finetti's example model.

$$
\begin{array}{c}
\\ \\ \mathrm{E}_1 \\ \mathrm{E}_2 \\ \mathrm{E}_3 \\ \\ \\ \\ \\
\end{array}
\begin{array}{cccccc}
 & & & & & \\
D_1 & D_2 & D_3 & D_4 & D_5 & D_6 \\
\left[a_{11} \right. & a_{12} & a_{13} & a_{14} & a_{15} & \left. a_{16} \right] \\
a_{21} & \mathrm{a}_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\
a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\
a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \\
a'_1 & a'_2 & a'_3 & a'_4 & a'_5 & a'_6 \\
a''_1 & a''_2 & a''_3 & a''_4 & a''_5 & a''_6 \\
a'''_1 & a'''_2 & a'''_3 & a'''_4 & a'''_5 & a'''_6
\end{array}
\quad
\begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}
\quad
\begin{array}{ccc}
H' & H'' & H''' \\
c' & c'' & c''' \\
p'_1 & p''_1 & p'''_1 \\
p'_2 & p''_2 & p'''_2 \\
p'_3 & p''_3 & p'''_3
\end{array}
$$

4 Algorithm Generalization

The decision algorithm proposed by de Finetti can be generalized as follows. We consider a decision problem $P = \{D, E, \boldsymbol{p}, \boldsymbol{A}\}$ where we have to choose the best decision from a set of n possible decisions $D = \{D_1, \ldots, D_n\}$. Whichever decision will be taken, we can have one out of m possible outcomes (events) $E = \{E_1, \ldots, E_m\}$, where each event E_i has probability p_i, and $\boldsymbol{p} = [p_1, \ldots, p_m]$ is the vector of all probabilities. For each possible combination of decision and event we have an earning a_{ij} where i indicates the event and j indicates the decision, where $1 \le i \le m$, $1 \le j \le n$ and $\boldsymbol{A}$ is the matrix of earnings.

For each decision D_j we can calculate the mathematical expectation (that is, the expected earning) $a_j = p_1 a_{1j} + \cdots + p_m a_{mj}$. The best decision corresponds to the maximum earning given by $a_h^* = \max(a_i)$, $1 \le i \le n$. We indicate the best decision with the symbol D_h^*.

Using matrix notation, we can obtain the vector of all expected earnings $\boldsymbol{a}$ by multiplying the vector of the probabilities with the matrix of the earnings: $\boldsymbol{a} = \boldsymbol{pA}$, where $a_h^* = \max(\boldsymbol{a})$ and D_h^* is the best decision. The Table 2 shows the schema in graphical form.

Table 2. The mathematical generalization of the decision algorithm.

$$
\begin{array}{cc}
 & \boldsymbol{p} \\
E_1 & p_1 \\
\vdots & \vdots \\
E_m & p_m \\
 &
\end{array}
\quad
\begin{array}{c}
\begin{array}{ccc} D_1 & \cdots & D_n \end{array} \\
\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} = \boldsymbol{A} \\
\begin{bmatrix} a_1 & \cdots & a_n \end{bmatrix} = \boldsymbol{a}
\end{array}
$$

Now we consider the case where we can ask for further information before taking any decision: let's call H the further research we can ask (and pay for) to add useful information before taking the decision, and with $H = \{H^1 \ldots H^r\}$ the possible outcomes of H. Before asking for H we should estimate what are the probabilities $\boldsymbol{c} = c^1 \ldots c^r$ of each one of the possible outcomes and, for each outcome H_i, we should estimate the probability vector $\boldsymbol{p^i} = p_1^i \ldots p_m^i$ of new probabilities for the events $E_1 \ldots E_m$ related to the outcome H_i.

This extended decision problem can be defined as $P^H = \{D, E, \boldsymbol{p}, \boldsymbol{A}, H, \boldsymbol{c}, \boldsymbol{p^i}\}$.

As de Finetti shows in [6], we will now have $p_i = p_i^1 c^1 + \ldots + p_i^r c^r$ that is the probability for each event now is the average of the probability we expect for each of the possible outcomes of the research, weighted with the probability which we expect for each H_i to happen.

We can calculate, for each of the H^i, the optimal value a_*^i as in the previous case as $a_*^i = \max(\boldsymbol{p^i A})$: if, for each of the H^i, we will have that $a_*^i = a_h^*$ this will mean that asking for H will not give any improvement so the extra information given by H will be not useful. If we have at least one different value, then we will have an improvement; the new expected earning is $a_H^* = c^1 a_*^1 + \cdots + c^r a_*^r \geq a_h^*$ and the best decision is the corresponding D_H^*.

The Table 3 shows graphically the extension of the decision algorithm.

Table 3. The generalization of the extended decision algorithm.

$$
\begin{array}{cccccccc}
 & & & & & H^1 & & H^r \\
 & \boldsymbol{p} & D_1 & \cdots & D_n & c^1 & \cdots & c^r \\
E_1 & p_1 & \left[a_{11} \right. & \cdots & \left. a_{1n} \right] & p_1^1 & \cdots & p_1^r \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
E_m & p_m & \left[a_{m1} \right. & \cdots & \left. a_{mn} \right] & p_m^1 & \cdots & p_m^r \\
 & & [a_1 & \cdots & a_n] & & & \\
 & & [a_1^1 & \cdots & a_n^1] & & & \\
 & & & \vdots & & & & \\
 & & [a_1^r & \cdots & a_n^r] & & &
\end{array}
$$

The new expected (and improved) earning is not free, but it comes at a cost (the cost of H) so, before asking for further information, we can not only estimate if we will have an improvement in the expected earning but also calculate if the cost of obtaining the improved decision information is excessive due to a too small improvement on the expected earnings.

4.1 Pseudo Code for the Algorithm

Starting from the mathematical generalization given in the section above, we can write an algorithm capable to calculate what is the best decision to make, with or without the additional information given by H, and what are the expected earnings for each decision.

The algorithm needs for input (i) all the estimated information about earnings and (ii) estimated probabilities for each event, (iii) the estimated probabilities for each outcome of H and (iv) the modified probabilities for each event corresponding to each outcome of H. The outputs of the algorithm are (i) the expected earnings with and without doing the additional research H, (ii) the best decision to take without doing the additional research H and, (iii) the best decision to take according to the possible outcome of the research H.

Note that the algorithm, as introduced in a mathematical formulation in the section above, accepts only one possible extra decision H but this is not a limitation because, if we have to choose one among several possible extra decisions we can run the algorithm for each one of the possible extra decisions to consider, to find which is the most convenient to make.

The algorithm deriving from the generalization can be described in mathematical-style pseudo code as follows:

```
algorithm wish is
    input: matrix A of earnings,
           vector p of probabilities,
           vector c = c^1 ... c^r of probabilities for H^1 ... H^r,
           vectors p^1 ... p^r of probabilities for H^1 ... H^r.
    output: expected earnings a*_h and a*_H,
            best decision D*_h to take before asking for H,
            vector D* = d^1_* ... d^r_* of the best decision to take
            for each of the possible results of H: H^1 ... H^r.

    a*_h ← max(pA)
    D*_h ← D_h

    for each i in {1 ... r} do
        a^i_* ← max (p^i A)
        d^i_* ← decision corresponding to a^i_*

    D_* ← [d^1_* ... d^r_*]
    a*_H ← c^1 a^1_* + ··· + c^r a^r_*
    return a*_h, a*_H, D*_h, D*.
```

5 Discussions and Conclusions

Within the framework of the wide deFinettian scientific production, the example model taken from *La probabilità: guida nel pensare e nell'agire* [8] has been chosen for its effectiveness to express the gain or loss related to decisions in monetary terms, instead of utility functions. It should be recalled that according to de Finetti there are no *a priori* absolute certainties, therefore any decision is made on condition of uncertainty and the latter may be reduced, but never completely removed.

With respect to the example revived in this work, the key role of information in decision theory has emerged: if the decision maker decides to make use of information (although that means that she supports a cost), this may allow new perspectives of earnings related to the different decision made, due to the fact of obtaining different probabilities of those known. By contrast, if the information only allows the decision maker to confirm the decision she would have already liked to make, it turns out to be merely a cost. Thus, the element of uncertainty is also present in this example and consists in the fact that we do not know in advance whether the information will increase our wished gain or less. Bruno de Finetti adopted this process because it allows to relate to the probability in terms of earnings associated with the degree of uncertainty. In fact, de Finetti argues that "*being able to reduce uncertainty of decision theory to a mere accounting is therefore not a decrease, but the greatest success; this success does not preclude, of course, the use of complex mathematical tools and high mathematical abilities to study in this same spirit complex and sensitive issues*." de Finetti [8] p. 55 (authors' translation).

Possible future developments of the algorithm proposed in this work concern further generalizations of it, identifying the opportunity to have not one but N possible extra information to be acquired: in this way, we will be able to identify the best subset of information that allows to maximize the earnings, considering further constraints on the costs of the additional information.

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FOREX Trading Strategy Optimization

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Abstract. Developing robust trading rules for forex trading remains a significant challenge for both academics and practitioners. We employ a genetic algorithm to evolve a diverse set of profitable trading rules based on weighted moving average method. We use the daily closing rates between four pairs of currencies – EUR/USD, GBP/USD, USD/JPY, USD/CHF – to develop and evaluate our method. Results are presented for all four currency pairs over the 16 years from 2000 to 2015. Developed approach yields acceptably high returns on out-of-sample data. The rules obtained using our genetic algorithm result in significantly higher returns than those produced by rules identified through exhaustive search.

Keywords: Trading rules · Forex market · Weighted moving average · Evolutionary algorithms

1 Introduction

The foreign exchange (forex) market facilitates trillions of dollars of trades a day, making it one of the most liquid financial markets in the world. Forex rates are quoted in terms of a base-quote currency pair; the rate represents the number of units of quote currency to be exchanged for each unit of the base currency. A profitable strategy is based on a simple principle: the base currency should be sold (exchanged to obtain quote currency) as the rate decreases and bought as the rate increases. Thus it is essential to forecast movements in foreign exchange rates accurately [1].

Rules for foreign exchange trading selected through back-testing on past data suffer from some limitations: No single rule consistently results in satisfactory profit levels over subsequent periods [2]. Consequently, traders make decisions based on a combination of rules. However, such ad hoc combinations of rules often yield poor returns on out-of-sample data. This problem is partly due to the fact that the volatility in the underlying data generation process changes over time. Developing robust trading rules for forex trading remains a significant challenge for both academics and practitioners.

We address this problem by proposing a systematic approach for developing foreign exchange trading strategies. Our method works as follows: First, we generate a diverse set of simple trading rules that yield good results on back-testing. These rules

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should be diverse in the sense that they have different strengths and weaknesses and work well under different levels of volatility in the underlying data generation processes. We evolve a set of profitable rules using a genetic algorithm, keeping mechanisms in place to ensure diversity. We then create an ensemble that combines the buy, hold, and sell signals generated by the evolved rules to produce a composite trading signal. Our additional contribution is also in consideration of transaction costs for evolving trading rules.

The paper is organized as follows: Sect. 2 provides a brief review of the related literature. Section 3 describes the methodology. Section 4 presents results from our experiments. Section 5 concludes with some observations on our findings and identifies directions of future research.

2 Literature Review

In this section we briefly review the role of technical analysis in foreign exchange trading and methods for evolving trading strategies.

2.1 Technical Analysis in Foreign Exchange Trading

The conceptual idea behind the currency market lies in facilitating the collaboration among the companies that accomplish their payments in the foreign currencies. Meanwhile, nowadays the essential part of market participants does not conduct any international trade of goods and services but leverages exchange rate movements to get profits. These facts, combined with the immense trading volume, and plethora of influencing factors of economic, political, and psychological nature, has made exchange rate prediction one of the most difficult and demanding applications of financial forecasting [3].

Technical analysis attempts to predict future assets prices based on the patterns detected in past prices. These patterns make foundation for creating trading rules important for generating trading signals (i.e. buy, sell, hold). Neely and Weller [4] argue about the philosophy of technical analysis that implies three main principles: (1) assets price history uses all relevant information so any research assets fundamentals is pointless; (2) assets prices are moving with trends; (3) history tends to be repeated itself. Lissandrin et al. [5] evaluate prediction performance of technical indicators for future markets.

A number of researchers prove profitability of the technical trading rules in currency exchange market [6–10]. Study of Owen and Palmer [11] shows that momentum trading strategies are more profitable with greater exchange rate volatility. Schulmeister's [12] results suggest that most of technical trading rules would have resulted in profitable trading strategies even after g for interest expense and transaction costs. Lento [13] focuses on extracting simple trading decisions when faced with multiple technical trading signals. Researcher assumes that it is necessary to determine the optimal number of trading rules for the decision-making mechanism using a more complex methodology.

We assume that the relationship between trading rules and trading strategy can be explained as follows: trader uses a number of trading rules to maximize the returns of trading strategy.

2.2 Evolutionary Approaches for Developing Trading Strategies

Genetic algorithms have already been employed to a number of financial problems [14, 15]. Some researches [16, 17] argue that the genetic programming approach of [18] is the most applicable and promising considering its flexibility for adjusting the trading rules to the current environment. Number of such experiments with genetic programing are observed with application on the foreign exchange markets [19, 20].

For instance, Neely and Weller find strong evidence of economically significant out-of-sample excess returns to technical trading rule over the period 1981–1995 using genetic programming techniques. Their testing results indicate that the trading rules detect patterns in the data that are not captured by standard statistical models. In [21] on application of evolutionary computation techniques to rule discovery in stock algorithmic trading authors find that a significant bias toward the applications of genetic algorithm-based and genetic programming-based techniques in technical trading rule discovery is observed in recent economic literature. [22] focus on how to accelerate the speed of computation with evolutionary approach for developing trading strategies, enabling the generation of more results in the same time and making it more feasible to analyze larger problems. [23] suggest another application of evolutionary approaches for trading. Their paper considers the multi-objective evolutionary optimization of technical trading strategies, which involves the development of trading rules that are able to yield high returns at minimal risk. [15] explore possibility of employing genetic programming to stock exchange markets. However, instead of using market indices such as Dow Jones, S&P 500, they concentrated on individual companies and their market performance.

3 Methodology

We first describe the data used to evaluate our proposed method. Next, we characterize the trading rules used in our study and discuss the genetic algorithm used to generate them. Finally, we describe our experimental set up to evaluate our proposed method.

3.1 Data Used

We use the daily closing rates between four pairs of currencies – Euro and US Dollar (EUR/USD), British Pound and US Dollar (GBP/USD), US Dollar and Japanese Yen (USD/JPY), US Dollar and Swiss Franc (USD/CHF) – to develop and evaluate our method; these are among the most widely traded currency pairs in the foreign exchange market. These publicly available data sets are obtained from: www.global-view.com/forex-trading-tools/forex-history/. Each time series contains rates for sixteen years (2000–2015) with a total of 4174 observations. The moving averages track the significant upward and downward moves of the rates with a lag while filtering out short term fluctuations due to volatility.

3.2 Trading Rules

Recall that a profitable trading strategy is based on the principle that the base currency should be sold (exchanged to obtain quote currency) as the rate decreases and bought as the rate increases. The random fluctuations in the rates due to noise should be ignored in determining trends. A moving average filters out noise to smoothen the rate curves while preserving the approximate turning points in rates; the higher the order of the moving average, the smoother the resulting curve. We monitor the sign of the slope of an order-moving average and issue sell signals when the sign changes from positive to negative and buy signal when the sign changes from negative to positive; hold signals are issued when there is no change in the sign of the slope. We use a weighted moving average of order p at time t that is computed as follows:

$$ma(\boldsymbol{x}, p, t) = (0.5p(p+1))^{-1} \sum_{k=t-p+1}^{t} w_k x_k, \quad \text{where} \quad w_k = k - t + p \tag{1}$$

Define the sign of the slope of a moving average of order p at time t as:

$$\delta(\boldsymbol{x}, p, t) = sign(ma(\boldsymbol{x}, p, t) - ma(\boldsymbol{x}, p, t-1)) \tag{2}$$

The signal is generated as follows:

$$s(\boldsymbol{x}, p, t) = \begin{cases} -1 & \textit{if } \delta(\boldsymbol{x}, p, t-1) > 0 \textit{ and } \delta(\boldsymbol{x}, p, t) < 0 \\ +1 & \textit{if } \delta(\boldsymbol{x}, p, t-1) < 0 \textit{ and } \delta(\boldsymbol{x}, p, t) > 0 \\ 0 & \textit{otherwise} \end{cases} \tag{3}$$

The lower the order of the moving averages, the lower is the proportion of hold signals and the higher is the proportion of executed trades (buy or sell). Since the transaction costs increase with the number of trades, transaction costs are lower when using higher order moving averages. However, higher order moving averages may lead to excessive smoothing and loss of opportunities to execute profitable trades based on short term trends. This problem may be addressed by using relatively lower order moving averages and explicitly setting limits on the frequency of trades. We model this by defining a function with a holding time parameter that specifies the minimum number of periods between consecutive trades. We model this by defining a function ρ with a holding time parameter h that specifies the minimum number of periods between consecutive trades. Let $prev(t)$ denote the last time period before t when a trade has been executed and signal $s_t = s(\boldsymbol{x}, p, t)$. Then:

$$\begin{aligned} \rho(s_t, h) &= s_t \quad \text{if } \; t - prev(t) \geq h; \\ \rho(s_t, h) &= 0 \quad \text{otherwise} \end{aligned} \tag{4}$$

We put attention to the concern motivated by transaction costs. The transaction is not profitable unless the absolute value of the percentage change in rates between consecutive trades exceeds a minimum threshold value. We model this using a function

τ with a minimum change parameter β. Since transaction cost of c is expressed as a percentage of the trade value, we set $\beta > 0.01c$ and define the function as follows:

$$\begin{aligned} \tau(s_t, \beta) &= s_t \quad \text{if } \left|x_t - x_{prev(t)}\right| / x_{prev(t)} \geq \beta; \\ \tau(s_t, \beta) &= 0 \quad \text{otherwise} \end{aligned} \tag{5}$$

A signal generated at time t for a time series $\boldsymbol{x}$ using a moving average of order p, holding time parameter h, and minimum change parameter β is given by:

$$signal(\boldsymbol{x}, p, t, h, \beta) = \tau(\rho(s(\boldsymbol{x}, p, t), h), \beta) \tag{6}$$

3.3 Genetic Algorithm for Rule Generation

We use Eq. (6) to generate trading signals at time t given parameters p, h and β. Thus a rule is characterized by a parameter vector p, h, β. We conduct the evaluation of the GA performance by calculating the return on investment given formula 2. An exhaustive search (ES) is performed over parameter space $p \in P$, $h \in H$ and $\beta \in B$ by back-testing on available data. The criterion for the use of the ES is the size of the parameter space, than the best rules may be identified. Our experimental findings demonstrate that the best solutions tend to be clustered around a few points in the P, H, B parameter space and lack diversity.

We posit that ensemble signals work better on out-of-sample data when the constituent signals are diverse. Hence we use a genetic algorithm (GA) to evolve a set of rules that result in sufficiently high returns. Mechanisms are implemented in the design of our GA to prevent premature convergence on local optima and to ensure that the rule set obtained are diverse in the sense that they represent a widely distributed set of points in the parameter pace. We outline our GA in Fig. 1, amplify on each step, and discuss our choice of GA parameter values.

Experimental design for evaluation

1. Generate an initial population of n_p candidate solutions
2. For generation i = 1 to n_G:
   a. Selection: Select n_P candidate solutions as parents and randomly pair them.
   b. Recombination: Generate a pair of offspring from each pair with probability p_r
   c. Mutation: Mutate each offspring with probability p_m
   d. Replacement: Replace the current population with the n_P mutated offspring
3. Return population.

Fig. 1. Overview of the GA.

Table 1. Out-of-sample returns for the 100 rules identified using exhaustive search and GA

Year	EUR/USD						GBP/USD					
	Exhaustive search			GA			Exhaustive search			GA		
	max	mean	min	max	mean	min	max	mean	min	max	mean	min
2001	1.57	0.75	0.00	2.48	1.47	0.98	1.88	1.20	0.42	3.11	2.89	2.11
2002	1.44	0.57	−0.24	3.29	2.21	1.31	0.57	−0.31	−0.94	1.94	1.12	0.42
2003	0.48	−0.22	−0.89	2.03	1.68	0.39	0.58	−0.20	−0.91	2.37	1.82	1.08
2004	2.67	1.61	0.78	2.72	2.36	1.64	1.09	0.38	−0.31	3.30	2.86	2.64
2005	0.85	0.00	−0.71	3.36	2.34	1.94	1.79	1.19	0.10	3.70	2.69	1.34
2006	2.39	1.48	0.92	3.69	2.88	2.04	2.04	1.30	0.21	3.26	2.10	1.91
2007	1.23	0.79	−0.11	3.58	2.13	1.51	0.86	−0.09	−0.93	3.86	3.43	2.11
2008	0.47	−0.09	−1.01	2.38	1.74	0.91	0.58	−0.28	−1.13	2.02	1.46	0.70
2009	1.27	0.29	−0.61	2.90	2.23	1.69	2.20	0.99	0.33	1.47	1.17	0.53
2010	0.79	−0.11	−1.13	3.67	2.98	2.16	1.48	0.63	0.00	2.06	1.53	0.91
2011	1.24	0.34	−0.39	2.73	2.11	1.28	1.72	1.30	0.49	3.23	2.29	1.47
2012	1.57	0.83	0.00	4.66	3.49	2.48	2.66	1.49	0.81	2.79	2.38	1.26
2013	1.81	0.83	0.09	4.01	3.37	2.98	0.91	0.51	−0.11	3.78	2.38	2.15
2014	1.23	0.55	−0.44	2.69	1.34	0.60	1.66	0.45	−0.23	3.50	3.06	2.26
2015	1.05	0.11	−0.47	1.68	1.12	0.28	1.27	0.74	−0.20	2.38	1.43	0.66
Year	USD/CHF						USD/JPY					
	Exhaustive search			GA			Exhaustive search			GA		
	max	mean	min	max	mean	min	max	mean	min	max	mean	min
2001	0.92	0.38	−0.22	2.28	1.35	0.94	1.08	0.18	−0.75	2.82	2.10	1.54
2002	0.46	−0.30	−1.22	3.66	3.00	2.35	0.55	−0.35	−1.00	3.17	2.09	1.61
2003	2.08	1.23	0.73	2.00	1.49	0.75	2.80	1.73	0.61	2.60	1.93	1.07
2004	2.42	1.11	0.49	2.00	1.16	0.21	1.26	0.50	−0.54	3.47	2.62	2.16
2005	0.97	0.09	−0.48	2.40	2.08	0.81	1.53	0.56	−0.33	2.42	1.84	0.80
2006	0.68	0.00	−0.72	3.33	2.80	2.44	1.10	0.59	−0.21	3.37	2.47	1.46
2007	0.59	−0.39	−1.40	2.82	2.02	0.90	2.37	1.38	0.77	2.79	1.89	1.14
2008	0.76	0.09	−0.43	3.72	2.59	2.03	1.32	0.47	−0.12	2.89	2.38	1.34
2009	0.52	−0.47	−1.31	3.79	3.09	2.22	0.27	−0.45	−1.10	2.84	2.47	1.61
2010	2.73	1.54	0.94	2.28	0.97	0.11	2.33	1.46	0.66	3.81	3.18	2.17
2011	1.77	0.87	0.22	2.02	1.37	0.62	1.53	1.20	0.42	2.36	1.43	0.57
2012	1.28	0.56	−0.10	3.28	2.71	1.47	1.99	1.09	0.19	3.34	2.97	1.91
2013	0.95	0.18	−0.45	3.56	3.33	2.19	0.50	−0.33	−1.55	4.01	3.11	2.16
2014	0.68	−0.24	−0.74	2.38	2.15	1.16	2.00	0.94	0.48	3.25	2.46	1.38
2015	1.42	0.42	−0.23	2.41	1.06	0.49	1.80	0.86	0.00	4.17	2.58	2.00

Foreign exchange rate data from each of the four currency pairs are partitioned by year (16 years from 2000 to 2015), thus producing 4 × 16 = 64 data sets. We identify trading rules separately for each data set based on back-testing. The rules identified are then tested using data from the subsequent year for the same currency pair. Thus, out-of-sample testing is performed on the 60 data sets for the years 2001 to 2015.

4 Results

We present results on comparison of rules identified by exhaustive search and GA. Results are presented for all four currency pairs over the 16 years from 2000 to 2015. Two important observations may be made from in-sample results: First, that the universe of rules considered in this study yield satisfactory returns on in-sample data. Secondly, that the returns produced using rules identified by the GA are only marginally lower than those produced by rules identified through exhaustive search. Our GA is capable of identifying such profitable rules efficiently. Each GA run took less than 20 s on a Windows desktop with 24 GB of RAM and an i7-4790 processor running at 3.6 GHz. However, since in-sample results are not necessarily indicative of the performance of these rules in future years, we next turn to performance of these rules on out-of-sample data.

The best rules obtained using back-testing in a year are applied to data for the subsequent year to obtain out-of-sample results. Table 1 compares the average out-of-sample returns produced by rules identified through exhaustive search and our GA for the four currency pairs over the 15 years from 2001 to 2015. On the average, the rules obtained using our GA result in significantly higher returns than those produced by rules identified through exhaustive search. In all but two of the sixty tests (USD/CHF in the years 2004 and 2010) the rules identified by the GA performed better. Indeed, in 14 of the 60 tests, the rules identified using exhaustive search resulted in negative returns on investment. This may be attributable to the fact that the rules identified by exhaustive search lack diversity and work well only on back-testing with in-sample data. The rules identified by the GA, on the other hand, are more diverse and on the average result in positive returns on out-of-sample data.

5 Conclusion

Paper examines the merit of evolutionary algorithms to generate trading signals for trading decisions at financial markets. We focus on foreign-exchange market. In-sample data shows slightly better performance of ES. Performance evaluation on out-of-sample data indicates that our approach is able to provide acceptably high returns on investment more efficient than ES.

Future research foresees investigating two different computationally efficient methods to adjust our ensemble approach: The first uses Dirichlet conjugate priors and updates parameters of the distribution. The second approach assumes that changing trends in exchange rate may be approximated by a Hidden Markov Model and uses a particle filter algorithm to adjust weights.

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Looking for Regional Convergence: Evidence from the Italian Case with Multivariate Adaptive Regression Splines

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Abstract. This paper examines the role of data mining analysis in explaining the Italian regional dualism with the aim of suggesting economic policies to fill the existing socio-economic gaps. We analyze the 2004–2014 period exploiting the capacity of MARS model in finding relationships among data. In Italy, the presence of a North-South divide is well-known for decades and present for several social and economic aspects. Recent studies prove that strong differences exist also in the regional human capital. Thus, we search for the causes of the local differences, also considering the entrepreneurial vitality and the international trade leverage. Among several variables, MARS is useful in showing the actual determinants on which to intervene. This is possible by comparing regions grouped homogeneously into clusters using recent data. MARS results are used for policy suggestions with the aim of filling the income gap.

Keywords: Regional convergence · Clusters · MARS · Regional policy

1 Introduction and the Italian North-South Dualism

The North-South divide in Italy is a problem studied for decades [10], strongly increased after the Italian unification [9]. Since that period, there was a progressive distancing of the economic development paths of the Northern regions with respect to the South. The North has been able to encourage industrial settlements, initially thanks to the natural resources, afterwards by supporting aggregate demand also thanks to the geographical proximity to European and international markets [1]. For Iuzzolino *et al.* [23] the last observed convergence period among the Italian regions was in the twenty years after the Second World War, while for Barro and Sala-I-Martin [5], in Italy and in other developed countries, there are some traces of convergence until the 1980s. Therefore, two different contexts must be analyzed in Italy, in which the differences between the population of the North and South also exist in the trust and cooperative behavior [8] and in the cultural and educational background [24].

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A specific data mining tool can improve the economic analysis. We use a MARS model (multivariate adaptive regression splines, [18]) to observe the nonlinear and multidimensional relationship between the income and several regressors at the regional level. We found MARS more efficient than traditional techniques. It is used in many fields of research in decision-making and forecasting models [25]. For example, Abraham *et al.* [2] argue that MARS is more efficient compared to several recent models of soft computing. MARS makes no assumptions about the original functional relationships that exist between a target variables and its related independent variables, thus this model is useful when there is an unknown relationship giving information on the parameters relevance from a high-dimensional panel data. Furthermore, in this study, MARS helps doing a selection of the variables for eliminating the presence of collinearity. In fact, MARS builds a model through the forward pass and the backward pass phases. The forward pass phase builds an overfit model characterized by a good fit to the data, and the backward pass phase eliminates the least effective terms finding the best sub-model [19]. The MARS ability to find relationships between variables can help explaining the relations with the target variable. In fact, the underground economy [4] contributes to hinder some relations linked to GDP in the analysis on the Italian case. MARS is also useful in limiting the multicollinearity problems thanks to its variable selection process. We must consider that in Italy there is the presence of a North-South dualism also regarding human capital quality [3], therefore this resource must be widely considered. For example, NEET rate is about 15–20% in the Center-North and 30–40% in some Southern regions, the workers involved in lifelong learning are respectively about 10% and 5% (Istat data). With the aim of comparing the wealthiest and the relatively poorest areas, *a priori* division of the regions in homogeneous group represents a fundamental step of the analysis [26]. However, we should find groups of spatially neighboring regions because the economic performance of a region affects the neighboring [14]. We apply MARS to the resulting groups and we compare the statistically significant determinants. What lacks in the less wealthy areas may be found among the reasons of the income divergence.

2 The Selection of the Income Determinants

The target variable considered in studies on regional inequality is GDP *per capita* (constant 2010 values, Istat data). Among the independent variables, we focus on the significant role played by the human capital. This type of capital represents one of the most important economic assets in the advanced economies [20] and it strongly influences the regional economic dynamics [16]. Furthermore, Abramo *et al.* [3] prove the presence of an Italian North-South dualism both in the research and in the educational system. Human capital is observed using educational [22] and lifelong learning data [13]. We consider the contribution of the principal economic sectors, through their added value contribution on the total, as Barro and Sala-I-Martin [5] consider, in a study of regional convergence, the contribution of each sector on GDP *per capita*. We also include data on the entrepreneurial vitality because the role of businesses is fundamental on the local development, despite not often used in studies on economic growth [27].

Of course, the international trade, observed with the export levels on GDP, represents one of the main supports to the aggregate demand, as Guerrieri and Iammarino [21] focus on the Italian regional specialization and diversification, that can represent a chance for the southern area through export. Finally, data on the financial sector must be consider. We select an Istat indicator representing the differential between the borrowing rates, calculated as the difference between the Centre-North and South, to represent the financial system dualism. This is due to the fact that the costs of borrowing increases during economic slowdown and in the worst performing areas (as Southern Italy) because, for example, of the increasing risk of default [11]. We present the list of variables (2004–2014) and the source of the data:

- population aged 25–64 with less than primary, primary and lower secondary education (M and F; levels 0–2 ISCED 2011, %) – Eurostat;
- population aged 25–64 with upper secondary and post-secondary non-tertiary education (M and F; levels 3–4 ISCED 2011, %) – Eurostat;
- population aged 25–64 with tertiary education (M and F; levels 5– ISCED 2011, %) – Eurostat;
- school dropout (M and F; % of population aged 18–24 with at most a sec. education, and who have not completed a training course (of more than 2 years) and who do not attend school courses or training) – Eurostat;
- NEET rate (M and F; young people neither in employment nor in education and training, %) – Eurostat;
- employed lifelong learning (employed 25–64 years engaged in training and education on 100 employed persons in the corresponding age group, %) – Istat;
- unemployed lifelong learning (M and F; unemployed 25–64 years engaged in training and education, %) – Istat;
- net enrollment rate in the Company Register (businesses registered minus the ceased ones on the total businesses registered in the previous year, %) – Istat;
- export/GDP ratio (%) – our elaborations on Istat data;
- differential in lending rates on loan facilities between the South and the Center-North of Italy; the lending rates are on total cash loans) – Istat;
- degree of use of PCs, Internet access, broadband availability and corporate website, for businesses with more than 10 employees – Istat;
- value added for agriculture, forestry and fishing (ratio of total value added) – our elaborations on Istat data;
- value added for quarrying, manufacturing, electricity supply, gas, steam and air conditioning, water supply, sewerage, waste management and remediation activities (ratio of total value added) – our elaborations on Istat data;
- value added for constructions (ratio of total value added) – our elaborations on Istat data;
- value added for wholesale and retail trade, repair of motor vehicles and motorcycles, transportation and storage, accommodation and food services, information and communication services (ratio of total value added) – our elaborations on Istat data;
- value added for financial and insurance activities, real estate, professional, scientific and technical activities, administrative and support services (ratio of total value added) – our elaborations on Istat data;

– value added for public administration and defense, social security, education, health and social work activities, arts, entertainment and recreation activities and other services (ratio of total value added) – our elaborations on Istat data.

Endogeneity problems can be present among some independent variables and the GDP *per capita*, however, our goal is not to explain the formation of the GDP but find the statistically significant variables.

3 Clustering of the Italian Regions

In order to examine the income determinants in the wealthiest and the poorest areas, the possible mobility of some regions in the studied period must be considered, staring from the official Istat grouping. We propose two clustering methods, K-means and Hierarchical. Considering the Eurostat NUTS2 level, we have data on the 19 regions and 2 autonomous provinces. The discriminating variables are 14 on human capital (the top 7 of the list for male and female) and GDP *per capita*, because we consider the inequality with a focus on education and lifelong learning.

In Fig. 1, we include Trentino-Alto Adige in the group of its most populous autonomous province, Trento. The results for the selected period, 2004–2014, show a dualism between the geographical North and South, as historically proven, and the two cluster techniques reveal two groups in the Center-North. Two central regions are in the South group in 3–b, but these regions have an average income very closer to the North. For this reason, we consider the K-Means division. The South group (white area in Fig. 1a) coincides with the official Istat *Mezzogiorno*, *i.e.* the Southern regions and major islands. This division confirms the historical dualism between the less wealthy area and the central and Northern regions (black and grey in Fig. 1a). We choose two representative subgroups of the richest area, not only for economic reasons (a difference is given by the fact that the black regions have the higher GDP *per capita*) but to have two possibilities of comparison. Furthermore, each group represents approximately one third of the Italian population considering these clusters (about 18, 22 and 21 million people).

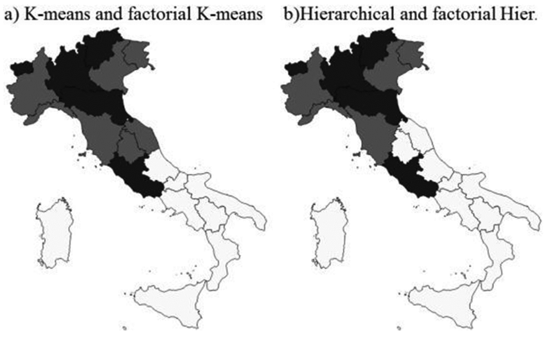

Fig. 1. Clustering of the Italian regions according to the human capital data and GDP per capita (2004–2014)

4 The MARS Model

MARS [18] is a non-parametric regression technique for solving regression-type problems. This model has no expectations on the underlying functional relationships between a target variable and the regressors. We apply two-sided truncated functions of the form $\pm(x-t)_+$ representing basis functions for linear or nonlinear expansions. Subsequently, with the aim of setting the coefficient values to fit the data in the most efficient way, the basis functions and the parameters (estimated via OLS) are combined to provide the predictions, assumed the inputs. The result is a geometrical procedure that is better than a standard approach. The multivariate splines algorithm derives from two-sided truncated functions of the predictors (x): $b_q^{\pm}(x-t) = [\pm(x-t)]_+^q$.

Basis functions are employed for generalizing spline fitting to higher dimensions. The multivariate spline basis function is (with two-sided truncated power basis for the univariate functions):

$$B_m^{(q)}(x) = \prod_{k=1}^{K_m} [s_{km} \cdot (x_{v(k,m)} - t_{km})]_+^q \tag{1}$$

with products involving the truncated power functions with polynomials of a lower order than q. These functions are the result of recursive partitioning and they are a subset of a complete tensor product ($q = 0$) spline basis with knots at every (distinct) marginal data point value [18]. The application of algorithms allows us to have the model:

$$\hat{f}(x) = a_0 + \sum_{m=1}^{M} a_m \prod_{k=1}^{Km} [s_{km} \cdot (x_{v(k,m)} - t_{km})]_+ \tag{2}$$

in which a_0 is the coefficient of the constant basis function B_1, while the sum is over the basis functions B_m. A transformation of the model is useful to have a better predictive evidence on the relation between the response y and the covariates x.

4.1 The Results

We apply the MARS model to the three groups (see Fig. 1a). The comparison between the determinants useful in the wealthiest areas and the South must show deficiencies on which formulate policy. We present the MARS results considering no. 22 variables for the three groups (the first Center-North group is the black in Fig. 1a, while Center-North 2 is the grey group):

GDP_{CN1} = 29366,3498343309 − 3589,35951639091 * max (0; − Differential_lending_rates − 0,03970285894958) + 564,977344570989 * max (0; 17,330847237003 − NEET_F) + 647,622010522125 * max (0; VA_comm − 23,1695158977861) − 338,738840601931 * max (0; 23,1695158977861 − VA_comm) − 291,628095772613 * max (0; Edu_5–8_F − 14,9) + 317,2903450178 * max (0; 14,9 − Edu_5-8_F) − 95,6111400965899 * max

(0; 30,266629949516 – Export) + 286,096817645155 * max (0; Edu_3–4_M – 41,8) + 322,856140634558 * max (0; 41,8 – Edu_3-4_M) – 1310,59787295588 * max (0; Enrollment_buss – 1,15056059797117) – 609,475268577884 * max (0; Edu_3–4_M – 46,9) – 75,5817185069516 * max (0; Broadband – 70,3460464008)

GDP_{CN2} = 32552,5479458084 – 181,177256150065 * max (0; 16,9 – Edu_5–8_F) + 705,807181891711 * max (0; VA_agr – 2,46543766459935) + 3495,79573171618 * max (0; 2,46543766459935 – VA_agr) – 199,697609189166 * max (0; VA_pubbl – 22,08488708359) – 300,423449225602 * max (0; NEET_M – 12,979390509693) – 497,853182545221 * max (0; VA_finance – 26,8758306675439) + 768,032672652473 * max (0; 26,8758306675439 – VA_finance) – 177,587312671335 * max (0; Dropout_F – 15,335292546086) + 449,159846179549 * max (0; Empl_lifelong_M – 6,81555362821625) – 24,309612064087 * max (0; 80,8871595330739 – Broadband) – 218,746529253119 * max (0; 46,1 – Edu_3–4_F) – 504,163985425754 * max (0; Unempl_lifelong_F – 6,41037014932596) + 383,086153331738 * max (0; 6,41037014932596 – Unempl_lifelong_F)

GDP_S = 17071,1322439226 + 131,320774988255 * max (0; 33,5309920231828 – NEET_F) + 155,796598835784 * max (0; Dropout_F – 18,9348238394318) – 342,820844783344 * max (0; Edu_0–2_F – 53,1) + 216,444004595303 * max (0; 53,1 – Edu_0–2_F) – 74,4855093336676 * max (0; NEET_M – 19,1838437206716) + 273,30143729301 * max (0; 19,1838437206716 – NEET_M) + 263,083417772284 * max (0; Edu_0–2_M – 46,8) – 151,55129092139 * max (0; VA_comm – 19,677182384134) + 443,382569327129 * max (0; 19,677182384134 – VA_comm) – 338,422499845198 * max (0; VA_finance – 23,3979742801912) – 91,286233129198 * max (0; 23,3979742801912 – VA_finance) + 250,627730663668 * max (0; Empl_lifelong_F – 7,73188152439938) + 708,175041261683 * max (0; 3,99276970915113 – VA_agr)

The results show differences between the two groups of the Center-North. The first one is based on the strength of manufacturing businesses in exporting abroad and obviously the group needs the credit leverage and a trained human capital. The second one encloses the Northern regions relatively more affected by the crisis, however, the added value of different sectors is important, but also the continuous training to qualify workers and retrain the unemployed. Even in this case the human capital plays an important role. In the South, the "useful" human capital is not present, and NEET and school dropout are social problems. It is significant the presence, albeit in subsequent knot of the model, of different sectors whose added value is statistically significant. For having a focus on education and vocational training, we also present MARS result on the solely human capital variables for the three groups:

GDP_{CN1} = 28040,8757383946 + 281,958908864165 * max (0; 19,2 – Edu_5–8_F) + 692,033056856368 * max (0; 17,330847237003 – NEET_F) – 1531,92671671789 * max (0; Edu_3–4_M – 46,9) – 1312,87441845612 * max (0; 4,90952417557076 – Empl_lifelong_M) + 664,422864118961 * max (0; Edu_3–4_F – 42,2) – 311,470529768982 * max (0; NEET_M – 12,392450034517) – 355,391872361449 * max (0; Unempl_lifelong_M – 7,82242927248468)

GDP_{CN2} = 55961,7225821171 – 7117,07669234711 * max (0; Edu_5–8_F – 16,9) + 6428,40611739239 * max (0; 16,9 – Edu_5–8_F) + 571,171256171591 * max (0; Unempl_lifelong_M – 9,95934959349594) – 262,481927561333 * max (0; 9,95934959349594 – Unempl_lifelong_M) + 1459,70787195025 * max (0; 5,59284116331096 – Unempl_lifelong_F) – 6472,49939488940 * max (0; Edu_0–2_F – 37,2) + 5975,92944332297 * max (0; 37,2 – Edu_0–2_F) + 696,174280430151 * max (0; Empl_lifelong_M – 6,81555362821625) + 722,070000598687 * max (0; Edu_5–8_M – 15) – 6383,39245658321 * max (0; Edu_3–4_F – 42,6) + 6607,32344887727 * max (0; 42,6 – Edu_3–4_F) + 641,953599419053 * max (0; 14,294401061366 – NEET_F)

GDP_{S} = 17085,4008884516 + 220,661529522481 * max (0; 33,5309920231828 – NEET_F) + 327,869417021748 * max (0; Dropout_F – 18,9348238394318) – 90,3335055675469 * max (0; NEET_M – 25,8345420570518) + 228,279499242398 * max (0; 25,8345420570518 – NEET_M) + 353,520059663269 * max (0; Edu_3–4_F – 38,6) – 321,184170529905 * max (0; Edu_0–2_F – 52,6) + 119,724901898192 * max (0; Edu_0–2_M – 46,8) – 575,788189577109 * max (0; 3,89405339219256 – Empl_lifelong_M) – 314,531903433760 * max (0; 7,70803092691886 – Unempl_lifelong_M)

This detailed focus confirms that, in the Southern area, early school dropout and unemployment afflict the local society damaging one of the most important long-term resources. In the last knots, values on vocational training (men only) are relevant, while completely lacks the relevance of secondary and tertiary education, which instead are confirmed (and in some cases in the first knots) in the other two groups (and for both genders, thus confirming more equality on education and employment opportunities).

5 Policy Suggestions and Conclusions

In this study, we investigate and compare the different income determinants in three cluster of Italian regions. The aim is to observe the deficiencies of the less wealthy area and most affected by the 2007 crisis, identified with the so-called *Mezzogiorno*. Our focus is on the level of human capital, seen as education and vocational training. We apply a MARS model to the three groups to search for the statistically significant variables. The results show that the strengths of the North refer to businesses capacity in export thanks to several local characteristics, as educated workers and a more efficient financial system. This is missing in the South, plagued by school dropout, unemployment and young NEET problems (see Sect. 1). Of, course, also in the North we would expect a greater contribution of human capital, while in the south only primary education is relevant, as in Di Liberto [12]. The poor economic vitality in the South discourages educated workers, forcing them to migrate toward the northern regions or abroad [7], enhancing regional inequality being a skill-selective migration [17]. The mobility of workers between the southern regions could be a short-term solution but there are deficiencies in the exchange of labor information required in this case [15]. Obviously, in the long term, incentives and facilities should be provided for businesses, which in the past had shown competitiveness with local specializations since the European integration [6]. The education system should also be improved, up to the universities [3], but for this purpose we should first change the social and cultural substrate, towards a model that encourages and rewards investment in advanced education.

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Information Manipulation and Web Credibility

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Abstract. Fake information, news, and reviews are overloaded in the era of big data. We use an agent-based model to simulate social interaction between information producers and consumers. Whether the information producers manipulate true or fake information depends on individual consumers attitude to truth or presentation of information. Consumers adapt themselves to accept or reject information and may evolve or learn socially from the others. Honest and dishonest producers select production strategies and also evolve from the same type of producers. We unexpectedly find that dishonest producers may produce true information because consumers co-evolve with producers by raising their standard on truth of information. To prevent fake information diffusion, let consumers take social responsibility by raising standard on truth of information improving social welfare and web credibility in the era of information overload.

Keywords: Information manipulation · Web credibility · Fake information

1 Introduction

Web content has become essential for many users in making decision for shopping, employment, education, health, finance, and investment. In the era of big data, surfing on the internet may deteriorate the information overload instead of solving or mitigating it. Social media not only makes information overload more prevalent, but also fake information, news, and reviews overload becomes more serious. A lot of fake information, news, and reviews has been surfed and diffused on the internet. For example, Facebook users complained that fake news had influenced the U.S. presidential election. The reviews made on trip site are deceiving because fake comments are posted without verification.

Online reviews influence opinions and change business trends, while firms adopt comments to create value for customers. Nonetheless, information overload deters consumers to receive true information when making a decision [2,4].

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Internet has become an important source of information that significantly affects people social, economic and political life. The content availability on web is the basis for the operation of digital economy. However, fake information is more powerful and devastating than negative information. Thus, Wierzbicki et al. (2014) classify information to true or false properties [8].

The effects of online review to restaurant and trip are the focus of Anderson and Magruder (2012) [1] and Mayzlin et al. (2014) [6], respectively. Although the effects of fake or positive reviews on consumer and producer choice are discussed in [7,9,10], how to prevent fake information diffusing is important but less studied. Let us focus on the issue of preventing fake news. By considering behavioral explanations and preference for punishing selfish, the rejection of trading information lessens the consumers gain but lessens the producers gain even more [3]. Even if there are laws that prohibit misleading information, revealing fake reviews is complicated [5].

We use an agent based model to simulate social interaction between information producers and consumers and express the dynamics whether the information producers manipulate true or fake information depending on individual consumers attitude to truth or presentation of information. Therefore, we rationalize and refine the model of Wierzbicki et al. (2014) which is overlooked. The contributions is summarized as follows. First, the good presentation of information has its value on consumers and results in those dishonest producers may produce true information as honest producer. Second, fake information but accepted by consumer has disutility. Under this circumstance, the honest and dishonest producers almost simultaneously choose good and truth strategy in the beginning. Third, punishment mechanism is social costly. Let consumers acknowledge that accepting fake information is deleterious and take their social responsibility to prevent fake information by raising signal-threshold. Dishonest producers voluntarily and eventually adopt good and true strategy. Consumer side approach benefits our society in the era of big data.

Section 2 provides the baseline model. Section 3 provides the refined model and simulation. Section 4 concludes.

2 The Baseline Model

The baseline model follows Wierzbicki et al. (2014). There are 100 producers and each one produce a piece of information. This information has two features or attributions: its content could be true or fake and its presentation could be good or bad. According to information attribution, producers are classified into two types. The first type is honest producers who intend to produce true information. The second one is dishonest producers who tell lies and intend to produce fake information. Accordingly, each type producer has four possible strategies as {GT, BT, GF, BF}, which represents Good and Truth (yellow), Bad but Truth (red), Good but Fake (green), and Bad and Fake (Blue) strategy, respectively. Consumers then consume this information and accept or reject it depending on a signal-threshold on their mind which is comprised by truth or fake content, and good or bad presentation. Once consumers read, listen, or watch this information, they compare it with signal-threshold. If consumers feel this information beyond their threshold, consumers accept it which is true information and thus gain positive utility +2. Otherwise, consumers accept it which is fake information and gain negative utility −2. Once consumers reject information, they get zero payoffs. Figure 1 shows payoffs of consumers.

Agents	Information is accepted by consumer				Information is rejected by consumer			
	GT (yellow)	BT (Red)	GF (green)	BF (blue)	GT (yellow)	BT (Red)	GF (green)	BF (blue)
Consumer	2	2	-2	-2	0	0	0	0
Honest Producer	4	5	1	2	-1	0	-3	-2
Dishonest Producer	1	2	4	5	-1	0	-3	-2

Fig. 1. Payoffs of consumer and producer

The payoff of information producer is denoted as

$$U(P) = S(TF) + C(TF, L)$$

S: the gain of content producer.
C: The costs function of information production.
The surplus of the content producer is represented as

$$\mathrm{S(TF)} = \theta\mathrm{TF} + \phi.$$

θ: $\theta > 0$ represents an honest producer and $\theta < 0$ represents a dishonest producer.

The cost function of the content producer is given by

$$\mathrm{C(TF,\ L)} = \lambda\mathrm{TF} + \mu\mathrm{L} + \tau$$

λ: $\lambda < 0$ implies that increasing the fake of the produced information raises the cost of its production because the costs is measured by mental and physical effort for manufacturing or manipulating fake information.

μ: $\mu > 0$ denotes that changing the presentation of information from bad to good looking increases the cost.

τ: $\tau > 0$ denotes a fixed cost.

TF: TF = 1 (0) denotes the true (fake) information. L: L = 1 (0) denotes the presentation of information is good (bad).

Given their sign remained the same and specific values of these previous parameters, producers payoff is also provided in Fig. 1.

Now, we explain consumer behavior by introducing the signaling game. In the signaling game consumers can not observe producers type. The signal is randomly chosen from a normal distribution because we assume that individual consumer is heterogeneous and has different preference about the truth or fake content and good or bad presentation of consuming information.

$$Mean = w_{TF} \times TF + w_L \times L$$

$$\text{Standard deviation} = \sigma$$

w_{TF}, w_L: are weights of the True/Fake and Good/Bad properties of the produced information. $w_{TF} + w_L = 1$

σ: σ is a constant which implies the degree or level of distraction in the era of information overloading. The higher σ it is, the more distractive of a consumer it is when the reviewer consecutively consumes a piece of information. Given $\sigma = 2/3$, we call them as distractive consumers whereas $\sigma = 0.05$ represents consumers are not distractive. Denote ϵ as the ratio of distractive consumer. There are distractive consumers if $\epsilon = 1$ and there are no distractive consumers if $\epsilon = 0$.

In each generation or 20 times, both producer and consumer have 1% chance to evolve or learn from each other. Producer randomly chooses one producer and compares its payoff with selected-producer payoff. Producer imitates or copies selected-producer strategy if the selected-producer payoff is larger than itself. Consumers evolve in the same way by adjusting their acceptance signal-thresholds.

3 The Refined Model and Simulation

We rationalize and refine the model of Wierzbicki et al. (2014). New insights are uncovered in Sect. 3.1. In Sect. 3.2, some unexpected results are revealed in the refined models.

3.1 Dishonest Producers Change Their Strategy Slowly to Tell Truth

Given different combinations of the ratio of distraction consumer ϵ and weights of the True/Fake properties w_{TF}, we simulate the producers strategy evolution and consumers threshold evolutionary dynamics. Each simulation runs 10,000 times as a round and 10 rounds are done. We select the classical ones which prevails the similar patterns and are showed as Figs. 2, 3 and 4.

The honest producers change its strategy from {GT}(yellow) to {BT}(red) at a relative low weight, $w_{TF} = 1/3$. On contrast, the dishonest producers strategy is changed from {GF}(green) to {BT} at a relative high weight, $w_{TF} = 2/3$. These dynamics are more prevalent when more consumers concentrate on the truthfulness of information or more consumers are less distractive. In other

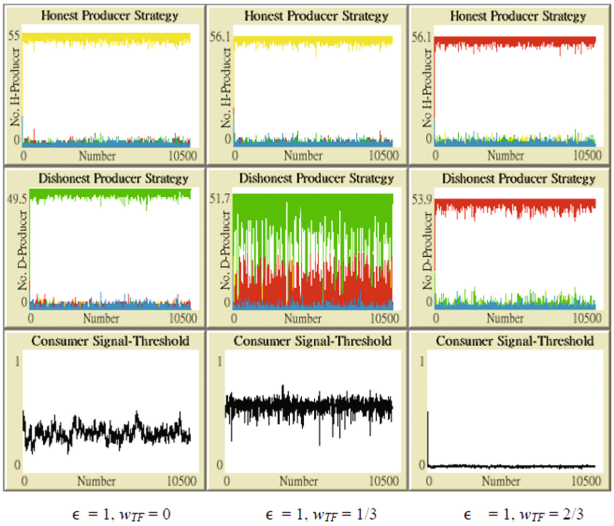


Fig. 2. Evolutions of producers strategy and consumers signal-threshold ($\epsilon = 1$)

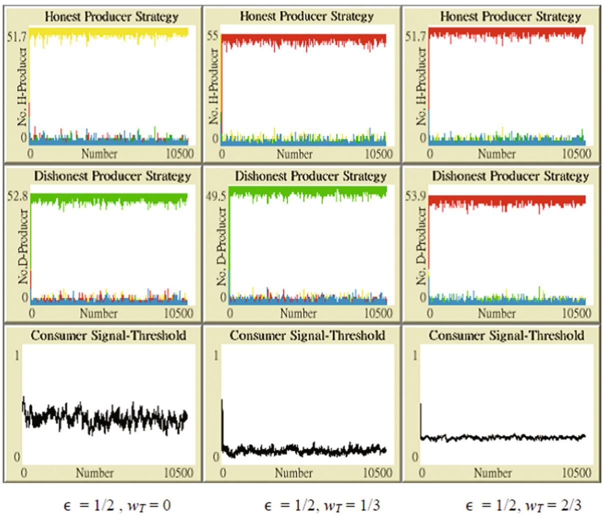


Fig. 3. Evolutions of producers strategy and consumers signal-threshold ($\epsilon = 1/2$)

words, honest producers change their strategy more quickly than that of dishonest producers. From the view point of honest producer, they would like to choose {GT} because all the consumers judge the information by presentation or appearance. When consumers reduce the weight on appearance and increase more weight on truth, producers find that the {GT} is no longer a prevailing strategy and it is replaced by {BT} to save the presenting cost when $w_{TF} = 1/3$.

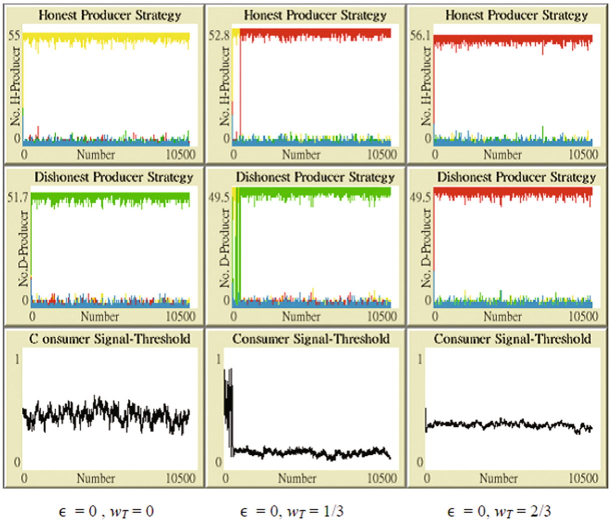


Fig. 4. Evolutions of producers strategy and consumers signal-threshold ($\epsilon = 0$)

The honest producers still adopt {BT} strategy when consumers continue to reduce the weight on appearance. On the other side, dishonest producers still adopt {GF} strategy to cheat the consumers when the truth weight is one third. Eventually, the dishonest producers change their strategy from {GF} to {BT} when consumers put more weight on truth, $w_{TF} = 2/3$. Comparing their strategies, we find honest producers change their prevalent strategy more quickly than dishonest producers. These results are true when there are little distraction consumer, $\epsilon = 0.5$ or $\epsilon = 0$. Because dishonest producers earn additional gain +2, they should be accompanied with consumers taking the truth of information more seriously. Furthermore, honest producers just can earn additional gain +1, they don't need that consumers take the truth of information so seriously.

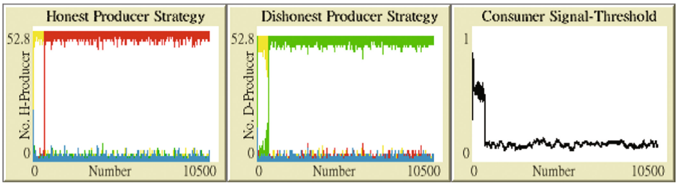
Now, we are going to discuss the evolution of consumers, which are showed by signal-threshold. A trend is revealed in Fig. 2, 3 and 4 except for $\epsilon = 1$ and $w_{TF} = 1/3$. Given the same weights of true, the less of the distractive consumers it has, the higher the signal-threshold it is. When consumers concentrate on the truth of information, they have more confidence on their decision of acceptance which results in a high signal-threshold.

3.2 Dishonest Producers May Produce True Information

In this section, we refine the baseline model in different ways. First, we argue that the good presentation of information has its value on consumers and producers which dishonest producers may produce true information as honest producer. The second argument is that fake information but accepted by consumer has disutility. Third, truth information but rejected by consumer also has disutility.

Finally, a way from consumers side that let the dishonest producers tell the truth is compared with punishment mechanism on producer.

The Good Presentation of Information Has Its Value. When a piece of information is presented well and accepted by consumer, consumers payoffs should become larger than that the situation of the baseline model. It is equivalent that we change the consumers payoff from {GT, BT, GF, BF} = $\{2, 2, -2, -2\}$ to $\{3, 2, -1, -2\}$. The interesting cases and regimes change are easily happened in the situation of $w_{TF} = 1/3$. In the beginning, honest and dishonest producers randomly choose their strategies. Consumers make decisions and evolve through social learning. Consumers then co-evolve their signal-threshold with producers. Honest producers revolution and dishonest producers revolution may emerge a situation that they both use {GT} or yellow strategy and a classical case is showed in Fig. 5.



$\epsilon = 0$, $w_{TF} = 1/3$ $\epsilon = 0$, $w_{TF} = 1/3$ $\epsilon = 0$, $w_{TF} = 1/3$

Fig. 5. Dishonest producers may produce true information

Now, we discuss the relation between consumer gain and signal-threshold. Figure 6 shows the detail of relation between consumer gain and signal-threshold. The consumer gain is measured for each generation. To maximize utility, consumers adjust their threshold at relative high level in the beginning because we randomly give producers strategy. It is unexpected that dishonesty producers also tell the truth facing high signal-threshold. It means that dishonest producers take high signal into account and tell the truth. As a result, we believe that the good presentation of information has its value on consumers and producers which dishonest producers may produce true information in the beginning as honest producer. However, the dishonest producers also evolve by social learning and produce fake news eventually. Consumers accept the fake information and get its zero expected utility by reducing signal-threshold.

Fake Information but Accepted by Consumer Has High Disutility. When fake information is accepted by consumer, its payoff should be worse because the consumer is cheated by producers. If we change the payoff {GT, BT, GF, BF} = $\{2, 2, -2, -2\}$ to $\{3, 2, -2, -3\}$, the regimes change also happen easily in the situation of $w_{TF} = 1/3$. Under this circumstance, the honest and dishonest producers almost simultaneously choose {GT} in the beginning of each round which is similar to Fig. 5.

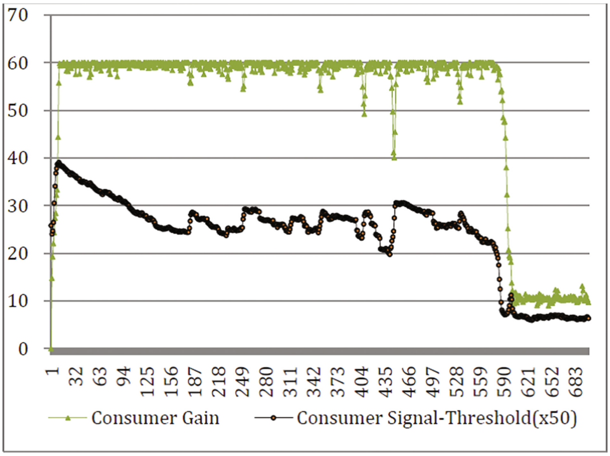
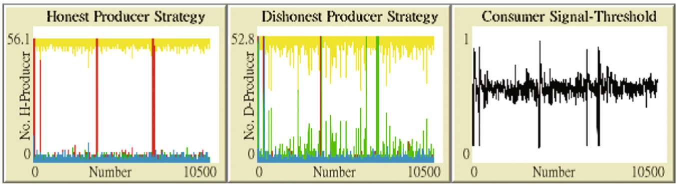


Fig. 6. Relation between consumer average gain and signal-threshold

Truth Information but Rejected by Consumer Also Has Disutility. A lot of fake information, news, and reviews spread out on the internet. Consumers often mislead by fake information without attention. Some of consumers may be aloof and refuse to accept true information. When true information is rejected by consumer, its payoff should be worse. Thus, we change the payoff {GT, BT, GF, BF} $= \{0, 0, 0, 0\}$ to $\{-2, -2, 0, 0\}$. Under this circumstance, the honest and dishonest producers would not like to choose {GT} in the beginning of each round. The intuition is straightforward. As consumers reject and generate disutility on true information, dishonest producers do not have incentive to produce true information.

Two Approaches to Prevent Diffusion of Fake Information. Punishment on rejected cases is an effective way to prevent the diffusion of fake information but it is costly. For example, Facebook provides their user a tool or button to raise a flag and implies the consumed information could be fake. Then, Facebook will ask the objective third party to verify whether this ostensible and flagged information is fake. If it were fake, Facebook reduces this information ranking on the site, which reduces information producers gain. We simulate the practical punishment mechanism as real world. Allowing sufficient high probability to check fake information on producer, we find that punishment is effective when consumers are easy to distraction. In contrast, punishment is less effective when consumers are less distractive. It requires $1/2$ probability to check the rejected or flagged information in this simulation. As a result, consumers reduce the signal-threshold and accept all the information. No matter it is true or not. Although punishment is effective, this kind of mechanism is costly from the view point of social welfare.



$\epsilon = 0$, $w_{TF} = 1/3$ $\epsilon = 0$, $w_{TF} = 1/3$ $\epsilon = 0$, $w_{TF} = 1/3$

Fig. 7. Dishonest producers produce true information eventually

Another positive way is originated from consumer. We may provide some training to teach consumers how to identify the fake information through education, for example. Let consumers acknowledge that accepting fake information is deleterious. It is equivalent that we change the consumers payoff from {GT, BT, GF, BF} = $\{2, 2, -2, -2\}$ to $\{3, 2, -3, -4\}$. We find not only dishonest producers tell the truth but also consumers raise their signal-threshold which is showed as Fig. 7. It implies that consumers take their social responsibility to prevent fake information by raising signal-threshold and let dishonest producers voluntarily adopt good and true strategy. This approach edifies us and benefits our society in the era of big data.

4 Conclusion

We rationalize and refine the model of Wierzbicki et al. (2014). New insights are uncovered. First, the good presentation of information has its value on consumers and results in those dishonest producers may produce true information as honest producers. Second, fake information but accepted by consumer has disutility. Under this circumstance, the honest and dishonest producers almost simultaneously choose good and truth strategy in the beginning. Finally, the way from consumers side that let the dishonest producers tell the truth is compared with punishment mechanism on producers. Punishment requires high probability to check the flagged information. No matter it is true or not, consumers reduce the signal-threshold and accept all the information. Therefore, punishment mechanism is social costly. Another positive way is originated from consumer. Let consumers acknowledge that accepting fake information is destructive and take their social responsibility to prevent fake information by raising signal-threshold. We find that dishonest producers voluntarily and eventually adopt good and true strategy. This approach improves our social welfare as well as web credibility in the era of big data.

Future work will discuss the strategic matching and ranking behavior of platforms. How negative reviews strategy is used in the framework of duopoly is also worth more in-depth research.

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A Data Mining Analysis of the Chinese Inland-Coastal Inequality

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Abstract. As in many countries, even in China the socio-economic changes have affected income inequality in recent decades. The various economic opportunities have led to different paths of development causing severe disparities in GDP *per capita* level. In addition to the well-known Chinese rural/urban inequality, in this work we study the inland/coastal differences. There are many known causes of inequality, but we aim to discover the actual determinants of the local GDP and, therefore, of income in a period that includes the international economic crisis started in 2007. With this aim, we use different variables to obtain clusters of the Chinese provinces in the period 2004–2015 and, subsequently, we investigate the determinants of income with a multivariate adaptive regression splines (MARS). There is an extensive economic literature on the Chinese case: MARS allows us to integrate this literature enabling us to find which GDP determinants are the most relevant in the certain areas of China.

Keywords: Inland/coastal income inequality · Chinese provinces · MARS

1 Introduction

Two major types of income inequality exist in China: urban-rural and coastal-inland. The first type causes more differences but is stationary in time, while the second is strongly increased over time in recent decades [10, 27]. In this study, we analyze the second type of inequality by comparing numerous socio-economic variables for the Chinese provinces (the first-level administrative divisions) with a MARS model, that is able to efficiently find relations among data within complex datasets (see Sect. 2). MARS analysis is done after a division of Chinese provinces in a wealthiest and in a relatively poor groups based on the current local characteristics. The analysis allows us to compare the determinants of GDP in order to observe the differences that cause severe disparities

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in income and economic development, on which to suggest policy intervention. In fact, a strong income inequality between the population of the coastal area and that of the inland zone exists, largely due to the different levels of development that occur between the provinces. The economically advanced coastal area is advantaged especially in trade - one of the strengths of the Chinese economy - whereas internal rural areas are distant from the first area in terms of wealth and growth opportunities. Inequality between provinces is also influenced by the different start of the Chinese economic reforms, industrialization and tertiarization, started before in the provinces nearby to the coast. Furthermore, the intervention was influenced by the fact that the coastal provinces were the more urbanized due to government interventions in the mid-1980s [20].

Both polarization and inequality measures have been tested with similar results proving the increasing differences among the Chinese provinces [27]. In addition to the interprovincial inequality, China is also characterized by wide income inequality (within country). The *China Family Panel Studies* of the Peking University[1] reveals as the richest 1% of households maintains a third of the total national wealth (also suggesting strong differences in education and health levels). In this regard, Gini index is 42.2 (2012) slightly higher than the US, while, at the same time, the poverty headcount ratio (at $ 1.90 per day), which affected more than 80% of the population in the 1980s, has become less than 2% after 2010 (World Bank data).

However, the divergence between growth paths of the coast and inland areas is greatly increased by the 1990s, in a period of strong economic growth [2]. This increasing socio-economic problem is observed as a North-South divide, that is the excessive inequality of income and development between two main areas of the same country [23] as in many advanced economies (e.g. [7]). Hao and Wei [8] evidence that the economic policies in the period subsequent to the 1978 economic reform [17] did not help the convergence between these areas. The coastal area exploits a geographical advantage that facilitates agriculture and trade (especially after the opening to international markets) and encourages the positioning of businesses and the spread of knowledge and spillovers. Several studies have tried to investigate other causes of inequality: Liu and Li [14] argue that the quality of human capital, the allocation of physical capital, and the level of available technology are key factors; Tsui [19] considers the role of the local productivity level; while Hao and Wei [8] synthetically define some important factors: «*globalization, decentralization and marketization*».

Our investigation regards the search of the main causes of inequality as in a traditional case of regional dualism, and is focused on the appropriate variables that the literature indicates as determinants of income and inequality. The first step of this investigation (Sect. 4) confirms that there is an evident division of the country into are as characterized by a different economic development, thus not only based on the average income but also considering many other socio-economic aspects. To analyze the causes of the income gap, we use a MARS analysis [6] applied to a dataset of 14 variables with respect to the Chinese local aggregates level for the 2004–2015 period (Sect. 5). This analysis allows us to observe efficiently the relationships between many variables and, at the same time, trying to limit the multicollinearity problems. The comparison of the

[1] http://www.isss.edu.cn/cfps/EN/.

most important determinants in the period considered tell us if there are chances of filling the gap by supporting the less wealthy area exploiting, for example, the development of human capital and the labor productivity, or the international and interprovincial trade.

2 Methodology

We use a MARS analysis [6] to select the variables that influence GDP *per capita* in the Chinese provinces because our dataset is made up of many heterogeneous variables. In fact, problems related to multicollinearity could be present, but MARS model can help in this regard. This is possible because this model builds relationships from the input variables. As in Friedman [6], MARS uses a forward pass and a backward pass phases: while the first phase creates an over fit model with a good fit to the data, the second phase examines (singularly) each term present in the dataset and eliminates the least effective ones in the search of the best sub-model. The multivariate equation considered is

$$\hat{f}(x) = \sum_{i=1}^{m} a_m B_m(x)$$

in which $B_m(x) = I[x \in R_m]$. MARS uses a specific class of basis functions as, these functions and the parameters estimated using OLS are used to provide predictions. The basis functions allow to select and study only sub-regions of data, and this is useful to find the effective interactions between data.

The linear functions follow the form $\max(0, x - t)$ with a knot defined at value t. Expression max(.) means that the only positive part of (.) is used otherwise it assigned a zero value. The multivariate splines algorithm forms models from two-sided truncated functions of the predictors (x) of the form: $b_q^{\pm}(x - t) = [\pm(x - t)]_+^q$.

The purpose is to set the coefficient values to fit the data efficiently. After several transformations, we obtain the model:

$$\hat{f}(x) = a_0 + \sum_{m=1}^{M} a_m \prod_{k=1}^{Km} [s_{km} \cdot (x_{v(k,m)} - t_{km})]_+ \quad (1)$$

where a_0 is the coefficient of the constant basis function B_1, and the sum is over the basis functions B_m.

3 Data

With the aim of studying the provincial convergence in terms of GDP, several studies suggest using data on the human and physical capital, the local infrastructure and their characteristics, the role of the institutions and the possible application of policy interventions [8]. As done by Jian *et al.* [9] for China, our target variable is GDP *per capita* (source: National Bureau of Statistics of China).

Data on education refer to the increasing role of human capital in the transition toward high-tech sectors, with a higher value added. Also in this case, strong differences exist in China in the inland-costal access to education [18]. A second group of variables refers to the contributions of each economic sector to GDP. As done by Barro and Sala-i-Martin [1], we consider the added value of the main sectors. Of course, an endogeneity problem is evident in this relationship [3], but we do not want to study the economic growth process in this work, since we are searching for the different variables influencing GDP. At the same time, our aim differs from that of an augmented Solow model.

Data on human capital are (source: National Bureau of Statistics of China):

– Edu_primary: % of population with less than primary, primary and lower secondary education (male and female);
– Edu_secondary: % of population with upper secondary and post-secondary non-tertiary education (male and female);
– Edu_tertiary: % of population with tertiary education (male and female).

Data on the value added and on the employment level (source: National Bureau of Statistics of China) are:

– VA_accomod: value added for accommodation and food services industry;
– VA_agric: value added for agriculture, forestry and fishing industry;
– VA_construct: value added for construction industry;
– VA_finance: value added for finance industry;
– VA_general: value added for general industry;
– VA_transport: value added for transportation, storage, information and communication services industry;
– VA_wholesale: value added for wholesale and retail trade industry;
– Unempl: unemployment rate (%).

4 Clustering

In order to define the various groups, we consider many socio-economic local characteristics, although we expect to observe groupings of neighboring territories because the economic performance of an area affects its bordering in an open economy [4]. We propose Hierarchical and K-means clustering of the Chinese provinces considering the no. 14 independent variables and GDP *per capita*. The analysis is repeated for no. 12 years and in the case of presence in more than one group (for the same number of years), we include the province in the most recent cluster, thus considering the post-2007 period as the most relevant.

We note that the Hierarchical clusters are not acceptable in forming a proper division useful to this study, while the K-Means gives us the opportunity to form two "wealthiest" group (groups 1 and 2) that can be compared with the "poorest" one (group 3).

5 MARS Results

We propose the synthetic results of three MARS (Table 2) and the resulting equations. The variables included in the equations are those significant in various groups on which to define policy implications. The numbers of the groups refer to Table 1, where the first two groups are formed by the wealthiest local administrations.

Table 1. Clustering division (clusters are represented by numbers)

	K-Means	Hierar.		K-Means	Hierar.
Beijing	1	1	Hubei	2	3
Tianjin	1	2	Hunan	3	3
Hebei	2	3	Guangdong	2	3
Shanxi	3	3	Guangxi	3	3
Inner Mongolia	1	3	Hainan	3	3
Liaoning	1	3	Chongqing	2	3
Jilin	2	3	Sichuan	3	3
Heilongjiang	3	3	Guizhou	3	3
Shanghai	1	1	Yunnan	3	3
Jiangsu	1	3	Tibet	3	3
Zhejiang	2	3	Shaanxi	3	3
Anhui	3	3	Gansu	3	3
Fujian	2	3	Qinghai	3	3
Jiangxi	3	3	Ningxia	3	3
Shandong	2	3	Xinjiang	3	3
Henan	3	3			

GDP_1 = 1033,96660322005 + 413160,376159238 * max(0; Edu_ter_F – 0,0383745886392903) + 252734,012324443 * max(0; VA_Transport – 0,051967824) + 1141246,62497094 * max(0; 0,051967824 – VA_Transport) – 249693,5024424 * max(0; 0,476195559 – VA_General) – 383528,211280377 * max(0; 0,266784837887184 – Edu_primary_M) + 1112684,66100817 * max(0; VA_Finance – 0,034604946) + 1053503,1986083 * max(0; VA_Construct – 0,049534162) – 743562,936596802 * max(0; VA_Finance – 0,078053468) + 296687,719896616 * max(0; VA_Wholesale – 0,11521967) + 391258,397828528 * max(0; Edu_sec_F – 0,572576717)

GDP_2 = 34978,0066470607 + 122718,953626549 * max(0; Edu_ter_F – 0,089028613) – 101734,935875406 * max(0; 0,089028613 – Edu_ter_F) – 10790,5116349984 * max(0; Unempl – 3,4) – 13824,4228528417 * max(0; 3,4 – Unempl) – 161686,568125691 * max(0; Edu_sec_F – 0,520147077469253) – 286368,620839801 * max(0; VA_agric – 0,108353436) + 283449,044390874 * max(0; 0,108353436 – VA_agric) + 209286,077729180 * max(0; 0,366677228 – Edu_primary_M) – 188473,908696592 * max(0; VA_General – 0,433561841) + 104668,130310659 * max(0;

0,433561841 – VA_General) + 212990,187373698 * max(0; Edu_sec_F – 0,564286792168107) – 983774,919851494 * max(0; VA_Accomod – 0,016677832) – 85778,7674524653 * max(0; 0,545898755619259 – Edu_sec_M)

GDP_3 = 19229,6178416053 – 152508,654081395 * max(0; Edu_ter_F – 0,103448275862069) – 26414,8573669962 * max(0; Edu_primary_M – 0,394430076089808) + 50403,5688466210 * max(0; 0,394430076089808 – Edu_primary_M) + 605770,697907295 * max(0; VA_Transport – 0,061497015) + 293799,430294194 * max(0; VA_Finance – 0,040181403) – 24230,3055091225 * max(0; VA_Agric – 0,092842803) – 188274,404690084 * max(0; 0,092842803 – VA_Agric) – 548253,602491482 * max(0; VA_Transport – 0,04,7983528) + 62237,8052988884 * max(0; VA_Construct – 0,086325195) – 2120,10134125125 * max(0; Unempl – 2,9) – 5076,65139101404 * max(0; 2,9 – Unempl) + 43285,6642159615 * max(0; 0,4,05201342 – Edu_primary_F) + 167074,584139715 * max(0; Edu_ter_F – 0,0451539001588885)

From these results, we note two important aspects: human capital, a fundamental resource in the current knowledge economy, is on average important in all Chinese areas, and many of the determinants of GDP are in common between the various groups. From Table 2, we note that the first group has an average GDP *per capita* equal to almost three times that of group no. 3 and it is the only group in which unemployment is not an economic problem. In the "poorest" group, the support of the added value of "general industry" lacks, and this macro sector is the most important among the added value types available for this analysis. Finally, a clear difference is noted in education: secondary education, although certainly important in the manufacturing industry, is missing in the poorest group no. 3.

Table 2. Summary statistics for the three groups.

GDP per capita	Group 1	Group 2	Group 3
Mean (observed)	58943,57	35938,97	21957,76
Standard deviation (observed)	25522,10	16939,31	10765,61
Mean (predicted)	58943,57	35938,97	21957,76
Standard deviation (predicted)	24913,36	16520,09	10271,13
Mean (residual)	0,00	0,00	0,00
Standard deviation (residual)	5540,92	3745,27	3225,26
R-square	0,95	0,95	0,91
R-square adjusted	0,94	0,94	0,90

Source: Authors' elaborations on National Bureau of Statistics of China data.

6 Conclusions

Inequality in China is a well-known phenomenon [8], a problem common to several advanced economies [1, 7]. Scholars generally refer to urban-rural duality in terms of income [11, 13, 24]. In this study, we aim to examine the national dualism identified in the coastal-inland disparity in terms of income and economic development. To this aim, we analyze several socio-economic variables related to the disparities at the Chinese provincial level, using a novel data mining technique (Friedman's MARS) that can find deeper relationships among data within complex datasets. We find that evident differences exist between the local administrations near the coastal area and in the inland area. Our cluster analysis highlights three distinct groups. The division gives us the possibility of a double rich-poor comparison between the determinants of GDP. The provinces of the first group, the wealthiest ones with an income almost double respect the rest of the country, benefit from a contribution of all macro-sectors with higher added value. The second group of the richest provinces confirms the importance of the general industry, which is lacking in the less wealthy group, in which, as in group 2, the importance of the agricultural sector (with low added value) is relevant. Regarding human capital, we see that advanced education is important throughout the country, and women's contribution is predominant. This is a very important aspect for long-term growth, coming from the result of previous specific investments. It is interesting to note the role of secondary education, which is useful for the productivity level of the average skilled workforce. Secondary education is not significant in the less wealthy provinces, while is present in the other two groups, confirming the different (and important) role of the general industry.

In addition to the variables analyzed in this study, a large part of the income divergence is definitely explained by total factor productivity [16] and productivity is strongly diverse in the various sectors considered in our analysis. Important roles are also related to education (for example, on the formation of the national elites [25]) and, of course, the ability to attract foreign direct investments [22]. In studies on inequality, the role of migration should be also considered (see a review of the literature in [5]). In this respect, the efficient movement of resources (in particular the labor force) has been studied as an efficient process that reduces disparities between the Chinese provinces [15]. Other factors explain the local differences. For Zhang [26], the entire coastal area has higher values of both industrial competitiveness and ability to attract foreign direct investments, indicating that this part of the country is the main site of production and exports of manufacturing goods. This is true since the mid-1980s, in which the strategic choices of open-door favored those areas privileged in business and with a specific cultural advantage [21]. At the same time, the excessive inequality implies a reduction in potential economic growth, because China needs to increase its level of human capital and this objective is not easily achievable by the poorest people, as generally happens in the hinterland and rural areas [12].

This preliminary investigation allows us to direct future research using other types of variables to investigate the Chinese local contexts. MARS analysis identified some important factors in various groups, but statistical problems remain: value added data pose the problem of endogeneity and should be treated with other econometric techniques or integrated with data on the characteristics of businesses and on other socio-economic aspects.

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The Cognitive Determinants of Social Capital. Does Culture Matter?

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Abstract. This paper addresses the relationship between social capital and cultural access. In doing that we provide a conceptual framework by moving from a cultural economics standpoint and by applying a Simultaneous Equation Model (SEM). Some linkages and relationships emerge through the analysis of cultural participation as a proxy of cultural capital and the accumulation of two selected dimensions of social capital.

Keywords: Social capital · Cultural capital · Simultaneous equation model

1 Introduction

Over the last three decades, social interactions have been replaced within the theme of development by a huge stream of research programs based on the social capital issue. In general, social capital has become an increasingly debated argument based on the belief that human (and economic) activity is deeply embedded in the social structure, and agents' decisions are always influenced by a wide range of social and cultural factors. This paper is placed within the multifaceted branch of research defined by cultural economics [18] and the scholars devoted to evaluating cultural capital (by cultural participation and consumptions) externalities [2, 3, 5]. Cultural Capital (CC) and Social Capital (SC) have been studied in different streams of research, but, to our knowledge, not much attention has been addressed to evaluating this supposedly virtuous relationship via cultural participation. It was difficult to find any space dealing with an independent role of culture in this intellectual body of work. The paper is divided into six sections: in Sect. 2, we discuss the conceptual framework that links SC and CC. In Sect. 3, we describe the empirical method by explaining the structural equation model and the econometric strategy adopted. In Sect. 4, we show data and discuss the results and in Sect. 5, we give our conclusions.

2 Conceptual Framework

Economic literature on social capital considers a social structure in which norms and social relations that cause reciprocity and civic engagement that foster social trust and

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cooperation and reduce the incentives for opportunistic behavior. We contribute to the debate in the literature by building on Schuller's work [21] and that of Onyx and Bullen [8] that posit that all forms of capital interact in complex ways. As for cultural capital, we move in the direction of Throsby [19, 20] who argues that it comes in both tangible and intangible forms. The culture fosters awareness of a multitude of socially relevant issues, and consequently might motivate individuals to taking more responsibility for the pro-social dimension of daily and longer-term practices, behaviors and habits. Cultural participation allows people to reshape their social identity. We can regard this behavioral dynamic as an advanced, post-industrial instance of the capability building process highlighted by Amartya Sen [13] in his seminal work. In that sense, it is important to stress that capability building and skills acquisition depend upon the social environment in which individuals are embedded [e.g. 4]. Cultural participation may be regarded as an investment activity with uncertain returns linked to the development, and active use, of the capability to be engaged more intensively by cultural experiences that contribute to accumulate a form of cultural capital. These characteristics of cultural participation are in line with the socially-situated theories of cognition [12, 15, 16] that have conceptualized identity as adaptive and embedded within social contexts. The importance of the cultural economics standpoint is that cultural participation is seen as an investment in experiences that combine (possible) monetary costs and cognitive costs [9]. The cognitive costs are related to the effort that people face during the cultural participation that is related to the sharpening of cognitive attitudes toward the unconventional and the unexpected, and to the harnessing of proactive responses to problematic situation related to low information. In that sense the open-mindedness and curiosity that comes with sustained cultural participation allow questioning existing conventions and meanings, inquiring about one's place in the world and in the society, and of reframing one's knowledge and belief systems into new coordinates [e.g. 1]. Although a full-fledged theoretical model of how cultural capital and social capital accumulation are related has not been developed yet to our knowledge, from our previous discussion we can conclude that there is a robust conceptual basis for some preliminary empirical work in this direction.

3 Methods

The two research questions of the study are: (1) Is there a simultaneous determination of linking and bridging social capital? (2) Does cultural capital affect the formation of social capital? To answer the questions, we will use a SEM estimated with 3SLS. We also add a 3SLS (CMP) estimated with a MLE technique, which produces heteroscedastic-consistent standard errors.

3.1 Simultaneous Equation Model

Usually, ordinary least square (OLS) is a good method to explain relationships between variables. Since we believe that there is a circularity process between the two types of social capital (linking and bridging social capital), OLS is a method that would produce inconsistent and biased estimates when the variables are jointly determined [see 6, 17]. Therefore, prior empirical research offers alternatives, i.e. the use of a set of equations in a simultaneous equation model (SEM) [7]. Each equation in a SEM should be a behavioral equation which describes how one or more economic agents will react to shocks or shifts in the exogenous explanatory variables, ceteris paribus. SEMs can be estimated with three-stage least square (3SLS), or two-stage least square (2SLS) [see 22]. Based on the development of hypotheses, and the argument of the direct and indirect relationship of linking and bridging social capital, our SEM is defined by the following equations:

$$VW_{it1} = \alpha_1 + \gamma_{11}MF_{it1} + \beta_{11}PW_{it1} + \beta_{21}cinema_{it1} + \beta_{31}pop_{it1} + \beta_{41}M\&E_{it1} + \beta_{51}theatre_{it1} + \mu_i + \lambda_t + \varepsilon_{it1} \quad (1)$$

$$MF_{it2} = \alpha_2 + \gamma_{12}VW_{it2} + \beta_{22}cinema_{it2} + \beta_{32}pop_{it2} + \beta_{42}M\&E_{it2} + \beta_{52}theatre_{it2} + \beta_{62}sport_{it2}\mu_i + \lambda_t + \varepsilon_{it2} \quad (2)$$

Where i is region in time period t, u is the error term, β_{nm} is the regression coefficient for the exogenous variable n in equation m. γ_{nm} is the regression coefficient for the endogenous variable n in equation m and α_m is the intercept in equation m. The endogenous, or jointly determined variables are VW and MF. The exogenous variables are cinema, pop, M&E, theater, sport and PW. μ_i represents a specific individual effect, λ_t represents a specific temporal effect. Table 1 summarizes the symbol and the description of variables.

Table 1. Symbol and description of variables

Variable	Symbol	Description
Social capital		
Voluntary work	VW	Percentage of people aged 14 and over to carried out voluntary work in the last 12 months
Meeting friends	MF	Percentage of people aged 6 and over who have met their friends daily in their spare time in the last 12 months
Cultural capital		
Cinema	Cinema	Percentage of people aged 6 and over to went to the cinema at least once in the last year
Pop music	Pop	Percentage of people aged 6 and over who went to a pop music concert at least once in the last year
Museum and exhibition	M&E	Percentage of people aged 6 and over who went to a museum and /or exhibition at least once in the last year
Theater	Theater	Percentage of people aged 6 and over to went to the theater at least once in the last year
Sport shows	Sport	Percentage of people aged 6 and over who went to a sports event at least once in the last year other variables places of worship PW percentage of people aged 6 and over who went to a place of worship at Ieast once in the last year
Other variables		
Places of worship	PW	Percentage of people aged 6 and over who went to a place of worship at least once in the last year

Source: ISTAT

The analysis focuses on the 20 Italian regions corresponding to the European level NUTS-2 over the period from 2001 to 2013. The temporal dimension of our database is 12 years instead of 13 years, because ISTAT (Italian national statistical institute) does not provide the data for the year 2004. We examine the significance level of the coefficient estimates in order to determine if a simultaneous determination between social capital variables exists. For example, to accept a two-way causality between linking and bridging social capitals we require that the coefficient estimates for VW and MF are significantly different from zero in Eqs. 1 and 2. Moreover, the signs of the coefficient estimates allow us to determine whether the two types of social capital are self-reinforcing; in other words, if they influence each other in a positive way. The Granger test performed on cultural capital and social capital shows that cultural capital Granger-causes social capital. In particular, we observe that the null hypothesis which assumes that cultural capital does not cause social capital is rejected at 1%. Conversely, when we test whether social capital Granger-causes cultural capital, the test does not reject the null hypothesis; consequently, social capital does not cause cultural capital[1].

3.2 Econometric Strategy

The most common system estimation method, in the case of SEM, is 3SLS, because it produces more efficient estimates than 2SLS [22, p. 560]. Why would 3SLS produce more efficient estimates? In 2SLS, the endogenous variables are regressed against the predetermined variables in the system. Then, the theoretical values are obtained and regressed as an OLS with the theoretical values instead of the empirical values in the endogenous variables. However, the simultaneous error is ignored between the equations and this will cause inefficiency. In 3SLS, a third step is added to 2SLS that considers these correlations. It is based on the efficiency argument that we chose to use 3SLS as the main system estimation method. However, we also chose to do 2SLS estimates in order to compare the different estimates. We apply the Beusch-Pagan LM test in order to test for overall system heteroscedasticity [14]. If heteroscedasticity is present in the model, it could affect the standard errors and maybe the hypothesis tests of the regression coefficients [6, p. 302]. Our 3SLS estimates do not reject the null-hypothesis of no overall system heteroscedasticity. For robustness, we add a new 3SLS, which is estimated with a method suggested by Roodman [10] in the CMP-function (Conditional (recursive) Mixed Process estimator). In particular, the CMP-function is built on maximum-likelihood estimator (MLE). MLE will find the parameters that are most likely to occur, which differs compared to the least square estimator (LSE) that will find the parameters that provide the most accurate description of the data. MLE is appropriate in multi-level equations such as SEMs [11]. 3SLS (CMP) with MLE produces heteroscedastic consistent standard errors (see Tables 2 and 3). Finally, in order to determine the potential simultaneous bias and see if the SEM with 3SLS as estimation method is justified, we estimate Eqs. 1 and 2 separately with OLS. In order to satisfy the OLS assumptions we need to test for heteroscedasticity and autocorrelation by using the Breusch-Pagan test

[1] Due to space limitations we do not report the results of the Granger test. Interested readers can make a request to the authors.

and examine the Durbin Watson statistic. The OLS estimates are affected by heteroscedasticity and autocorrelation (see Tables 2 and 3). We use the Newey-West standard errors, in order to obtain heteroscedastic and autocorrelated consistent standard errors [6, pp. 356–357].

Table 2. The voluntary work (VW) equation

Variables	3SLS	3SLS (CMP)	2SLS	OLS
Intercept	–5.077*** (–4.37)	–5.045*** (–5.61)	–5.077*** (–4.29)	–4.344*** (–4.47)
MF	0.145*** (2.61)	0.146*** (3.34)	0.145*** (2.56)	0.0668** (2.25)
PW	0.093*** (4.23)	0.093*** (8.40)	0.093*** (4.15)	0.132*** (5.58)
Cinema	–0.274*** (–13.60)	–0.261*** (–19.83)	–0.274*** (–13.36)	–0.256*** (–12.27)
Pop	–0.031 (–0.52)	–0.030 (–0.25)	–0.031 (–0.51)	0.006*** (0.13)
M&E	0.496*** (15.70)	0.490*** (16.97)	0.496*** (15.42)	0.507*** (0.13)
Theater	0.153*** (4.22)	0.154*** (5.17)	0.153*** (4.14)	0.084*** (1.73)
Temporal effects	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes	Yes
Hansen-Sargan over identification statistic:	2.845 [0.60]		3.287 [0.54]	
Overall system heteroscedasticity tests:	–250.768	–254.809	–172.704	
H0 = : No Overall System	[1.000]	[1.000]	[1.000]	
Heteroscedasticity Breusch-Pagan/ Cook-Weisberg test for heteroscedasticity:				41.21***
H0: Constant variance				[0.000]
Wooldridge test for autocorrelation in panel data				63.069***
H0: no first-order autocorrelation				[0.000]
# observations	240	240	240	240
R^2	0.9815		0.9815	0.9696

Note: ***,**,* statistically significant at level 0.01, 0.05 and 0.10.
The OLS model uses Newey-West standard errors.
The 3SLS (CMP) is built on a MLE, which produces heteroscedasticity-consistent standard error.
t-statistics are in parenthesis. p-value are reported in brackets.

Table 3. The meeting friends (MF) equation

Variables	3SLS	3SLS (CMP)	2SLS	OLS
Intercept	18.360*** (6.93)	18.359*** (6.93)	18.360*** (18.360)	23.092*** (7.32)
VW	1.451** (2.59)	1.456** (2.59)	1.457** (2.55)	0.479** (2.46)
Sport	0.898*** (3.32)	0.898*** (3.32)	0.898*** (3.26)	0.897*** (4.16)
Cinema	0.471*** (3.40)	0.471*** (3.40)	0.471*** (3.34)	0.275*** (4.40)
Pop	0.158 (0.81)	0.158 (0.81)	0.158 (0.80)	0.411** (2.22)
M&E	–1.293*** (–7.06)	–1.293*** (–7.26)	–1.293*** (–6.94)	–1.038*** (–11.51)
Theater	–0.323*** (–2.01)	–0.323*** (–2.04)	–0.323*** (–1.98)	–0.081*** (–1.10)
Temporal effects	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes	Yes
Hansen-Sargan over identification statistic:	2.845 [0.60]		3.287 [0.54]	
Overall system heteroscedasticity tests:	–250.768	–254.809	–172.704	
H0 = : No Overall System	[1.000]	[1.000]	[1.000]	
Heteroscedasticity Breusch-Pagan/ Cook-Weisberg test for heteroscedasticity:				94.40***
H0: Constant variance				[0.000]
Wooldridge test for autocorrelation in panel data				1350.700***
H0: no first-order autocorrelation				[0.000]
# observations	240	240	240	240
R^2	0.9815		0.9815	0.9358

Note: ***,**,* statistically significant at level 0.01, 0.05 and 0.10.
The OLS model uses Newey-West standard errors.
The 3SLS (CMP) is built on a MLE, which produces heteroscedasticity-consistent standard error.
t-statistics are in parenthesis. p-value are reported in brackets.

4 Results and Discussion

4.1 The Voluntary Work (VW) Equation

Table 2 presents the results of the 3SLS, 3SLS (CMP), 2SLS, and the OLS estimates.

Examining the 3SLS and the 3SLS (CMP) results in Table 3 we observe that the coefficient of MF is positive and significant at the 0.01 level. In other words, the informal meetings, with friends encourage social capital (that derived from volunteering). In addition, we see that attendance at places of worship positively and significantly influences the participation in voluntary activities. Volunteering is associated with the principles of soul searching and brotherhood that can encourage and nurture voluntary work. Going to the cinema has a negative impact on participation in voluntary activities. Cinema reduces much of interpersonal relationships, as watching a movie requires a direct relationship between the viewer and the screen. The same effect occurs on the consumption of pop music, although this is not significant. Visiting museums and theaters have a positive effect on participation in voluntary activities. Visiting museums requires an atmosphere of silence and visits take place, in most cases, in groups of people that gather without a predetermined order. Specifically, voluntary activities are guided by a certain predisposition towards others; accordingly, visiting a museum seems to stimulate this tendency. The theater, in addition to encouraging meetings with a small circle of people (such as a club) also shares the effect that attending art exhibitions may have, namely it stimulates the more sensitive parts of individuals.

4.2 The Meeting Friends (MF) Equation

Table 3 reports the results for the meeting friends (MF) equation. From the 3SLS and the 3SLS (CMP) estimates we observe that the coefficient of VW is positive and significant at the 0.05 level. Volunteering has the effect of a double product: (1) direct, aimed at those benefiting from the volunteering; (2) indirectly, addressed to him/her and the offering of voluntary work (inner enrichment, knowing new people, etc.). Volunteering is born from the desire to be useful to others. The others are the beneficiaries of the voluntary action. As shown by scientific studies, the relevant legislation and European legislation and national practices of social and educational work (with adolescents, people from a criminal background or challenged, the elderly) and guidance services employment (off workers, unemployed), doing voluntary work can be a life experience that creates more opportunities for human relationships, and mental well-being as well as participation in social life (BES Report 2014). It follows then, that volunteering generates and reinforces informal capital. The informal capital that derives from volunteering, given its positive connotation, drives people to accumulate more capital result of volunteering. This process has a circular self-strengthening connotation. Voluntary activities create sharing relationships that can turn into friendship and thus go beyond the context in which volunteering is expressed. There is a relationship of reciprocal interplay between capital and capital from informal volunteering.

In addition, we assume that it only makes sense to include the meeting (meeting friends) among the regressors. This assumption stems from the hypothesis that the difference from volunteering to MF, given its transitive nature, namely a set of actions whose objective is the good of those who are worse off than us, could be stimulated by more introspective cultural consumption, touching the most sensitive sphere of the human being (positive effect of M&E and theatre of VW).

Conversely, the main objective of attendance at sports events is fun and entertainment and touches the innermost chords of the human being. It has the positive effect of stimulating the informal networks that in turn, may generate voluntary activities. As regards the effect of cultural capital on MF, we observe that the informal capital is positively stimulated by cultural consumptions that require an agreement before the consumption of the asset happens (i.e. before going to the cinema there will be discussion with friends regarding the choice of film). Equally, when attending sports events we make an appointment with friends before going to watch our favorite team. By contrast, the consumption of introspective culture (museums and theater) has a negative effect on stimulating informal social capital.

5 Conclusion

The outcome for society as a whole does not simply depend on the quantity of the connections but also on their quality [21]. In this paper, we provided a first attempt to evaluate how cultural capital via cultural access can foster social capital and, in line with Westlund, we first explored the qualitative characteristic of social capital starting from a cultural standpoint. Anchoring the paper in the literature of cultural economics the output of the analysis are:

(1) the share capital and the capital generated by informal volunteering stimulate each other and are thus connected by a virtuous circular process;
(2) the capital generated from volunteering is positively stimulated by more introspective and niche cultural consumption;
(3) informal social capital is stimulated by cultural consumption related to recreation and the stimulation of relationships whose goal is entertainment and fun.

Accessing cultural experiences increasingly challenges individuals to develop their own capabilities to assimilate and manipulate the cultural contents they are being exposed to in personal ways. The key of the argument lies in focusing that cultural access changes the behavior of individuals and groups. In that sense, culture as a platform runs as a space of multi-cultural interaction and social exchange in socially critical areas, facilitating mutual knowledge and the acquaintance of people from increasingly different, and often mutually segregated, ethnic communities. The indirect effects of cultural participation on social cohesion are due to the fact that increased participation gives individuals and groups new skills to conceptualize and understand diversity and to reprogram their behavior from defensive hostility to communication, while at the same time uncovering new possibilities for personal development. Considering the costs of social conflict across Europe, this link might well be the object of some target experiments with possibly serious macroeconomic (and of course social) consequences. Concluding, further analyses investigating the causality of the relationship, and including other factors that may have an important influence on these indicators, could provide useful insights for the understanding of the dynamics of social and cultural participation, and in addition provide a constructive perspective for policy makers working in these fields.

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A Unified Framework for Multicriteria Evaluation of Intangible Capital Assets Inside Organizations

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Abstract. It is of high importance for modern organizations the capability concerning the internal metrics used to evaluate intangible assets within them, as it enables better governance and competitive advantages. This paper presents a unified framework to measure, assess and develop intangible capital assets within organizations giving the possibility of enhancing decision making within the operational and strategic governance. Once identified the assets under investigation, the idea is to focus on a method based on a data model approach.

Keywords: Knowledge economics · Data model · Decision making · Economic experiments · Continuous improving
JEL codes: C81, E22

1 Introduction

Nowadays the detection and measurement of intangible capital assets are fundamental to build a competitive advantage [12]; one of the most important ability for any organization is to be able to analyze and develop its intangible assets, especially in the knowledge society where the availability of information and the ability to extract knowledge allows the creation of valuable assets and better strategic management. In many modern organizations the value - not only economic value but also as a driver of development - is mainly given by intangible capital assets such as people skills, organization's reputation, consumer confidence, and business processes adopted. To improve strategic management decisions is very important to implement a measurable and repeatable process leading to develop intangible assets internally generated (among others, see [1,4–6]).

The framework presented in this work is conceived as a unified system that gives the possibility of building an analytical model with measurable indicators, conceiving experiments and analyzing the outcome. The vision is to have a reproducible model that can be effectively used to analyze the intangible capital assets and possible evolutions of their value over time. The main idea is to integrate, within one framework, the following phases: (i) building of the theoretical framework, (ii) data collection (via experiments, surveys, focus groups,

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interviews, observational studies from private or public sources, etc.), (iii) statistical data elaboration and analysis, (iv) reporting, (v) knowledge database and (vi) improvement actions. This framework is conceived to overcome the inherent technical difficulty faced by organizations in evaluating intangible assets and making decisions, providing a coherent methodology which is relatively data intensive and, at the same time, reliable.

2 The Theoretical Framework

The model is based on three fundamental questions:

- Which kind of intangible assets do we desire to measure and improve?
- How can we identify the changes to be implemented (such as the improvement actions)?
- How do we preemptively know that the changes to be implemented bring about improvements?

The combination of these three questions with the Plan-Do-Check-Act cycle (also known as Deming's cycle, typical of quality control systems [7,18]) forms the basis of the unified framework, which is composed of the following steps:

1. Identify the intangible capital assets to be investigated;
2. Define the data model that describes the assets as a set of variables, measurable with specific data collection tools;
3. Quantify the variables by collecting the data with appropriate tools;
4. Analyze the results;
5. Define actions that should improve the results over time;
6. Implement the improvement actions with appropriate experiments to evaluate their efficacy (economic experiments can be very useful in this regard);
7. Make decisions based on the results of experiments;
8. Repeat from step 3 for continuous improvement.

The first step deals with the individuation of the strategic intangible assets to be investigated (e.g. using Balanced Scorecards and Strategy Maps [10,11]) and then passing to the identification of the variables that best describe each single aspect of the phenomenon under investigation: the composition of these variables defines the *data model*.

In addition to the specification of the data model that describe the assets, the construction of the framework requires the specification of the *subjects* that identify the "things" that influence the phenomenon investigated. The same subjects are the source of the measurable data. These subjects can be classified according to a set of attributes that helps during the analysis phases.

The data model is structured on three hierarchical levels (see Fig. 1):

1. *Classes*: variables that describe the phenomenon at a macroscopic level;
2. *Elements*: intermediate variables that specialize the classes;
3. *Indicators*: variables that specialize the elements and are measurable.

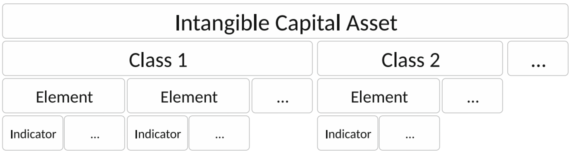

Fig. 1. Data model hierarchy

While indicators are measured directly and aggregated using statistical methods, elements and classes are calculated by aggregating the variables with weights using an aggregation function f (where f typically is the weighted average).

In formula, a data model M is made up by a set of n classes:

$$M = \{C_1 \dots C_n\}$$

Each class $C_i \in \{C_1 \dots C_n\}$ is made up by two sets of elements and weights (respectively E_{C_i} and W_{C_i}) each containing m_{C_i} items:

$$C_i = \{E_{C_i}, W_{C_i}\},\ E_{C_i} = \{e_1 \dots e_{m_{C_i}}\},\ W_{C_i} = \{w_1 \dots w_{m_{C_i}}\}$$

The measure of the class C_i is calculated using a function that combines the value of each measured element with the weight. If the value function f is the weighted average and g is the function that gives the value of each element, we have:

$$f(C_i) = \sum_{t=1}^{m_{C_i}} g(e_t) w_t$$

Each element $E_i \in \{E_1 \dots E_F\}$ is made up by two vectors of o_{E_i} indicators and weights (respectively $\boldsymbol{v}_{E_i}$ and $\boldsymbol{p}_{E_i}$) and has a value function g to measure it (weighted average of values in $\boldsymbol{v}_{E_i}$ with weights in $\boldsymbol{p}_{E_i}$):

$$E_i = \{\boldsymbol{v}_{E_i}, \boldsymbol{p}_{E_i}\},\ \boldsymbol{v}_{E_i} = \{v_1 \dots v_{o_{E_i}}\},\ \boldsymbol{p}_{E_i} = \{p_1 \dots p_{o_{E_i}}\},\ g(E_i) = \boldsymbol{v_{E_i}} \cdot \boldsymbol{p_{E_i}}$$

The indicators are the measurable entities and their value is determined using the appropriate data collection algorithm (experiments, surveys, observational studies, etc.), taking into consideration the statistical significance of the data.

After the completion of the first two steps found in the framework, we can start collecting the data, calculating the values for all the indicators, elements and classes, and then analyzing the results versus the *subjects* and their attributes, in order to discover the improvement potential and define the improvement actions.

Finally, we can discover the potential improvements and implement the improvement actions with appropriate scientific experiments, typically dividing the *subjects* in two or more groups, with one group serving as a baseline or control group with no improvement actions applied on it. The repeatability of the measurements will give us the opportunity to analyze the results of the experiments in order to guide the subsequent decisions.

2.1 Defining the Data Model

Suppose to study the business climate inside an organization. The *subjects* involved are obviously the organization's workers. The related classification attributes can be represented, for example, by the job function, age, gender, and education. The attributes will help during the analysis phase of the data model.

With the collaboration of specialists (people with in-depth experience in approaching the know-how of the subject matter of the research, in this case the business climate), we have to identify which kind of *classes* to consider and measure: for example, we can decide to measure the business climate over the following three classes, but not limited to:

1. The confidence among the workers and towards the organization;
2. The perception of the organization's reputation by the workers;
3. The pleasantness of the workplace.

For each one of these classes we have to identify one or more *elements*. For example, considering the third class "pleasantness of the workplace", the elements can be the physical conditions of the workplace, the relations between workers, the benefits in kind, and so on.

For each element, we have to find those indicators that help use to measure the element itself. For example, taking into account the element identified as "physical workplace", we can measure what workers think about the building structure in which the organization operates, the parking facilities, the perceived safety of the workplaces, and so on.

Lastly, we have to decide how to measure each indicator (e.g. by an economic intranet experiment), and decide all the weights for the various level of measurement: the weights can be used to associate an importance level to each class, element and indicator.

To make the data collection more effective, it is better if workers do not know the weights, so that they cannot be able to pilot the result.

Once the model is ready, we can start to measure the indicators and, at the end of the data collection, we will have a complete view of the intangible assets under investigation and we can mine the data to find strengths, weaknesses, opportunities and threats for the organization regarding the measured assets.

2.2 Decision Making and Efficacy Measurement

The knowledge extracted from the data model using data mining techniques enables us to find a set of improvement actions to implement. The framework requires to make an economic experiment in order to determine the efficacy of the improvement actions.

According to the framework, we can divide the subjects under investigation in two or more groups, applying the improvement actions on the treatment groups for a certain period of time but leaving one group without applying any improvement action, so that to be our control group. After running the experiment, we collect the data again and analyze the results.

By comparing the results of the experimental sessions, the organization will be able to discover what are the actions that really improve the intangible assets measured (e.g. the business climate), and discard the actions that do not improve or even that could deteriorate the measured value of the assets.

The framework supports decision making both at the *strategic* level (generally at the *classes* level) and at the *operational* level (generally at the *elements* level). Indeed, the executives initially help to define the weights of the *classes* and *elements* according to the business vision. Subsequently, they can use the results of the overall evaluation to take better strategic decisions. The managers can monitor the *elements* in order to achieve a vision of the critical factors that help them to make operational decisions.

3 Practical Economic Applications

The unified framework above introduced can be applied to several production processes and areas. In this section, we show a few ideas describing how to operationalize the framework to model some intangibles in many organizations.

3.1 Human Resources

One practical application is to find ways to increase the success of the organization by improving the workers' performance, taking into consideration their motivation and growth potential (among others, see [3,9]). For this application, the workers will be the subject matter of the research. To this purpose, we can consider at least three different aspects to be analyzed (*classes* in the framework): (i) the performance related to the worker with respect to the business objectives, (ii) the social skills, and (iii) the worker's ability to take initiative.

The workers' performance generally represents the basic data that is collected by every organization, where, the *elements* are modeled by the objectives given to the worker for each year. Each objective generally has several *indicators* that can be automatically recovered from the company data warehouse (e.g. the performance of the worker on the production line) or can be gathered from the worker's immediate supervisor.

Using the proposed framework, we can go beyond the basic data collection regarding workers, by focusing on the evaluation of social skills and initiative ability.

To evaluate the social skills, the identified elements will include the teamwork ability, the interaction and communication with others, the stewardship and the ability to delegate. The indicators will be typically collected with surveys compiled not only by the immediate supervisor but also from the co-workers.

Finally, for the initiative ability, the elements to evaluate will include the problem solving abilities and creativity, and the indicators will be collected with experiments and surveys. Note that, the social skills and initiative ability are elements valuable in order to allow workers to assess, in turn, their respective supervisors. In fact, this gives an important feedback concerning the adequacy of every worker in a responsibility role.

The definition of the data model and the analysis of the aggregated data, if made properly, will provide a lot of knowledge to the executives. Accordingly, the executives will be able not only to know if workers are meeting the business objectives but also if they are happy with the job tasks they are required to do. In a particular working environment, for example, the results can show that we may encounter workers whose skills are undervalued or with inadequate social skills that can undermine the entire organization.

The proposed framework enables the measurement of the effectiveness of the improvement actions over time, increasing the workplace intangible value and helping the organization's capability to meet its long-term goals.

3.2 Sales and Operations

It has become standard for any organization to consider multiple factors when studying sales with the objective of defining correct marketing decisions, and quite often the intuition of some manager or executive guides the strategy (among others, see [14,15]). However, with a correct model for evaluating intangibles it is possible to go beyond the mere intuition and obtain practical data to deal with.

In this sub-section, we consider a retail company: using the proposed framework, it becomes possible to evaluate the intangible relations between the company, the retail network and the customers, by measuring the efficacy of the business actions.

The main *classes* to study are the product sales, the relations with customers and the relations with the retail network. The sales are quite standard to study, because the company has the exact numbers for each store and, very often, for each customer thanks to fidelity cards or other data (e.g. credit cards). The framework, with appropriate data collection tools (experiments, surveys, big data sources, etc.), enables the possibility to study the value of the sales combined with intangible assets such as the customers' sentiment, their opinion regarding the product and related service, the social ability of the sales accounts, and the trust placed in a specific brand. Therefore, the *subjects* of the research will be the products and the customers.

Thanks to the data mining to be carried out with the proposed framework, it is possible to discover hidden knowledge that can be very valuable. For example, the executives may find that an increase in revenue, which is always welcome, is correlated to a worsening of the relation with the customer which could compromise future profitability.

3.3 Sustainability and Development

Many organizations implement sustainability strategies with the purpose of obtaining economic and social corporate benefits. Principally, organizations seek long-run profitability via sustainability initiatives giving them new opportunities in terms of competitive advantages.

It is important not only to adopt a proper methodology for the assessment of sustainability(for an overview, see [17]), but also to be able to adopt improvement actions and measure their efficacy. The subjects to evaluate can vary depending on the kind of initiatives, and the proposed framework can be used in any scenario by defining the appropriate *classes* to investigate. However, there are a couple of classes that should always be considered: the impact of policies concerning sustainability (i) on workers, and (ii) on the company's reputation. The framework enables the possibility of studying each single initiative, evaluating what each stakeholder thinks about it.

The data collection will be conducted typically with experiments and surveys. The most fundamental elements of each class will be the level of knowledge of the initiative, the impact on the people and the significance given to the initiative. The indicators will be the single task of the experiments or the single questions of the surveys. To assess the impact on workers and on the company's reputation, a number of experiments and surveys will be performed.

By collecting and mining the data, the company will have evidence of the positive or negative impact of each initiative and can take appropriate actions to correct each initiative. Afterwards, the company will be able to re-evaluate the improvement of the perceived value of each initiative.

4 Conclusion and Future Directions

As described in the previous sections, the idea behind this work is to build a unified framework usable in several contexts, that provides the capability to investigate intangible capital assets with the purpose of improving their value and, consequently, the organization's management and decision-making processes.

The proposed framework includes an evaluation system that is intended to be both technically reliable and useful for practical applications, and enables the possibility of studying very different intangible capital assets within a unified data model. Moreover, the continuous improvement through the iterations over the model is taken into account: with appropriate economic experiments (improvement actions) it gives the possibility of studying the intangibles on a long-term period, obtaining deep knowledge over the subjects under investigation and improving decision-making both at the operational and strategic level.

We are developing a prototype software architecture that will be the base for future research applications. This architecture is based on the integration of the existing software components (scientific computing, data mining, etc.) under a unified and coherent user interface.

The future developments of the framework presented will regard the integration of several statistical methods to evaluate the quality of the results and the integration of advanced data collection methodologies in order to enhance the functionalities of the framework, for example to extract information from big data sources and study the related change over time.

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Processing and Analysing Experimental Data Using a Tensor-Based Method: Evidence from an Ultimatum Game Study

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Abstract. This work investigates how newer economic behavioural research can be applied to human group behaviour and how it can be enriched using a relatively novel knowledge discovery approach. Based on an ultimatum game study conducted in the context of an extra-lab experiment, the authors propose a tensor-based method to analyse their experimental results and, therefore, to address a multi-dimensional approach. The authors prove that subjects do not behave as game theory would predict, but rather they basically prefer fair divisions of gains. This evidence confirms significant implications for theories addressing the evolution of, and the mechanisms underpinning, human group behaviour in economics, cognitive, and organizational studies.

Keywords: Economic behavioural research · Experimental economics · Knowledge discovery in databases · Tensor-based analysis · Fairness preferences

JEL Classification: C39 · C78 · C99

1 Introduction and Methodological Issues

In analysing human group behaviour as a complex system, it is customary to distinguish between two major organizational issues which mainly concern economic behaviour. The first relates to incentives and alignment of interests behind a common vision arising from the practice of using comparison across relative payoffs. The second issue pertains to the need for a common ground and coordination in joint activity that encourages prevention and/or resolution of problems regarding the interdependence of actions, which implies interdependence among individuals. Both issues are necessarily related to cognitive and behavioural determinants, and many great advances in the field of experimental and behavioural economics research have been made in the last decades (for an overview, see [1, 2]) that nowadays serve also as a frame of reference for a number of possible applications in the field of social Artificial Intelligence. In particular, one of the most stable results of the contributions in this regard focuses on the system of incentives. The incentives pivoted on the Hobbesian perspective on human nature, that is to say the assumption of a self-interested

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behaviour of individuals, are centered on a distorted view of human motivations and can therefore produce results largely counterproductive, especially in the economic realm. Correspondingly, not only in the economic realm but also in many others, individuals do not respond only to their own narrow interests but also to motives of reciprocity; for example, they tend to respond fairly to a fair behaviour and, conversely, they tend to punish an unfair behaviour, even when the punishment includes an effort to the punisher. In the last two decades, indeed, behavioural economics research has confirmed the existence of significant deviations from the standard economics – consisting of several anomalies and shortcomings – that these can no longer be seamlessly supported by the standard assumption of economic agents taking strictly rational decisions. Meanwhile, it is regarded as an established fact that economic agents tend not to approve of unfair behaviour: if they feel to be unfairly disadvantaged or discriminated, they tend to relinquish their claims on the optimization of their own benefits for the purpose to reject and condemn the unfairness as a violation of a general social contract (among the many, see [3]). In fact, economic decisions transmit information to other agents with whom one has relations. Not surprisingly, when an individual makes an economic decision, the latter is never exhausted exclusively in the mere economic sphere, being determined by the identity preferences and social values as well as by perceptions and not just mere mechanical rationality. Furthermore, these decisions contribute to the evolution of both the organisation in which individuals live and operate, and the relationships that they develop among them. It follows, therefore, that an economic decision can be summarized in a linear fashion, as often happens in the standard economic theory, only on condition of an extreme methodological simplification, also in terms of aggregation, *"reducing Economics to a mathematical application of the hedonistic calculus of Bentham!"* Keynes J.M. [4] p. 332. This is demonstrated by the fact that *"Individual actions that are carried out by a large number of individuals can generate a socioeconomic result, which is different from what would be expected on the basis of generalized microeconomic behaviour. […] Individual actions, if common to a large number of individuals, will generate an outcome different from what was intended by each."* Dow S. [5] p. 85. This finding of particular pertinence of behavioural economics has not yet affected economic theory. It is no coincidence that economic policy decisions of numerous countries and major international economic institutions are inspired by, if not taken directly from, the standard economic theory models (examples of this are the so-called models called Dynamic Stochastic General Equilibrium, DSGE). It is therefore crucial that the theoretical foundations of these models are critically discussed and revised to take account of the most recent acquisitions in the field of behavioural research. The pure game theory, for example, can perhaps take us only so far in understanding why actual policies often different from optimal policies. Nevertheless, the role of social values and relations has been gradually recognized by several economists (for example, see [6, 7]) who helped push economic theory both to look beyond the standard model and to start offering new methods of investigation in order to analyse that role. Among these new methods, which are the result of interdisciplinarity within social sciences and between them and natural sciences, one of the newest innovations is the agent-based simulation, which replicates computationally certain real-life scenarios and populating them with artificial adaptive agents driven by specific algorithms (see, for example, [8, 9]). However, if on one hand the simulation techniques seem indispensable to include interactions and heterogeneity in economic models, on the other hand even the most sophisticated algorithms find it hard to reproduce the actual human behaviour in all its complexity, especially when they have to reproduce subjective evaluations and ethical judgments. Recently, the news that a popular social network has assigned to human operators the task of assessing the content posted by its users, in addition to algorithms, has aroused a certain interest. Algorithms, in fact, were considered solely responsible for the indexing of the content offered to users so far. This has opened the debate on the so called *human training* of algorithms leading some authors to wonder *"how artificial is Artificial Intelligence?"* concerning the human labour in the loop driving AI ([10], mentioned in an earlier insight by [11]). Accordingly, to ensure that algorithms can be successfully implemented in order to more realistically replicate human decisions, or at least approach them as much as possible, it becomes necessary to look more closely at human behaviour without losing any relevant information. A possible methodological contribution in this direction may come from the field of experimental and behavioural economics, whose real-world data might even serve as alternative sources for simulations. This field of research has developed several tried and tested methods of observation and interpretation of human behaviour deemed relevant for a more effective modeling of economic decisions (*e.g.*, for lab experiments, see [12]). By using experimental techniques, indeed, well-defined economic decisions can be reproduced (in the lab, extra-lab, or field), preferences of experimental subjects can be elicited, and their behaviours can be revealed. In the wake of these behavioural studies, the general objective of this work is to contribute to improved *knowledge discovery in databases* through the implementation of a tensor-based analysis in order to gain insights into individuals' behaviour in an extra-lab ultimatum bargaining experiment. Particularly, Sect. 2 lays out a number of conditions to be fulfilled when processing the experimental results and developing the data analysis approach. Section 3 presents a tensor-based method in order to analyse experimental data considering each experimental subject's behaviour within a specific human group. Section 4 provides a sample application of the method showing the main results. Conclusions and some ideas for future work can be found in Sect. 5.

2 From Experimental Results to Data Analysis: Key Conditions

Starting from the dataset obtained through an ultimatum game[1] conducted in the context of an extra-lab based experiment in 2015 (for further details, see [18]), we acquire knowledge in processing and analysing experimental data, addressing a multi-dimensional approach. Particularly, in [18] we found a significant role both for different

[1] This is a one-shot two-stage sequential bargaining game methodologically based on studies concerning game approaches to interactions between individuals [13–15]. Although the ultimatum game is frequently used to describe the backward induction method of solving for a sub-game perfect Nash equilibrium for monetary payoffs maximising individuals, this bargaining game provides evidence for fairness concerns on individuals' preferences. Indeed, there are multiple reported results of equal-split or close to equal-split outcomes from several experiments. Results from these experiments contradict the standard economic theory and have been used to argue that pro-social preferences are important in a wide range of real-world contexts (*e.g.*, [16, 17]).

structures of preferences and meta-ranking (see also [6]). In this work, particularly, our aim is to specify and provide a rationale for the method used to analyse experimental data in [18] so as to provide valuable information on the structures of individuals' preferences. However, switching from experimental results to summarized information may result in the loss of information regarding the relational nature of economic decisions. For that reason and in order to retain most of the information found in the experimental data, we argue that the method of processing the experimental results and the development of the data analysis approach have to fulfill several conditions:

(i) ***Unity***: data related to a single experimental subject have to be processed as a single object of analysis, thus subjects' decisions cannot be analysed individually [19, 20] but need to be considered as a whole, taking into account subjects' indivisible relational structure;
(ii) ***Sociality***: experimental subjects have to belong to a socially identifiable group provided with a decomposable architecture (*e.g.* a school or university classroom, or a business unit structure); data collected in the experiment must result from an interaction between experimental subjects who belong to the same group (neither explicit nor implicit deception are not allowed [21]); the analysis has to take into account relationships between subjects and social groups they belong to, consistent with the concept of *near-decomposability*, that is the possibility to subdivide the study of a complex system by analysing sub-systems related to each other; more specifically, the behaviour of one subject depends more closely on the behaviour of other subjects belonging to the same group than on subjects belonging to other groups [22–24];
(iii) ***Completeness***: instructions and information available to the experimental subjects have to be entirely used in the analysis of data (particularly when constructing one or more utility functions); this is consistent with the definition of the economy as a holistic system where an individual's behaviour cannot be described without taking into account the entirety of relations with her community [25, 26];
(iv) ***Heterogeneity***: in addition to the standard preference for selfishness, the analysis has to take into consideration different structures of preferences identified in the literature [6, 27–30];
(v) ***Sufficiency***: the analysis requires a minimum level of sufficiency in the consistency of experimental subjects' decisions, that is the analysis has to consider decisions compatible with the hypothesis of bounded rationality [31] allowing a certain flexibility in the internal consistency among different decisions.

These conditions fall within the theoretical framework of *knowledge discovery in databases* [32, 33] based on an interactive and iterative process of discovering valid and useful patterns in several collected experimental results (knowledge extraction from real-world datasets). Principally, the conditions affect both the processing of experimental results and data analysis. In the remainder of this section we introduce the implications for the processing of experimental results, while in the next section we investigate the implications for data analysis. At the very least, generalizing, two experimental subjects participate in an ultimatum game experiment. There are two stages: in stage 1, the first subject (proposer) chooses one pair of payoffs between two pairs of payoffs:

$(p_1^{1,A}; p_1^{1,B})$ and $(p_1^{2,A}; p_1^{2,B})$. Each pair of payoffs corresponds to a specific split of a fixed amount of money or resources. Afterwards, she proposes her decision to the second subject (responder). In stage 2, the second subject can either accept the proposed split or reject it. If she accepts, the pair of payoffs is divided according to the first subject's proposal. If she rejects, neither subject gets anything: $(p_1^{0,A}; p_1^{0,B})$. Therefore, standard economic theory would suggest that any rational responder should accept even the smallest positive payoff regardless of any other consideration, since the alternative is getting nothing. The proposer, consequently, should be able to claim almost the highest payoff. The procedure followed for processing the experimental results obtained is given hereunder. To fulfill the condition of *unity*, all choices referred to an experimental subject have to be considered as a unitary entity. More formally, we can represent the proposed payoffs in matrix $\boldsymbol{E}$ and the theoretical results in matrix $\boldsymbol{F}$. Running $\boldsymbol{n}$ ultimatum games, for instance, we have:

$$\boldsymbol{E} = \begin{pmatrix} p_1^{1,A} & p_1^{1,B} & p_1^{2,A} & p_1^{2,B} & p_1^{0,A} & p_1^{0,B} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ p_n^{1,A} & p_n^{1,B} & p_n^{2,A} & p_n^{2,B} & p_n^{0,A} & p_n^{0,B} \end{pmatrix}; \boldsymbol{F} = \begin{pmatrix} p_1^{1,A} & p_1^{1,B} \\ \cdots & \cdots \\ p_n^{0,A} & p_n^{0,B} \end{pmatrix} \tag{1}$$

However, having no information on the two experimental subjects' theoretical decision paths, the (1) could result in a misrepresentation of the theoretical results with a loss of information on decisions that have generated a certain experimental result. Therefore, this form of data processing does not fulfill the condition of *completeness*. In order to overcome this misrepresentation, we can represent the experimental data through vector $\boldsymbol{c}$ whose elements assume a certain value according to experimental subjects' decisional path, as shown in Fig. 1:

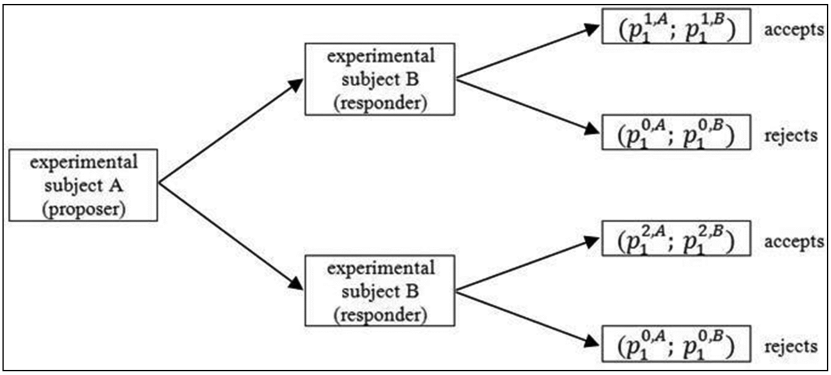

Fig. 1. The tree diagram adopted.

Let vector $\boldsymbol{g}$: $(\boldsymbol{g}_1, \ldots, \boldsymbol{g}_n)$ denote the *vector of the results* of an experiment. By combining all vectors of the experimental results with $\boldsymbol{h}$ subjects participating in an experiment with $\boldsymbol{n}$ ultimatum games, we obtain matrix $\boldsymbol{G}_{hn}$ that we call general matrix of the experimental results. By relating matrix of payoffs $\boldsymbol{E}$ with matrix $\boldsymbol{G}$, we obtain a structure of the results that allows to fulfill the condition of *sociality* (*i.e.*, it is capable to represent all the relationships inside a defined group of experimental subjects). Since matrix $\boldsymbol{G}$ consists of experimental data, the conditions of *sufficiency* and *heterogeneity* are obviously fulfilled. Nevertheless, both conditions may suggest the experimenter possible treatments to be included in the experimental design. The *heterogeneity* may refer to maximising the potential information gained by submitting to the experimental subjects tasks that require to choose between different structures of preferences. Concurrently, the condition of *sufficiency* suggests to stress the internal consistency of the decisions to be made in the experiment, by presenting choices among payoffs progressively more extreme.

3 Data Analysis: A Tensor-Based Method

Among the modern approaches to data analysis in experimental economics, there has been little work focused on a tensor-based data representation approach. Broadly speaking, tensors are multi-dimensional generalizations of matrices (two dimensional) and vectors (one dimensional) featuring multilinear relations between instances. The analysis of such multi-way data has become increasingly popular within data mining research. The purpose of the method of data analysis proposed is to gather information on the experimental subjects' preference structures fulfilling the conditions presented in the previous section. In order to analyse all information contained in the experimental data and ensure compliance with the five conditions, we introduce the use of the tensor-based modeling approach so as to enhance the potential of linear analysis tools such as the utility functions. As a result, this approach leads to modify the basic research question of the analysis. Indeed, in the experimental literature on which we focus on in this study [29, 30, 34, 35] the basic question can be summarized as follows: *which preference structure is capable to explain the behaviour of a group of experimental subjects?* In our investigation, however, the research question becomes: *what structures of preferences are capable to explain the behaviour of individual subjects in an experimental group?* The reformulated question is provided in the context of *knowledge discovery framework* and arises as to how newer economic behavioual approach can help understand fairness preferences in economic decision-making and extract valuable insights from experimental data, addressing a multi-dimensional approach. The proposed method is based on two fundamental steps: (1) the construction of a tensor with all possible results obtainable from the discretisation of the parameters of a utility function; (2) the comparison between the experimental data adequately processed and the tensor: this comparison is carried out through a specific matching function. First, we configure a utility function capable of capturing different preference structures. The function describes different structures of preferences (*e.g.*, egoism, altruism, cooperative action, inequity aversion, etc.; for an example, see Sect. 4) including only one parameter ($\boldsymbol{s}$). This parameter enables the utility function to determine the prevalence and characteristics of different preferences structures. Second, we use this utility function to calculate result $\boldsymbol{e}_i$ of the i^{th} $\boldsymbol{n}$ ultimatum game with the payoffs of matrix $\boldsymbol{E}$. The generalized utility function held by the first subject (subject A, the proposer) is given by the preferred pair of payoffs (p^A, p^B) and by parameter $\boldsymbol{s}$:

$$U_A = f(p^A, p^B, s) \tag{2}$$

$$e_i = f(U_A, U_B) = f(E, s^A, s^B) \tag{3}$$

The sequence of all $\boldsymbol{e}_i$ allows to build vector $\boldsymbol{e}$ of the results of ultimatum games involving two experimental subjects whose structures of preferences are set respectively by parameters $\boldsymbol{s^A}$ and $\boldsymbol{s^B}$. Once the interval of discretisation of parameter $\boldsymbol{s}$ has been set, one can construct vector $\boldsymbol{s^A}$ with $\boldsymbol{l}$ of the h^{th} intermediate discrete values of parameter $\boldsymbol{s^A}$ for the first subject (A) and vector $\boldsymbol{s^B}$ with $\boldsymbol{m}$ of the k^{th} intermediate discrete values of parameter $\boldsymbol{s^B}$ for the second subject (subject B, the responder). Thus, one can calculate every vector of the results $\boldsymbol{e}_{sA}$, $\boldsymbol{e}_{sB}$ for each combination of the values of vectors $\boldsymbol{s^A}$ and $\boldsymbol{s^B}$. The outcome is represented by a tensor denoted as $\boldsymbol{T^{nlm}}$ containing all the experimental results that can be interpreted through the utility function (2). The dimensions of the tensor depend on the number of the ultimatum games played ($\boldsymbol{n}$) and on the number of discrete values assigned to the two parameters $\boldsymbol{s}$ ($\boldsymbol{l}$ and $\boldsymbol{m}$). Each element $\boldsymbol{e}_{ihk}$ that populates the tensor is determined by:

$$\left[\begin{array}{l} f\left(p_i^{1A}, p_i^{1B}, s_h^A\right) > f\left(p_i^{2A}, p_i^{2B}, s_h^A\right) \cap f\left(p_i^{1B}, p_i^{1A}, s_k^B\right) > f\left(p_i^{0B}, p_i^{0A}, s_k^B\right) \rightarrow e_{ihk} = I \\ f\left(p_i^{1A}, p_i^{1B}, s_h^A\right) > f\left(p_i^{2A}, p_i^{2B}, s_h^A\right) \cap f\left(p_i^{1B}, p_i^{1A}, s_k^B\right) < f\left(p_i^{0B}, p_i^{0A}, s_k^B\right) \rightarrow e_{ihk} = II \\ f\left(p_i^{1A}, p_i^{1B}, s_h^A\right) < f\left(p_i^{2A}, p_i^{2B}, s_h^A\right) \cap f(p_i^{2B}, p_i^{2A}, s_k^B) > f\left(p_i^{0B}, p_i^{0A}, s_k^B\right) \rightarrow e_{ihk} = III \\ f\left(p_i^{1A}, p_i^{1B}, s_h^A\right) < f\left(p_i^{2A}, p_i^{2B}, s_h^A\right) \cap f\left(p_i^{2B}, p_i^{2A}, s_k^B\right) < f\left(p_i^{0B}, p_i^{0A}, s_k^B\right) \rightarrow e_{ihk} = IV \end{array}\right.$$

where I, II, III, and IV are possible results of the ultimatum game.

Based on a data processing consistent to that described in the previous section, the proposed tensor fulfills the conditions of *unity*, *sociality* and *completeness*. Furthermore, the use of a utility function capable to adapt to different structures of preferences ensures the fulfillment of the condition of *heterogeneity*. If necessary, it is equally possible to use a utility function including more parameters that will lead to designing a multi-way tensor. To analyse the experimental data organized within matrix $\boldsymbol{G}$. we use a special *matching* function that assigns to each experimental subject a value of parameter $\boldsymbol{s}$. The *matching* function compares the vectors of experimental data that constitute matrix $\boldsymbol{G}$ with the vectors of tensor $\boldsymbol{T}$. The function operates following three rules:

(i) When the matching function detects a number of equal results between a vector $\boldsymbol{g}$ and a vector $\boldsymbol{e}$ in amounts exceeding a given threshold of sufficiency (set by the researcher, in our case it is set to 67% of positive matches), the function assigns the experimental subjects the discrete values of parameter ($\boldsymbol{s_i^A}$, $\boldsymbol{s_i^B}$);
(ii) When several vectors of $\boldsymbol{T}$ exceed the value of the threshold, the function assigns the matching to the vector having the highest number of equal results;
(iii) When several vectors $\boldsymbol{e}$ have the same number of positive matches, the function assigns the matching to the vector that involves the least loss of utility (see [36]).

The matching function described herein complies with the condition of *sufficiency* as it admits that not all decisions are perfectly consistent with each other, and takes into account the bounded rationality of experimental subjects. The outcome of the analysis is the assignment to each subject of a value of parameter ***s*** and, consequently, of a specific structure of preferences among those described by the utility function. This is accomplished in accordance with the five conditions indicated in the previous section.

4 A Sample Implementation of the Method of Analysis

Following [29, 34], we develop a utility function that is consistent with (2) to represent different structures of individuals' preferences and the role of meta-ranking [6, 27, 28]. Although through the concept of *near decomposability* numerous decision-making levels can be analysed, in this study we simply perform the analysis of the structures of preferences and the meta-ranking. Different functions allow to describe individuals' behaviour and, at the same time, the study of the distribution of different structures of preferences allows to describe the entire experimental group's behaviour. The utility function adopted in this sample describes different structures of preferences by means of a single parameter ***s*** and the role of meta-ranking through a single parameter ***m***. This utility function is described under the following hypothesis:

1. $0 \leq s \leq 1$
2. $U(p_i) = p_i$
3. $p_i^A - p_i^B > 0$

with p_i which refers to payoffs of the i^{th} ultimatum game, where the payoff of subject A (proposer) is always higher than that of subject B (responder). The utility associated with experimental subject A (U_i^A) is determined by the sum of the utility arising from her particular structure of preferences (U_{Mi}) and the utility deriving from the choice of that structure in accordance with her meta-ranking among different structures of preferences (U_{mi}). This latter utility $\left(U_{mi}\right)$ can be defined as the subject's meta utility, which is calculated considering also the utility of the pair of payoffs alternative to that chosen by experimental subject A ($\bar{U}_i$). Function (2) is thus developed as follow:

$$U_{Mi}^A = \left(1 - s^A\right)p_i^A \; + s^A\left(\frac{p_i^A}{(p_i^A + p_i^B)/2}p_i^B\right) \tag{4}$$

$$U_{mi}^A = r\left(\max\left(0, (\bar{U}_{mi}) - U_{Mi}\right)\right) \tag{5}$$

$$U_i^A = U_{Mi}^A + U_{mi}^A \tag{6}$$

The function (4) allows to describe four different structures of preferences by means of a single mathematical expression, as parameter ***p*** varies, between those structures identified by [29], see also [18]:

1. with $s = 0 \Rightarrow U_{Mi}$ describes a standard neoclassical structure for preferences based purely on selfishness, that is to say *self interest* (SI);
2. with $0 < s \leq ½ \Rightarrow U_{Mi}$ describes preferences for maximisation of the overall welfare of society, that is to say *social welfare* (SW);
3. with $½ < s \leq 1 \Rightarrow U_{Mi}$ describes the aversion to inequity and resistance to inequitable outcomes, that is to say *inequity aversion* (IA);
4. with $s = 1 \Rightarrow U_{Mi}$ describes preferences for maximisation of welfare of other individuals, that is to say *altruism and charity* (AC).

After portraying the experimental data through individual vectors and creating the related database, we calculate the utility function, following which we populate the tensor and perform the matching. To do this, we decide to discretise the parameters so as to vary parameter ***s*** in a manner consistent with the hypotheses of the utility function: range of variation equal to 0 – 1 and associated discrete values with intervals equal to 0.1. Instead, parameter ***r*** is discretised with a range equal to 0 – 10, with incremental values of 0.1. The threshold of sufficiency is set at 67%. On the basis of the analytical framework mentioned above, the operations are processed through multiple spreadsheets and a database management system. Through this method it is possible to calculate the value of parameter ***s*** and the related structure of preferences for each subject. The distribution function of parameter ***s*** is presented in Fig. 2:

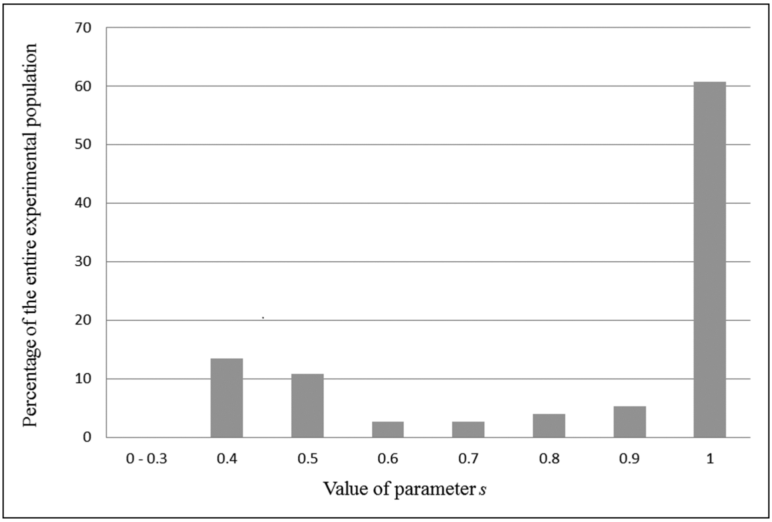

Fig. 2. Distribution of parameter *S* Source: our elaboration on experimental data collected in [18]

The analysis shows a prevalence of the structure of preferences corresponding to *altruism and charity* ($s = 1$ with over 60% of the entire experimental population) and the concurrence of preferences corresponding to *social welfare* ($0 < s \leq ½$) and *inequity aversion* ($½ < s \leq 1$) both with over 10% of the entire experimental population. These results are consistent with the reference literature [29, 34, 35].

5 Conclusions and Future Work

In this work, we provide the fundamentals necessary to the implementation of a tensor-based analysis in order to gain insights into individuals' behaviour in an extra-lab ultimatum bargaining experiment and, therefore, to address a multi-dimensional approach. Indeed, the tensor-based method enables us to fulfill several conditions – *unity*, *sociality*, *completeness*, *heterogeneity*, *sufficiency* – that ensure the use of all experimental data as well as the consistency and relational nature of subjects' decisions. The results obtained with the tensor-based method proposed in this work allow a high degree of detail in the study of experimental subjects' preferences so as to provide a number of insights into microeconomic theory and to further understand the economic decisions made by humans. More specifically, we highlight the role of preferences and shared values within a social group called upon to make decisions ascribed to the economic sphere. According to Herbert A. Simon, furthermore, the method of analysis is consistent, notably with the concept of *near decomposability* of a complex system which can be analysed into many components or dimensions having relatively many relations among them, so that the behaviour of each component depends on the behaviour of others. Tensors are, in this respect, the most appropriate analytical tools to take account simultaneously of all dependency relationships in a social system and, hence, in a human group's behaviour, being able to address a multi-dimensional approach. Therefore, it is possible to outline a bottom-up path through the different sub-systems from the individual level to the entire system, which can contribute to overcome the boundaries of the standard microeconomic generalizations [5, 7]. In a future perspective, however, the increase of the available experimental data and the parameters within the function used to describe structures of preferences can substantially increase the complexity of processing. Looking ahead, therefore, we intend to create a sophisticated and complex algorithm developing a specific fully-fledged mathematical library that will automate all operations of data analysis. In addition, a further possible research direction is to move from the approach based on *knowledge discovery in databases* to a more complex algebraic elaboration, designed on the typical properties of tensors. The proposed method also is suitable to be used in social AI applications, where there is a growing need to "train algorithms" so as to approach them to behave like human beings. It is no coincidence that this research field cannot be divorced from a better understanding of human behaviour and its relational nature. The method used herein is open as well to a possible generalization, confirming the preliminary identified conditions. From our point of view, the basis for possible generalizations is represented by the complexity approach: the results presented, indeed, do not aspire to be represented within an exhaustive discussion and conclusion, but they demonstrate the feasibility of the proposed method and its potential in analysing certain experimental data. Among the different directions of possible improvement, we list some of them which, in our opinion, are the most promising. They concern the formalization of preferences through non-linear functions (see also [37]); the focus on the concept of *procedural fairness* [38]; the application of tensor decomposition methods and analysis of possible patterns [39]. Finally, we believe that the opportunity to simultaneously analyse and represent different structures of preferences would be an appropriate starting point for a more open definition of our understanding of human group behaviour. What remains to be further investigated is the use of tensor-based method with the aim of developing automatic models with sophisticated techniques for *model learning* that may represent most closely human behaviour in the field of decision-based economics.

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The Mediating Effect of the Absorptive Capacity in the International Entrepreneurial Orientation of Family Firms

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Abstract. This paper analyzes the mediating effect of absorptive capacities (ACAP) on the impact of international entrepreneurial orientation on the international performance of family firms. We focus on family businesses because of their importance in generating employment and wealth. For data analysis, we used a structural equation model PLS-SEM. The main conclusions of this study are that the international performance of family firms can be explained by the influence of the international entrepreneurial orientation and that the absorptive capacity has a mediating role in the previous relationship.

Keywords: Absorptive capacity · Entrepreneurial orientation · Family firms · Mediating effect · PLS-SEM

1 Introduction

Entrepreneurial orientation is one of the main research topics in business management [1–4]. The first analysis of entrepreneurial orientation is thanks to Miller [1], for whom "*entrepreneurial orientation can be understood as the business behaviour engaged in innovativeness, proactiveness and risk-taking*" [1] p. 771. Therefore, it is a decision-making process affecting firms' willingness to innovate, to be more proactive and aggressive than their competitors and to take risks [5]. Nowadays, entrepreneurial orientation can be defined as a firm's ability to carry out activities related to innovativeness, risk-taking and being pioneers in new actions [6]. While some studies establish that entrepreneurial orientation positively influences business performance [*e.g.* 3, 7, 8], others do not find such relationship [8]. The transformation process of entrepreneurial orientation into improved business profits is not so simple, or as direct. Further progress is needed in the analysis of the process through which entrepreneurial orientation turns into improved business performance [3, 4], based on different factors that may influence such process [9]. This study aims at responding to this need by focusing on absorptive capacities. Absorptive capacity refers to the identification, assimilation and utilisation of new knowledge [10]. Firms' success depends on their ability to recognise, assimilate and apply new knowledge [11]. To them, absorptive capacity is "*a set of organisational routines and processes by which firms systematically acquire, assimilate, transform and*

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exploit knowledge" [12] p. 186. The firms under study are family businesses located in Spain, as defined by the European Family Businesses. The rationale for this choice lies in the importance of this type of business: they represent 89% of companies in Spain, 57% of the Spanish GDP and 67% of private employment [13]. To analyze results and contrast hypotheses, this study suggests a PLS-SEM model of structural equations, using SmartPLS 3.2.6 software [14].

2 Theory and Hypothesis

The present work follows the line traced by other authors in previous works which emphasise the explanatory capacity of the entrepreneurial orientation approach to analyze the process of internationalization [4]. This gives rise to what is known as international entrepreneurial orientation, which is a different and dynamic way to explain how businesses become internationalised. In this way, international business orientation refers to the international business orientation derived from the greater propensity of companies to innovate, to be proactive and to take risks beyond their country of origin [15].

The ACAP has been conceptualized as a multidimensional construct representing the firm's dynamic capability to create and use knowledge relating to the firm's ability to compete [12]. The mediating effect of absorptive capacity has been extensively analysed in the literature. For instance, Aljanabi et al. [16] analysed the mediating effect of absorptive capacity between the organisational support factors and technological innovation. Leal-Rodríguez et al. [17] examined the results of innovativeness; Sáenz, et al. [18] analysed innovativeness in buyer-supplier relationships; Adisa & Rose [19] did so in knowledge transfer.

The conceptual model suggested is shown in Fig. 1.

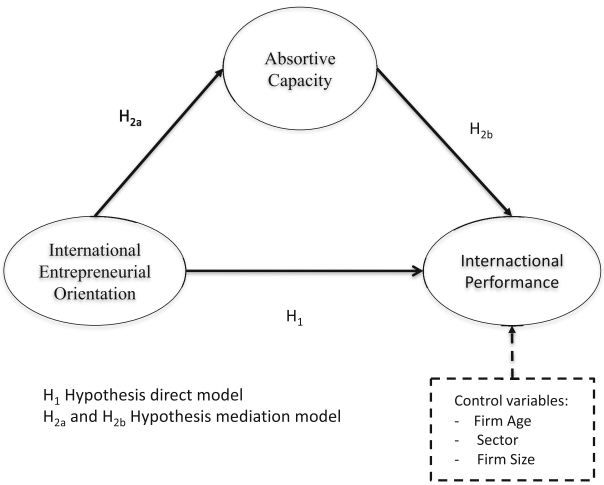

Fig. 1. Conceptual model

Based on this, the research hypothesis can be drawn:

H_1: International entrepreneurial orientation has a positive impact on international family business performance.

H_2: Absorptive capacity has a mediator impact in the influence of international entrepreneurial orientation on international family business performance.

The mediating model approach involves the consideration of two relationships. On the one hand, entrepreneurial orientation positively influences absorptive capacity. And on the other, absorptive capacity positively influences business performance.

H_{2a}: International entrepreneurial orientation positively influences the absorptive capacity of family businesses.

H_{2b}: Absorptive capacity positively influences the international family business performance.

3 Methodology

3.1 Data

Data was obtained from a questionnaire sent by email through the Limesurvey v.2.5. tool to the highest-ranking executive of a sample of companies taken from the Spanish Family Business Institute (IEF) between November 2015 to March 2016. The questionnaire sent contained Likert (1–5) type questions. Data were contrasted with the Iberian Balance sheet Analysis System (SABI), as well as with data from exporting businesses in the directory of the Spanish Institute for Foreign Trade (ICEX). A total number of 232 valid responses were eventually collected.

3.2 Variables

Independent variable: International entrepreneurial orientation—this variable was measured according to the scale proposed by Miller [1] and them modified by Covin and Miller [4]. These authors think that international entrepreneurial orientation can be measured in three dimensions: innovation (3 items), proactiveness (3 items) and risk taking (3 items). These variables were applied to a 5-point Likert scale.

Dependent variable: Internacional performance—in the present work, international performance is measured according to a multi-item scale composed of exporting intensity, which was included as a measure of international performance by some authors such as Zahra et al. [20], and Morgan et al. [21]. We also included perceived satisfaction in exporting performance, which was previously included by some authors such as Balabanis & Katsikea [22], and Dimitratos et al. [23]. Both previous variables were measured according to a 5-point Likert scale. Finally, the third item included to measure international performance is referred to exporting results, and had previously been used by some authors such as Zahra et al. [20], and Morgan et al. [21].

Mediating variable: ACAP—Measurement of ACAP used a four-dimension scale validated by Flatten et al. [24] who evaluate the extent to which the firm engages in knowledge acquisition activities (acquisition, three items), assimilates acquired information with existing knowledge (assimilation, four items), transforms recently adapted knowledge (transformation, four items), and commercially exploits knowledge transformed into competitive advantage (exploitation, three items).

Control variables—size, sector and age were used as control variables. These variables are often used in studies on family business [25].

In order to analyze the results and contrast the hypotheses, we propose a model of structural equations through the PLS-SEM through the software SmartPLS 3.2.6 [14].

4 Results/Findings

To interpret and analyze the model proposed in the PLS-SEM, two stages were developed [26]:

(1) measurement model analysis; and
(2) structural model analysis.

This sequence assures the scales proposed for measurement are valid and reliable.

4.1 Measurement Model Analysis

Table 1 shows the parameters associated to the assessment of the measurement model. All the values of load factors exceed 0.5, which is considered as an acceptable level by Barclay et al. [26], and Chin [27]. The values of composite reliability and average variance extracted (AVE) exceed the 0.7 and 0.5 recommended limits, respectively [28].

The obtained values support the convergent validity of the considered scales. Finally, to guarantee discriminant validity, the correlations between each pair of constructs was meant not to exceed the square root of each construct's AVE (Table 1).

Table 1. Correlation, composite reliability, convergent and discriminant validity

Composite/measures	AVE	Composite reliability	1. IEO	2. ACAP	3. INTPERF
1. International entrepreneurial orientation (IEO)	0.628	0.840	0.802	0	0
2. Absorptive capacity (ACAP)	0.677	0.923	0.478	0.866	0
3. International performance (INTPERF)	0.664	0.837	0.561	0.456	0.749

Note: correlations are from the second-order CFA output. The diagonal elements are the square root of the AVE.

In addition, the HTMT index can be calculated for type A compounds. This index measures discriminant validity among indicators of the same compound and among indicators of different compounds. For discriminant validity to occur, HTMT values must be below 0.85 [29] (see Table 2).

Table 2. Ratio heterotrait-monotrait (HTMT) and descriptive statistics

Ratio heterotrait-monotrait (HTMT)	1. IEO	2. ACAP	3. FIPERF
1. International entrepreneurial orientation (IEO)			
2. Absorptive capacity (ACAP)	0.748		
3. International performance (INTPERF)	0.725	0.682	
Cronbach's alpha	0.770	0.845	0.837
Mean	4.25	4.34	4.08
Typical deviation	1.09	0.99	0.94

4.2 Structural Model Analysis

Once the measurement model's convergent and discriminant validity has been guaranteed, the relationship between different variables was tested. To identify possible effects, we followed the steps proposed by Hair et al. [30] so as to apply the approach proposed by Preacher & Hayes [31] to the proposed measurement model.

We firstly confirmed the direct relation between international entrepreneurial orientation (IEO) and international performance (INTPERF). With this purpose, the bootstrapping procedure was applied (500 sub-samples). This effect proved both positive and significant (β = 0.419; p < 0.001; Fig. 2).

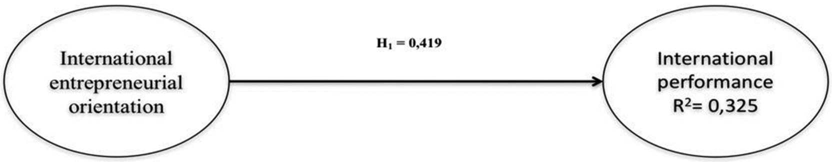

Fig. 2. Direct model

The second step is to include the effect of the mediating variable (i.e., ACAP). The indirect effect is positive and significant between IEO and ACAP (H_1: β = 0.696; p < 0.001) and between ACAP and international performance (H_2: β = 0.439; p < 0.001), with a suppressor effect [32]: the variance accounted for (VAF) is greater than 1 (VAF = 1.08), hence the disappearance of the direct effect. In the model, a significant positive path relationship without the mediator variable becomes non-significantly negative following the inclusion of the mediator variable (β = −0.093; p < 0.001). Full mediation occurs [32]: Absorptive capacity totally mediates the relationship between IEO and organizational performance (Fig. 3). Furthermore, the evaluation of the structural model displays good fit (GoF = 0.62), high consistency (R^2 = 0.54), good accuracy, and good predictive relevance (Q^2 ACAP = 0.31; Q^2 INTPERF = 0.44).

Analysis of control variables reveal no significant path, so they were excluded from the model.

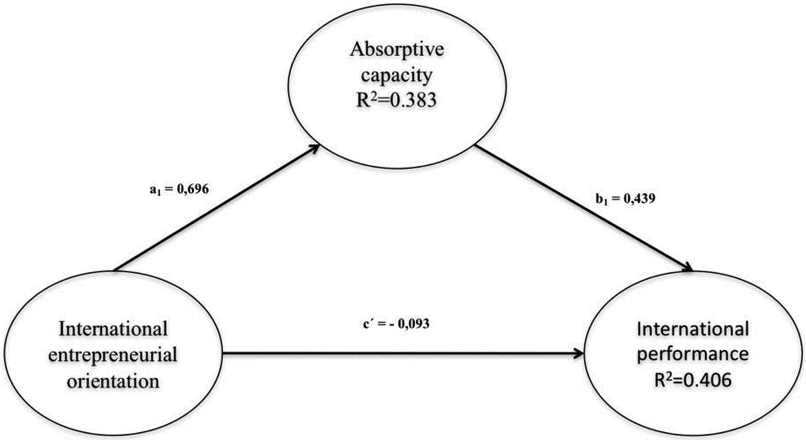

Fig. 3. Mediating model

5 Conclusions

The first conclusion to be drawn is that international family business performance can be explained, to a large extent by international entrepreneurial orientation. Thus, the latter can explain 32,5% of the variance in international performance. This result agrees with previous works [5, 6, 33] who state that innovation affects family businesses' capacity to become international. On the other hand, innovation makes businesses obtain new products, new techniques and new technologies to have access to a wider range of countries [34].

The second conclusion is that the absorptive capacity plays a mediator role in the relation between international entrepreneurial orientation and international family business performance. This mediator effect means increasing the model's capacity to explain international performance's explained variance up to 40,6%.

This study contributes significantly by identifying a new role of absorptive capacities. Thus, in addition to the roles of absorptive capacities that scholars already report in the literature, absorptive capacities are applicable to entrepreneurial orientation. This finding results in the following implications for managers: the family firms should evaluate different absorptive capacities (especially exploitation capability) and should then decide which resources to allocate to these capacities [35].

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