New Frontiers in Regional Science: Asian Perspectives 24

Hiroyuki Shibusawa
Katsuhiro Sakurai
Takeshi Mizunoya
Susumu Uchida *Editors*

Socioeconomic Environmental Policies and Evaluations in Regional Science

Essays in Honor of Yoshiro Higano

Springer

New Frontiers in Regional Science: Asian Perspectives

Volume 24

New Frontiers in Regional Science: Asian Perspectives

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Preface

This book is a volume of essays celebrating the life and work of Yoshiro Higano, Professor of Environmental Policy, Doctoral Program in Sustainable Environmental Studies, Graduate School of Life and Environmental Sciences, University of Tsukuba. Japan. Prof. Higano's research strongly focuses on the comprehensive evaluation of resources and research content for decision science and engineering, including simulation modeling for environmental quality control, the evaluation of environmental remediation technologies, integrated river (lake) basin management, and synthesized environmental policy.

Prof. Yoshiro Higano has provided long and outstanding services to the development and organization of the Regional Science Association International (RSAI), the Pacific Regional Science Conference Organizations (PRSCO), and the Japan Section of the RSAI (JSRSAI). Prof. Higano served as the vice-president of RSAI from 2008 to 2010 and the president of RSAI from 2010 to 2012. He made efforts as the executive secretary of PRSCO from 1998 to 2010. He supported the development and the organization of Regional Science in Pacific Rim area and Japan. The local sections of Chile, Colombia, and Bangladesh were established and were jointed to PRSCO and RSAI. In China, three international conferences of the RSAI on Regional Science and Sustainable Regional Development were successfully held with his strong support. Prof. Higano organized pacific conferences of RSAI and PRSCO summer institutes which were held in Tokyo (1983), in Tsukuba (1996), in Nagoya (1998), in Tokyo (2005), and the world congress of RSAI held in Tokyo (1996).

Prof. Higano supported the human network in the RSAI world by offering many parties and social and private events. He invited many RSAI colleagues to JSRSAI meetings. He provided genuine hospitality for RSAI development. In Japan, Prof. Higano organized and supported many local conferences as the JSRSAI executive director. Many young scholars and students were brought up by his powerful support. He contributed greatly to the progress of JSRSAI for long time. He also served as the president of JSRSAI from 2012 to 2016.

This edited volume covers a wide range of regional science approaches, theory, policy, evaluation, modeling, simulation, and practice. It is a valuable reference work for researchers, scholars, policy makers, and students in the field of regional science. This volume celebrates Prof. Higano's contributions to the JSRSAI, PRSCO, and RSAI. Essay contributors include his former students and a wide array of regional scientists, each with a personal connection to Prof. Higano.

Three parts of this book from RSAI, PRSCO, and JSRSAI contributors are devoted to Prof. Higano. In Part I, contributors are discussing topics of regional science in view of global region (except Asia-Pacific and Japan). In Part II, contributors examines a wide range of topics of social, economic, and environmental issues in Asia-Pacific regions. In Part III, topics are focused on urban and regional economy and the environmental and energy issues in Japan.

Part I: Global Perspectives

Antoine Bailly and Lay Gibson (Chapter "Regional Science in the Twenty-First Century") give a direction to a new regional science. They propose new dimension for establishing the new regional science.

David Plane (Chapter "The Sustainability of Demographic Progress Around the World") examines the concept of demographic progress and speculates about the types of regional science and population geographic research that will be critically needed as we transition into a post-demographic transition world.

Marco Modica, *Aura Reggiani, and Peter Nijkamp* (Chapter "Methodological Advances in Gibrat's and Zipf's Laws: A Comparative Empirical Study on the Evolution of Urban Systems") explore the methodological advances in Gibrat's and Zipf's law. They examine empirical experiments based on case studies on the dynamics of the urban population of five countries: Botswana, Germany, Hungary, Japan, and Luxembourg.

Peter Batey (Chapter "How Can Cross-Sector Partnerships Be Made to Work Successfully? Lessons from the Mersey Basin Campaign (1985–2010)") gives lessons from the Mersey Basin Campaign. The experience of public-private voluntary partnership in the United Kingdom over 25 years is discussed as a former leader. Factors for successful partnership are shown.

*Philip Morrison and Ben Bee*r (Chapter "Consumption and Environmental Awareness: Demographics of the European Experience") address the relationship between the consumer's age and their level of environmental awareness they bring to their consumption decisions. Their study is based on a large sample survey from 28 countries across Europe.

Roberta Capello and Giovanni Perucca (Chapter "Cultural Capital and Local Development Nexus: Does the Local Environment Matter?") discuss the relationship between tangible cultural capital and regional development. They show the impact of tangible cultural elements, physical cultural heritage, and the cultural industry, on the economic growth of Italian NUTS2 regions.

Chunhua Wang, *Jean-Claude Thill, and Ross Meentemeyer* (Chapter "Who Wants More Open Space? Study of Willingness to Be Taxed to Preserve Open Space in an Urban Environment") examine people's willingness to support tax increase for the preservation of open space in a fast-growing urban area based on the a data set collected through a survey conducted in the Charlotte, North Carolina, USA.

Amitrajeet Batabyal (Chapter "On Capital Taxation and Economic Growth and Welfare in a Creative Region") studies the effects of physical capital or investment income taxation on economic growth and welfare in a creative region. A creative region is described by the Ramsey-Cass-Koopmans model.

Kieran Donaghy (Chapter "Some Extensions to Interregional Commodity-Flow Models") introduces several extensions to extant commodity-flow models, including explicit treatment of trade in intermediate goods, so-called new economic geography behavioral foundations for production and interindustry and interregional trade, and endogenous determinate of capital investment and employment.

Tomaz Ponce Dentinho (Chapter "Evaluation of Ecosystem Services Through Revealed Policy Preferences: Exchange Rates Between Scientific Currencies") proposes a methodology able to estimate the decision rules revealed by public choice by combining ecological, environmental, social and economic valuations and applied for three types of decision, the designs of a terrestrial protected area, land use plan and a marine protected areas in islands of Portugal.

Katsuhiro Sakurai (Chapter "Optimal International Investment Policy for the Sea Environment in East Asia: Case Study of the Sea of Japan") discusses emission of land-based water pollutants created by socioeconomic activity in the coastal area (Japan, China, South Korea, and Russia) of the Sea of Japan by using a multiregional socioeconomic environmental system model. He derived the optimal international investment policy and the emission reduction rate.

Part II: Asia-Pacific Perspectives

William Cochrane, *Arthur Grimes*, *Philip McCann*, *and Jacques Poot* (Chapter "Spatial Impacts of Endogenously Determined Infrastructure Investment") estimate the impact of local authority infrastructure spending on regional economic and demographic outcomes within New Zealand. By using a spatial estimation methodology, they show a significant spatial dependence in infrastructure investment.

James Giesecke and John Madden (Chapter "Migration Responses to a Loss in Regional Amenities: An Analysis with a Multiregional CGE Model") examine demographic and economic effects of a relative decline in a region's amenities by using a three-region dynamic multiregional computable general equilibrium model with lagged migration responses in Australia.

Mia Amalia, *Budy Resosudarmo*, *Jeff Bennett*, *and Arianto Patunru* (Chapter "Valuing the Benefits of Cleaner Air in Jakarta Metropolitan Area") estimate the benefit of having cleaner ambient air for the Jakarta Metropolitan Area's (JMA) citizens. Choice modeling approach and conditional logic model are applied into case studies in Indonesia.

Yoko Mayuzumi and Takeshi Mizunoya (Chapter "Study of Fair Trade Products for Regional Development -Case of Bali, Indonesia") conducted surveys that are expected to be useful to improve management of fair trade products in agroforestry projects in Indonesia. They find an appropriate price for these products.

Elizabeth Aponte, *Emma B. Castro*, *and Lilian A. Carrillo* (Chapter "Social Public Spending in the Countries That Comprise the Andean Community of Nations (CAN)") examine the relationship between the social public spending and the improvement of quality of life condition in the Andean Community of Nations. They show a social spending growing, but an in adequate quality of life persists allowing to argue for a promising future.

Sutee Anantsuksomsri, *Nattapong Puttanapong, and Nij Tontisirin* (Chapter "Global Backward and Forward Multiplier Analysis: The Case Study of Japanese Automotive Industry") analyze the global backward and forward multiplier focusing on the Japanese automotive industry based on the global input-output table. By the structural path analysis, the paths of global value chain of Japanese automotive industry are shown.

Zhenhua Chen and Kingsley Haynes (Chapter "Transportation Infrastructure and Economic Growth in China: A Meta-analysis") gain a comprehensive understanding of the linkages between transportation infrastructure and economic growth with a focus on China using a meta-analysis. They identify the cause for the variation of output estimates based on a statistical investigation.

Guoping Mao's work (Chapter "Statistical Analysis of Sustainable Livelihood in China") establishes a statistical indicator system of China's livelihood from the perspective of sustainability. This study indicates five urgent problems to be solved regarding the Chinese livelihood.

Bin Li, *Wen-Hong Cheng, and Cheng-Long He* (Chapter "Green Environment Social Economic System for Urban-Rural Integration") highlight a small-scale green water environmental social economic system in the context of New Normal for China's urban-rural integration. They also discuss the land and infrastructure in Jiaxing and give some recommendations on the system.

Md. Fakrul Islam and Wardatul Akmam (Chapter "Climate Change and Livelihood Adaptation Strategies of Farmers in Northern Bangladesh") focus on the problems of socio-environmental vulnerability due to climate change and livelihood adaptation strategies of farmers in Northern Bangladesh. Based on the analysis of a survey, they give some recommendations.

Wardatul Akmam and Md. Fakrul Islam (Chapter "Nongovernment Organizations' Contributions to Poverty Reduction and Empowerment of Women through Microcredit: Case of a Village in Gaibandha District, Bangladesh") discover the impacts of NGO activities (particular disbursing micro credit) on women in a village in Gaibandha District, Bangladesh. They find that though some instances of positive outcomes of micro credit on poverty reduction and empowerment indicators are observed, it is not as per expectation.

Part III: Japan Perspectives

Yasuhiro Sakai (Chapter "On Environmental Risk Management: The Interactions of Economic and Noneconomic Factors") proposes a general theoretical framework for environmental risk management from a new point of view. He attempts to combine both economic and non-economic factors into the traditional expected utility theory.

Makoto Tawada and Tomokazu Sahashi work (Chapter "Product Design for Recycling and Recycling Industry") is the analysis of a recycling industry in an economy where the quality of product design is incorporated. In three types of market failure, monopoly power, environmental damage, and cost for recycling, three policy instruments are derived in a theoretical setting.

Moriki Hosoe (Chapter "Optimal Policy and the Threat of Secession") gives an analysis of the possibility of integration and secession between a majority region and a minority region. It is shown that the change of two forms of governance, i.e., centralized integration or decentralized integration, depends on the cost level of public goods.

Yuzuru Miyata, *Hiroyuki Shibusawa, and Tomoaki Fujii* (Chapter "Economic Impact of CO_2 Emissions and Carbon Tax in Electric Vehicle Society in Toyohashi City in Japan") explore the economic impacts of promotion and realization of an electric vehicle society in Toyohashi City in Japan. Using a regional CGE model, the impacts of subsidies for EVs promotion and carbon tax for CO_2 reduction are simulated.

Geoffrey J.D. Hewings and Michael Sonis (Chapter "Initial Explorations into the Spatial Structure of the Japanese Regional Economies") present the analytical approaches for input-output tables over time to visualize and compare economic structure. Their approach is applied to the interregional input-output table and the empirical findings for Japan are presented.

Lily Kiminami and Akira Kiminami (Chapter "Rural and Agriculture Development in Regional Science") discuss the trends and the outlook of the study of rural and agriculture development in regional science. They introduced the theoretical framework of a new approach of strategic development for regional agriculture.

Suminori Tokunaga, *Mitsuru Okiyama, and Maria Ikegawa* (Chapter "Impact of Climate Change on Regional Economies Through Fluctuations in Japan's Rice Production Using Dynamic Panel Data and Spatial CGE Model") evaluate the impact of climate change on regional economies through fluctuation in Japan's rice production using spatial CGE model. They show that global warming-induced climate change has different impacts on each region and it creates regional economic disparities.

Saburo Saito, Mamoru Imanishi, *Kosuke Yamashiro, and Masakuni Iwami* (Chapter "Risk Evaluation of Social Decision Process: A Two-Stage Auction Game Model for Japanese Urban Redevelopment Procedure") formulate the urban redevelopment procedure as a two-stage auction game. By defining the risk of the urban development produce, they show the risk can theoretically be derived in a closed form and can be calculated numerically.

Soushi Suzuki and Peter Nijkamp (Chapter "Preference Elicitation in Generalized Data Envelopment Analysis: In Search of a New Energy Balance in Japan") develop a balanced decision-support tool for achieving an efficient energy supply in all Japanese prefectures. They propose a new variant of Data Envelopment Analysis by means of an application to prefectural energy efficiency strategies in Japan.

Yasuhide Okuyama (Chapter "Note on the Framework for Disaster Impact Analysis with Environmental Consideration") examines the framework for extending disaster impact analysis to include the impacts on and from the natural environment. The potential of the ECLAC methodology and the environmentally extended social accounting is discussed.

Hiroyuki Shibusawa and Yuzuru Miyata (Chapter "Evaluating the Economic Impacts of Hybrid and Electric Vehicles on Japan's Regional Economy: Input-Output Model Approach") evaluate the impacts of hybrid and electric vehicles on Japan's regional economy using the inter- and intraregional input-output model approach. They explore the impacts of shifting the production system in the automobile industry from the conventional automobile technology to an electric and hybrid vehicle technology.

Katsuhiro Sakurai, *Hiroyuki Shibusawa*, *Kanta Mitsuhashi, and Shintaro Kobayashi* (Chapter "Evaluation of the Water-Environment Policy in the Toyogawa Basin, Japan") develop a socioeconomic model to evaluate the water environment policy for the Toyogawa Basin, Japan. The analysis encompasses the option of vegetable cultivation factory systems, a high-value-added agricultural system, as a choice of environmental improvement technology.

Katsuhiro Sakurai (Chapter "A Management Policy of Demand-Driven Service for Agricultural Water Use in Japan") clarifies the present condition and consciousness of rice farmers about water use by interview survey in case of Aichi-yosui irrigation area. He analyzes the agricultural water management system. It suggests that demand-driven irrigation facilities can fit appropriately with the needs of each farmer and increase the productivity of the entire region.

Takeshi Mizunoya (Chapter "An Analysis on Social Benefit Derived by Introducing New Technology and Optimal Environmental Policy: Case Study in Lake Kasumigaura") evaluates social benefit derived by introducing new technologies and analyzes a dynamic optimal policy to improve the water quality of Lake Kasumigaura. The impacts on the pollutants measured by total nitrogen (TN), total phosphorus (TP) and COD are clearly shown.

Susumu Uchida (Chapter "Promotion Policies for Sustainable Energy Technologies: Case Studies in Japan") develops a simulation model for analyzing the effects of specific promotion policies for sustainable energy technologies in Japan. The simulation results reveal the effectiveness of specific promotion policies, a combination of GHG emissions tax and subsidy, for sustainable energy industries.

In composing these essays, much support was given by the JSRSAI, the PRSCO, and the RSAI. In the 51st JSRSAI Annual meeting which was hosted by Okayama University in Japan, many contributors presented their papers for Prof. Higano. We wish to express our thanks to all the contributors to this essay.

Tokyo, Japan
November 2015

Hiroyuki Shibusawa
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Takeshi Mizunoya
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Contents

Part I
Global Perspectives

Regional Science in the Twenty-First Century

Antoine Bailly and Lay Gibson

Abstract Regional science has been a research field for over 50 years; it continues to enjoy a solid reputation as a useful approach for problem solving for economic, sociocultural, political, and even environmental issues. Its methods, techniques, and perspectives contribute to understandings of regions and of interactions both between regions and within a given region. Its challenge for the future is to fully incorporate new technologies and approaches such as geographic and regional information systems while continuing to be useful to those wishing to evaluate the structure and evolution of established regions and the emergence of new regional identities.

Regional science has been a recognized enterprise for only 50 years, and it is still a young field. W. Isard, the founder, who for more than 40 years had a profound influence on regional science curricula, published a series of fundamental books on methods and introduction (Isard W, Methods of regional analysis; an introduction. M.I.T, Cambridge, 1960; Isard W, Introduction to regional science. Prenctice Hall, Englewood Cliffs, 1975). Regional science was seen as a science of places, locations, and networks. But the discovery in the 1980s, through social and natural sciences, of other possible approaches (Hägerstrand T, Pap Reg Sci Assoc 24:7–21, 1973) marked the beginnings of new lines of research that we present in this paper.

Keywords Region • Regional science • Regional geography • Regional identities

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1 What Is the Purpose of Regional Science?

Human locations were first seen as a reflection of economic patterns. Recent research widened the scope to take into account human/environmental relationships, cultural patterns through the evolving values of societies (Bailly and Coffey 1994). New regional science raises new questions, not only where, how far, and how much but also who, to whom, how, and why (Table 1). It does not deal with the short term, but with the sustainable in a more global approach.

The new regional science stresses the links between human decisions in space, environment, economic, cultural, and social life, by proposing more global models at the regional level (Gibson 1998; Bailly et al. 1996). New studies deal not only with the impact of distance on location, hierarchies, and centralities but also on actor representations and on environmental consequences of their decisions. Regional science moves into the realm of both the economic sciences and the social sciences and humanities. Its purpose is now to analyze from different points of view the way in which actors group themselves, adapt to their environments, and fight to make use of space in a sustainable way.

Regional science must take into account works in social and environmental sciences; new regional geography using mental maps and GIS, cognitive psychology developing researches on the mutual influences of the people on their environments, humanities studying the role and attachment of place, and environmental sciences developing risk analysis and sustainable development are among these new fields. At a time when new regional communities are emerging, regional scientists are questioning the very foundations of their discipline and their function in societies. What is the region they are studying?

2 The Concept of Region

The concept of region is still difficult to define; is it a homogenous area from a physical point of view and can one talk of a natural region? Is it a heterogeneous area with a basic structure such as a river or a fluvial basin? Is it a cultural area based

Table 1 New questions for regional science

Questions	Concepts	Extension
Who and to whom?	Identities	Social life
	Milieus	Strategies
		Risks
How?	Representations	Quality of life
Why?	Understanding	Powers
	Explanation	Convergence-divergence
		Sustainability

on a common way of life or an area based on a city and its hinterland – a so-called nodal region? In fact, all are regions even if, for a long time, natural regions were the only ones considered by the scientists owing to the dominance of the naturalist point of view. This was the case in the nineteenth century when a "Darwinian" and determinist approach emphasized the influence of nature on mankind. Close relations between environment and people were used to explain life in a region often called "pays." It was a way to organize the biosphere into regions, by labeling the species and the drawing biome boundaries. This approach was well developed by the German school. The regions were classified, like plants, by their geology, soils, nature, and climate – giving birth to nations of people behaving in a similar way. This type of approach was pushed to its extreme by the National Socialist thinkers to impose German culture in Germanic world, and sometimes elsewhere, since their culture was considered to be superior.

In contrast, the French School of Geography (Claval 1993) at the beginning of the twentieth century was developing a "possibilist" approach. The basis for this was that if there is a natural environment in a region, people can choose from the possibilities to develop their economic, social, and cultural life. The physical environment is just seen as a base for territorial development. Since regions composing France were diversified, each of them could create its own way of life and choose to be part of France despite the physical differences. The concept of landscape was closely linked to this approach. The landscape expresses a natural, social, and aesthetic unity, the intimacy between a culture and a region. Regional landscapes have been shaped by human activity, and a special attention is given to the patterns of forests, fields, and roads, since cultural groups have different ways of settling the land. This concept is associated with the idea of a common human life, a community, building its way of life and its sense of place (Frémont 1976).

This concept was used after World Wars One and Two to reorganize European nations. As an example, each of the Balkan countries was created by uniting a cluster of regions – the underlying hypotheses being that they would share a sense of national unity. History shows us that this was not the case and the word "balkanization" is now used to show a dislocation of territories; cultural regions had more identity than the new nation-states, and this led to ethnic and religious conflicts.

The concept of region, invented in Europe, was also exported in other parts of the world. It had significant effects on the development of regional identities and sometimes separatist movements, as in Québec, for linguistic and cultural reasons. Following the recent growth of sustainability concepts, the regions can be now considered as open spatial systems, with their structures and regulations, men, resources, capital, and know-how, which build forces for regional development organized from the cities.

Regional indicators deal, through geographic information systems (GIS), with environmental variables (global warming, pollutions, etc.), land planning (buildings, places, infrastructures, etc.), and flows (of water, energy, cars, inhabitants, etc.). This very complex reality is integrated in regional information systems (RIS), composed by databases, which can also integrate social values, such as quality of life indicators and citizen satisfaction criteria. Decision makers can consult the RIS for the monitoring and action processes. The added value of RIS comes from its capacity to present and manage quantitative and qualitative data and to take into account the satisfaction level of the population (preferences, value systems) and the objectives of regional planning. By developing this RIS approach, regional science can focus on sustainability issues at the regional level, in a real strategic planning approach.

3 New Regional Identities

Globalization and fragmentation are terms of a new dialectic between the global and the regional. Our relationship with the world has changed. Before, it was local-local. Now it is local-global (Rees 1999). Globalization has made us discover other forms of citizenships, not only the citizen of the world but also the importance of regional identities as we have seen. The forging of regional communities has coincided with the establishment of the world and continental systems. Let just see what is going on in Europe since the rise of the European Union. Scotland is asking for independence from the United Kingdom, and Catalonia is seeking independence from Spain. Russia is moving Crimea and the Eastern Ukraine toward new Russian citizenship. Just to use these examples and those of past Yugoslavia, more than 15,000 km of new frontiers have emerged in Europe since 1990! We are far from the unified world of Montesquieu and Huxley.

Inside the European Union, many of these regions now have representatives in Brussels, to promote their culture and economy. Inside the nation-states, many regions develop marketing policies to attract tourism or firms, on the basis of their landscapes, climate, and quality of life. The competition among regions is as important as the one between nations to get more activities and more wealth. Some economists and regional scientists developed the concept of "milieu" to explain how local authorities, combining political, educational, and entrepreneurial groups, could promote regional attractiveness. The milieu theory, based on regional "savoir faire" (know-how) and control, is used to show the bottom-up potential of regions confronted with the demand of the world economy. Instead of waiting for top-down decisions from multinationals, they create their own economic and social environment to find niches in the world market. French spatial economists call this a "micro global" approach, micro by taking into account the region and its enterprises and global since they are integrated into the world system. Examples of these successful milieus are numerous: the watch industry of Jura in Switzerland, the Third Italy or the shoe and leather industry of Choletais in France, etc. All of these regions have an economic base founded on local entrepreneurship and knowledge and a positive image due to their successes in the world competition.

Table 2 New citizenships

Regional communities	Nation-states	Supranational communities
For when, why, to what purpose?		
Identities	Nationality	Legitimacy
Convergence	Development	Global concept
Governance	Governance	World system

In all the continents, regional movements are emerging, raising new questions for regional science. Recent regional-national citizenship systems, based on local advantages and governance at the local level, are shaping the political world. New spatial divisions and of their geopolitical implications is at the center of debates in many countries. Questions of identities and citizenship convergence or divergence, autonomy, or federation must gradually be incorporated in regional science (Table 2).

Essential to the notion of new regional identities are flows and linkages. The study of flows and linkages is nothing new for regional scientists, but it might be argued that what is new if the magnitude and the contemporary geographic scale of the flows and linkages are variable. A well-known cliché is “the world is getting smaller.” Whereas this phrase is certainly a cliché, it also appears to be true. Substantial flows of Chinese to California, Arizona, and Mexico; of Japanese to Brazil; of Vietnamese to Texas and California and to France; of Algerians to France; and of Indians to Africa have been recognized for decades. Movements between all settled continents and the cultural changes that come with such movements are familiar topics in both scholarly and journalistic writing.

The reasons for migrations are known and include economic opportunity, reunification of families, flights from war-torn regions, flights from religious and other forms of persecution, and both natural and cultural amenity seeking. Often less well understood are the sociocultural and economic consequences for both the sending and receiving regions and in some cases for regions which fill the gap between origins and destinations.

Intra-regional movements within Europe or within North America have substantial consequences. But perhaps interregional flows such as those that bring populations from places such as Ethiopia, Mali, and Libya to Italy or those from the Middle East to Europe or Australia will have even more dramatic effects. As already noted given the magnitude and geographic scale of movements and the sociocultural and economic backgrounds of migrants, it is easy to imagine that established regional identities will be challenged and that new regional identities will develop over time.

As the world changes, regions are becoming more and more important, so does regional science also, to analyze and answer major geopolitical and economic questions at the regional level and deal in a democratic way with new citizenships.

References

Bailly A, Coffey W (1994) Regional science in crisis: a plea for a more open and relevant approach. Pap Reg Sci 73:3–14
Bailly A, Coffey W, Gibson L (1996) Regional science: back to the future. Ann Reg Sci 30: 153–163
Claval P (1993) Initiation à la Géographie Régionale. Nathan, Paris
Frémont A (1976) La Région Espace Vécu. P.U.F, Paris
Gibson L (1998) Institutionalizing regional science. Ann Reg Sci 32:459–467
Hägerstrand T (1973) What about people in regional science? Pap Reg Sci Assoc 24:7–21
Isard W (1960) Methods of regional analysis; an introduction. M.I.T, Cambridge
Isard W (1975) Introduction to regional science. Prenctice Hall, Englewood Cliffs
Rees J (1999) Regional science: from crisis to opportunity. Pap Reg Sci 78:101–110

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Lay Gibson Distinguished Outreach Professor Emeritus, past Regional Science Association International President, recipient of the Association of American Geographers Anderson Medal for work in applied geography, and has written numerous scholarly books and articles and has conducted applied research studies for a variety of private firms and governmental agencies.

The Sustainability of Demographic Progress Around the World

David A. Plane

Abstract In contrast to the current enthusiastic embracing of the concepts of sustainability and adaptation, the idea of progress has, in recent times, fallen out of vogue. Sack (Progress: geographical essays. The Johns Hopkins University Press, Baltimore, 2002) noted: "contemporary science rarely thinks of nature in terms of design. Nature is constantly changing, but, generally speaking, it has no preferred direction or goal." In this paper, I examine the concept of demographic progress and speculate about the types of regional science and population geographic research that will be critically needed as we transition into a post-demographic transition world, one in which countries and people are confronted with the economic and societal issues attendant to population momentum, aging, and shrinking labor forces, together with significant global environmental change. I track the recent course of a number of demographic indicators for countries from around the world to argue the case for an ongoing role for demographic progress. As humans grapple to harmonize their affairs and adapt their socioeconomic systems on a planet now embarking on a radically altered demographic course, I argue that relatively predictable population trends can and should inform a policy-relevant agenda for regional science research capable of contributing to sustainable human progress.

Keywords Progress • Sustainability • Population trends • Demographic indicators • Demographic transition theory

1 Introduction

In contrast to the current enthusiastic embracing of the concept of sustainability and adaptation, the idea of "progress" has, in recent times, fallen out of vogue. Landscape paintings during the heyday of the industrial revolution often featured

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steamboats belching plumes of coal smoke into the air. Today, postmodernist thought questions whether the seemingly inexorable directions of change in human affairs necessarily point toward improved states of being.

A book of commissioned essays entitled *Progress*: *Geographical Essays* (Sack 2002) attempted to assess the concept of progress in various branches of scholarship in geography and, more broadly, the relationships between geography and progress. In the introduction to the book, editor Robert Sack notes: "Contemporary science rarely thinks of nature in terms of design. Nature is constantly changing, but, generally speaking, it has no preferred direction or goal" (p. xi).

In the book's first essay, Thomas Vale assesses whether ideals of progress exist in physical geographic research. He cites Stephen Jay Gould. Gould contends that the concept of progress (together with adaptationism, determinism, and gradualism) constitutes one of the four *biases* of modern science. In evolutionary history, Gould has been a proponent for a view of directionless diversification rather than of "linear, directional pathways and development toward 'higher' or 'better' forms" (Vale, in Sack, p. 2).

Progress: *Geographical Essays* does not specifically treat population geographic or regional science research or the interconnections of demographic change and the economic issues at the forefront of contemporary regional science research. It seems to me, however, that many of the theories of demography intrinsically embed concepts of progress. And, similarly, much of our thinking about the world's geography of population takes as largely non-problematic the connections between demographic change and regional economic development trends. There are clear and obvious connections between the basic quantities studied in population geography – that is, demographic indicators – and notions of quality of life (QOL) or human well-being. Indeed, social accounts often directly deploy basic demographic indicators as constituent components of QOL.

Is a concept of progress intrinsically less problematic for population geography and regional science than it is for other branches of the social and natural sciences? A critical theorist's stance on this question might be that population geographers have been troglodytes for being so accepting of such a directionally rooted paradigm. The counter assertion would be that – for the overwhelming majority of the world's now more than seven billion people – demographic progress is not merely some ethereal academic construct; it is, rather, a concrete goal toward which groups of human beings aspire, thus inspiring their collective actions. It seems to me that given the normative focus of much regional science – quantitative analysis undertaken to contribute to better economic and social policy – a notion of social welfare, betterment, advancement, improvement, or progress must almost necessarily lie at the heart of our enterprise. And many of the key variables of demography lend themselves, directly or indirectly, to attempts to measure the quality of life.

It is hard to argue that it is not progress when a country's infant mortality is lowered. Nor would many assert that the long-term trend of increasing average life expectancy at birth is not, on balance, all to the individual and communal good. And what of the strong empirical evidence (provided in case after case) that reductions in a country's fertility – at least reductions down from levels substantially in excess of the replacement total fertility rate (TFR) of ca. 2.1 babies per woman – have seemingly gone hand-in-hand with increased economic empowerment of women and thence rising material prosperity?

The heritage of transition theories so pervasive in demography is, I think, also reflected in the style and topics of regional science research carried out to date. Not coincidentally, regional science was founded and came of age concurrently with the formulation by demographers of theories of demographic transition. Both were products of the post-World War II period in North America, Europe, and Japan, where economies were rapidly developing concomitant with these regions moving through what has come to be called the third or late-expanding stage of demographic transition. The post-World War II baby booms experienced in these countries generated youthful population age structures that, when coupled with the subsequent shift in preferences for smaller families, provided the labor forces and consumer demand for an unprecedented period of long-term economic expansion.

As the boomer generations of today's most developed countries (MDCs) reached working ages, the advancement of material prosperity was sustained as their capitalistic economies reaped a so-called demographic dividend. Such a dividend is the possibility for accelerated economic growth that a country may reap as a result of a lagged change in its population age structure after mortality and fertility levels are brought down. With fewer births, a country's young dependent population for a period of time grows smaller in relation to its working-age population. With fewer children to support, and as women increasingly enter the labor wage economy, a country has a window of opportunity for rapid economic growth, presuming the right social and economic policies are developed and wise investments made (Grimner and Bremner 2012).

The rising tide of material prosperity and rapid technological innovation after World War II drove academic interest in enhancing and developing new quantitative tools for studying and advancing economic and social well-being. Now, as demographic transitions and subsequent demographic dividends are available to other parts of the world, for the MDC countries, a critical focus becomes how to sustain one's own society's economic progress while sharing a world in which former economic disparities are much reduced. The regional science focus on normative science is shared with the field of demography, where it developed from a long history of concern with accurate measurement and numerical methods for estimation, projection, and analysis.

Given the nature of this initial impetus for the founding of regional science as an academic endeavor and the inherent interconnectivity of population geography with demography, it should not be surprising that adherents to these two fields have been somewhat resistant to the bufferings of postmodernist thought. Questioning of scientific approaches has come into vogue, in part, because of the changed global economic landscape driven by demographic transition and the spotlight it has put on marginalized populations in an era when returns to the owners of capital have soared. It thus seems critical, for the future of the regional science movement, to focus on understanding how, once most all countries' demographic transitions are completed, can ongoing enhancement of quality of life be sustained in all regions of the world? At present, it is the formerly less developed countries that are being given the potential to reap their demographic dividends and rise on the development spectrum. Ultimately, however, once all these finite-period population-driven labor effects have been expended, will the large demographic divide characteristic of the demographic transition period of human history become a relic of the past? Or will other comparative advantages lead, again, to a world of "haves" and "have nots"?

While such big-picture economic prognosis lies beyond my expertise or ambitions in this paper, inexorable, big, and fairly predictable demographic trends have been, and will continue to be, underway for some time. Most countries' populations are aging, and their age compositions shifting. But the demographic divide that has characterized the world over the past century or more ensures it will still be several generations before a convergence of age structures around the world becomes a possible future system state. In any of several possible such future, post-demographic transition worlds, can there be a continuing role for a notion of demographic progress? Can demographic progress be an empirically sustainable paradigm over the long term for scholarship in demography and regional science? Or, like modernity, does demographic progress contain the seeds of its own nihilism? Transition theories imply a state of completion. But as the countries of Europe, Japan, and others are now wondering, what comes afterward? And is, in fact, the direction of demographic evolution the wiping out of economic and demographic differences among rich and poor nations? Or does global capitalism inherently promote the continuance of inequities in nation-scale demographic outcomes as a result of the nature of the transnational competition for access to resources and material prosperity?

In this essay, I won't provide any firm answers to all these broad questions! Rather, I shall share only some tentative thoughts, buttressed by the results of a simple exploratory empirical exercise. In the third section of the paper, I shall look at the changes within a set of selected indicators for the world's countries over a two-decade period of time up through the tech boom that ended in the early 2000s. I shall then, more cursorily, look at the subsequent period up to the present. Before getting into that exercise, however, I wish first to briefly survey the progressive elements of our basic transition theories, because such theories form the backdrop against which we shall examine the results of recent empirical evidence on the direction of change in world demographic patterns.

2 The Role of Progress in Theories of the Geography of Population Change

In assessing change, the geographical analyst of population makes frequent use of the so-called components of population change, which are summarized in the basic demographic accounting equation (sometimes called, simply, "the demographic equation"):

$$\Delta P = B - D + NM.$$

The change in the total population of an area of the earth is the difference between births and deaths (this difference termed also "natural increase" or, more properly these days, "natural change") plus net migration: the difference between the number of in-migrants and out-migrants for the area. Three major transition theories summarize the long-term processes countries appear to experience in these constituent components of overall population change. The concept of progress is embedded in each of these three theories.

The science of demography began with the systematic study of mortality. The epidemiological transition summarizes changes over time in the societal risk of death (Omran 1971, 1977). The epidemiological transition theory is closely related to the mortality component of the overall demographic transition theory, which summarizes change over time of both death and birth rates, i.e., of a country's natural increase.Omran (1982) summarizes the theory to be constituted of five propositions. The first is simply the premise that mortality is a fundamental factor in population dynamics. The second, however, asserts that:

> . . . a long-term shift occurs in mortality and disease patterns whereby pandemics of infection are progressively (but not completely) displaced by degenerative and man-made diseases as the leading causes of death. (Omran 1982, p. 172)

The theory typically posits three stages in this *progressive* process: (1) the age of pestilence and famine, (2) the age of receding pandemics, and (3) the age of degenerative and man-made diseases.

Omran's third proposition is that, in terms of the enhancement of life spans, the transition tends to "favor" the young over the old and females over males. The fourth proposition asserts that the transitions occurring prior to the twentieth century in the more developed countries:

> . . . have a closer association with rising standards of living and improved nutrition than with medical progress. In contrast, the twentieth-century transitions (i.e., in the less-developed countries) are initiated by medical progress, organized health care, and disease control programs that are usually internationally assisted and financed, and thus largely independent of the socioeconomic level of the country. Further maturation of the transition, however, depends on a beneficial synergy of health care progress and socioeconomic development. (Omran 1982, p. 172)

Note, here, his observation regarding the sustainability of the transition, e.g., of demographic "progress" with respect to the enhancement of life spans.

Finally, Omran's fifth proposition builds from the above observations to recognize a "basic" or "classical" model (derived from the historical experience of today's more developed countries) and three variants: (a) an "accelerated" version to account for differences in Japan, Eastern Europe, and the former Soviet Union, (b) a "delayed" one for most Third World countries, and (c) a "transitional variant of the delayed model" to describe the experiences of countries that have recently rapidly developed, such as Taiwan, South Korea, Singapore, Hong Kong, Sri Lanka, Mauritius, Jamaica, and China.

Whereas the epidemiological transition theory does not posit a single pattern of change for all countries to pass through, there is obviously an inherently assumed unidirectionality of change, with tight linkages between mortality, scientific advances, economic development, and forces of globalization.

Notestein (1945) coined the term “the demographic transition” to describe the demographic history of Western Europe. The characteristic drops that occurred first in death rates and then in birth rates can be summarized by a pair of overlain, reversed S-curves. The lag between the time of the declines in mortality and those of fertility, however, resulted in a transition period of rapid population growth.

In addition to the resultant drops in mortality that stem from the epidemiological transition, demographic transition theory is dependent on fertility decline occurring concomitant with “modernization” of a country’s lifestyle. Conventionally, the theory has involved a country passing through four stages: (1) the high stationary, (2) the early expanding, (3) the late expanding, and (4) the low stationary. Explosive population growth is brought about by the divergence of birth and death rates during Stage 2 and the considerable population “momentum” due to young age structures that perpetuates high growth rates even as birth and death rates are converging during Stage 3.

Research has focused on triggers for fertility declines and the relevance of the Western Europe experience to the contemporary settings of lesser developed countries (Teitelbaum 1975). Economic theory has contributed a basic framework to analyze the microfoundations of such declines (e.g., Easterlin 1975), while the roles of cultural factors have been highlighted in empirical studies as extremely significant influences on the onset and spread of the fertility decline (Knobel and van de Walle 1982). Despite a large number of caveats, the basic thrust of demographic transition theory is the irreversibility of family limitation practices and thus fertility decline. Examine, for instance, this summary of the European demographic experience in terms of four main findings:

> (1) Fertility declines took place under a wide variety of social, economic, and demographic conditions. (2) The practice of family limitation was largely absent (and probably unknown) among broad segments of the population prior to the decline in fertility, even though a substantial portion of births may have been unwanted. (3) Increases in the practice of family limitation and the decline of marital fertility, once underway, were essentially irreversible processes. (4) Cultural settings influenced the onset and spread of fertility decline independently of socioeconomic conditions. (Knobel and van de Walle 1982, p. 268)

The third and final transition theory concerns the characteristic evolution of migration patterns within countries. It stems from the logical linkages between industrialization, economic development, and urbanization, perhaps first summarized in a coherent way by Ernst Georg Ravenstein in his classic papers on the “laws of migration.” Ravenstein provided a series of cogent observations concerning urbanization and the geography of the flows of human capital underway in Great Britain during the epoch of the industrial revolution (Ravenstein 1885, 1889).

The longer-term trends in the internal migration experiences of countries were summarized by Zelinsky (1971) in his “Hypothesis of the Mobility Transition.” As explained by Weeks (1999):

> The demographic transition helped to unleash migration ... migration is a ready adaptation that humans (or animals for that matter) can make to the pressure on local resources generated by population increase... Because the demographic transition occurred historically in the context of economic development, which involves the centralization of functions in cities, migrants have been drawn to cities, and urbanization is an important part of the migration transition (p. 238).

As in the other two transition theories, in Zelinsky's model, a country is posited to undergo a progression of changes in three waves of major movement: (1) rural to rural, which involves the settlement of frontier regions; (2) rural to urban, i.e., urbanization; and (3) urban to urban, which becomes the dominant mode once a fully developed urban system has been achieved.

Shortly after Zelinsky formulated the mobility transition hypothesis, considerable attention came to be focused on a newly postulated fourth mode of movement: urban to rural. Newly extended migration transition theories have more recently been developed with reference to "counter-urbanization" and the changing economic roles of cities at different levels of national hierarchies (e.g., Geyer and Kontuly 1996).

All three transition theories share a focus on the dynamic interrelationships of microscale demographic behavior and macroscale processes of economic systems, which are brought about as a result of accumulating scientific knowledge and the technology changes that it facilitates. In the case of all three theories, the state-of-the-art research focuses on the question: What happens next? All three are essentially post hoc descriptions of events that have occurred in a part of the world being extended to countries in other areas. While historical progress is largely uncontested in these theories, interesting questions arise as to the sustainability of the embedded notions of progress once the transitions, as they were originally conceived, become completed.

Let's turn, then, to a simple assessment of two recent decades of experience through the lens of demographic progress. The time period chosen for my analysis, 1982–2002, is somewhat arbitrary, just as would any time period for researching a set of continuously evolving time trends (Boulding 1985). The analysis was originally carried out preparatory to my (unpublished) 2003 Pacific Regional Science Conference Organization (PRSCO) Presidential Address and contemporaneous with the appearance of the Sack (2002) book, both of which provided the impetus for my thinking on these matters. The year 2002 is also, however, the most fortuitous one for our purposes here, marking the proximate end of the "tech boom" period in the USA and other highly developed countries. By then, too, the window of opportunity known as the "demographic dividend" had passed to elsewhere in the world. In 2002 the first members of the US baby boom generation (those beginning with the 1946 cohort) were entering their late 50s, and the last members (born in 1964) were into their late 30s and had already been absorbed into the labor force. It could be argued that, by 2002, not only was the demographic transition within MDCs completed, so too were the subsequent demographically driven labor force effects. The period 1982–2002 was equally interesting for our purposes here, when the "sweet spot" in population age structure was starting to be reached by a number of highly populous countries within the middle tier of development status, including the world's two most populous: China and India.

3 Demographic Status and Progress of Countries Around the World

Truly comparable, exact international population data for any given point in time do not exist. The Population Reference Bureau, in its annual World Population Data Sheets, attempts to provide a set of indicators that are as consistent, as feasible, given the different years when countries enumerate their populations, as well as the variations in basic data definitions and reporting practices employed by countries across the world. These data cannot be used reliably as an annual time series, but they are suitable for longer-term, general comparison purposes, such as here. For the analysis that follows, I used data from Population Reference Bureau (1982, 2002, 2015).

To examine the recent course of demographic change for the world's countries, I decided to focus on eight key demographic indicators, those shown in Table 1.

In choosing these, I limited myself to indicators widely available for the approximate end points of the 1982–2002 study period, and I excluded countries that had total 2002 populations of less than one million. Unfortunately, countries that split up during the two decades (the former Soviet Union, Czechoslovakia,

Table 1 Demographic indicators used in the study

Demographic indicator (variable name)	Definition
Infant mortality rate (IMR)	Deaths of infants less than 1 year per 1000 live births
Average life expectancy at birth (Life Exp)	Expected years lived, based on current age-specific death rates
Total fertility rate (TFR)	Total number of babies born to a hypothetical woman passing through all childbearing ages if she gives birth at current age-specific birth rates
Youth dependency ratio (YDR)	Population 0–14 years as a percentage of population 15–64 years
Elderly dependency ratio (EDR)	Population 65 years and over as a percentage of population 15–64 years
Female labor force participation rate (Fem LFPR)	Percentage of all females 15–64 years who are employed or actively seeking work while unemployed
Urban percentage of population (Urb Pop)	Percentage of people living in urban areas as based on country-specific urban area definitions
Net immigration rate (Net ImmR)	Number of immigrants less emigrants per 1000 midyear population

and Yugoslavia) also had to be excluded from my database because of the lack of ca. 1982 information for the new, smaller-bounded units.[1] Conversely, I was able to include countries that had unified by 2002 (namely, East and West Germany and North and South Yemen). I used total populations of the formerly separated countries to combine, on a pro rata basis, their 1982 demographic indicators.

3.1 Mortality and Longevity

Let us begin our examination of demographic progress around the world with mortality and longevity statistics. The simplest of these is the crude death rate (CDR), which is simply the number of deaths recorded in a population per 1000 people alive at the midpoint of the period. The original demographic transition theory was framed in terms of the CDR and the similarly defined crude birth rate (CBR) statistic.

While reasonably useful for studying trends over time, the CDR can be a misleading indicator to deploy for intercountry comparisons. It is strongly affected by age composition. Mexico, for example, with its still child-dominated age structure, currently has a lower CDR than does the USA even though Mexicans, at all ages, have higher age-specific probabilities of dying. A composite indicator constructed from age-specific death rates would be preferable for such comparisons, but age-specific information is not available for all countries.

The infant mortality rate (IMR) is an age-specific death statistic that is almost universally available and consistently reported. Surely demographic progress is evidenced when a country achieves greater success in preventing unnecessary deaths of its babies! The IMR is a telling indicator of social welfare; it is sometimes used as a proxy for both the level and degree of diffusion throughout a country of quality medical care, nutrition, and sanitation. With just 2.2 infant deaths per 1000 live births, Singapore registered the world's lowest infant mortality in 2002; it was followed by Hong Kong, Japan, Sweden, Finland, and Norway – all with rates below 4.0. In 2002 the countries with the world's highest infant mortality were Sierra Leone and Afghanistan, where rates exceeded 150.

As can be seen in Table 2, substantial progress was, in fact, being made around the world in the likelihood of infants living to their first birthdays. Of the 130 countries in the data set, 124 achieved lower IMRs by 2002! Offsetting this encouraging news, however, was that fact that, on average, the *percentage* reductions

[1] This data unavailability problem is unfortunate in the context of examining demographic progress, in that the dislocations of the economic and political transformations in countries that split apart have interesting demographic repercussions. Those, however, must be the subject of other research. In terms of migration impacts, see, for instance, Mitchneck and Plane (1995).

Table 2 Change in the infant mortality rate for world countries, 1982–2002

Area or country	Infant mortality rate 1982	Infant mortality rate 2002	Rank 2002	Percentage change	Rank by change
World	85	54	–	–36.5	–
More developed countries	20	7	–	–65.0	–
Less developed countries	96	60	–	–37.5	–
Largest decrease: Oman	128	17	39	–86.7	1
Largest increase: Jamaica	16.2	24	50	48.1	130
Most populous countries					
Germany	12.5	4.4	7	–64.8	20
Brazil	77	33	62	–57.1	40
Japan	7.4	3.2	3	–56.8	42
Mexico	56	25	52	–55.4	44
Bangladesh	136	66	85	–51.5	64
Indonesia	93	46	74	–50.5	67
India	123	68	86	–44.7	74
Nigeria	135	75	92	–44.4	75
USA	11.8	6.6	26	–44.1	77
Pakistan	126	86	101	–31.7	92
China	45	31	59	–31.1	93

Sources: Population Reference Bureau (1982, 2002); percentage changes and country ranks calculated by the author

were greater in the more developed than the less developed countries (LDCs), despite the much higher 1982 rates of LDCs than MDCs.

Among the world's dozen most populous countries (a list that excludes, for data limitation reasons mentioned, Russia), two of the world's most highly developed countries, Japan and Germany, and two currently at intermediate levels of development, Brazil and Mexico, led the pack of those achieving the greatest percentage reductions. The USA trailed most MDCs on this measure due to its high degree of inequality of access to high-quality medical care.

In terms of infant mortality, the reductions achieved – even in those countries that already had the lowest rates two decades earlier – suggest that demographic progress, as measured by this indicator, remained an attainable and worthy goal for most countries in the near-term future. Continued medical advances, better pre- and postnatal care, and improved nutrition and sanitation all increase the percentages of infant deaths that are considered preventable. But the 1982–2002 analysis clearly shows that the most potential for sustained demographic progress is to further the diffusion around the globe of "best practices."

The experience since 2002 is that sizable further progress has, indeed, been made. From 2002 to 2015, the reductions in infant mortality did not simply continue apace, but actually sped up! The worldwide IMR dropped from 54 to 37 infant deaths per 1000, which is an annualized decrease of 2.4 percentage points versus the 1.8 percentage point per year improvement registered over the 1982–2002 period. By 2015, the rate across the MDCs had been brought down to 5 and that for all LDCs combined to 40.

Almost as non-problematic as not wanting babies to die is the nearly universal interest in achieving greater human longevity. Another telling indicator with respect to many of the same factors as infant mortality (nutrition, health care, sanitation, and so forth) is average life expectancy at birth. In 2002, Japan (at 81 years) ranked #1, and Australia, Italy, Sweden, and Switzerland (tied at 80 years) ranked #2 among all world countries for longevity of their citizens. At only 37 years, Zambia's people had the shortest life expectancy.

Table 3 summarizes the 1982–2002 progress in extending life spans around the world. The greatest percentage gain was in Oman, and, among the most populous countries, truly spectacular increases took place in Indonesia, India, Bangladesh,

Table 3 Change in life expectancy at birth for world countries, 1982–2002

	Life expectancy at birth				
Area or country	1982	2002	Rank 2002	Percentage change	Rank for change
World	60	67	–	11.7	–
More developed countries	72	76	–	5.6	–
Less developed countries	57	65	–	14.0	–
Largest increase: Oman	47	73	41	55.3	1
Largest decrease: Zimbabwe	54	38	127	–29.6	130
Most populous countries					
Indonesia	48	68	68	41.7	4
India	49	63	77	28.6	11
Bangladesh	46	59	81	28.3	14
Pakistan	51	63	77	23.5	22
Mexico	65	75	31	15.4	40
Brazil	62	69	62	11.3	56
China	65	71	52	9.2	69
Germany	72	78	11	8.3	72
Nigeria	48	52	98	8.3	72
Japan	76	81	1	6.6	92
USA	74	77	21	4.1	102

Sources: Population Reference Bureau (1982, 2002); percentage changes and country ranks calculated by the author and Pakistan. In the span of less than a single generation in these four countries, which together accounted for almost exactly a quarter of the world's population, average expected years of life were extended by more than 20 %!

In a large part of the world, however, the AIDS epidemic was substantially setting back progress that otherwise should have occurred. Life expectancy at birth went down from 1982 to 2002 in 15 African countries and in Haiti. In 11 of the 15 African cases, life spans were reduced by more than 15 %, and they went down by more than 20 % in Zimbabwe and Zambia.

As with infant mortality, the period since 2002 has been one of remarkable, continued improvement. Worldwide average life expectancy at birth continued to rise, reaching 71 years in 2015. People born in 2015 in MDCs could expect to live 3 years longer than in 2002, while those in LDCs gained, on average, four more years of expected longevity. The differential between those living in less and more developed parts of the world has also substantially narrowed. Back in 1982, those born in LDCs could expect to live only 79 % as long as those born in MDCs. By 2015, however, life expectancy in LDCs was 87 % of that found in MDCs.

Most of the world's countries have by now passed through Stage 2 of the demographic transition, which is the period when the most rapid drops in mortality take place. Whereas we may be bumping into physiological constraints on longevity in MDC contexts, as with infant mortality, considerable room exists for extending the life spans of the majority of the world's people.

3.2 Fertility

Turning from mortality to fertility, the concept of demographic progress becomes substantially more complex. During the last two-decade 1982–2002 study period, a downward trend in childbearing propensity was taking place in most every country of the world regardless of preexisting typical family sizes. From an environmental sustainability perspective, for the long term, a lower rate of planetary population growth is most welcome news. In the shorter term, however, the rise in material prosperity for the majority of the world's people that accompanies family size reductions poses challenges.

Table 4 shows the situation with respect to total fertility rates, which are the average numbers of children to be born per woman if age-specific period fertility rates were to apply throughout the childbearing years. The TFR of the world as a whole dropped dramatically in the 20 years, 1982–2002, from almost four children per woman down to fewer than three. Most of the more developed countries by 2002 had rates below the long-term "replacement level" of 2.1, whereas the typical rate for less developed countries was close to 3.

The 1982–2002 period was a significant one for many countries on the path toward completing their demographic transitions. Among the 130 countries in the data base, fertility rates dropped over those 20 years in 110 cases; rises were experienced in only 18 countries. Among the world's most populous countries,

Table 4 Change in the total fertility rate for world countries, 1982–2002

Area or country	Total fertility rate 1982	Total fertility rate 2002	Rank 2002	Percentage change	Rank for change
World	3.9	2.8	–	–28.2	–
More developed countries	2.0	1.6	–	–20.0	–
Less developed countries	4.6	3.1	–	–32.6	–
Largest decrease: Hong Kong	2.4	0.9	1	–62.5	1
Largest increase: Somalia	6.1	7.2	128	18.0	129[a]
Most populous countries					
Brazil	4.4	2.2	40	–50.0	12
Bangladesh	6.3	3.3	65	–47.6	17
Indonesia	4.7	2.6	50	–44.7	22
India	5.3	3.2	63	–39.6	39
Mexico	4.8	2.9	56	–39.6	40
China	2.8	1.8	27	–35.7	49
Japan	1.8	1.3	4	–27.8	61
Pakistan	6.3	4.8	92	–23.8	67
Germany	1.6	1.3	4	–18.8	82
Nigeria	6.9	5.8	108	–15.9	89
USA	1.9	2.1	36	10.5	121

Sources: Population Reference Bureau (1982, 2002); percentage changes and country ranks calculated by the author

[a]Change data exist for only 129 countries because of missing 1982 data for Cambodia (Democratic Kampuchea)

the USA was the only one that registered a rising total fertility rate. This was mostly attributable to high levels of immigration, with the US foreign-born having significantly higher fertility than the native-born.

So how to define demographic progress with respect to changing fertility levels? If progress is a march toward "the greatest good for the greatest numbers," does increasing the world's population through natural increase represent progress? Or, as has more commonly been the prevailing view during modern times, does progress lie in achieving the greatest gains in quality of life for the planet's residents? Maximizing the increase of material prosperity and thence QOL seems to be achieved when a country brings its population growth rate down to a level where economic expansion is not stifled by excessive dependency, when the productive capacity of its women is harnessed in the labor force rather than exclusively in bearing and caring for youths. Children are, of course, the labor force populations of the future, but, equally, an overly high proportion of children in a country's population can stifle development.

It is during Stage 3 of the demographic transition when birth rates lower. Stage 4 has conventionally been defined as one when a new equilibrium is reached and maintained. Births and deaths were foreseen to come into a new balance at levels far below those of Stage 1, which pertains to most of human history, when unchecked mortality had kept natural increase to essentially zero, despite fertility levels close to the upper limits of fecundity. Stage 4 was similarly posited to be associated with no natural increase and was thus dubbed the *low stationary* stage. However, a remarkable aspect of our 1982–2002 study period was that in most all of the world's most developed countries, TFRs plummeted to well below the replacement level of 2.1, raising cause for alarm. In the long run, a total fertility rate below 2.1 is non-sustainable: the country will become depopulated, or, if experienced for the world as a whole, our species would ultimately go extinct. Both high and low TFRs, benchmarked around the 2.1 "replacement level," can be considered unsustainable over the long course.

So how, then, do we apply the concept of sustainable progress to fertility trends? Is progress not then simply measurable by unidirectional reductions from former levels but, rather, by a narrowing of the difference in either direction between a country's current level and that magic number of 2.1? Or would the inhabitants of some parts of the earth, and the planet itself, perhaps be better off with either more or fewer inhabitants than implied by a TFR of 2.1 and zero natural increase? This is an interesting unresolved question at this juncture of human history. On some parts of the planet, birth limitation is pursued as a primary societal goal, while, elsewhere, pro-natal measures enjoy strong support to ensure the sustainability of national cultures and economies.

3.3 Age Dependency

Age dependency ratios are interesting measures to examine in the context of assessing potentials for future economic development and for enhanced or sustained quality of life. Tables 5 and 6 present the data for the 1982–2002 period changes in youth and elderly dependency ratios.

As fertility rates have dropped, the world's youth dependency ratio (YDR) has dropped also. As shown in Table 5, the decrease has been the greatest overall in LDCs rather than MDCs. Japan at just over 20 % had the world's lowest ratio in 2002, whereas YDRs for Uganda, Niger, and Burkina Faso exceeded 100 (meaning there were more children in the 15 1-year age groups of 0–14 than there were adults in the 40 years from age 15 to 64, traditionally considered to be those of labor force participation).

Since 2002, youth dependency worldwide has continued to plummet. By 2015 it stood at 39.4, less than two thirds of its 1982 level. How should we measure progress with respect to changing youth dependency ratios? The name itself suggests that reductions might normally be desirable to achieve future greater per capita prosperity. But are YDRs in the low 20s, such as now found in Japan, Italy,

Table 5 Change in the youth dependency ratio for world countries, 1982–2002

Area or country	Youth dependency ratio		Rank 2002	Percentage change	Rank for change
	1982	2002			
World	59.3	47.6	–	–11.7	–
More developed countries	34.8	26.9	–	–8.0	–
Less developed countries	68.4	53.2	–	–15.2	–
Largest decrease: Kuwait	81.5	35.6	33	–56.3	1
Largest increase: Chad	73.2	98.0	122	33.8	129[a]
Most populous countries					
Japan	35.8	20.6	1	–42.5	11
China	51.6	32.9	30	–36.3	23
Brazil	73.2	46.9	45	–36.0	24
Indonesia	75.0	48.4	48	–35.4	26
Mexico	76.4	53.2	56	–30.3	39
Germany	30.8	23.5	5	–23.5	53
India	70.2	60.0	67	–14.5	78
Pakistan	90.2	77.8	85	–13.8	81
Nigeria	92.2	83.0	97	–9.9	83
USA	34.8	31.8	29	–8.7	86
Bangladesh	76.4	70.2	76	–8.1	88

Sources: Youth dependency ratios, percentage changes, and country ranks calculated by the author using age composition data from Population Reference Bureau (1982, 2002)
[a]Change data exist for only 129 countries because of missing 1982 data for Cambodia (Democratic Kampuchea)

Spain, Greece, Portugal, and Germany, a harbinger of future declines in material well-being and decreased QOL for those countries' citizens? Is there an optimal age structure and thus a target YDR for a country to seek?

The question of a sustainable family size to sustain a vigorous labor force is even more complicated by the fact that reductions in fertility and increased life expectancy are now beginning to contribute to rising elderly dependency ratios (EDRs) around the world. Elderly dependency is of concern most especially in those MDCs where reduced levels of childbearing have been the norm for the longest times.

In 2002, Italy and Japan had the highest EDRs in the World. As shown in Table 6, Japan's percentage increase was almost 100 % over just the two decades since 1982. By 2015 Japan's EDR was twice its YDR: for every 100 people aged 15–64, there were 42.6 who were 65 or over.

Table 6 Change in the elderly dependency ratio for world countries, 1982–2002

Area or country	Elderly dependency ratio		Rank 2002	Percentage change	Rank for change
	1982	2002			
World	10.2	11.1	–	9.3	–
More developed countries	16.7	22.4	–	34.3	–
Less developed countries	7.0	8.1	–	14.9	–
Largest increase: Mali	2.0	6.0	95	206.0	1
Largest decrease: United Arab Emirates	4.8	1.4	129	–71.2	129[a]
Most populous countries					
Indonesia	3.6	7.8	65	118.8	2
Japan	13.4	26.5	2	97.1	4
Brazil	5.4	9.4	45	75.0	5
Mexico	5.5	8.1	60	47.8	18
Nigeria	3.9	5.7	105	44.3	22
India	5.3	6.7	81	26.7	50
Pakistan	5.9	7.4	74	25.9	51
USA	16.7	19.7	21	18.2	62
China	9.7	10.0	38	3.3	90
Germany	23.1	23.5	9	2.0	91
Bangladesh	5.5	5.3	122	–3.5	96

Sources: Elderly dependency ratios, percentage changes, and country ranks calculated by the author using age composition data from Population Reference Bureau (1982, 2002)
[a]Change data exist for only 129 countries because of missing 1982 data for Cambodia (Democratic Kampuchea)

In the majority of less developed countries, rising EDRs probably do not pose much of an obstacle for these countries' near-term aspirations for improving well-being. (China, now on the cusp of entering the ranks of the MDCs, is a major exception.) Rather they reflect the positive aspect of enhanced life expectancy.

3.4 Female Labor Force Participation

In addition to age composition changes, the other major controlling factor for many countries' changing productivity situations has been rising female labor force participation. Table 7 summarizes these trends over the primary study period.

Worldwide, female labor force participation increased moderately between 1082 and 2002, going from 57 to 61 % of women of labor force age. What's more, the rate of increase was almost twice as great in MDCs than in LDCs.

Table 7 Change in the female force participation rate for world countries, 1982–2002

Area or country	Female labor force participation rate 1982	2002	Rank 2002	Percentage change	Rank for change
World	57	61	–	7.0	–
More developed countries	59	65	–	10.2	–
Less developed countries	57	60	–	5.3	–
Largest increase: Oman	8	20	128	150.0	1
Largest decrease: Central African Republic	77	68	33	–11.7	129[a]
Most populous countries					
Mexico	31	42	104	35.5	27
Pakistan	28	37	114	32.1	29
Brazil	36	47	92	30.6	31
Indonesia	46	58	62	26.1	39
USA	58	70	30	20.7	46
Japan	52	62	52	19.2	47
Germany	56	62	52	10.7	64
China	76	80	9	5.3	71
Nigeria	50	50	80	0.0	85
Bangladesh	70	68	33	–2.9	112
India	48	45	98	–6.3	124

Sources: Rates from *2002 Women of Our World*, Population Reference Bureau, Washington, D.C., http://www.prb.org. Data for Taiwan from Directorate-General of Budget, Accounting and Statistics (DGBAS) Executive Yuan http://www.stat.gov.tw/main.htm; percentage changes and country ranks calculated by the author

[a]Change data exist for only 129 countries because of missing 1982 data for Puerto Rico

The countries with the largest percentage additions of women to their workforces were certain rapidly developing countries where participation in 1982 had been at considerably below the world average. For example, among the most populous countries, Mexico, Pakistan, and Brazil posted the biggest percentage increases. Mexico, however, remained in the bottom third of all countries in terms of its actual rate.

Among MDCs, the female participation increase in the USA is notable, going from one percentage point below the MDC average in 1982 to a full five points above it by 2002. Nonetheless, among MDCs, by 2002 the USA still trailed Canada (72 %) and the Scandinavian countries (Finland, 73; Norway, 74; Denmark, 77; and Sweden, 82).

If gender equity in the workforce is taken as a reflection of social progress rather than economic necessity, the last two generations of working-age women in some countries have made progress by taking wage jobs in greater proportions than their mothers. But, in many parts of the world, there remains the potential for many more women to pursue workforce careers, and, for those employed, there is certainly a need to achieve better rewards and conditions for their wage labor.

3.5 Migration and Urbanization

Let's turn now to the migration component of population change. Extraordinarily high rates of urbanization have been the norm in many LDCs. More developed countries, on the other hand, seem to have entered a period of oscillating waves of movement up their urban hierarchies and of counter-urbanization down them (see, for instance, Kontuly 1988; Geyer and Kontuly 1996; Plane et al. 2005). Considerable regional science research has been conducted since the first "turnaround" phenomena were noted in the 1970s (e.g., Vining and Kontuly 1978; Vining et al. 1981).

Care should be taken in interpreting data for the proportions of countries' populations who inhabit urban and rural areas, because statistical practices differ greatly around the world with regard to both minimum threshold population sizes and how urban areas are bounded. Table 8 strongly illustrates, however, the impressive magnitude of the increases over the two decades in the study period in LDCs. Among the world's largest countries, the most populous of all – China – has had the greatest relative urbanization. Note, however, that back in 2002 it was still lagging by two percentage points the average level for LDCs in general. By 2015, however, China's 55 % urban percentage exceeded both the world and LDC averages (which, by then, stood at 53 % and 48 %, respectively). Bangladesh, Indonesia, and Nigeria have also experienced massive rural-to-urban internal population redistribution, which has resulted in the hyper growth rates of their primate megacities.

Does the urbanization being experienced in most LDCs, or the counter-urbanization sometimes now found in MDCs, represent demographic progress? Or do both of these trends? For the most part, internal or domestic migration, more than other demographic phenomena, represents the freewill decision-making behavior of individuals who "vote with their feet." The fact that so many people have been on the move within countries around the world might be interpreted as yet another sign of demographic progress and of market forces to establish altered settlement patterns in response to changed economic realities.

The last demographic indicator that I had wished to report was one for foreign immigration. Unfortunately, international migration statistics are extremely problematic. I report in Table 9 selected summary statistics derived from estimates given in the *2002 World Factbook*, a website of statistical data maintained by the US Central Intelligence Agency (CIA).

Statistics on net foreign immigration do, I think, help round out the demographic profiles of the world's countries. For most countries, foreign immigration is negligible in comparison to natural increase. The CIA reports essentially zero net immigration for 35 of the countries on my database, net immigration for 37, and net emigration for 56. Just as in the case of internal migration, there appears to be a tendency for the destinations of in-migration to be more spatially focused than the

Table 8 Change in the urban percentage of the population for world countries, 1982–2002

Area or country	Urban percentage of the population 1982	2002	Rank 2002	Percentage change	Rank for change
World	37	47	–	27.0	–
More developed countries	69	75	–	8.7	–
Less developed countries	26	40	–	53.8	–
Largest increase: Oman	7	72	33	928.6	1
Largest decrease: Namibia	45	27	103	–40.0	130
Most populous countries					
China	13	38	86	192.3	6
Bangladesh	10	23	111	130.0	10
Indonesia	20	39	82	95.0	18
Nigeria	20	36	91	80.0	23
Brazil	63	81	19	28.6	54
India	22	28	100	27.3	56
Pakistan	28	33	93	17.9	67
Mexico	67	74	29	10.4	85
Germany	83	86	12	3.6	99
Japan	76	78	22	2.6	101
USA	74	75	27	1.4	106

Sources: Population Reference Bureau (1982, 2002); percentage changes and country ranks calculated by the author

source areas of out-migration. Only a dozen countries have annual net emigration at or exceeding 2 per 1000, whereas there are half again as many immigrant receptor countries with rates at or above 2 per 1000.

For the world's most populous countries, note that for the emigrant senders, Mexico, Pakistan, Bangladesh, China, and Indonesia, the 2002 rates of outflux were relatively insignificant for balancing these countries' still fairly high rates of natural increase. Although not very effectively staunching population growth, in terms of the exportation of human capital, however, positively selective out-migration may pose policy concern. On the other hand, these are countries that still have momentum for growth due to their young age structures. Emigration, which is highly focused on the young labor force ages, can provide some relief from labor market entrants swamping the ability of their expanding economies to provide new jobs.

Note that for the two immigrant-receiving countries on the most populous list, Germany and the USA, immigration in 2002 was an extremely important constituent component of population change. By 2015, US net immigration was substantially down from the levels recorded over the 1982–2002 study period. Germany, however, is now grappling with trying to accommodate a massive influx of refugees. In

Table 9 Rates of net immigration compared to rates of natural increase for world countries, 2002

Country	Net immigration rate	Rank	Rate of natural increase
Highest net immigration rate: Singapore	26.11	1	8
Highest net emigration rate: Liberia	–10.80	129[a]	31
Most populous countries			
Germany	3.99	12	–1
USA	3.50	13	6
Nigeria	0.27	37	27
Japan	0.00	40	2
Brazil	–0.03	75	13
India	–0.07	76	17
Indonesia	–0.21	82	16
China	–0.38	89	7
Bangladesh	–0.75	100	22
Pakistan	–0.79	101	21
Mexico	–2.71	121	21

Sources: Net immigration rate estimates from US Central Intelligence Agency, *The World Factbook 2002*, http://www.cia.gov/cia/publications/factbook/index.html; country ranks calculated by the author; rates of natural increase from Population Reference Bureau (2002)

[a]Data exist for only 129 countries because of no immigration estimate for Cameroon

Germany's case, immigration offsets population loss that would otherwise occur from natural decrease, whereas for the USA, even during the high immigration period of 1982–2002, it represented no more than half the level of positive natural increase.

In contrast to Germany, Japan has, to date, been less sure about using immigration to counterbalance its natural decrease, but it will be interesting to see how that dynamic plays out over the next couple of decades. One observation I would hazard about the future of international migration is that I would expect emigration and immigration to play an increasingly important role as each country tries to define the rather complex equation of what constitutes its own version of ongoing and sustainable demographic progress.

4 Composite Indexes and World Demographic Country Groupings

We have now examined the values and rates of change of eight demographic indicators for the world's countries. What are the general conclusions to be drawn from all this information? As has been seen, the picture is very different around the globe during this stage of world history when the majority of developing countries are well along the path to completing their demographic transitions, whereas the most developed countries, having completed there's, are starting to come to terms with the new realities of actual or pending natural decrease.

Table 10 Varimax rotated factor loading matrix derived from 8 demographic indicators for 130 world countries in 2002

Demographic indicator (variable name)	Factor: 1	2	3
Total Fertility Rate (TFR)	**.951**	.022	-.002
Infant Mortality Rate (IMR)	**.919**	.225	-.040
Life Expectancy at Birth (Life Exp)	**-.906**	-.278	.059
Youth Dependency Ratio (YDR)	**.960**	.004	-.103
Elderly Dependency Ratio (EDR)	**-.833**	.316	.046
Female Labor Force (Fem LFPR)	.084	**.963**	.001
Urban Population Percentage (Urb Pop)	**-.754**	-.380	.254
Net Foreign Immigration (Net ImmR)	-.082	-.005	**.991**

In an attempt to group countries and summarize the geographic dimensions of the aforementioned indexes of demographic status and their trends, I submitted my variables to two different factor analyses. In both cases, I calculated factor scores and examined how world countries placed on those. I then cluster-analyzed both the standardized values of the original data and the factor scores to study how the world's countries group together demographically. Which countries exhibit the most similar overall levels of demographic status and which seem to be following the most similar trends?[2]

My first factor analysis was carried out using the eight demographic indicators measured at their year 2002 values. Principle components analysis was used as the extraction method. Based on an examination of eigen values and a scree plot, I determined that three factors, accounting for 89 % of overall variance, should be extracted[3]; these were then submitted to a Varimax rotation. The rotated factor loadings are presented in Table 10.

As can be seen, all but two of the variables load on the first factor, which, based on the signs for the loadings of the specific variables, I have termed "underdevelopment." High *positive* scores on this factor are associated with *high* youth dependency ratios, *high* total fertility rates, and *high* infant mortality rates, as well as with *low* levels of life expectancy at birth, *low* elderly dependency ratios, and *low* urban population shares.

The single variable with a primary loading on Factor 2 is the female labor force participation rate. The positive sign indicates that countries with high *positive* factor scores are those with *high* percentages of working-age women in the labor force. The extraction of a unique factor suggests that cultural norms can trump developmental levels in arraying countries along the dimension of female labor force participation.

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[2]An early classic study taking this same sort of an approach to examine countries' positions on a wide range of demographic and development indicators (and one that generated considerable controversy in its day!) was Brian J. L. Berry's statistical analysis contained in Part VIII "Basic Patterns of Economic Development" of Norton Ginsburg's (1961) *Atlas of Economic Development*. Berry refers to his "second pattern" as a "demographic scale" or as a "scale of economic-demographic development."

[3]Eigenvalues for the first three factors are, respectively, 4.931, 1.207, and 0.993; they account, respectively, for 61.632, 15.084, and 12.408 % of the variance in the data.

Factor 3 contains the loading for the remaining variable that is not strongly correlated with the others: net foreign immigration.

Country scores on Factors 2 and 3 pretty much mirror the single variable that loads on the factors, and the patterns of those indicators were already discussed in Sect. 3 of the chapter. The scores on the "underdevelopment" factor are, however, quite revealing. They provide, in essence, a demographic spectrum of world countries, showing where they stood in 2002 with respect to the primary recent demographic trends in mortality, fertility, age structure, and urbanization.

Table 11 gives the factor scores for countries at the opposite poles of this spectrum. Included are all those having factor scores, whether positive or negative, of greater than one standard deviation.

Table 11 Countries with the highest positive and highest negative factor scores[a] on the composite demographic index: "underdevelopment"

Positive factor scores		Negative factor scores	
1. Niger	1.77	1. Italy	–1.74
2. Sierra Leone	1.75	2. Japan	–1.74
3. Afghanistan	1.74	3. Sweden	–1.71
4. Somalia	1.55	4. Belgium	–1.59
5. Burundi	1.52	5. UK	–1.57
6. Uganda	1.51	6. Bulgaria	–1.55
7. Swaziland	1.45	7. Germany	–1.52
8. Angola	1.43	8. Spain	–1.51
9. Burkina Faso	1.41	9. Denmark	–1.49
10. Malawi	1.39	10. France	–1.46
11. Mali	1.36	11. Switzerland	–1.46
12. Mozambique	1.33	12. Norway	–1.44
13. Chad	1.32	13. Greece	–1.43
14. Congo, Dem. Rep.	1.31	14. Finland	–1.42
15. Yemen	1.30	15. Portugal	–1.37
16. Zambia	1.29	16. Hungary	–1.32
17. Rwanda	1.28	17. Austria	–1.31
18. Guinea-Bissau	1.27	18. Canada	–1.28
19. Cote D'Ivoire	1.24	19. Hong Kong SAR	–1.27
20. Ethiopia	1.16	20. Australia	–1.26
21. Benin	1.15	21. Netherlands	–1.24
22. Guinea	1.12	22. Poland	–1.21
23. Togo	1.11	23. Uruguay	–1.21
24. Liberia	1.07	24. Romania	–1.20
25. Iraq	1.07	25. USA	–1.20
26. Congo	1.04	26. Cuba	–1.14
27. Madagascar	1.04	27. New Zealand	–1.14
28. Tanzania	1.01	28. Taiwan	–1.03

[a]All countries shown have factor scores of greater than one standard deviation

In addition to examining factor scores, I experimented with a variety of clustering methods to explore how the world's countries split out into demographic blocs. I tried, first, a hierarchical clustering of the z-scores of the original eight demographic indicator variables. Because of missing data for two countries, the sample size is 128.

The first countries to combine in this clustering are Spain and Greece. At the next step, the USA joins together with New Zealand. Shortly afterward (at the 119-cluster stage) Australia joins New Zealand and the USA. This is in fact the only three-country cluster to emerge throughout the early stages of the clustering. Still fairly early in the process (at 102 clusters), Canada also enters this same Anglophone cluster. Other countries paired up in the early steps (125–120 clusters, respectively) are Angola⇔Mali, Honduras⇔Guatemala, Austria⇔Netherlands, Thailand⇔China, Norway⇔Denmark, and Colombia⇔Turkey. Although it would seem that cultural and geographic proximity leads to similar demographic profiles, similar economic development levels can, as in the case of Colombia and Turkey, outweigh physical or cultural proximity.

Continuing with the 118- to 115-cluster steps, the pairings are Senegal⇔Mauritania, Sri Lanka⇔Mauritius, Hungary⇔Albania, but then France⇔Japan. By the way, the MDC cluster containing France does not join the one with the USA until the world is divided into only 41 total clusters.

The latter stages of this clustering are not all that interesting, in that the world still shows the legacy of the demographic divide, with essentially two large and largely expected groupings. The more developed countries are in one cluster, and all the others (except three outliers[4]) are in an even larger LDC grouping. Because six out of the eight original variables are all correlated with economic development levels, it should not be surprising that the endgame of a hierarchical clustering produces blocs of countries at similar stages of development.

An alternative to clustering the original variables in a data set is to cluster factor scores. In the present case, this will give greater weight to the cultural differences underlying female labor force participation and to foreign immigration as sorting variables relative to the other six indicators (assuming one chooses not to weight the factor scores by, say, eigenvalues before submitting them to the clustering procedure). When the scores on the three-factor scores were clustered, however, the results were not radically different from those based on the z-scores of the original variables.

To experiment further, I tried using a K-means procedure to obtain separate optimal groupings of world countries for successively larger numbers of clusters. In carrying out clustering in that fashion, different blocs of countries are allowed to emerge depending on how many divisions of the world are specified. In a hierarchical clustering, once two countries become joined, they are never separated. That is not the case when optimal clusters are found at each step.

[4]Liberia, Kuwait, and Singapore.

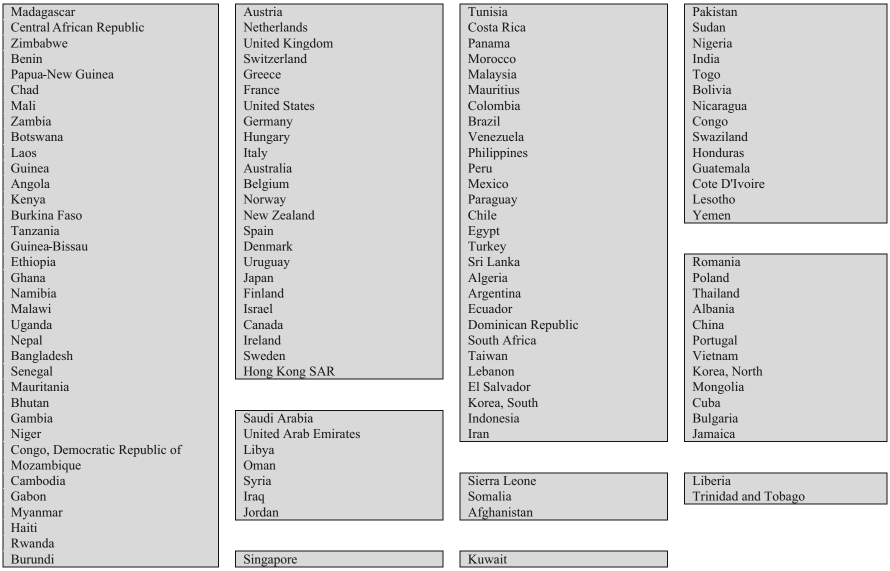

Fig. 1 A ten-cluster optimal demographic groupings of world countries based on the three-factor classification

The two-cluster solution is not a very interesting one since only three outlier countries[5] are split off from all others. In the three-cluster case, most of the world is bifurcated into a (49-country) least developed country group and an (77-country) intermediate to more developed one, with the third cluster containing just two outliers.[6] At the four-cluster stage, medium developed and more developed countries form into separate clusters, and three similar large groupings are the pervasive feature of the optimal five-, six-, and seven-cluster groupings (which differ, largely, in the composition of "breakaway" clusters that contain just a few outlier countries in each). The eight- and nine-cluster groupings feature four main blocs of countries. Space limitations do not permit showing the results of each of these optimal clusterings.

Figure 1 shows the ten-cluster solution. Note the separate group of 7 Middle Eastern countries (not including Iran), along with the 12 member group that includes the world's remaining Communist countries (China, Vietnam, North Korea, Mongolia, and Cuba) clustered with a number of members of the former Soviet bloc, plus Thailand, Albania, Portugal, and Jamaica.

To study how the changes in the levels of the demographic indicators further help to classify countries, I carried out a second factor analysis using a larger, 15-variable data set that included the 8 demographic indicators at their 2002 values and the 7

[5] Kuwait, Afghanistan, and Singapore.

[6] Kuwait and Singapore.

Table 12 Varimax rotated factor loading matrix based on eight demographic indicators (2002) and seven change variables (1982–2002)

Variable:	Factor:						
	1	2	3	4	5	6	7
TFR	**.885**	.002	*.405*	.002	-.022	-.091	.085
%Ch TFR	.145	.165	**.929**	-.132	.100	-.024	.005
IMR	**.869**	.249	.252	-.119	-.045	-.037	.102
%Ch IMR	*.481*	.293	.169	**-.528**	-.282	-.077	.031
Life Exp	**-.855**	-.282	-.184	.269	.027	.042	-.114
%Ch Life Exp	.049	-.166	-.059	**.941**	-.044	.014	.036
YDR	**.922**	.041	.268	.000	-.105	-.063	.083
%Ch YDR	***.526***	.231	**.744**	.002	-.059	-.055	.039
EDR	**-.885**	.165	.213	-.108	-.007	.130	-.098
%Ch EDR	-.150	.066	-.049	.034	-.029	**.982**	.041
Fem LFPR	-.024	**.851**	.239	-.152	.021	.024	.122
%Ch FemLFPR	-.269	**-.835**	-.074	.170	.073	-.063	.060
Urb Pop	**-.730**	*-.472*	-.040	-.077	.189	-.019	-.134
%Ch Urb Pop	.246	.165	.025	.027	-.014	.045	**.952**
Net ImmR	-.105	-.043	.063	.013	**.978**	-.032	-.012

change variables for 1982–2002 time period. Again, I used principle components analysis. This time, examination of the eigenvalues led me to extract seven factors,[7] which together accounted for 90.2 % of the variance in the data. These were then submitted to a varimax rotation, producing the factor loadings displayed in Table 12.

Like in the case of the 2002 indicators, the first factor in this analysis encompassing both 2002 status and 1982–2002 change variables is a demographically based composite index of "underdevelopment." Again loading highly and positively on this factor are the youth dependency ratio, the total fertility rate, and the infant mortality rate, whereas the elderly dependency ratio, the life expectancy at birth, and the urban population share load with high, negative values. In addition, two of the change variables have significant secondary loadings on this first rotated factor. Countries with positive scores on Factor 1 tend to have either increases or only small decreases in their infant mortality rates and youth dependency ratios: these are the world's least developed countries.

The second factor is again associated with those cultural differences that result in differential rates of female labor force participation for countries at equivalent levels of development. Countries with high positive scores on this factor are those that have generally high percentages of women in the work force. Additionally, however, the large negative loading on the change variable for female LFPR

[7]The first seven factors have, respectively, eigenvalues of 6.555, 2.112, 1.415, 1.149, 0.912, 0.753, and 0.637; they account, respectively, for 43.699, 14.081, 9.436, 7.658, 6.080, 5.022, and 4.243 of the variance.

indicates that countries with high scores on this factor also have low rates of increase in participation; this is likely because in many cases their rates as of 1982 were already relatively high.

I term Factor 3 “younger age structure” because it involves the change variable for the total fertility rate. Countries having positive scores on this factor are those that actually experienced rising rates of childbearing or ones that failed to reduce their TFRs by very much. Such countries are found both among LDCs and MDCs. Logically enough, this factor also receives the primary (and positive) loading for the variable measuring changes in youth dependency ratios. Further, note that it contains a secondary loading for the TFR variable itself. Most of the countries experiencing big drops in childbearing are LDCs that remained at above-average TFR levels in 2002.[8]

I label Factor 4 “improved survivorship,” because it involves the change variables for the two life span indicators; positive scores on Factor 4 are associated with increases in life expectancy at birth and reductions in the infant mortality rate. Factors 5, 6, and 7 represent “immigration,” “aging,” and “urbanization” influences. These are unique factors that take the primary loadings for, respectively, the net foreign immigration rate, change in the elderly dependency ratio, and change in the urban population share.

5 Conclusions

Progress and sustainability are, I think, very interesting twinned concepts to explore in the context of demographic change. Since the period of the Enlightenment, science has been a paradigm inextricably bound together with notions of progress. Demographic indicators have been used as benchmarks for measuring the efficacy of technological advances in such areas as food security, nutrition, sanitation, and medicine. The demographic transition theories suggest a rather different course of evolution than visualized by Malthus or the Club of Rome. With respect to sustainability, demographic transition theory can be seen as a systemic equilibrium perspective providing countering evidence to the inevitable non-sustainability of population growth.

In a “radical non-Malthusian perspective,” Kleinman (1980) argued that Hardin’s “The Tragedy of the Commons” represents a fundamental misreading of history, and there is not an “inexorable progression to ruin as a result of uncontrolled breeding.” Rather, he ascribes much of the concern with population growth to the fact that it “appears to threaten those who are well off, perhaps because change may be required to accommodate such growth” (p. 266). His conclusion is that:

> The welfare of future generations is not likely to depend on the numbers of people. Population, resources and technology maintain a dynamic balance as they change, moved

[8]TFR and ΔTFR are positively correlated ($R = 0.512$).

> by and compensating for socio-structural stress. The welfare of future generations will depend on a different legacy, the character of the institutional structures and the knowledge developed by preceding generations. Human societies have, in general, been fairly proficient in resolving technological problems: at least they have been more proficient in this area than in others. They have been least proficient in coping with problems of power and inequity. The legacy that would most benefit future generations would be resolution of the contradictions in social and economic organization which make 'social justice' sound utopian if not platitudinous while peace, equity, and security are made to appear incompatible with enterprise, productivity, and freedom (p. 273).

My simplistic exploratory data exercise has suggested that, during the current stage of demographic history, the world is still very much divided between two blocs. The first includes those countries that have "completed" the transition and are now facing a somewhat uncertain demographic future with fertility at unprecedented and unsustainably low levels; the second encompasses the majority of countries where demographic progress – as conventionally conceived – seems to be proceeding apace, if not at wholly unprecedented rates.

The population and development challenges of the future will be very much influenced by how societies around the world puzzle out how to structure their geographic interactions with one another. Communications, trade, and immigration should be front-burner issues as the globalization of the world economy and LDC fertility reductions continue to evolve.

Regional science, with its legacy of holistic, systems thinking, and big-picture modeling, with its focus on the connectivity of economic, social, and environmental systems, and with its touchstone concept – the region – is ideally positioned to play a central role in the critical policy debates of the future. To inform future research in regional science during the period while the vast majority of countries complete their demographic transitions and move into new dynamic trajectories with respect to population growth or decline and age composition change, I believe there will be a need to reconceptualize what is meant by demographic progress. It may well need to become more nuanced and more contingent on specific circumstances. Although more problematic to define, the concept of progress should continue to be of central import.

In the decades ahead, humans will be grappling to build new forms of economic and institutional entities to deal with the vastly greater interconnectivity of all parts of the planet as well as with ongoing, rapid technological changes. Future generations will need to harmonize their affairs and adapt to socioeconomic systems on a planet now embarked on a radically altered demographic course. Compared to other parts of the nexus of relevant economic and social trends, population trends derive in large measure from the inexorable aging of each member of our species. Population trends, therefore, are relatively predictable. As drivers of economic models, demographic measures and trends can and should inform a policy-relevant agenda for regional science research. A concept of demographic progress could be critically important in searching to find the creativity and policy means necessary to ensure sustainable human progress.

References

Berry BJL (1961) Basic patterns of economic development. In: Ginsburg N (ed) Atlas of economic development. University of Chicago Press, Chicago, pp 110–119

Boulding K (1985) Regions of time. Pap Reg Sci Assoc 57(1):19–32

Easterlin RA (1975) An economic framework for fertility analysis. Stud Fam Plann 6(3):54–63

Geyer HS, Kontuly TM (eds) (1996) Differential urbanization: integrating spatial models. Arnold, London

Grimner JN, Bremner J (2012) Achieving a demographic dividend. Population Bulletin vol 63, no 2. Population Reference Bureau, Washington, DC

Kleinman D (1980) Human adaptation and population growth. Allanheld, Osmun & Co, Montclair

Knobel J, van de Walle E (1982) Fertility decline: European transition. In: Ross JA (ed) The international encyclopedia of population. The Free Press, New York, pp 268–275

Kontuly T (1988) International comparisons of counter-urbanization. Geogr Perspect 61(Spring):1–5

Mitchneck BA, Plane DA (1995) Migration patterns during a period of political and economic shocks in the former Soviet Union: a case study of Yaroslavl' oblast. Prof Geogr 47:17–30

Notestein F (1945) Population—the long view. In: Schultz TW (ed) Food for the world. University of Chicago Press, Chicago, pp 36–57

Omran AR (1971) The epidemiological transition: a theory of the epidemiology of population change. Milbank Memorial Fund Q 49:509–538

Omran AR (1977) Epidemiological transition in the United States. Population Bulletin 32(1). Population Reference Bureau, Washington, DC

Omran AR (1982) Epidemiologic transition. In: Ross JA (ed) The international encyclopedia of population. The Free Press, New York, pp 172–175

Plane DA, Henrie CJ, Perry MJ (2005) Migration up and down the urban hierarchy and across the life course. Proc Natl Acad Sci 102:15313–15318

Population Reference Bureau (1982) 1982 world population data sheet. Population Reference Bureau, Washington, DC

Population Reference Bureau (2002) 2002 world population data sheet. Population Reference Bureau, Washington, DC

Population Reference Bureau (2015) 2015 world population data sheet. Population Reference Bureau, Washington, DC

Ravenstein EG (1885) The laws of migration. J R Stat Soc 48:167–227

Ravenstein EG (1889) The laws of migration. J R Stat Soc 52:214–301

Sack R (ed) (2002) Progress: geographical essays. The Johns Hopkins University Press, Baltimore

Teitelbaum MS (1975) Relevance of demographic transition theory for developing countries. Science 188(4187):420–425

Vining DR Jr, Kontuly T (1978) Population dispersal from major metropolitan regions: an international comparison. Int Reg Sci Rev 3:49–73

Vining DR Jr, Pallone R, Plane DA (1981) Recent migration patterns in the developed world: a clarification of some differences between our and IIASA's findings. Environ Plan A 13:243–250

Weeks JR (1999) Population: an introduction to concepts and issues, 7th edn. Wadsworth Publishing Company, Belmont

Zelinsky W (1971) The hypothesis of the mobility transition. Geogr Rev 61:219–249

Methodological Advances in Gibrat's and Zipf's Laws: A Comparative Empirical Study on the Evolution of Urban Systems

Marco Modica, Aura Reggiani, and Peter Nijkamp

Abstract The regional economics and geography literature has in recent years shown interesting conceptual and methodological contributions on the validity of Gibrat's law and Zipf's law. Despite distinct modelling features, they express similar fundamental characteristics in an equilibrium situation. Zipf's law is formalised in a static form, while its associated dynamic process is articulated by Gibrat's law. Thus, it seems that both Zipf's law and Gibrat's law share a common root. Unfortunately, although several studies analyse both the laws looking at the validity of these regularities, very few empirical investigations assess the implication of one law from the other one (i.e. deviations from Zipf's law result in a deviation from Gibrat's law). Moreover, due to heterogeneity in data sources, comparative analyses between countries are difficult to perform. The present chapter aims at building the basis for further innovative research in this field, while it also aims to provide some caveats in empirical research. Specifically, we pay particular attention to the role of the mean and the variance of city population as key indicators for assessing the (non-)validity of the so-called generalised Gibrat's law. Our empirical experiments are based on illustrative case studies on the dynamics of the urban population of five countries with entirely mutually contrasting spatial-economic characteristics: Botswana, Germany, Hungary, Japan and Luxembourg. We provide evidence on the following results: if (i) the mean is independent of city size (first necessary condition

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of Gibrat’s law) and (ii) the coefficient of the rank-size rule/Zipf’s law is different from 1, then the variance is dependent on city size.

Keywords Rank-size rule • Zipf’s law • Gibrat’s law (generalised) • Hierarchical structure • City growth

1 Gibrat’s Law vs. Zipf’s Law: Preliminary Considerations

Cities all over the world offer an amazing variety in terms of size and growth rates. Despite these differences, systems of cities do not exhibit a random pattern, but a strict regularity in terms of urban hierarchies and interurban connectivity. The genesis of such hierarchical perspectives on city size and urban systems can already be found in the seminal contributions of Christaller (1933) and Lösch (1940). The validity of these frameworks has extensively been tested in subsequent statistical experiments in many countries around the world. The conceptual foundation for the existence of central place hierarchies rests on various pillars: agglomeration advantages in cities (depending on city size), smart specialisation of industries (depending on scale advantages in different size classes of cities) and transportation and logistics costs (depending on distance frictions between cities or between cities and their hinterlands). Urban hierarchies and interurban connectivity are therefore two sides of the same coin (see Paelinck and Nijkamp 1976).

Clearly, it ought to be added that the spatial range of interurban linkages has extended drastically over recent decades. Whereas a century ago, most cities were at best part of an interlinked regional or national system, nowadays cities are often part of a globally connected network.

Surprisingly, despite the complex evolution of current socio-economic spatial networks, two robust empirical regularities seem to hold: Gibrat’s law affirming that city growth does not depend on size (Gibrat 1931), and Zipf’s law stating the proportionality of a given city size to its rank (Zipf 1949).[1]

More in details, Gibrat’s law states that the growth rate of a city’s population does not depend on the size of the city. In other words, although cities can grow at different rates, no systematic behaviour exists between their growth and their size, so we cannot affirm that larger cities grow faster than smaller ones or vice versa.

Analytically, we can write the following logarithmic expression, as in Steindl (1968):

$$\log P(t) = \log P(0) + \varepsilon(1) + \varepsilon(2) + \cdots + \varepsilon(t) \tag{1}$$

[1]Another way to refer to Zipf’s law is a Pareto distribution, with a shape parameter equal to 1. It is investigated using the so-called rank-size rule. We note here that the slope coefficient of the rank-size rule represents the inverse form of the parameter of the conventional Pareto distribution. For more details, we refer inter alia to Adamic (2000) and Parr (1985). In this paper, we refer to Zipf’s law (Zipf’s distribution), when the rank-size coefficient is exactly equal to 1. In all the other cases, we refer to the rank-size rule (rank-size distribution).

where $P(t)$ is the size of a certain city at time t, $P(0)$ is the initial population and $\varepsilon(t)$ is a random variable (indicating random shocks), i.i.d random variable with mean μ and variance σ^2. Equation 1 identifies the logarithm of the size of a given city as the sum of the initial size and past growth rates.

This law can now be interpreted as follows: *A variate subject to a process of change is said to obey the law of proportionate effect if the change in the variate at any step of the process is a random proportion of the previous value of the variate* (Chesher 1979, p. 403). The implication of Gibrat's law is that the growth processes of cities have *a common mean* (*equal to the mean city growth rate*) *and a common variance* (Gabaix 1999, p. 741), that is, both the mean and variance have to be independent from the size of the cities.

The second well-known spatial regularity is given by the so-called Zipf's law (on the basis of a first study by Auerbach[2] in 1913). Zipf's law states that the size of the cities in a country is proportional to their rank. This means that, for example, in Botswana, the size of the largest city, Gaborone, is roughly twice the size of Francistown, the second largest city, three times the third largest city, Molepolole, and so on. Formally, this can be written as:

$$P_i = KR_i^{-q} \tag{2}$$

Equation 2 is known as the rank-size rule and is usually expressed in logarithmic form, as follows:

$$\log{(P)_i} = \log(K) - q\log{(R_i)} \tag{3}$$

where P_i is the population of city i, R_i is the rank of the ith city and K is a constant. Zipf's law holds precisely, when the coefficient q is equal to 1.

Several interpretations of the Zipf coefficient, q, have been proposed in the literature. In principle, the q-coefficient can be seen as an indicator of the hierarchical degree of a system of cities (Brakman et al. 2001; Reggiani and Nijkamp 2015; Singer 1930). In fact, the q-coefficient measures how unequal the city distribution is: the higher the q-coefficient, the more unequally distributed is the city system. On the contrary, the smaller is the value of q, the more even is the system of cities (in the extreme, when $q = 0$, we have a very even system of cities all of the same size; when $q = \infty$, instead, we have only one city hosting the entire population).

In summary, Gibrat's law expresses the growth process of a certain variable (firm, city, income, wealth, etc.), independent of its size, while Zipf's law presents the static relationship of the size of this variable with its rank. In the field of spatial economics, these two regularities have given rise, especially since the late 1990s, to an increasing number of empirical studies, testing cities and economic growth at various spatial levels (national, regional, local), by means of Gibrat's law and Zipf's law.

[2] *The population of a city is inversely proportional to the number indicating its rank among the cities of a given country* (Auerbach 1915, p. 384).

It seems that in the majority of urban studies, Zipf's law and Gibrat's law are generally confirmed by empirical data (Eeckhout 2004; Gonzalez-Val 2010; Ioannides and Overman 2003; Gabaix and Ioannides 2004; Giesen and Suedekum 2011). However, other studies seem to reject these two empirical regularities (Black and Henderson 2003; Cuberes 2011; Gonzalez-Val et al. 2012; Henderson and Wang 2007). These contrasting results have prompted a continuous debate in the literature, on the (non-)validity of Gibrat's law and/or Zipf's law.

These two laws are often analysed together, at least from the theoretical point of view, given their possible complementarity. Indeed, Champernowne (1953) and Simon (1955) have shown that rank-size distributions arise naturally, if Gibrat's law is satisfied. Gabaix (1999) has demonstrated that Gibrat's law leads to a Zipf distribution, while Cordoba (2003) argues that a weak version of Gibrat's law leads to more general rank-size distributions, where weak means that only the mean of the city growth is independent from city size, while its variance can change according to size (Cordoba 2003). In this setting, Cordoba, for the first time, shows an unknown relationship between the two laws; indeed, he shows that Zipf's law might imply Gibrat's law.

More in details, Cordoba (2008, p. 1463) proposes a *generalisation of Gibrat's law that allows size to affect the variance of the growth process but not its mean*. In particular, one of the implications of Cordoba's generalised model is that non-proportionality of the variance is required to take into account a q-coefficient different from 1 (in Eq. 3). More specifically, the larger the q-coefficient, the more unequal the distribution; this finding makes a growth process more volatile.[3] On the basis of Cordoba's results, we can outline the following relationships between Zipf's law and Gibrat's law:

(a) If $q = 1$, Zipf's law holds. In order that Gibrat's law applies, neither the mean nor the variance of growth can depend on size.
(b) If $q > 1$, the distribution is more unequal. In order that Gibrat's law applies, it is necessary that the mean is independent of the city size, but not the variance; indeed, the associated growth process implies that smaller cities face a greater volatility in growth than larger cities.
(c) If $q < 1$, the distribution is more evenly distributed. Again, in order that Gibrat's law applies, it is necessary that the mean is independent of the city size, but not the variance. Hence, larger cities face a greater volatility in growth than smaller cities.

Given these premises, there are very well-known problems associated with empirical verification of Gibrat's law (and Zipf's law as well) that are often ignored or that are not jointly considered. First, it should be noted that empirical investigations of the relationship 'Gibrat's law vs. Zipf's law' in the Cordoba view are still rare. This means that, typically, scholars investigate about the validity or

[3]The volatility is a measure of fluctuation of a process. We will use the variance as an indicator of the volatility of an underlying proportionate growth process.

non-validity of the laws singularly, i.e. without any empirical comparison between the two. Namely, if Zipf's law does not hold the corresponding 'behaviour' of Girat's law is unknown (or unexplored). At the same time, if Gibrat's law deviates we do not know the implications on Zipf's law, at least empirically.

Second, the results critically depend on the choice of the geographic unit, i.e. municipalities vs. urban areas (González-Val et al. 2013). Third, even though the geographic unit is the same, i.e. municipality, this does not necessary mean that two municipalities in two different countries are comparable. This is because the 'legal' or even 'intrinsic' definition of municipality (or urban area) might change by countries (e.g. a Japan municipality is quite different from a German one). Fourth, scholars adopt truncated samples in the analysis. However, the way in which this should be done it has been addressed only recently (see for instance, Bee et al. 2013; Ioannides and Skouras 2013; Fazio and Modica 2015). Finally, it is not well clear whether the two laws apply over a long time period or span or, on the contrary, they are in operation even in the short run.

For all these reasons, there are very few analyses that run international comparisons of the two laws (to our knowledge the only two papers are Rosen and Resnick (1980) and Soo (2005)). This chapter, then, aims at building the basis for a rigorous analysis on the empirical link between Zipf's law and Gibrat's law. To do that, we will present five case studies that explore the empirical link between the two laws but also underline the common shortcomings of the empirical analysis and the difficulties in the comparison of the results between countries. Notice that we focus only on five countries because of the illustrative purpose of this work. Indeed, this contribution wants to be just a baseline for further research in this field. At the same time, this chapter highlights caveats in empirical research. Finally, it does not pretend to be a complete analysis and further works are needed for a better comprehension of the issue.

The chapter is then organised as follows. Section 2 describes the main characteristics of the data, while subsequent sections illustrate the results of the empirical analysis devoted to testing Gibrat's law (Sect. 3), as well as the link between Gibrat's law and Zipf's law (Sect. 4). The chapter concludes with some methodological considerations and directions for future research (Sect. 5).

2 Data: Descriptive Statistics

We have selected in our empirical study five distinct countries characterised by different socio-economic typologies, but also different 'data characteristics' (i.e. in terms of time series and time span and different 'intrinsic' definitions of municipality). These countries are Botswana, Germany, Hungary Japan and Luxembourg. The selection of these five countries, although mainly illustratively, may be representative of countries with different characteristics. However, our work is to be considered only as a demonstrative analysis with any attempt to be a rigorous (in statistical terms) study from which we can draw meaningful results.

Table 1 Rationale for country selection

	Population density			GDP per capita	
		High	Low	High	Low
Size	High	Germany, Japan	Botswana	Germany, Japan	Botswana
	Low	Luxembourg	Hungary	Luxembourg	Hungary

Table 1 is an overview of the countries analysed in our empirical research. They range significantly in size, economic development and geographic position. This selection was done deliberately, in order to test whether likely common findings in Zipf's law and Gibrat's law would be robust in the case of contrasting countries.

In Table 2 we report, for each country, some economic indicators (e.g. GDP per capita, growth rate and percentage of investment over GDP), as well as some other important indicators for the mobility and transportation system (such as the length of railways and roadways and the number of cars per thousand people). We collected data from the National Institute of Statistics for all five of these countries.[4] In particular, we collected data from the Central Statistics Office of Botswana, the Institute for Employment Research[5] (IAB) in Germany, the Hungarian Central Statistical Office, the Statistics Bureau of Japan and the STATEC (Institute National de la Statistique et des Etudes Economiques) of Luxembourg.

Some points are worth noting here. Botswana is the only non-OECD country, while all the others are OECD countries. Botswana shows the features of a non-advanced[6] economy; however, it exhibits a trend towards an increase in population and economic growth. Germany was a founding member of the European Community in 1957 (which became the European Union (EU) in 1993); it is central in Europe and is a large country in terms of surface area and population, with an advanced economy. Hungary joined the EU in 2004; it is located in central Europe, but shows a non-advanced economy and a decreasing population. Japan is an Asian country, and it is the most populated country among the selected ones; however, its population is spread in very few municipalities. Luxembourg, like Germany, was a founding member of the European Community in 1957; it is a small country, but geographically very central in Europe and a high income per capita. Moreover, its subdivision in municipalities is a purely administrative fact rather than a subdivision de facto. Clearly, other choices could have been made, but the present set of countries aims to represent a sufficiently interesting collection of cases for preliminary investigation addressing all the shortcomings listed in the previous section.

[4]For all countries, we have data over all cities from the biggest to the smallest one.

[5]The authors wish to thank Uwe Blien and Anette Haas (IAB, Germany), for kindly providing the data used in our study on German cities (sections 'Testing Gibrat's' Law: Method and Results' and 'Gibrat's Law and Zipf's Law: A Comparative Study').

[6]According to the IMF classification

Table 2 Spatial-economic characteristics of the five countries under analysis

Country	Year	Km^2 (thousands)	Population (million)	Density	% Urban population	% Population growth	Railways per 1000 km	Roadways per 1000 km	GDP per capita	Growth (%)
Botswana	2011	581	1.85	3.19	62.00	1.47	0.90	25.80	9481	5.1
Germany	2007	357	81.78	229	74.00	−0.20	41.90	644.50	40,403	2.7
Hungary	2011	93	9.99	107.4	69.00	−0.18	8.10	197.50	13,045	1.70
Japan	2010	378	128.06	338.8	91.00	0.23	27.16	1217	42,909	4.70
Luxembourg	2011	2,5	0.51	205.6	85.00	1.13	0.27	5.20	106,958	1.00

Table 3 Descriptive statistics of the five countries under analysis

Country	Year	No. of cities	ln (mean)	ln (variance)	ln (median)	Skewness	Kurtosis
Botswana	2011	461	7.15	1.22	6.97	0.78	2.23
Germany	2007	12,262	7.42	1.50	7.30	0.34	0.17
Hungary	2011	3154	6.75	1.34	6.70	0.40	0.95
Japan	2010	1719	11.21	2.10	10.13	0.036	3.16
Luxemburg	2011	116	7.81	0.92	7.61	0.86	1.45

Indeed, it should be noted that an extensive debate, concerning the type of spatial unit under analysis, is very much alive; however, several studies have been carried out using metropolitan areas, i.e. by considering the entire population in a given city, as well as all population of suburban areas. Nevertheless, our object is to carry out comparative analysis between the five countries, by also including all the cities in the countries under analysis. We then do not constrain the analysis only to the larger cities. For these reasons, we consider in this work all the entities legally defined as cities or villages in their countries, although we are aware that the administrative definition given by legal borders might not fulfil our scopes exactly. Indeed, the 'intrinsic' definition of municipalities is quite different in the selected countries. To underline the different 'intrinsic' definitions of municipality, we report in Tables 2 and 3 descriptive statistics of the five countries. We can see how Japan shows a number of municipalities of 1719 against a total population of about 128 million in an area of 378 km^2. At the same time, Germany shows quite the same area (i.e. 357 km^2) with a slightly lower population (about 82 million), but it shows a huge number of municipalities in comparison to Japan (12,262).[7] It is evident that in the case of Japan, the municipality covers an area much more larger than that in the case of Germany. Then, the concept of municipality in Japan might be much more close to that of urban areas with respect to the concept of German municipality, and, thus, the two objects may be difficult to compare.

Another shortcoming that should be addressed is that the selected countries show temporal horizons consistently differ. Indeed, for Botswana, we have only two census observations (2000 and 2010). In Hungary we cover a period of 30 years (1980–2011), but with only four census observations. For Germany, however, although the time span is 15 years, we have annual data (1993–2007). On the contrary Japan data cover the period 1995–2010 and four census observations. Finally, Luxembourg has a long time series considering all census data from 1821 until 2011 for Luxembourg; however, the time span between two subsequent observations is not constant even in the same country and especially before World War II.

[7] Another example, not included in this analysis, is France with more than 30,000 municipalities and quite same surface area of Germany.

Following on from the above observations, in Sect. 3, we focus our attention on the validity of Gibrat's law, in order to design an analytical framework that is useful for the analysis on Gibrat's law and Zipf's law.

3 Testing Gibrat's Law: Method and Results

In this section, we will use an OLS regression model and report the results from the parametric analysis. We check dynamic deviations from the proportionality of mean growth and variance to size, by using a method firstly proposed by Kalecki (1945). In particular, the adopted model is the following OLS model:

$$g_t^i = \beta_t g_{t-1}^i + \varepsilon_t^i \tag{4}$$

where $g_i(t)$ is the deviation of the logarithm of the population of city i from the mean of the logarithms of the city populations at time t and ε is the error term. β is the parameter to be estimated and *provides an estimate of the divergence/convergence of the size distribution towards its mean* (Bottazzi et al. 2001, p. 1184). Gibrat's law holds if β is equal to 1.[8] As an indicator of the volatility of the growth process, we use two different measures: (i) the variance of growth, σ_t^2, and (ii) the variance ratio, θ_t, between the variance of g at time t, $\sigma(g_t)$ and the variance of g at time t-1, $\sigma(g_{t-1})$. The reason why we report both the indicators is because Gibrat's law is a dynamic concept, while Zipf's law is static. Including both the measures allows us to be more confident in taking into consideration both the aspects of dynamicity and staticity. Moreover, the variance ratio is also adopted for testing mean reversion and stationarity of the series so it is a further control for Gibrat's law. Formally, it is given by:

$$\theta_t = \frac{\sigma^2\left(g_t^i\right)}{\sigma^2\left(g_{t-1}^i\right)} \tag{5}$$

Gibrat's law holds if θ_t in Eq. 5 is equal to 1. Tables 4a and 4b shows the results; the column p-value shows the p-value of a t-test with null hypothesis $\beta = 1$; accordingly, the significance has to be interpreted in the relation of our H_0. Two main conclusions arise from here. Firstly, looking at the parameter β, Gibrat's law does not always hold (over time). Germany and Luxembourg are clear examples of this

[8]We report here only the condition on the estimated β. However, it should be noted that another condition is necessary to affirm that Gibrat's law is in operation; indeed, the error terms have to be serially uncorrelated. We, then, add one more lag in Eq. 4 to this very additional condition. In most of the cases, the error terms result serially uncorrelated. Moreover, notice that when β is lower than 1, this means that size converges towards its mean, namely, the larger a city, the smaller the expected growth. On the contrary, when β is greater than 1, the larger a city, the larger the expected growth.

Table 4a Model A estimates (Countries: Botswana, Germany, Hungary, Japan and Luxembourg; different years)

Country	Year	β	p-value	θ	R^2	No. of obs.
Botswana	2011	0.995	0.773	1.0782	0.92	460
Germany	1994	0.999***	0.002	1.0009	0.99	12,280
	1995	0.999**	0.048	0.9983	0.99	12,291
	1996	0.999**	0.011	0.9987	0.99	12,291
	1997	0.998***	0.000	0.9978	0.99	12,291
	1998	0.998***	0.000	0.9984	0.99	12,291
	1999	1.00	0.375	1.0011	0.99	12,293
	2000	0.999	0.509	0.9998	0.99	12,294
	2001	1.001***	0.000	1.0024	0.99	12,294
	2002	1.001***	0.000	1.0017	0.99	12,294
	2003	1.00**	0.026	1.0009	0.99	12,293
	2004	1.001***	0.000	1.0027	0.99	12,292
	2005	1.001***	0.000	1.0031	0.99	12,293
	2006	1.001***	0.000	1.0027	0.99	12,993
	2007	1.001***	0.000	1.0039	0.99	12,259
Hungary	1990	1.055***	0.000	1.1215	0.99	3121
	2001	1.034***	0.000	1.0806	0.99	3121
	2011	1.028***	0.000	1.0674	0.99	3121
Japan	2000	1.014***	0.000	1.0290	0.99	1716
	2005	1.016***	0.000	1.0332	0.99	1716
	2010	1.020***	0.000	1.0427	0.99	1719

*Significant at 10 %, **significant at 5 %, ***significant at 1 %

intermittency: we can see periods where Gibrat's law holds and others where it does not. Secondly, it seems that the effect of the (non-)validity of the law is lengthy: namely, Gibrat's law in general holds (or does not hold) continuously for two or three periods. Consequently, the first result of our analysis is that testing Gibrat's law requires a data set of considerable length or as many possible observations as we can. It is also interesting to note that in general, when Gibrat's law does not apply, the variance at time t is higher than the variance at the previous times; this is denoted by the parameter θ in Eq. 5 greater than 1. This is, of course, consistent with the idea of Gabaix (1999) which, according to Gibrat's law, both the mean and variance of the growth rate have to be independent with respect to the size.

In more detail, by observing β in Tables 4a and 4b, we can see that in Botswana and Luxembourg, Gibrat's law holds quite often ($\beta = 1$). In Germany it does not apply more than half of the time and in Hungary and Japan Gibrat's law never holds.

It should be noted, however, that, although this analysis is suitable for an 'internal' validity of the law, this does not allow for an international comparison between countries, due to the availability of the data worldwide. Indeed, even in the five case studies shown before, our data present different characteristics that may affect the results: for Germany we have only annual data, and this is not enough for

Table 4b Model A estimates (Country: Luxembourg, different years)

Country	Year	β	p-value	θ	R^2	No. of obs.
Luxembourg	1851	0.941**	0.029	0.9557	0.93	116
	1871	0.993	0.828	1.0779	0.92	116
	1880	1.005	0.852	1.0667	0.95	116
	1890	1.048***	0.009	1.0855	0.93	116
	1900	1.109***	0.001	1.2833	0.96	116
	1910	1.079***	0.000	1.1803	0.99	116
	1922	1.01	0.408	1.0473	0.97	116
	1930	1.103***	0.000	1.2406	0.98	116
	1935	1.001	0.839	1.0059	0.99	116
	1947	1.014**	0.020	1.0355	0.99	116
	1960	1.069***	0.000	1.1725	0.98	116
	1970	1.044***	0.005	1.1198	0.97	116
	1981	1.016	0.255	1.0576	0.98	116
	1991	0.993	0.515	0.9964	0.99	116
	2001	0.955***	0.000	0.9199	0.99	116
	2002	0.994***	0.000	0.989	0.99	116
	2003	0.99	0.247	0.9926	0.99	116
	2004	0.997	0.129	0.9947	0.99	116
	2005	0.996	0.110	0.9926	0.99	116
	2006	0.997	0.185	0.9961	0.99	116
	2007	0.992***	0.009	0.9851	0.99	116
	2008	0.992***	0.001	0.985	0.99	116
	2009	0.996	0.104	0.994	0.99	116
	2010	0.996**	0.017	0.9924	0.99	116
	2011	0.999	0.919	1.00	0.99	116

*significant at 10%, **significant at 5%, ***significant at 1%

a robust analysis, since a longer time window seems to be more appropriate. Second, Botswana shows very few observations (we have only one test). Finally, the concept of municipality in Japan seems to differ to the other. Indeed, a sample of only 1716 municipalities might cover different economic characteristics, the one for Germany (12,280) resulting in a higher level of aggregation for the former.

4 Gibrat's Law and Zipf's Law: A Comparative Study

4.1 Role of the Adopted Parameters

In the previous sections, we have shown that Botswana and Luxembourg seem to obey Gibrat's law, while this seems not to be the case for Germany, Japan and Hungary. The final step in our analysis is then the investigation of the relationship between Gibrat's law and the rank-size/Zipf's law, by means of the rules (a), (b) and (c) (outlined in Sect. 1).

From the operational viewpoint, we investigate the relationship between the q-coefficient in Eq. 3 and the estimated parameters β and θ from Eqs. 4 to 5 and σ_t^2, on the basis of Cordoba's propositions (a), (b) and (c). In particular, we estimate the q-coefficients in the rank-size rule (3) by means of a modification proposed by Gabaix and Ibragimov (2011), according the following:

$$\log(P_i) = \log(K) - q\log(R_i - 0.5) \tag{6}$$

where P_i, K, q and R_i are the same as in Eq. 3.

In Tables 5a and 5b, we report the estimated q-coefficients and the parameters β, θ and σ_t^2, according to Eqs. 4, 5 and 6, respectively, for each of the five countries. Overall, by means of these five parameters, we can experiment with the propositions (a), (b) and (c) in Sect. 1.

Concerning the coefficient q (Eq. 6), it should be noted that we interpret the q-coefficient as a measure of hierarchy of city size distribution. In this sense a positive change in the estimated q-coefficient denotes a situation where larger cities have grown more than smaller ones (in relative terms); thus, an increasing q-coefficient (see Eq. 6) reflects the tendency towards agglomeration economies in the country at hand (see Sect. 1).

For example, an increasing/decreasing q-coefficient – indicating changes in the growth rate between large and small cities – should lead to a generalised Gibrat's law. It appears that the q-coefficients, together with the β-, θ- and σ_t^2-parameters, offer insights into different aspects of the same growth process: the q-coefficient captures the output of the growth process, while the β-, θ- and σ_t^2-parameters take into account the mean and variance of the growth process.

In the latter context (regarding the role of the mean and variance), it seems worthwhile to test the different dynamics of the large cities vs. the small cities, in order to explore in more detail where a greater volatility shows up. We can then split, for each country, our sample into two halves by defining two subsamples: one for the large cities and the other one for the smaller cities. This rule is as arbitrary as the other rules typically proposed in the literature (this issue has been addressed by Bee et al. 2013; Ioannides and Skouras 2013; Fazio and Modica 2015; the reader might consult these papers for more details). We then estimate the parameters β and θ according to Eqs. 4–5 and σ_t^2 for these two subsamples. In this way we can analyse, firstly, whether Gibrat's law holds separately for large and small cities and, secondly, whether the growth process is more volatile. In this way we will also show how the truncation rule may affect the results on Gibrat's and Zipf's law.

In the next subsections, the role of the various parameters q, β, θ and σ_t^2 in capturing the relationship 'rank-size rule vs. Gibrat's law' will be illustrated with reference to the empirical analyses in each of the five countries.

Table 5a The Zipf's and Gibrat's parameters (Countries: Botswana, Germany, Hungary, Japan and Luxembourg; different years)

Country	Year	q-coefficient	Robust s.e.	β	θ	β_{BIG}	θ_{BIG}	σ_{BIG}	β_{Small}	θ_{Small}	σ_{Small}
Botswana	2001	1.137	0.0746	–	–	–	–	–	–	–	–
	2011	1.173	0.0746	0.995	1.0078	0.979	1.000	3.632	0.76***	1.011	5.065
Germany	1993	1.399	0.0178	–	–	–	–	–	–	–	–
	1994	1.397	0.0178	0.999***	1.0009	0.996***	0.994	2.998	1.001	1.009	6.030
	1995	1.396	0.0178	0.999**	0.9983	0.996***	0.994	2.583	1.00	1.004	4.347
	1996	1.394	0.0177	0.999**	0.9987	0.997***	0.995	2.101	1.001	1.006	4.235
	1997	1.392	0.0177	0.998***	0.9978	0.997***	0.994	2.099	0.999	1.002	4.033
	1998	1.390	0.0177	0.998***	0.9984	0.997***	0.994	1.906	0.997	1.000	3.863
	1999	1.390	0.0177	1.00	1.0011	0.998***	0.996	1.716	1.004**	1.012	3.582
	2000	1.390	0.0177	0.999	0.9998	0.998***	0.998	1.536	0.998	0.998	4.644
	2001	1.391	0.0177	1.001***	1.0024	0.999***	0.999	1.419	1.002***	1.006	2.872
	2002	1.392	0.0177	1.001***	1.0017	0.999	0.999	1.278	1.00	1.002	3.114
	2003	1.392	0.0177	1.00**	1.0009	0.999	1.001	1.188	0.998***	0.998	2.904
	2004	1.393	0.0177	1.001***	1.0027	1.000	1.001	1.270	1.001**	1.004	2.889
	2005	1.396	0.0178	1.001***	1.0031	1.001***	1.002	1.162	1.001	1.003	2.775
	2006	1.398	0.0178	1.001***	1.0027	1.001***	1.001	1.074	0.999	1.000	2.728
	2007	1.401	0.0178	1.001***	1.0039	1.002***	1	1.438	1.001**	1.005	2.847
Hungary	1980	1.129	0.0285	–	–	–	–	–	–	–	–
	1990	1.186	0.0300	1.05***	1.12	1.018	1.04***	0.8129	1.07***	1.194	1.005
	2001	1.223	0.0309	1.034***	1.08	1.08	0.993	0.999**	1.404	1.054***	1.429
	2011	1.258	0.0316	1.028***	1.06	1.005	1.02**	1.219	1.010	1.070	1.410

*Significant at 10 %, **significant at 5 %, ***significant at 1 %

Table 5b The Zipf's and Gibrat's parameters (Countries: Botswana, Germany, Hungary, Japan and Luxembourg; different years)

Country	Year	q-coefficient	Robust s. e.	β	θ	β_{BIG}	θ_{BIG}	σ_{BIG}	β_{Small}	θ_{Small}	σ_{Small}
Japan	1995	1.254	0.0428	–	–	–	–	–	–	–	–
	2000	1.270	0.0433	1.014***	1.0290	1.01***	1.012	.8264	1.02***	1.028	1.045
	2005	1.292	0.0441	1.016***	1.0332	1.02***	1.019	.7699	1.02***	1.031	0.9519
	2010	1.318	0.0449	1.020***	1.0427	1.02***	1.031	.7921	1.03***	1.054	1.041
Luxembourg	1821	.5031	0.0660	–	–	–	–	–	–	–	–
	1851	.4965	0.0652	0.941**	0.9557	0.949	0.978	.6141	0.730***	0.764	0.7822
	1871	.5154	0.0676	0.993	1.0779	0.962	1.070	1.296	0.887**	0.981	0.6157
	1880	.5350	0.0702	1.005	1.0667	1.003	1.060	1.693	0.811	0.871	1.904
	1890	.5881	0.0772	1.048***	1.0855	0.995	1.160	3.327	0.944	0.965	0.6451
	1900	.6744	0.0885	1.109***	1.2833	1.115**	1.340	2.651	0.947	0.969	0.6763
	1910	.7350	0.0965	1.079***	1.1803	1.09***	1.210	1.332	0.986	1.035	6178
	1922	.7500	0.0984	1.01	1.0473	0.998	1.025	2.095	1.042	1.140	0.5105
	1930	.8377**	0.1100	1.103***	1.2406	1.09***	1.240	2.574	1.01	1.048	0.5981
	1935	.8391**	0.1101	1.001	1.0059	0.986	0.976	1.045	1.033**	1.081	0.7215
	1947	.8543**	0.1121	1.014**	1.0355	1.013	1.034	.5543	0.982*	1.009	5250
	1960	.9252**	0.1214	1.069***	1.1725	1.011	1.059	1.395	1.006	1.109	0.7906
	1970	.9735**	0.1278	1.044***	1.1198	0.965**	0.963	1.930	1.016	1.162	1.308
	1980	.9923**	0.1302	1.016	1.0576	0.94***	0.922	1.815	1.022	1.150	1.268
	1991	.9803**	0.1287	0.993	0.9964	0.94***	0.920	1.395	1.053	1.145	0.881
	2001	.9409**	0.1235	0.955***	0.9199	0.94***	0.907	.874	0.910***	0.871	1.337
	2002	.9365*	0.1229	0.994***	0.989	0.998	0.997	1.291	0.990**	0.983	2.177
	2003	.9330**	0.1225	0.995	0.9926	1.00	1.00	1.366	0.997	1.00	3.356
	2004	.9302**	0.1221	0.997	0.9947	1.00	1.00	1.209	1.00	1.020	2.465
	2005	.9270**	0.1217	0.996	0.9926	0.995	0.992	1.529	0.992	0.989	2.812

	2006	.9253**	0.1215	0.997	0.9961	1.001	1.00	1.109	0.994	0.991	2.254
	2007	.9195**	0.1207	0.992***	0.9851	0.99**	0.988	1.412	0.974*	0.955	3.498
	2008	.9140**	0.1200	0.992***	0.985	0.999	0.998	1.291	0.976**	0.955	2.501
	2009	.9120**	0.1197	0.996	0.994	1.00	1.00	1.672	0.989	0.981	2.219
	2010	.9094**	0.1194	0.996**	0.9924	1.00	1.00	1.247	0.986***	0.974	1.787
	2011	.9094**	0.1194	0.999	1.00	1.00	1.00	1.073	0.997	0.996	2.137

*Significant at 10 %, **significant at 5 %, ***significant at 1 %

4.2 Botswana

Starting with Botswana, we can see that the estimated q-coefficient is greater than 1 for both the years 2001 and 2011, indicating a predominance of larger cities. In particular, in 2011 the estimated q-coefficient is slightly greater than that 1 in 2001, thus showing a tendency – in the last decade – towards a higher economic development. By considering the relationship with Gibrat's law, we then investigate condition (b) of Sect. 1. Considering the entire sample, we have already shown that Gibrat's law holds in 2011 with an estimated β-parameter not significantly different from 1 ($\beta = 0.995$). However, considering the two subsamples, we find evidence of Gibrat's law for large cities ($\beta_{\text{BIG}} = 0.979$) but not for small ones ($\beta_{\text{small}} = 0.761^{***}$).[9] This indicates that larger cities of the subsample of small cities (i.e. medium-size cities) have an expected growth lower than smaller ones. This is still consistent with proposition (b) of Sect. 1 predicting that the associated growth process requires that smaller cities face a greater volatility of growth than larger cities. For this reason we now analyse the behaviour of the variance.

The variance ratio for the entire sample in Botswana is greater than 1 ($\theta = 1.078$), indicating a greater volatility of the process in 2011. This latter condition is not enough to investigate our statements (b) of Sect. 1, because it only refers to the 'temporal' non-stability of the variance, without considering the 'spatial aspect', namely, the (non)independence of the variance with respect to the size of the cities.[10] For this reason, we analyse the two subsamples separately, as previously anticipated, and we look both at the variance ratio, θ, and variance of growth, σ_t^2.

The variance ratio, θ, for large cities shows a striking stability ($\theta_{\text{BIG}} = 1$), while, for the small cities, it is slightly greater than 1 ($\theta_{\text{small}} = 1.011$), implying an increasing change in the underlying volatility of the growth process for small cities. Moreover, the variance of growth $\sigma^2{}_{\text{BIG}}$ is less than $\sigma^2{}_{\text{small}}$.

Given these facts, we can affirm that at time t (2011), the variance is unchanged for large cities but increases for the small ones, indicating a dependence of variance with respect to size; in particular, smaller cities face a greater volatility than large cities.

In summary, statement (b) (Sect. 1), which affirms 'if $q > 1$, in order that Gibrat's law occurs, it is necessary that the mean is independent from the city size but not the variance; indeed, the associated growth process requires that smaller cities face a greater volatility of growth than larger cities', is satisfied for the whole sample.

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[9] where *** indicates a significance level at 1 %

[10] It suggests a change in the variance over the time, and then this might also imply changes in the dependence of the variance over the size.

4.3 Germany

Germany shows a U-shaped q-coefficient: it decreases until 1999 and then it increases. In fact Germany shows a lower degree of agglomeration between 1993 and 1999, namely, larger cities become less 'heavy' in the city system. After 1999, Germany shows again a process of concentration indicated by the increasing q-coefficient. By considering the relationship with Gibrat's law, we then investigate condition (b) of Sect. 1.

Considering the entire sample, we have 2 years in which Gibrat's law holds. In particular, in 1999–2000, the estimated β-parameters are not significantly different from 1.

Now if we focus on the period 1993–1999, where a decreasing q-coefficient applies, we can note that β_{BIG} is significantly lower than 1, whereas β_{small} is not significantly different from 1 in most cases, indicating a situation in which the larger the city, the lower the expected growth. On the contrary, in the period 2000–2007,[11] where an increasing q-coefficient applies, we can notice that β_{BIG} are often not significantly different from 1, whereas β_{small} are (most of the time) significantly greater than 1, indicating a situation in which the larger the city, the larger the expected growth (in the small subsample, i.e. medium-size cities). In this situation we can figure out the following growth processes: when q-coefficient is decreasing, we have modifications on the growth process of large cities; in particular, the larger the city, the lower the expected growth. On the other hand, when q is increasing, small cities present a different growth process, namely, the larger the city, the larger the expected growth. By considering the entire sample, the variance ratio, θ, is often close to unity, but slightly lower than 1 until 1999 when it becomes stable (and equal to 1). Again, this latter condition says few things about the independence of the variance from the size.

We then analyse the two subsamples separately, and in particular we analyse those years where Gibrat's law holds (according to proposition (b) of Sect. 1), i.e. 1999 and 2000.

In these years, it should be noted, firstly, that when Gibrat's law holds, the variance ratios for large cities, θ_{BIG}, are less than 1, that is, the variance at time t is lower than that at time t–1. Instead, the variance ratios for small cities, θ_{small}, are greater than 1. At (any) time t, large cities face a lower volatility, while small cities face a greater (or almost stable) volatility. Second, the variance of growth $\sigma^2{}_{\mathrm{BIG}}$ is always less than $\sigma^2{}_{\mathrm{small}}$. Then, both these facts are again consistent with proposition (b) of Sect. 1. Again we can affirm that for those years in which Gibrat's law holds ($\beta = 1$), statement (b) (Sect. 1) is satisfied for the whole sample.

[11]Notice that in the years in which the q-coefficient is equal to that of previous year (i.e. 1999 and 2000), Gibrat's law holds. The stability of the process should not lead to any changes in the hierarchical structure of cities.

4.4 Hungary

In Sect. 3, we have shown that Gibrat's law does not hold in Hungary. We have already mentioned the role of the capital (Budapest) in this country, which attracts most of the total population of the country. In percentage terms, more than half of the total population of Hungary lives in the Budapest urban area. Moreover, it faces a migration flow from its rural area to the centre of the city. The evolution of the q-coefficient in this country reflects the tendency to agglomeration in the large cities: indeed the estimated q-coefficient is increasing and greater than 1. In this situation we can check for statement (b) of Sect. 1. Unfortunately Gibrat's law never holds, since the β-coefficients are always significantly greater than 1. This means that size diverges towards its means, namely, the larger a city, the larger the expected growth. Then, it is straightforward that the variance ratio, θ, increases for both large and small cities. However, it should be noted that the variance of small cities, θ, is always greater than the variance of large cities and that the variance of growth $\sigma^2{}_{\text{BIG}}$ is always less than $\sigma^2{}_{\text{small}}$; thus, although we cannot formally show evidence of generalised Gibrat's law (in particular regarding statement (b)), we again show a greater volatility for small cities when $q > 1$.

4.5 Japan

In Sect. 3, we have shown that Gibrat's law does not hold (Table 4a). So the evolution of the q-coefficient in this country reflects the tendency to agglomeration in the large cities and again Gibrat's law never holds, since the β-coefficients are always significantly greater than 1. This means that size diverges towards its means, namely, the larger a city, the larger the expected growth. However, as we have repeatedly said throughout this chapter, Japan shows a higher level of aggregation on the definition of its municipalities, so that the comparison between countries is difficult. Nevertheless, we suppose that Japan show characteristics of aggregation more pronounced of that for Germany, as represented by the q indicator.

The analysis carried out over these three countries provides an important first conclusion. On the basis of statement (b), we have shown that when $q > 1$ and Gibrat's law holds ($\beta = 1$), the variance (θ- and σ^2-parameters) is actually greater for small cities. Moreover, when the q-coefficient is greater than 1 but decreasing, we have modifications on the growth process of large cities, but not on those of small cities: in particular, the larger the city, the lower the expected growth. On the other hand, when the q-coefficient is greater than 1, but increasing, small cities present the opposite growth process: namely, the larger the city, the larger the expected growth. Consequently, we find evidence of the generalised Gibrat's law – as in statement (b) of Sect. 1 – in the countries displaying $q > 1$, where the independence of the mean with respect to the size is in operation, while the same is not true for the variance.

A reasonable criticism, at this point in the analysis, could be that, generally, small entities (cities, firms and so on) present a greater volatility than larger ones. We can anticipate that we will find the opposite evidence in the case of $q < 1$.

We now move to the situation where $q < 1$. By considering the relationship with Gibrat's law, we investigate condition (c) of Sect. 1 which predicts that the associate growth process requires that smaller cities face a lower volatility of growth than larger cities.

4.6 Luxembourg

Luxembourg shows an estimated q-coefficient lower than 1. It increases until 1930, and after that it is not significantly different from 1. Between 1821 and 1922, we are in condition (c) of Sect. 1. Considering the entire sample, we have already shown that Gibrat's law holds in the years 1871 and 1880 and in 1922 with estimated β-parameters not significantly different from 1. Moreover, considering the two subsamples, most of the time we find evidence of Gibrat's law for both large and small cities. At a first glance, it seems that large and small cities face the same underlying growth processes. However, to test statements (c), we need to take into account the behaviour of the variance.

The variance ratio for the entire sample in Luxembourg in the period 1821–1922 is always greater than 1, indicating a greater volatility of the process as time goes by. Indeed, when we split the sample in two halves, the variance ratios for the large cities show values always greater than 1, while, for the small cities, they are always below 1. This implies an (increasing) change in the underlying volatility of the growth process for large cities, in contrast to a (decreasing) change in the underlying volatility of the growth process for small cities. Moreover, in those years, the variance of growth $\sigma^2{}_{\mathrm{BIG}}$ is always greater than $\sigma^2{}_{\mathrm{small}}$. Given these facts, we can affirm that at time t, the variance is increased for the large cities but decreased for the small cities, indicating a dependence of variance with respect to size; in particular, smaller cities face a lower volatility than large cities. In summary, statement (c), which affirms 'if $q < 1$, in order that Gibrat's law occurs, it is necessary that the mean is independent from the city size but not the variance; indeed, the associated growth process requires that smaller cities face a lower volatility of growth than larger cities', is satisfied for the whole sample in 1821–1922.

In the period 1930–2011, the q-coefficient is not statistically different from 1. By considering the relationship with Gibrat's law, we then investigate condition (a) of Sect. 1 which predicts that the associated growth process requires that smaller cities face the same growth as larger cities. Considering the entire sample, we have already shown that Gibrat's law holds most of the time (estimated β-parameters not significantly different from 1). Considering the two subsamples, we find similar evidence for both large and small cities, even with same exceptions. However, it is interesting to note that in those years where Gibrat's law does not hold, the estimated parameters β, θ and σ^2 show very different behaviours (i.e. $\theta_{\mathrm{BIG}} = .963$ and θ_{small}

Table 6 Relationship between Zipf/rank-size and generalised Gibrat

Country	Year	q	q trend	Gibrat	θ	σ^2	Generalised Gibrat validity
Botswana	2001–2011	>1	↑	True ($\beta = 1$)	$\theta_{BIG} < \theta_{small}$	$\sigma^2{}_{BIG} < \sigma^2{}_{small}$	Yes (statement (b))
Germany	1993–2000	>1	↓	Weak ($\beta = 1$)	$\theta_{BIG} < \theta_{small}$	$\sigma^2{}_{BIG} < \sigma^2{}_{small}$	Yes (statement (b))
	2001–2007	>1	↑	False ($\beta \neq 1$)	$\theta_{BIG} < \theta_{small}$	$\sigma^2{}_{BIG} < \sigma^2{}_{small}$	No
Hungary	1980–2011	>1	↑	False ($\beta \neq 1$)	$\theta_{BIG} < \theta_{small}$	$\sigma^2{}_{BIG} < \sigma^2{}_{small}$	No
Japan	1995–2010	>1	↑	False ($\beta \neq 1$)	$\theta_{BIG} < \theta_{small}$	$\sigma^2{}_{BIG} < \sigma^2{}_{small}$	No
Luxembourg	1821–1930	<1	↑	Weak ($\beta = 1$)	$\theta_{BIG} > \theta_{small}$	$\sigma^2{}_{BIG} > \sigma^2{}_{small}$	Yes (statement (c))
	1935–2011	=1	↔	True ($\beta = 1$)	$\theta_{BIG} = \theta_{small}$	$\sigma^2{}_{BIG} = \sigma^2{}_{small}$	Yes (statement (a))

Notice that weak Gibrat's law means that Gibrat's law holds only for few years

= 1.162; $\sigma^2{}_{BIG}$ = 1.93 and $\sigma^2{}_{small}$ = 1.31 in 1970), but, in general, in those years where Gibrat's law holds, the differences between the estimators are not so large (i.e. θ_{BIG} = 1.03 and θ_{small} = 1.01 and $\sigma^2{}_{BIG}$ = 0.55 and $\sigma^2{}_{small}$ = 0.53 in 1947). In summary, statement (a) which affirms 'if $q = 1$, then in order that Gibrat's law occurs neither the mean nor the variance of growth can depend on size' is satisfied for the whole sample.

4.7 Synthesis

A synthesis of the above results – summarising the possible empirical link between Gibrat's and Zipf's law – is presented in Table 6.

The analysis carried out in this section prompts several interesting conclusions. We gave some empirical clues about the presence of a 'generalised Gibrat's law', as theoretically predicted by Cordoba (2003). In particular, we have controlled for statements (a), (b) and (c) of Sect. 1. In more detail, we have evidence that when $q > 1$ (statement (b)) and Gibrat's law holds ($\beta = 1$), the variance ratio (θ-parameter) and the variance of growth, σ^2, are actually higher for the small cities, in comparison to that for large cities, indicating a larger volatility for small cities. On the contrary, when $q < 1$ (statement (c)) and Gibrat's law holds ($\beta = 1$), the variance ratio (θ-parameter) and the variance of growth, σ^2, are actually lower for the small cities, in comparison to that for large cities, indicating a larger volatility for the smaller ones.

When $q = 1$ (statement (a)) and Gibrat's law holds, our findings agree with previous research, as both the mean and variance appear to be independent from the size.

Moreover, when the q-coefficient is greater than 1 but decreasing, we have modifications on the growth process of large cities, but not on those of small cities; in particular, the larger the city, the lower the expected growth. On the other hand, when $q > 1$ but increasing, small cities present the opposite growth process, namely, the larger the city, the larger the expected growth. We have, of course, an opposite behaviour when the q-coefficient is less than 1.

5 Conclusion

The aim of our research work was to explore specific conditions leading to a generalisation of Gibrat's law in connection with the different typologies of rank-size distribution but also to underline some common shortcomings of the empirical analysis on Gibrat's and Zipf's law.

For these purposes we empirically explored the link between the rank-size exponent, q, and the necessary conditions for Gibrat's law (i.e. mean and variance of the growth have to be independent from the size). We started our analysis based on the conclusion of Cordoba (2003, p. 3): *Pareto distributions with larger exponents* (*more unequal distributions*) *require more volatile growth processes*. As far as we know, the conventional methodologies (Sect. 3) used to test Gibrat's law do not address this issue. In particular, a greater (lower) volatility of the variance is usually not empirically envisaged. We showed, instead, that, according to Cordoba (2003), the variance can be dependent on size if the rank-size coefficient is different from 1; in particular, we empirically show what Cordoba (2003) calls a 'generalised Gibrat's law' for different countries with different spatial-economic characteristics: Botswana, Germany, Hungary, Japan and Luxembourg. We found clues of this generalised Gibrat's law for Botswana and Luxembourg. We found weak evidence of Gibrat's law for Germany and no evidence for Hungary.

Our results seem to support the propositions provided by Cordoba (2003). In particular, when $q = 1$, neither the mean nor the variance of growth depend on size; when $q > 1$, the mean is independent of the city size, but not the variance, and small cities face a greater volatility in growth than larger cities; alternatively, when $q < 1$, the mean is independent from the city size, but not the variance, and large cities face a greater volatility in growth than smaller ones. Gibrat and Zipf have offered complementary perspectives on city size and systems of cites in a given country. Their contributions are not necessarily identical, but offer new perspectives on the same multifaceted prism of the space economy. These results might be useful to 'relax' Gibrat's law in its strict interpretation, by reinforcing the hypothesis that small entities face a greater volatility in the growth process.

However, we also present some common shortcomings that may affect international comparisons between results or even the correctness of the results.

Our analysis prompts various intriguing research questions in the future. While Gibrat's law and Zipf's law mirror important organised structures in the topology of systems of cities, other relevant structural patterns may be investigated as well, such as the existence of fractal structures in urban systems (based, e.g., on Mandelbrot's principles) or the persistent existence of spatial population or socio-economic disparities (based, e.g., on Herfindahl's index). Clearly, the dynamics of such processes deserve due attention. In addition, the above applied investigation also calls for more fundamental research into the functional or behavioural backgrounds of such regularities. Three research directions are important here: (a) the interdependence between population indicators and broader socio-economic indicators for a system of cities, (b) the degree of various cities in the same national system and (c) the relationship between recent strong evolutionary trends in the digital world and the development of cities (and systems of cities).

References

Adamic LA (2000) Zipf, power-laws, and pareto – a ranking tutorial. Retrieved from www.hpl.hp.com

Auerbach F (1913) Das Gesetz der Bevolkerungs Konzentration. Petermanns Geogr Mitt 59:73–76

Auerbach F (1915) The law of population concentration. Sci Am Suppl 76:384

Bee M, Riccaboni M, Schiavo S (2013) The size distribution of US cities: not Pareto, even in the tail. Econ Lett 120(2):232–237

Black D, Henderson V (2003) Urban evolution in the USA. J Econ Geogr 3(4):343–372

Bottazzi G, Dosi G, Lippi M, Pammolli F, Riccaboni M (2001) Innovation and corporate growth in the evolution of the drug industry. Int J Ind Organ 19(7):1161–1187

Brakman S, Garretsen H, van Marrewijk C (2001) An introduction to geographical economics. Trade, location and growth. Cambridge University Press, Cambridge

Champernowne DG (1953) A model of income distribution. Econ J 63(250):318–351

Chesher A (1979) Testing the law of proportionate effect. J Ind Econ 27:403–411

Christaller W (1933) Die Zentrale Orte in Süddeutschland. Eine Ökonomisch-Geografische Untersuchung Über Die Gesatzmässigkeit Der Verbreitung Und Entwicklung Der Siedlungen Mit Städtischen Funktionen. Gustav Fischer, Jena

Cordoba J (2003) On the distribution of city sizes. Urban/Regional. 0302002, EconWPA

Cordoba J (2008) A generalized Gibrat's law. Int Econ Rev 49(4):1463–1468

Cuberes D (2011) Sequential city growth: empirical evidence. J Urban Econ 69:229–239

Eeckhout J (2004) Gibrat's law for (all) cities. Am Econ Rev 94(5):1429–1451

Fazio G, Modica M (2015) Pareto or log-normal? Best fit and truncation in the distribution of all cities. J Reg Sci 55(5):736–756

Gabaix X (1999) Zipf's law for cities: an explanation. Q J Econ 114(3):739–767

Gabaix X, Ibragimov R (2011) Rank-1/2: a simple way to improve the OLS estimation of tail exponents. J Bus Econ Stat 29(1):24–39

Gabaix X, Ioannides YM (2004) The evolution of city size distributions. In: Henderson JV, Thisse J-F (eds) Handbook of regional and urban economics, vol 4. Elsevier, Amsterdam, pp 2341–2378

Gibrat R (1931) Les Inégalités Economiques. Libraire du Recueil Siray, Paris

Giesen K, Suedekum J (2011) Zipf's law for cities in the regions and the country. J Econ Geogr 11(4):667–686

González-Val R (2010) The evolution of U.S. city size distribution from a long-term perspective (1900–2000). J Reg Sci 50(5):952–972
González-Val R, Lanaspa L, Sanz-Gracia F (2012) New evidence on Gibrat's law for cities, Working papers 2012/18. Institut de Economia de Barcelona (IBE), Barcelona
González-Val R, Lanaspa L, Sanz-Gracia F (2013) Gibrat's law for cities, growth regressions and sample size. Econ Lett 118(2):367–369
Henderson JV, Wang HG (2007) Urbanization and city growth: the role of institutions. Reg Sci Urban Econ 37(3):283–313
Ioannides YM, Overman HG (2003) Zipf's law for cities: an empirical examination. Reg Sci Urban Econ 33(2):127–137
Ioannides YM, Skouras S (2013) US city size distribution: Robustly Pareto, but only in the tail. J Urban Econ 73(1):18–29
Kalecki M (1945) On the gibrat distribution. Econometrica 13(2):161–170
Lösch A (1940) The economics of location (trans: Woglam W and Stolper W in 1954). Yale University Press, New Haven
Paelinck JHP, Nijkamp P (1976) Operational theory and method in regional economics. Saxon House, Farnborough
Parr JB (1985) A note on the size distribution of cities over time. J Urban Econ 18:199–212
Reggiani A, Nijkamp P (2015) Did Zipf anticipate spatial connectivity structures? Environ Plan B 42:468–489
Rosen KT, Resnick M (1980) The size distribution of cities: an examination of the Pareto law and primacy. J Urban Econ 8(2):165–186
Simon H (1955) On a class of skew distribution functions. Biometrika 42(3/4):425–440
Singer HW (1930) The "Courbe Des Populations". A parallel to Pareto's law. Econ J 48(182):254–263
Soo KT (2005) Zipf's law for cities: a cross-country investigation. Reg Sci Urban Econ 35(3):239–263
Steindl J (ed) (1968) Size distributions in economics, in International Encyclopedia of the Social Sciences, vol 14. Macmillan and the Free Press, New York
Zipf G (1949) Human behavior and the principle of least effort: an introduction to human ecology. Addison-Wesley, Cambridge

How Can Cross-Sector Partnerships Be Made to Work Successfully? Lessons from the Mersey Basin Campaign (1985–2010)

Peter Batey

Abstract Experience suggests that cross-sector partnerships can turn out to be a big disappointment: a cozy talking shop with plenty of warm words but not a lot of action to show for it. The Mersey Basin Campaign, however, was a major exception. As a government-sponsored 25-year initiative to clean up the rivers, canals, and estuary of the Mersey River Basin in North West England, the Campaign was a pioneer in public-private-voluntary partnership working and, in the period it was active (1985–2010), made great progress in improving water quality, promoting waterside regeneration, and engaging stakeholders, in a region with a history of severe industrial dereliction and pollution. In this paper, by a former leader of the Campaign, a number of themes are explored: Why was a Campaign needed? What did it try to achieve? How did it do this? What particularly factors led to successful partnership working?

Keywords Partnership working • River Mersey • River basin management

1 Introduction: River Basin Management in the UK

The industrial revolution in the UK in the early nineteenth century brought about a dramatic rise in the urban population, from approximately 3.1 million in 1800 to almost 28 million a century later (Petts et al. 2002, p. 23). A major consequence of such rapid, unplanned expansion was insanitary and unhealthy housing in the cities and the emergence of slums. Open ditches and streams had long been the receptacles for domestic sewage and trade refuse, as well as rubbish from street surfaces, and their flowing water provided a simple means of waste disposal. With growing populations, the ability of streams to disperse, dilute, and assimilate organic wastes became overwhelmed, and channels often became blocked. The expense of cleaning and maintenance led to widespread neglect. The pressure on urban

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space prompted the widespread culverting of streams and ditches, and even where streams survived, they were often straight-jacketed in concrete-lined channels edged by embankments to accelerate their flows and increase their capacity to transport rubbish – downstream from the urban area (Petts et al. 2002, p. 24).

Mounting concern in the late nineteenth century about water quality and public health led to the appointment of a number of Royal Commissions, charged with examining the problems and making recommendations and to the passing of the first legislation concerned with river management: the Public Health Act (1875) and the River Pollution Prevention Act (1876) (Newson 2009, p. 277).

By the start of the twentieth century, there was greater appreciation of the need to manage rivers in a more coordinated way. Up to this point, management activities such as water supply and sewerage, land drainage, and navigation had been carried out in a highly fragmented fashion by separate organizations which often had little to do with each other. In England and Wales, for example, public water supply was the responsibility of more than 2000 separate bodies, ranging from local authority departments to licensed private companies. Sewerage and sewage treatment remained a separate local government function (Watson 2005, p. 180).

The first attempts to achieve whole-catchment management were focused on land drainage. This may be explained by the fact that, without the maintenance of drainage and flood defense works, a large proportion of England and Wales would be waterlogged and unfit for habitation. A total of 47 separate catchment boards were first established in England and Wales under the 1930 Land Drainage Act and with direction from the Ministry of Agriculture; each board drew together the various public and private interests to plan and allocate investment for land drainage across the entire catchment.

Gradually, over the next 40 years, through a complex process of consolidation, the various aspects of river management were brought together into a system of catchment-wide bodies. In 1974, this culminated in the creation of ten regional water authorities (RWAs), operating within river basin boundaries. Each RWA was responsible for water development and conservation, water treatment and distribution, sewerage and sewage treatment, water quality regulation, pollution control, flood alleviation, land drainage, recreation, fisheries, and navigation. While this meant that, for the first time, England and Wales had a truly multi-purpose form of river basin management, there were nevertheless significant drawbacks. According to Watson (2005, p. 183), the most serious problem lays in the combination of regulatory and operational functions within the same organizations. It meant that the RWAs were expected to police themselves to ensure that effluent from sewage treatment works was within consented limits. Pressures on public funds left the RWAs short of resources to carry out their demanding range of functions, and particularly infrastructure investment, with the result that it became necessary to relax discharge consents at some of their own sewage treatment works in order to comply with the law while at the same time avoiding additional expenditure. The unfortunate outcome was that water quality in the lowland sections of many rivers in England and Wales was very poor in the late 1970s and early 1980s (Watson 2005, p. 184).

Even bigger changes were to come. In 1986 the Conservative Government under Margaret Thatcher announced plans to privatize the RWAs. Legislation was introduced in 1989 to create a dual public and private system, splitting the RWAs into privatized companies and an environmental regulatory body, the National Rivers Authority. The water industry would be subject to an economic regulator, the Office of Water Services (OFWAT). The privatized water companies would be expected to prepare 5-year asset management plans, setting out their programs of infrastructure investment, and OFWAT would determine the pricing scheme for water, taking into account the priorities expressed in these plans and the ability and willingness of water consumers to pay.

In 1996 the National Rivers Authority, along with a number of other environmental bodies, was amalgamated to form a new regulatory organization, the Environment Agency. The agency was expected to contribute to sustainable development generally and, in the case of rivers, to the sustainable use of water. This was accomplished through a series of Local Environment Action Plans (LEAPs). In theory, these plans were created in consultation with local communities and stakeholders, but in practice, they were largely "top-down" documents with little local buy in (Kidd and Shaw 2000; Gregory 2012).

National priorities have changed significantly in the time since the Environment Agency was set up. In the last 15 years, there has been a heavy emphasis upon floodplain management as a result of a number of extreme flooding events. The traditional approach to the control of river flooding was "structural" or "engineered" in character (Newson 2009, p. 279). The response to the threat of flooding was to deepen and straighten river channels to accommodate more water and to remove rough bed material to reduce resistance to flow. Flood walls were constructed to contain the flow of water that overflows the river banks (Watson 2005, p. 185). Little thought was given, however, to the consequences this might have for settlements downstream. More recently, greater awareness of flood risk management, combined with increasing concern for biodiversity management, has led to the development of policy statements about floodplain restoration. A good example is the Department for Food and Rural Affairs (DEFRA) policy document "Making space for water" which takes a more holistic approach to flood risk management and has had the effect of prompting the Environment Agency to focus upon projects which restore natural channel and floodplain functioning (Gregory 2012, 229).

Watson (2005, p. 187) observes that most rivers in Britain have been altered from their natural state in some way, and many have been degraded. Rather than accept this as the inevitable price to be paid for economic progress, he argues instead for an approach which aims to restore rivers to a healthy state and ensure that their future use has a stronger backing of environmental protection. Under this new philosophy, to which all public bodies now subscribe, rivers are seen as valuable resources fulfilling a range of needs: economic, social, cultural, and environmental. Balancing those needs is not easy and calls for a wider range of management tools and, as well as legislation and regulation, there is an important role for voluntary action and community involvement. For integrated river management to be fully achieved, a cross-sector partnership approach is needed, drawing together government, industry, commerce, and community organizations.

In this chapter, the focus is on how this partnership-based approach can be achieved in practice, by reference to one particular example drawn from the UK, the Mersey Basin Campaign.

2 The Mersey Basin Campaign

The Mersey Basin Campaign, a government-sponsored 25-year initiative to clean up the rivers, canals, and estuary of the Mersey River Basin in North West England, was a pioneer in cross-sector (public-private-voluntary) partnership working and, in the period it was active (1985–2010), made great progress in improving water quality, promoting waterside regeneration, and engaging stakeholders, in a region with a history of severe industrial dereliction and pollution. The following themes are explored in this chapter:

- How the Campaign came to be formed
- How it was organized, governance arrangements, and how these evolved over time
- Engaging with local communities: bringing the partnership to the local level
- How projects were implemented

The chapter includes a case study that illustrates some of the activity undertaken by the Campaign and its partners. It concludes by considering what made the Campaign distinctive and, drawing on 25 years of experience, some of the lessons that can be learnt for partnership working more widely.

2.1 Background to the Creation of the Campaign

In the nineteenth century, the North West of England became the world's first industrialized region. The rapid industrial growth created a high level of demand for labor and thus brought about very rapid expansion of urban areas. Domestic sewerage systems were based on untreated disposal directly into rivers and sea. Manufacturing industry became established along the region's rivers and new canal system, which served as the major conduits for removing and transporting industrial waste.

By the second half of that century, the Mersey, and its major tributary the Irwell, which in 1721 had supported fish as a commercial industry, had become so grossly polluted that a Royal Commission on the Prevention of Pollution of

Rivers was appointed to study and report on the problem.[1] In so far as the problems were recognized, little priority was attached to addressing them by the municipal authorities. Certainly, as late as the 1980s, the Mersey was the most polluted estuary and river system in the UK (Jones 2000). Throughout the twentieth century, progressive changes to legislation and institutions,[2] including the formation of the RWAs in 1974, brought about significant improvement, but, even so, toward the end of the century, the region's waterways were among the most polluted in the world, and industrial decline was manifest in dereliction, poor housing, and growing social problems.

These problems came to a head in 1981 when disturbances in Toxteth, an inner city area of Liverpool, turned into full-blown riots. This civil unrest focused its attention in a powerful way on the severe problems – social, economic, and environmental – faced by many of the larger towns and cities in the North West. Concerted action on several fronts was widely seen as the way forward. This would require new ways of working, extending beyond the traditional role of the public sector.

The poor state of the environment presented a particularly difficult challenge, nowhere more so than in and around the region's watercourses. Despite the major asset that rivers and canals had once been in fostering the development of industry, by the early 1980s, they had become a serious constraint to urban regeneration and economic revival. Water quality had degenerated to an extent that was completely unacceptable and many waterside areas were abandoned and derelict.

The gravity of the situation was soon recognized by Michael Heseltine, then Secretary of State for the Environment in the UK government, and, as Minister for Merseyside (the Liverpool city region), he was the government politician charged with the task of finding ways of alleviating the severe problems faced by the city. In a deliberately provocative call for action, Heseltine had this to say about the Mersey in 1983:

> *Today the river is an affront to the standards a civilized society should demand of its environment. Untreated sewage, pollutants, noxious discharges all contribute to water conditions and environmental standards that are perhaps the single most deplorable feature of this critical part of England.* (Department of the Environment 1983)

It was Heseltine's own initiative to create a Mersey Basin Campaign, aimed at addressing the problems of water quality and associated landward dereliction of the River Mersey and its tributaries. The development of the Campaign was to break new ground in British administrative practice and has proved to be the forerunner of the practice of cross-sector partnership working which is now so deeply ingrained in British public life (Menzies 2010).

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[1] The Royal Commission on the Prevention of Pollution of Rivers sat over the period 1864–1873, took evidence from industrialists located alongside the Mersey and the Irwell, and produced a series of reports and recommendations. See Elworthy and Holder (1997).

[2] For further information about river management policy in the UK, see Watson (2005), Newson (2009), and Gregory (2012).

The Mersey Basin Campaign began in 1985 as a 25-year, government-backed movement to clean up the entire Mersey River system. From the outset, the approach was bold and innovative. The use of the word *campaign* reflected the need to engage broadly based support around a common set of objectives. It conveyed very clearly the notion of a practical approach involving a range of interested parties working together to produce tangible results.

From the outset, the core vision of the Campaign was to work toward the delivery of a system of rivers and other waterways that sustained and contributed to, rather than detracted from, the quality of life of the region's population.

During the lead-up to the launch of the Campaign, Heseltine argued the case for a comprehensive program of environmental improvements:

> *To rebuild the urban areas of the North West we need to clean and clear the ravages of the past, to recreate the opportunities that attracted earlier generations to come and live there and invest there . . . A Mersey Basin restored to a quality of environmental standards fit for the end of this century will be of incalculable significance in the creation of new employment*. (Department of the Environment 1983)

In saying this, he was recognizing, quite explicitly, the interdependence of economic prosperity and quality of environment. The Campaign was therefore conceived as a "sustainable development" approach long before these words were in common currency (Menzies 2008). This translated into three key aims for the Campaign, identified at the start of the initiative:

- To improve river quality across the Mersey Basin to at least a "fair" standard by 2010 so that all rivers and streams are clean enough to support fish
- To stimulate attractive waterside developments for business, recreation, housing, tourism, and heritage
- To encourage people living and working in the Mersey Basin to value and cherish their watercourses and waterfront environments

These three simple, but meaningful, aims proved to be remarkably durable and remained the same throughout the life of the Campaign. The Campaign sought to achieve these aims through involvement in a wide range of programs and activities at the local, subregional, regional, national, and European levels, in some instances playing a major, and often a central, role; in others its role and impact were more indirect, adding value to the activities of others.

With the benefit of hindsight, the water quality aim looks modest, but at the time the Campaign was starting, it was regarded as extremely ambitious. In particular, no practical solutions were available to reduce the impact of storm water sewage discharges from extensive urban areas. Such solutions as there were then received little attention because they were seen as impossibly expensive. Only later did feasible solutions emerge when the water industry was privatized, and therefore not subject to public sector borrowing constraints, and as the result of considerable pressure to comply with a series of European Union directives.

Figure 1 shows the Campaign area and its location within Great Britain. The catchment of the Mersey covers an area of 4680 km^2. It drains into the Mersey Estuary, which is 26 km long, before entering Liverpool Bay and the Irish Sea.

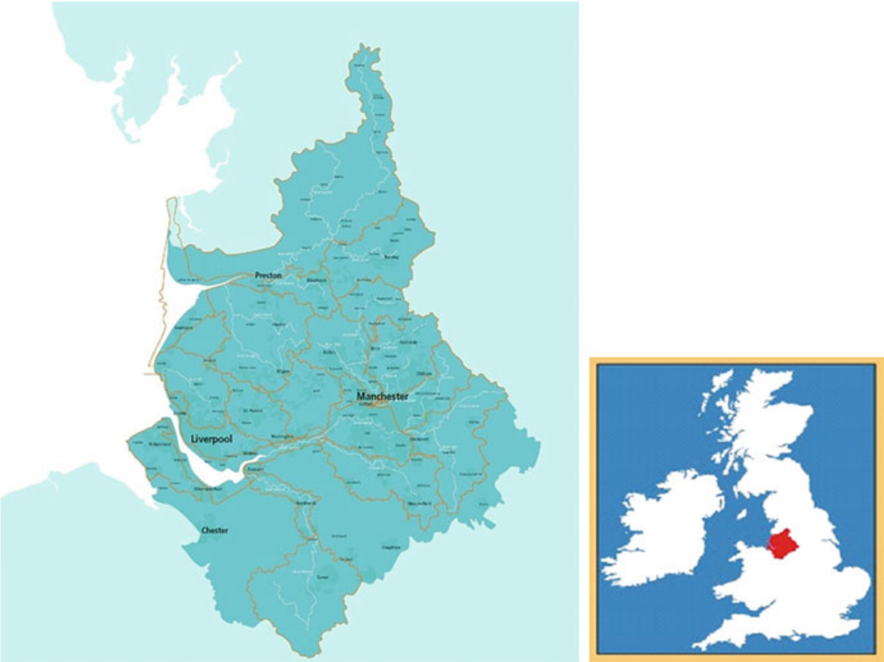

Fig. 1 Map to show the geographical area covered by the Mersey Basin Campaign

Prominent tributaries to the Mersey include the rivers Irwell, Tame, Goyt, Bollin, and Weaver. The Campaign area also included the River Ribble catchment,[3] adjacent to the Mersey to the north. A number of canals lie within the Campaign area, most notably the Manchester Ship Canal, extending from the inland extent of the Mersey Estuary to Manchester, a total of 58 km. The catchment has a population of around five million and includes the cities of Manchester in the upper part of the catchment and Liverpool on the banks of the Mersey Estuary.

The definition of the Campaign area was deliberately based upon the notion of river systems – Mersey and Ribble – rather than the alternative of city regions based upon local authority boundaries. This avoided the possible separation of problems and solutions in relation to the rivers, thus helping to escape the political wrangling that might otherwise have proved a major distraction. This was important given that, at the time the Campaign was set up, the UK government had announced plans to abolish the metropolitan counties, including those based upon Liverpool and Manchester city regions (Batey 2009).

[3] The River Ribble catchment was added to the Campaign area in the late 1990s at the request of the environmental regulator, the Environment Agency. The agency was keen to ensure that the improvements in water quality, starting to be felt in the Mersey catchment, were extended to the Ribble.

2.2 The Emergence of a Distinctive Form of Partnership Working

The scale and complexity of the cleanup program required to deal effectively with the gross water pollution and waterside dereliction was too great for any one authority or agency.[4] A civil servant heavily involved in setting up the Campaign, Peter Walton, commented in 1983:

> *The task of cleaning up the Mersey – the watercourses and waterside areas of the whole catchment – is a comprehensive and formidable one. The task calls for a team effort, in which the inputs of all sectors encourage each other and generate a momentum of improvement greater than could be achieved otherwise*. (Department of the Environment 1983)

It was this recognition that a combination of public, private, and voluntary sector action was necessary to bring about the total process of renewal for the water and bordering land that led to the Campaign being formed in 1985. At the time, partnerships were quite rare and, where they did exist, they operated just between the public (government) and private (business) sectors or were confined to different parts of the public sector.

The Mersey Basin Campaign partnership was conceived differently from the start. It was organized around an independent chair leading a unit from the government's Department of the Environment. Key partners were brought in, including the (then publicly owned) water authority, local authority representatives, and professional officers with an advisory role from a number of nongovernmental organizations (Mersey Basin Campaign 1986). Later, as part of a re-structuring of the Campaign, the partnership was enhanced by involving the voluntary (not-for-profit) sector, a wider cross-section of private sector organizations and the academic sector.

2.3 Governance, Management, and Decision-Making

The organization of the Campaign changed significantly over its life span to reflect regional changes and developments and to build upon experience. Two major changes in structure took place over its 25-year history to reflect the growing and changing needs of the Campaign and the region. First, in 1996, the Campaign gained some independence from government as it became an "arms' length management organization." This "privatizing" was considered to be necessary to allow the

[4] At the time, there was no environmental program for water quality improvements: that would not come until water privatization in 1989 and the introduction of 5-year asset management plans (see Gregory 2012).

Campaign to be more effective for engagement of the private and voluntary sectors. Throughout the remainder of its life, the Campaign, working in arms' length mode, nevertheless retained its core funding from the UK central government and continued to enjoy the ongoing support of successive governments. Secondly, a review of the partnership in 2001 brought about further changes to the governance of the Campaign, allowing even wider participation in the Campaign and its work through changes to the organizational structure, and the development of a constitution for the Campaign Council.

These two fundamental changes led the Campaign to develop from a government-run initiative, albeit led by an independent chair, to the partnership status it had during the final 8 years, as discussed below.

The Campaign partnership from 2002 onwards was based upon active involvement through a number of organizational structures (Fig. 2). This partnership governance can be summarized as:

- The council, as the formally constituted, nonexecutive governing body of the Campaign, determined strategic guidance and approved the annual corporate plan.
- The Mersey Basin Business Foundation (MBBF) was a mechanism for business and financial management, contracts, and the employment of the Mersey Basin Campaign staff. It was the legal personality of the Campaign.

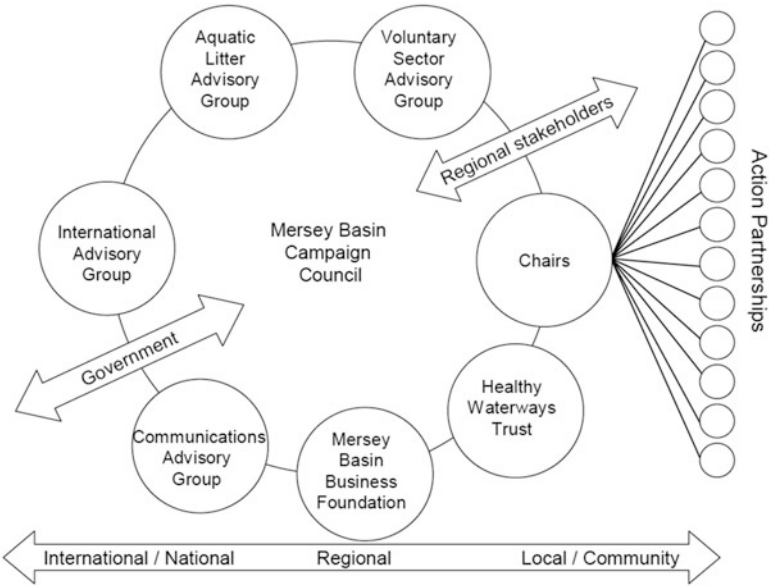

Fig. 2 Organizational structure of the Mersey Basin Campaign

- The Healthy Waterways Trust was the Campaign's charitable arm and was (and still is) a registered environmental body.[5]
- Advisory groups providing focus for more specific policy development and guidance for the work of the Campaign.

The Campaign structure also allowed spatial flexibility in the partnerships. Regional stakeholders played key roles within the Campaign Council and MBBF. Local stakeholders partnered the Campaign through its Action Partnerships (Wood et al. 1999). Action Partnerships reflected local challenges and needs and were composed of key local partners, with the Campaign employing a number of Action Partnership coordinators to support the individual steering groups and to take decisions forward through fund raising, managing projects and events, and awareness raising activities.

2.4 Leadership and Decision-Making

The Campaign was led throughout by a **chairman**, appointed by the relevant central government cabinet minister, but expected to be independent. Over the 25 years of the Campaign, four individuals served in this position, in each case for 6 or so years. Three were drawn from senior roles in industry, while the fourth and final chairman, the present author, was a senior academic with wide experience of university management. The role of Campaign chairman called for a high-profile champion who could influence opinion among potential partners across all sectors and secure their support and continuing involvement. Each of the chairmen had a distinctive style and fortunately this turned out to be well matched to the particular needs of the Campaign during their period of office. There can be no doubt that the chairmen's leadership was crucial to the success of the Campaign.

The **council** was set up as the governing body for the Campaign within which key regional stakeholders provided strategic direction and policy guidance to the Campaign in delivering its objectives. It was an unincorporated stakeholder partnership of 38 representatives with two types of members: partners, with voting rights, and advisers/observers without voting rights. Members of the council were appointed as representatives for their organizations, sectors, or area of interest. Core partners on the council included representatives of the water company (United Utilities), the environmental regulator (Environment Agency), local government, the Regional (economic) Development Agency, and a number of other public bodies

[5]The Healthy Waterways Trust continues to this day (http://www.healthywaterwaystrust.org.uk/), fulfilling some of the Campaign's role in a more low key way. Since 2010 much of its activity has focused on mediation in relation to the maintenance of water quality standards in some of the most sensitive locations in the Mersey Basin, e.g., Salford Quays, a major site for waterside regeneration.

(e.g., Natural England). The voluntary sector was also represented on the council, with the voluntary sector forum, and advisory group to the Campaign council, providing representation.

The **Mersey Basin Business Foundation**, a nonprofit-making limited company, carried out the task of overall operational management for the Campaign. Directors were partners from industry, based on an initial partnership between the Campaign, ICI (in 1987), Shell (1988), and Unilever (1989). MBBF was launched as a separate and increasingly important arm of the Campaign in 1992 and, by the time the Campaign ended in 2010, had 12 members. It actively sought to expand the number of businesses linked to the Campaign and specific Campaign projects. Member organizations were encouraged to incorporate Campaign objectives into their daily activities and business practices. The MBBF was the recipient of the core government grant to the Campaign.

These two structures (the Campaign Council and MBBF) enabled partners to work with the Campaign at different levels and degrees of commitment. The Campaign found that one of the keys to successful partnerships was ensuring there were many opportunities to build relationships with partners and connections at all organizational levels, from the top of an organization down. For long-term commitment, the Campaign found it essential to establish a relationship at the top of the organization, thereby ensuring commitment throughout that organization.[6]

2.5 Building Trust and Developing a Long-Term Partnership

One potential stumbling block to good partnership working is lack of consistency between partners' objectives. Partnerships such as the Mersey Basin Campaign bring together disparate groups and sectors to work together toward a shared mission. The Campaign had its own unique objectives and mission. Partner organizations, especially core partners, generally had objectives that complemented at least one of the three key Campaign objectives.

One of the strengths of the partnership was the relationship between United Utilities Water plc and the Campaign. Prior to water privatization in 1989, the North West Water Authority (NWWA) had been investing to deal, inter alia, with the crude waste discharges to the Mersey. Collaborating with the Campaign, industry mirrored NWWA's investment, cleaning up its own discharges.

On privatization of water services, the then North West Water Ltd (which later became part of United Utilities plc) was charged with delivering a £2.2 billion, 5-year investment program to improve the region's water infrastructure and make inroads into the worst of the region's water pollution. The company's objectives matched those of the Campaign, and, for the first time, the necessary investment

[6]See I. Gilfoyle (2000) "Memories of the Mersey Basin Campaign," available at: http://www.merseybasin.org.uk/archive/assets/244/original/Memories_of_MBC_by_Ian_Gilfoyle.pdf

existed to make these objectives a reality. The company and Campaign enjoyed a constructive, collaborative relationship throughout the period since then, across all levels of the organizations. For United Utilities, the Campaign provided a broader context for environmental improvements, helping make connections to waterside regeneration and providing third-party publicity for the United Utilities' water quality achievements. For the Campaign, United Utilities was a core funder, the main contributor to improving water quality, and a source of support and technical advice.

It is reasonable to ask to how partners manage to collaborate if their objectives are not the same. The answer is that by establishing and identifying the benefits in working together, the complementary nature of the respective organizations' objectives becomes more focused and allows the partners to recognize the added value in working together. In the case of the Campaign, collaboration on a project basis over the years allowed trust to develop between the partners through working together, producing positive results and both partners obtaining benefits from working together rather than individually.

For example, businesses are keen to work with organizations that can supply niches they do not supply themselves, for example, delivering community engagement. These opportunities enable the partnership and private sector to develop shared vocabularies, in so doing finding common areas of interest and understanding. Such an approach enables the delivery of complex regeneration projects, which a single partner alone cannot realize.

Only once the benefits have been established can trust develop between the partners. The government origins and continued support for the Campaign provided the basis from which a good reputation was developed. This reputation developed over time by building upon achievements in water quality improvements within the catchments and by having a good track record in project delivery. This was achieved through working with the partners in order to gain continued improvements in water quality in the Mersey and Ribble catchments and large-scale regeneration programs, especially targeted at derelict waterside environments.

2.6 Delivering Action on the Ground

The Campaign was essentially a project-based organization, with projects delivered at the catchment or sub-catchment scale. The decision-makers at the catchment scale were the council members. However, at the sub-catchment scale, that decision-making transferred to an individual steering group of the Campaign's Action Partnerships, where partners played a key role through the steering groups for each partnership or through specific projects and action within the partnership's work. For example, a partner may have provided the Chair for an Action Partnership steering group, leading the local initiative. Alternatively, a partner may have participated within a specific project being undertaken by an Action Partnership coordinator, such as a cleanup event or habitat rehabilitation program. The Campaign found this action-led partnership approach was successful in maintaining partners' interest in the Campaign and its work. This organizational structure provided a framework in which all partners could gain from their own inputs.

An annual corporate plan set out the proposed activities, funding and output targets for the forthcoming year, as well as providing an opportunity to consider progress toward the Campaign's main aims. Developed in conjunction with the Campaign's council as part of an annual cycle and agreed by the Government Office North West, acting on behalf of the central government, the corporate plan served as the base reference document for considering the short- and medium-term performance of the Campaign. The corporate plan set out in very broad headings how the block grant from government was to be spent.

The main contributor to the plan was the Campaign's chief executive, and it was he in particular who used the plan to reflect on the constantly changing policy and institutional context and suggest how the Campaign might position itself. This applied particularly to national and European initiatives where, because of the many opportunities for the Campaign to be involved, there was a need to be selective and to avoid "mission drift." Where projects were being considered, the ability to bring together a funding package, with many different sources, was important and sometimes proved to be a highly complex task. In any given year, the block grant from the government was added significantly as a result of the Campaign's efforts to draw in funding from elsewhere. A gearing ratio of 4:1 was typical during the last 5 years of the Campaign.

Toward the end of the Campaign, a typical set of priority actions for the year would have included contributing to the delivery of the EU Water Framework Directive, joint working with European and local partners on INTERREG programs, and strengthening and increasing the activities of the Action Partnerships.[7]

Each of the Action Partnerships was required to produce an annual program according to a common format. A series of standard headings was used to elicit information on the following:

- Action Partnership management and development, providing an opportunity to review priorities and to match these against those of the Campaign as a whole.
- Mersey Basin Campaign program delivery, including the contribution the Action Partnership intended to make toward Campaign-wide activities, such as Mersey Basin Week, the North West Business and Environment Awards competition, and World Environment Day.
- Communications and awareness raising.
- Litter abatement.
- Funding/support secured: rather than bidding into a single competitive Campaign "pot," Action Partnerships were expected to identify their own external funding

[7]The Campaign's final Corporate Plan, for 2009–2010, is available at: http://www.merseybasin.org.uk/archive/assets/53/original/53_mbc_CORPORATE_PLAN_2009-10.pdf

sources for projects they wanted to implement; funding from the government block grant was used primarily to pay the salary of the Action Partnership coordinator; in general it was easier to obtain external funding for specific projects than for core staffing.
- Project delivery, specifying each project separately.
- Work with schools and communities.
- Work with local businesses.
- Student projects.
- Strategic links with other bodies.

The annual program for each Action Partnership was divided into quarters and where possible a target was set for each quarter. This might refer to events to be organized, surveys to be undertaken, articles to be written for the local press, or funds to be raised from particular sources during the course of the year. Laying out a program in this fashion made each Action Partnership accountable and showed what was expected of a local partnership in terms of the scope of activity. It also enabled comparisons to be made between Action Partnerships, highlighting not only the successful partnerships but also those where performance could be improved.

Action Partnership programs were produced in a largely "bottom-up" manner, relying heavily on a Partnership coordinator's ability to understand local community needs and preferences. They were informed by the Partnership's action plan. Regular meetings were held in which coordinators could share best practice and understand how the Campaign as a whole was developing and the policy context for this.

2.7 How the Campaign Worked

The Mersey Basin Campaign has been described as an "esoteric concept," quite difficult to grasp for those not heavily involved (Kidd and Shaw 2000). Indeed, Peter Walton, who did much to bring the Campaign into being, made reference in the introduction to the first periodic report to:

> *. . . the seemingly elusive federal nature of the operation . . . I am convinced that understanding the true character of the Campaign calls for a kind of conversion in outlook – after which the 'modus operandi' becomes clearer. In providing a framework in which all partners can gain from their own inputs, the Campaign seeks continually for added value.* (Mersey Basin Campaign 1995, p. 3)

The present author, soon after taking over as Campaign chairman in 2004, found that even those occupying central positions sometimes had difficulties in conveying how the Campaign worked. This prompted him to propose five verbs in an attempt to capture the essence of the Campaign. Those verbs, and their relevance to Campaign activities, are set out in Fig. 3.

Influence: The Campaign sought to ***influence*** opinion and priorities among stakeholders, politicians, government officials, the business community and the local population by diplomatic means. This influence was felt at all geographical levels: local, sub-regional, regional, national and international.

Enable: The Campaign strove to forge connections between policy and action, to ***enable*** projects to be delivered by the Campaign itself and the full range of partners.

Mediate: By acting as a ***mediator***, the Campaign was able to identify common ground between partners that enabled them to work together more productively and effectively.

Enhance: The Campaign sought to ***enhance*** the work of partners by raising their aspirations and identifying circumstances in which the Campaign's involvement was likely to lead to timely, better coordinated and higher quality outcomes.

Communicate: The Campaign ***communicated*** with a wide range of different audiences in several ways: in putting its own messages across; in providing a forum for partners to discuss and debate matters of mutual interest; and in listening and responding to views expressed by partners about the Campaign and its activities.

Fig. 3 Five verbs used to describe how the Campaign operated

2.8 A Case Study of Campaign Activities: Action Partnerships

The Campaign set up the Action Partnership model in the early 1990s as a way of delivering the aims of the Campaign locally. It was felt that this approach would enable local people and organizations to identify more closely with the objectives of the Campaign and take action themselves. A framework was set up whereby local partnerships could form. They would first establish the issues and opportunities in an area and identify ways in which improvements could be made, harnessing the assistance of local volunteers, businesses, local authorities, and nongovernmental organizations. In all, there were 20 Action Partnerships at various times during the Campaign's life.

For an Action Partnership to be established, it was important for there to be evidence of local interest in taking action on watercourses. This might be shown by a number of agencies or organizations already taking an interest, by projects being planned or already taking place, or by concern being expressed about water-related issues. Typically, the Campaign approached key organizations such as the Environment Agency (the environmental regulator); United Utilities (the privatized water company); British Waterways (the government agency then responsible for canals); local authorities; third sector environmental organizations, such as groundwork; and voluntary sector groups to see if they would support an Action Partnership in their area. A meeting was then convened for key personnel from interested parties, plus the Campaign itself.

From this meeting, an Action Partnership steering group would be established. It would meet quarterly to determine the strategy that the initiative was to follow and to make decisions about the general operation of the Partnership. The steering group would have input to the action planning process and in reviewing progress. The steering group meetings also acted as an important mechanism for information exchange by partners – for example, flagging up where a partner organization could assist with a particular project.

Clear aims and objectives were set for each partnership by the steering group. These reflected local needs and aspirations but also met the wider aims and targets of the Campaign (Kidd and Shaw 2000). Common themes included:

- Improving water quality
- Enhancing land adjacent to the river and identifying suitable sites for conservation, landscape improvement, and community access
- Raising the public profile of the watercourse; improving access to the river, mainly through the construction of integrated footpaths and cycle networks
- Ensuring community involvement in these initiatives

Each Action Partnership produced an action plan that showed how its objectives were translated into policies and actions. This could either be developed under a number of themes, e.g., water quality, habitat, education, awareness, or be area based, dividing the river catchments into geographical sections, e.g., river stretches and tributaries. Having an action plan of this kind helped an Action Partnership develop its detailed program for the year ahead, an input for the Campaign's corporate plan, as described above.

The projects developed by the Action Partnerships were on a variety of scales, from small-scale local projects addressing local issues and engaging local communities, to large-scale strategic projects. The project coordinator did not necessarily have to deliver the projects themselves, but aimed to promote innovative ideas and support partners in delivery.

Appointing a coordinator to develop projects, partnerships and funding packages and to act as a point of contact for the community was found to be essential in achieving progress in the Action Partnerships. The coordinator could also help resolve any conflicting interests between partners.

The Campaign provided line management and organizational backup for the project coordinators where it had funded the post. A representative from the Campaign's central office team sat on each steering group and the partnership was led by a local chair. The chair of each steering group reported on the progress of their Action Partnership through a chairs' group. A representative of this group reported directly to the Mersey Basin Campaign Council, the governing body of the Campaign.

Where the membership of the steering group was large, it was found helpful to establish a project officer group. This consisted of a small number of representatives of the steering group which helped to deal with the day-to-day running of the Action Partnership and to oversee implementation of the steering group's strategy. The project officer group also brought forward projects and helped coordinate funding bids.

Security of core funding was essential in enabling the long-term employment of the project coordinator. The staff costs and basic running costs were provided, in most cases, by the Campaign using its funding from central government. Funding was also secured from a range of different, often local, public and private organizations and grant schemes. In some cases, in-kind funding such as office space was provided by partner organizations. Maintaining the level of funding proved to be increasingly difficult, and this led to the amalgamation of some areas and the gradual reduction in the number of Action Partnerships.

Kidd and Shaw (2000), who carried out an evaluation study in the late 1990s, concluded that three main lessons could be learned from the Campaign's experience in operating Action Partnerships:

- The need to devise mechanisms which reflect the varying priorities of different types of community and facilitate their involvement while at the same time ensuring broad consistency with strategic objectives: there is no one size that fits all.
- Awareness raising in the form of publicity, events, and projects is essential to the active involvement of organizations at all scales.
- It takes time to engender a sense of local stewardship, and consistency of effort and appropriate resources, especially staff input, are vital ingredients: a long-term perspective is essential.

2.9 Example of an Action Partnership: Alt 2000

The River Alt was one of the most polluted streams in the entire Mersey Basin. An Action Partnership, Alt 2000, led by the present author, was founded in 1994 and was active until 2003. Strong local champions, among them Friends of the Earth, had promoted the idea of an Action Partnership, and in the early days of the Partnership, a successful application was made to Merseyside Objective One for European Structural Funds amounting to £250,000 over 2 years. There was community involvement at steering group level, with the British Trust for Conservation Volunteers (BTCV) and the North West Ecological Group both having representatives. Alt 2000 also maintained positive community links through a loose network of local organizations which were more informal partners. In this case, the project officer acted as facilitator and point of contact for the groups. According to Kidd and Shaw (2000), who carried out an evaluation after 5 years, it was the active utilization and expansion of this network that appeared to be critical to stimulating a sense of local environmental stewardship. The constant raising of awareness and participation through publicity and events was also thought to be vital. Successful community participation events on the River Alt included the involvement of primary schools in stream cleanups, tours by environmental theaters in schools, stream cleanups organized by BTCV, publicity events, cleanups and community barbecues organized by the North West Ecological Group, and

"Alt walks" organized by the local authority ranger service, securing resources and negotiating with local authority partners to rebuild a bridge across the River Alt, in so doing filling an important long-standing gap in the footpath network of the Alt catchment (see Kim and Batey 2001). Kidd and Shaw, in their study, saw Alt 2000 as a good practical example of how notions of local environmental stewardship can be brought to fruition. In their view, the critical factors in this process appeared to be "time, consistency of effort and appropriate resources, particularly in the form of staff input" (Kidd and Shaw 2000, p. 207).

3 Conclusions: What Factors Made the Mersey Basin Campaign Such a Successful Partnership?

Over its 25-year life, the Mersey Basin Campaign won recognition as a world leader in demonstrating the benefits of close partnership working in pursuit of water quality and waterside regeneration objectives. It developed a strong record of influence and achievement at different spatial levels.

The Campaign succeeded in linking strategy and delivery in a balanced way, by setting high aspirations and taking on tasks that required a long-term approach, while at the same time working to ensure that tangible results were achieved in a large number of shorter, more modest projects. It therefore avoided the criticism often made of partnerships as "mere talking shops."

The Campaign attracted the long-term support and commitment of a full range of stakeholders, including central government. This was in spite of huge changes in institutions and in personnel over a 25-year period. Time spent in garnering support before the Campaign launch in 1985 proved helpful in this respect, and in later years, the active review of Campaign membership drew attention to the need to cultivate engagement from new partner organizations and key individuals. The Campaign itself proved to be resilient and flexible, adjusting its structure and ways of working to reflect new challenges, priorities, and opportunities over a 25-year period.

After 25 years, the Campaign made an honest assessment of what it had achieved since it was established and decided that it had, to a large degree, fulfilled its original aims[8] and, unlike some organizations which "die a lingering death," it prepared for its own demise, making a well-planned, tidy exit in March 2010 (Gregory 2012). Arguably, developments since then, particularly in relation to funding and institutional reform, have shown the wisdom of that decision.

The Campaign left an important legacy of successful completed projects which were often the result of productive collaboration between partner organizations. In doing so, it nurtured a remarkable "can-do" attitude toward apparently

[8]For detailed evidence of the impact of the Campaign, see: Handley et al. (1997), Jones (2000), (2006), and EKOS Consulting (2006). All of these documents may be found on the Mersey Basin Campaign Legacy Website: http://www.merseybasin.org.uk/

insurmountable challenges. Undoubtedly, however, people were its greatest asset. It is largely as a result of the efforts of those individuals, now working in a range of different organizations in North West England and beyond, that the Campaign's ethos continues to flourish today.

References

Batey PWJ (2009) Comment: there may be no more Mersey basin campaign after 2010, but part of its legacy should be the innovative geographical notion on which it was founded. SourceNW 20:26

Department of the Environment (DoE) (1983) Letter from Michael Heseltine and Government Consultation Paper

EKOS Consulting (2006) Evaluation of the Mersey basin campaign; report to the government office north west. EKOS Consulting, Manchester

Elworthy S, Holder J (1997) Environmental protection: text and materials. Butterworths, London

Gregory CE (2012) Enabling sustainable river futures: exploring institutional interventions. PhD thesis, University of Auckland. Available at: https://researchspace.auckland.ac.nz/handle/2292/19480

Handley JF, Wood R, Kidd SJ (1997) Building a healthier economy through a cleaner environment: mid-term report. Mersey Basin Campaign, Manchester

Jones PD (2000) The Mersey Estuary: back from the dead? Solving a 150-year old problem. J Chart Inst Water Environ Manag 14:124–130

Jones PD (2006) Water quality and fisheries in the Mersey Estuary, England: a historical perspective. Mar Pollut Bull 53:144–154

Kidd SJ, Shaw D (2000) The Mersey Basin and its River Valley Initiatives: an appropriate model for the management of rivers? Local Environ 5:199–209

Kim JS, Batey PWJ (2001) A collaborative partnership approach to integrated waterside revitalization: the Mersey Basin Campaign, North West England. Int J Public Priv Partnerships 3:145–150

Menzies W (2008) The river that changed the world. In: Scheibenbogen S (ed) River journeys. International Riverfoundation, Brisbane, pp 12–15

Menzies W (2010) Partnership: no one said it would be easy. Town Plan Rev 81(4):1–7

Mersey Basin Campaign (1986) Mersey Basin Campaign: new life for the North West, unpublished document

Mersey Basin Campaign (1995) First Periodic Report: changing for the better. Mersey Basin Campaign, Manchester

Newson MD (2009) Land, water and development, 3rd edn. Routledge, London

Petts G, Heathcote J, Martin D (eds) (2002) Urban rivers: our inheritance and future. IWA Publishing, London

Watson N (2005) The management of British rivers. In: Owen S, Pooley C, Folkard A, Park C, Clark G, Watson N (eds) Rivers and the British landscape. Carnegie, Lancaster, pp 169–194

Wood R, Handley JF, Kidd SJ (1999) Sustainable development and institutional design: the example of the Mersey Basin Campaign. J Environ Plan Manag 43:341–354

Consumption and Environmental Awareness: Demographics of the European Experience

Philip S. Morrison and Ben Beer

Abstract Who are the most pro-environmental in their purchasing behaviour? Is it the young, middle-aged or older consumers? The answer to this question has important implications for the marketing of pro-environmental products.

Our analysis of the Flash Eurobarometer Survey No. 256 released in 2009 reveals that it is not the young nor the very old, but the middle-aged buyers who are the most environmentally conscious. The relationship of environmental awareness and age takes an inverse U shape: awareness rises with age, reaches a peak in early to late middle age and then declines with the oldest age groups. Middle-aged consumers are more likely to declare knowledge of the environmental impact of the products they buy and are most likely to appreciate the importance of the environmental consequences of their purchases. They are also the most likely to support eco-labelling and to the mandatory labelling of carbon footprints. At the same time, the magnitude of the difference between ages varies depending on which measure of environmental awareness is being considered.

The non-linear association between pro-environmental awareness and consumers' age holds even after controlling for gender, education, occupation and size of settlement. Although levels of environmental consciousness and age profiles vary across the countries of Europe, the greater awareness of the middle-aged consumer is sustained when we control for country.

Keywords Environmental awareness • Sustainable consumption • Pro-environmental • Demographics • Eco-labelling • Economic footprint • Europe

1 Introduction

In a globalised world complete with online shopping and express delivery service, consumption occurs on enormous scales, covers vast distances and supports ever-increasing demand for the latest and greatest products (Robins 1999). Research into

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the adverse effect human consumption has on the environment accompanied these developments. The aim of our chapter is to identify patterns of pro-environmental consciousness among European residents. Our contribution lies in highlighting the middle-aged consumer as the most environmentally conscious in contrast to the young to whom such attitudes are often attributed.

During the 1992 Earth Summit, it was acknowledged that 'the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in the industrialised countries' (UNCED 1992, cited by Robins 1999). In the last half-century, the world has experienced a rapid increase in the level of consumption. From the period 1960 to 1998, global consumption quadrupled (Robins 1999) and shows no sign of slowing down. The way in which the world's natural resources are being extracted to support the consumer industry is not sustainable over the long term, and it is estimated that with current consumption levels in Western society alone, we would require the equivalent of three earth planets to continue to facilitate this lifestyle (Carlisle and Hanlon 2007).

According to research done by Schor (2005), the world passed the point of sustainability in 1978. Succinctly described, '... "reckless consumption" of planetary resources has led to, among other things, accelerated rates of climate change, air and water pollution, deforestation, soil degradation and species loss' (Soron 2010: p. 172). Even economists, notorious for turning a blind eye to natural resource depletion, have begun to recognise the unsustainable nature of today's consumption (Carlisle and Hanlon 2007). There is a growing awareness of the need to address our consumption habits as a necessary course of action to reduce the drivers of environmental degradation.

Over the last 40 years, there has been some degree of success in creating increased demand for environmentally friendly products. Recognition of environmental impact has created a niche consumer market referred to commonly as 'green consumers'. The term 'green' is interchangeable with 'pro-environmental' and is broadly defined as indicating 'concern with the physical environment (air, water, land)' (Shrum et al. 1995: p. 72). Green consumption involves choosing goods that have minimal adverse impact on the natural environment. 'Eco-friendly' products are defined as '... ecologically safe products that can facilitate the long term goal of protecting and preserving our natural habitat' (Datta 2011: p. 126). Research into consumer trends relating to the production and marketing of green products has 'sought to identify and analyse green consumption values, attitudes and behaviours as well as explore ways to segment and target green consumers' (Schaefer and Crane 2005: p. 79). Identifying the characteristics, or profile, of the green consumer is a much coveted goal that has given rise to numerous articles (e.g. Jain and Kaur 2004, 2008).

A common finding has been the failure of demographic variables to provide consistent results (Straughan and Roberts 1999; Shrum et al. 1995; Peattie 2001). Some studies found green consumers to be older (e.g. Balderjahn 1988; Samdhal and Robertson 1989; Scott and Willits 1994; Roberts 1996b; Gilg et al. 2005), while other studies found them to be younger (e.g. Anderson and Cunningham

1972; Tognacci et al. 1972; Van Liere and Dunlap 1980; Zimmer et al. 1994; Diamantopoulos et al. 2003). Most studies find that higher educated persons are greener (e.g. Van Liere and Dunlap 1980; Arcury and Christianson 1990; Roper Organization 1992; Jain and Kaur 2008); however, some surveys reveal no relationship or inconclusive results (e.g. Shrum et al. 1995; Laroche et al. 2001; Pepper et al. 2009; Abeliotis et al. 2010). At best the evidence suggests that the relationship between demographic variables and pro-environmental consciousness (or concern) is a complex one. As a result, some authors have concluded that in order to effectively establish the green consumer profile, attitudinal variables are a more reliable than demographic ones (e.g. Straughan and Roberts 1999; Laroche et al. 2001; Shrum et al. 1995; Roberts 1996b; Balderjahn 1988).

Nevertheless, demographic characteristics continue to be frequently used to profile the green consumer (Jain and Kaur 2008). It is a method that is still favoured by many researchers – especially market research companies who can more easily target demographic segments than groups of people divided along attitudinal lines (Peattie 2001; Roberts 1996b). One summary concluded that 'demographic analysis is useful in three ways: it can be used in trend analysis, used as market segment descriptors and it can also provide helpful information for policy questions related to macro marketing' (D'Souza et al. 2007: p. 372). The ability to identify trends between demographic variables and pro-environmental purchase behaviour will therefore greatly assist various businesses. As an example, Saphores et al. (2007) found age, income and education to be good indicators of willingness to pay more for 'green' electronics in California. Zarnikau (2003) uses the same variables to find correlations in willingness to pay more for sustainable energy products.

The illusive search for the profile of the green consumer continues after four decades of research. US-based researchers, Berkowitz and Lutterman (1968), Anderson and Cunningham (1972) as well as Webster (1975), were some of the first to conduct analysis in this field. Berkowitz and Lutterman (1968) concluded that a socially conscious consumer is likely to be a young female, highly educated and of a higher socio-economic status. Both Anderson and Cunningham (1972) and Webster (1975) drew similar conclusions. Studies continue to the present day and now cover many countries with little prior research in this area (e.g. Bodur and Sarigollu 2005 (Turkey); Sinnappan and Rahman 2011 (Malaysia); Abeliotis et al. 2010 (Greece) and Alibeli and Johnson 2009 (Middle East)).[1]

The rest of this chapter contains Sects. 2, 3, 4, 5, and 6. Section 2 offers a brief review of an extensive literature. Section 3 introduces the European Flash Barometer Survey that forms the empirical base for our enquiry. Section 4 outlines our methodology which involves post-estimating probabilities of responses to four different questions about consumers' environmental awareness. Levels of environmental awareness are expressed as a function of the respondent's age, while

[1] A full list of studies organised by publication date may be found in Beer (2013) which is available online: http://researcharchive.vuw.ac.nz/xmlui/bitstream/handle/10063/2646/thesis.pdf?sequence=2

controlling for gender, education, occupation, settlement type and country. The core of the paper is in Sect. 5 where we assess the role of consumers' age in answering the four questions: how much they know about the products they buy, the importance they attach to the product's impact on the environment, the degree to which eco-labelling plays a role in their purchasing decision and how strongly they feel about whether the carbon footprint labelling of a product should be made mandatory or not. Our conclusions are presented in Sect. 6.

2 Literature Review

That younger persons are more environmentally concerned was conventional wisdom in the earliest years of research into consumption behaviour (Berkowitz and Lutterman 1968; Anderson and Cunningham 1972; Van Liere and Dunlap 1980). However, Laroche et al. (2001) proposed that there was a reversal in the early 1990s when older persons became more likely to show environmental concern. Xiao and McCright (2007) demured, maintaining that younger persons fit the profile of the green consumer better. Our own literature review finds no clear evidence that either conclusion is correct.

Part of the disparity in results lies with the way the issue is framed. Some studies separate the dependent variable into environmental knowledge, attitudes and behaviour; for example, Diamantopoulos et al. (2003). Their review uncovered only 2 out of 33 studies with significant relationships between age and environmental knowledge (both were negative). They concluded on this basis that there was no relationship between environmental knowledge and age. After their own data set was analysed, a negative albeit weak relationship was discovered, demonstrating that younger persons were slightly more likely to have greater environmental knowledge than older persons.

Diamantopoulos et al. (2003) predicted the correlation between environmental attitude and age would be negative, and their results supported this. The justification was based on Van Liere and Dunlap (1980) who argued that younger persons were more likely to embrace social change necessary for environmental protection, whereas older persons were more established in their habits and less malleable. However, as described by Diamantopoulos et al. (2003: p. 471):

> [researchers have] often found that age is negatively related to (intended) behaviour, while those employing indicators of current behaviour have found that older people display higher levels of green behaviour ... It is possible that such inconsistencies are due to a lack of resources among younger members of the population. Although younger people are likely to state that they will commit more resources to protecting the environment in the future ... many do not currently have the financial security necessary to support environmental causes.

Jain and Kaur (2008) observed that while a few studies identify a non-significant relationship between pro-environmental consciousness and age (e.g. Kinnear et al. 1974; Meffert and Bruhn 1996; Roper 1992; Shrum et al. 1995), the majority of studies favour younger persons. Like Diamantopoulos et al. (2003), Jain and Kaur (2008) identified three outcome measures: environmental knowledge, attitude and behaviour. Their prediction was that the relationship between pro-environmental consciousness and age would yield results in favour of younger persons for all three categories. Their results only partly supported their prediction. Environmental attitude and environmental behaviour were both positively correlated with age (although only a weak relationship was found), and the relationship between environmental knowledge and age was not statistically significant.

Our own literature review suggests that reports on the relationship between age and pro-environmental consciousness are fairly evenly split between older and younger persons. From the 50 reviewed studies listed in Beer's Table 2.1, 11 found that older persons were more environmentally concerned, 14 determined younger persons, 3 found the middle age group the greenest, 16 studies gave results that were not significant and the remaining 6 studies did not test for age (Beer 2013). At the same time, in more recent years, there does seem to be some evidence of high levels of pro-environmental consumption in the midlife age group (see, e.g. Finisterra do Paço and Raposo 2010; Abeliotis et al. 2010).

In summary, despite the large number of enquiries, the evidence for a demographic bias in environmental awareness is mixed with no clear consensus as to whether it is the young, middle or older consumers who are more likely to express higher than average levels of environmental awareness. As a contribution to the debate, our paper applies a robust methodology to a unique data set and shows quite categorically that higher levels of environmental awareness are characteristic of the middle-aged consumer and, by extension, a relatively lower propensity of the young exhibit environmental awareness and pro-environmental behaviour often attributed to their age group.

3 Data

Identifying the relationship between age and levels of environmental awareness requires questions on knowledge of and attitudes towards the environmental consequences of product choice. Our analysis is based on a survey designed to elicit such information – the Flash Eurobarometer Survey – No. 256, 'Sustainable consumption and production', which was conducted in Europe in 2009. The survey was undertaken by the Gallup Organisation in 2009 on the request of the European Commission Directorate General Environment coordinated by EC Directorate General *Communication* (European Commission 2009).[2]

[2]The data were provided free on request from the GESIS (Leibniz Institute for the Social Sciences, Cologne) Archive Study (ID: ZA4983, Flash Eurobarometer 256, April 2009). See http://www.gesis.org/eurobarometer/. The data set was provided on the understanding that neither the depositors, institutes nor GESIS bears any responsibility for the analysis or interpretation of the data.

A sample of over 25,000 consumers was drawn from 28 countries – almost 1000 people in each. Telephone interviews were conducted between 21/04/2009 and 25/04/2009 by a range of different institutes who translated the original English questionnaire into their respective national language(s).[3] The average length of interview was just over 9 min.

We selected four indicators of 'greenness' from the wider set of questions asked: how much people know about the products they buy, the importance they attach to their products' impact on the environment, the degree to which eco-labelling influenced their purchasing decision and finally how strongly they feel about mandatory carbon footprint labelling. Each of these four questions is reproduced in Appendix 1.

The distributions of responses over the four categories of each question are given in Table 1. For the purpose of this study, we collapse the responses to each question into binary responses. For example, in the case of product awareness, the majority of respondents said they know about the most significant impacts of the products they are purchasing although only 3533 of the 25,482, or 14 %, believed they were fully aware. From the columns of Table 1a, we learn that up to 45 % say they knew little or nothing about the environmental consequences of the products they were buying. The four rows are collapsed into the two columns in Table 1a, b.

Knowing about a products' impact and acknowledging its importance are two different things. Table 1b shows that while about (987 + 2915)/25,206 or 15.5 % regarded the product's impact as not important, under half (47.1 %) viewed it as rather important, leaving only a third (37.3 %) who regard it as very important. It is this last group whose decisions we model below.

When it comes to measuring product awareness, there are mixed results. According to Table 1c more than half admitted that eco-labelling did not play an important part or they simply never read any labels. These three responses are collapsed into two. The first says that 'eco-labelling plays an important part in my purchasing decisions'. The rest says it does not play an important part or admit to not reading any labels. Over three quarters believed carbon footprint labelling should be mandatory (Table 1d). Only a small proportion, well under 10 %, said that the carbon footprint was not of interest.

In addition to our selection of these four questions about sustainable consumption, we also drew on the responses to the respondent's gender, age, years of

[3]In most EU countries and Croatia, the target sample size was 1000 respondents, except Malta, Cyprus and Luxembourg where the target size was 500 interviews. A weighting factor was applied to the national results in order to compute a marginal total where each country contributes to the European Union result in proportion to its population. These weights are not applied in our analysis so each country is weighted equally. A comparison of weighted and unweighted estimates in Appendix 2 shows that the differences in proportions are minimal, i.e. between 1 and 2 %. Furthermore the essential relationship between age and question responses is not sensitive to the presence of weighting even though the latter correctly adjusts for wider standard errors.

Table 1 Indicators of sustainable consumption. The construction of binary variables from responses to four questions from the 'Sustainable consumption and production' Flash 256 European Commission Survey 2009

A. Product awareness			
Awareness about the environmental impact of products bought or used	Awareness of the impact		Total
	Know little	Am aware	
I know nothing	2,117	0	2,117
I know little about this	9,341	0	9,341
I know about the most significant impacts	0	10,491	10,491
I am fully aware	0	3,533	3,533
Total	11,458	14,024	25,482
	45	55	100 %
B. Product importance			
Importance of the product's impact on the environment when purchasing	Product's impact is very important		Total
	Not very important	Very Important	
Not at all important	987	0	987
Rather not important	2,915	0	2,915
Rather important	11,880	0	11,880
Very important	0	9,424	9,424
Total	15,782	9,424	25,206
	63	37	100 %
C. Eco-labelling			
Some products have an eco-label which certifies they are environmentally friendly	Importance of eco-labelling		Total
	Not very important	Important	
Eco-label plays a part	0	12,567	12,567
Eco-label does not play a part	6,112	0	6,112
I never read any label	6,611	0	6,611
Total	12,723	12,567	25,290
	50	50	100 %
D. Carbon footprinting			
Should a label indicating the carbon footprint of a product be mandatory in the future	Importance of carbon footprint label		Total
	Non-mandatory	Mandatory	
Yes	0	18,920	18,920
No, voluntary only	3,620	0	3,620
Is of no interest	1,855	0	1,855
Total	5,475	18,920	24,395
	22	18,920	24,395

Source: Eurobarometer Flash Survey No. 256
Note: Percentage missing values, 0.81, 1.88, 1.56 and 5.04, of full sample, respectively

education and their occupational scale.[4] Just under half the sample population were aged over 50 years, a quarter were below 38 and a quarter above 64 years. A surprising feature of the sample is that less than 40 % of respondents were male (37 %). Just under half (45.3 %) recorded 15 years of education or less, 33.75 % were still in education and 5.23 % had between 16 and 22 years of study. When it came to occupation, as defined, half the sample of those 18 years and over were employed, the majority being in clerical, sales, etc. Of those outside the labour force, by far the largest proportion was retired. Settlements were broken down into three categories with nearly 20 % defined as metropolitan; a further 44.5 % were in the remaining town sizes leaving a third as rural.

In summary, we have at our disposal a very large sample of respondents from 28 countries across Europe who were interviewed in 2009. The four questions we selected tapped different aspects of the sustainability question: their awareness, the importance they attach to environmental impact and how they regard information tags such as eco-labelling and environmental footprints. The sample covers the full range of adult ages, but is somewhat light on male responses; otherwise, it captures the range of education levels, the occupations of the employed as well as the main activities of those not employed including those unemployed and those searching for work.

4 Method

Our aim is to assess the degree to which responses to the four environmental questions vary with age and in particular whether there is a significant difference between young, middle and older age groups. Since many other influences can moderate such attitudes, we control for gender, education, occupation, settlement size and country of residence.

We apply the following logistic model to the responses to each of the four questions on environmental impacts of consumption (awareness, importance, eco-labelling and carbon footprint). We refer to these responses quite generally as E. Our primary or focal argument is the vector of 5 year age categories, A, to which we later add a set of covariates denoted by the vector D. The responses are those of the ith sampled individual:

$$E_i = a_o + \beta_i A_i + \gamma_i D_i + \varepsilon_i \quad (1)$$

Since E is binary (1,0), the model is rendered linear model by taking the log odds of the event. The parameters β_i and γ_i capture the marginal impact of age and controls,

[4] Tabulations of responses over the categories of the variables are available on request. The categories themselves appear in Table 2 along with the regression results.

respectively. Taking the exponent of the estimates of these parameters yields the odds ratios, $e^{\beta i}$ and $e^{\lambda i}$, which we report in our tabular results.

To aid communication we convert the odds ratios into probabilities using the following transformation:

$$P_i = e^{a_o+\beta_i A_i+\gamma_i\ D_i} / \left(1 + e^{a_o+\beta_i A_i+\gamma_i\ D_i}\right) \tag{2}$$

where P_i is the estimated probability of the event for the *i*th respondent.

In summary, our aim is to understand the way responses to questions on sustainable consumption vary by age. Four logit models based on binary responses to each survey question are estimated as a function of age before and after controls. The pattern of estimated probabilities and their sensitivity to controls is used to identify the age groups most likely to consume in an environmentally sustainable manner.

5 Results

The results are presented in Fig. 1. Panel 1a illustrates the mean probability of being environmentally aware by 5 year age category, and panel 1c presents the age effects after the controls have been added.[5] Panels b and d are explicit tests of the contrast between the predicted probabilities of awareness by age and the base age (the age with the highest level of awareness). The confidence intervals are used to judge whether the differences between the base maximum and its adjacent age groups are statistically significant Fig. 1.

The horizontal line running through panel a of Fig. 1 is the mean probability of awareness for the sample as a whole. It indicates that about half the population (0.545) are aware of the environmental impacts of the products they buy and use. The average probability of being aware rises from 0.438 among those under 20 year to a maximum average of almost 0.6 (0.599) among the 40 <45 year age group. This level of awareness remains fairly stable over the middle age years through to 65 years (0.558) after which it drops to its lowest point of 0.434 among those 80 years and over. The young and the old residents of Europe therefore report very similar low levels of environmental awareness.

We contrast the point estimates of the highest age group with the other age groups in turn. The result is shown graphically in panel b, Fig. 1. The shaded 95 % confidence band around the estimated means of Fig. 1a refers to the point estimates. They expand in size with the relative sample size of each age group. The age group with the maximum probability of being aware (the 40 <45 year age group) is the

[5]These graphs are generated using the *marginsplot* commands following *logistic* and *margins* in Stata 12. The survey (*svy*) function is used to generate the weighted results which are graphed in Appendix 2.

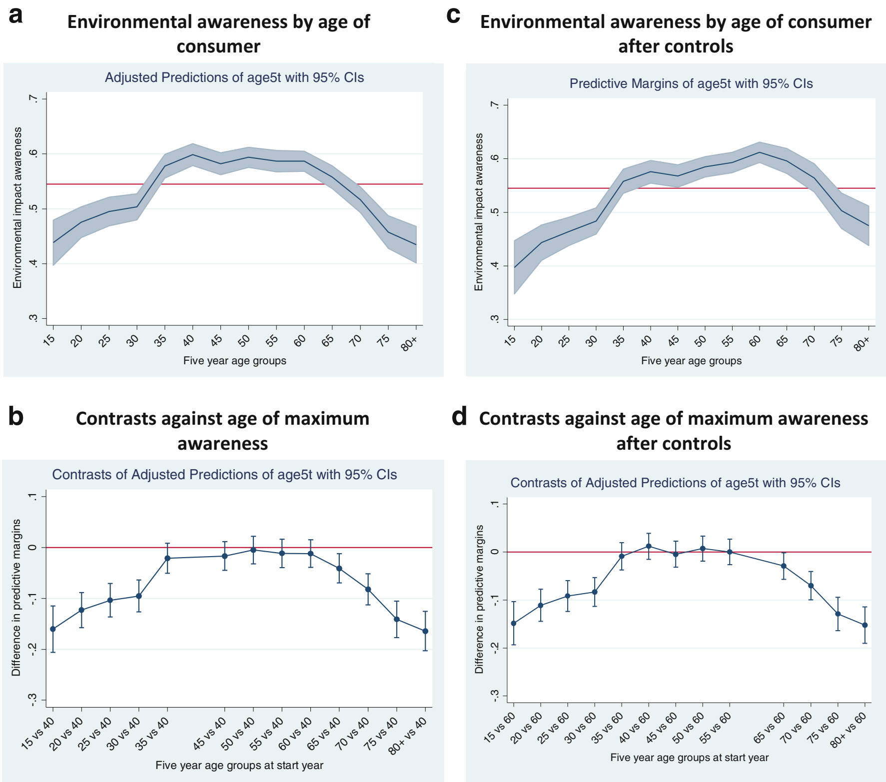

Fig. 1 Awareness of the environmental impact of consumer goods by age of consumer (Europe 2009)

line 0.[6] An inspection of the confidence intervals around these contrasts shows no significant difference between the base and the three 5 year age intervals before and after the two 5 year age intervals that follow. In other words, there is a 30 year span of ages, from 35 to 64, over which mean levels of awareness of products' impact on the environment hardly vary. The distinction therefore is clearly between the middle-aged consumers on one hand and the young and old on the other hand. The maximum difference between the mean probability of awareness among the most and least aware age group is 0.165.

Although it is common to use 'age' as an explanatory variable, in practice chronological age picks up different stages in the life course, such as periods when incomes are low and when they are high and when chances of unemployment are high and low, and so on. The variable 'age' therefore not only denotes chronological

[6]These *marginsplot*, *contrast* graphs, as drawn by Stata, designate the base by omitting it from the X label. Implicitly the base in panels b and d is zero as marked.

age but also captures the life characteristics typically associated with a given age. In order to narrow the interpretation of a chronological age effect, we need to control for characteristics of the population associated with different life stages.

The results of applying Eq. (1) in its full form are reported in Table 2. Six models have been estimated beginning with model 1 which uses the age categories alone as arguments. The estimates from this regression are transformed via Eq. (2) to the predicted margins plotted in panel a of Fig. 1. While the table estimates are reproduced in the log-odds metric, the graphs are presented in the probability metric.

Moving across the columns in Table 2 from left to right allows us to monitor the effect of age on the odds of the positive binary response E. The 5 year age effects alone are presented in model 1. The first control in model 2 shows the negative (<1.0) effect of being a male on environmental awareness. It is negative but not significant. One might have expected that the proportion of women rising with age might have countered some of the negative effect of age on awareness, but the estimates in model 2 hardly change compared to model 1.

There are much clearer effects on age when the four education categories are added to the model, that is, when we move from model 2 to model 3 in Table 2. When the positive effects of years of education are added, the pseudo-R^2 rises noticeably. 'Removing' the effect of years of education effectively decreases the differences in awareness between the young and middle age groups and noticeably reduces the gap between the middle and older consumers. However, adding the occupation, both inside and outside the labour force, returns the age categories to their pre-education effects, model 4. Settlement is also added in model 5 but, apart from suggesting lower levels of awareness outside metropolitan centres, does not moderate the effects of age on environmental awareness.

Adding country dummies in model 6 has two primary influences. In cases where there are marked country differences, as in unemployment, for example, adding country fixed effects reduces the impact of variables like job seeking on awareness. On the other hand, the entry of country indicators increases the gap between the professions and other occupations, and it considerably increases the influence of the older middle age on environmental awareness. Other influences can also be read off from Table 2.[7]

Therefore, by the end of the first decade after the millennium, the age groups most aware of the environmental products they purchased were the middle aged – a broad 30 year span of ages running from those in their mid-30s to their mid-60s. While the relative levels of awareness shifted within this age group, in terms of statistical significance there was little change. The net result of adding controls

[7]Corresponding tables for the remaining three responses are not reproduced here but are available on request.

Table 2 Consumer awareness in Europe (2009) (odds ratios)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Age 5						
15	(Base)	(Base)	(Base)	(Base)	(Base)	(Base)
20	1.16	1.16	1.24*	1.22	1.23	1.22
25	1.26*	1.25*	1.37**	1.31*	1.32*	1.34*
30	1.3**	1.3**	1.45**	1.39**	1.41**	1.46**
35	1.75**	1.75**	2.01***	1.9***	1.9***	2.0***
40	1.91***	1.91***	2.23***	2.1***	2.1***	2.16***
45	1.79***	1.78***	2.13***	1.99***	2.01***	2.09***
50	1.87***	1.87***	2.29***	2.16***	2.19***	2.25***
55	1.82***	1.82***	2.28***	2.18***	2.21***	2.33***
60	1.82***	1.81***	2.4***	2.29***	2.3***	2.54***
65	1.62***	1.61***	2.15***	2.05***	2.07***	2.36***
70	1.37***	1.36***	1.9***	1.81***	1.84***	2.05***
75	1.08	1.08	1.53***	1.45**	1.47**	1.58**
80+	0.984	0.981	1.43**	1.36*	1.36*	1.4*
Male						
Female		(Base)	(Base)	(Base)	(Base)	(Base)
Male		0.98	0.948*	0.929**	0.926**	0.928**
Education						
No education			(Base)	(Base)	(Base)	(Base)
Up to 15 years			1.57***	1.53***	1.52***	1.47***
16<=20 years			2.29***	2.02***	2***	2.1***
Still in education			2.4***	2.14***	2.12***	2.21***
Occupation						
Prof and man				(Base)	(Base)	(Base)
Middle man				0.901	0.904	0.846***
Clerical, sale				0.752***	0.754***	0.711***
Manual				0.569***	572***	0.531***
Homemaker				0.632***	0.637***	0.565***
Student				0.789	0.793	0.74*
Retired				0.748***	0.751***	0.627***
Seeking job				0.748***	0.751***	0.627***
Settlement						
Metropolitan					(Base)	(Base)
Urban/town					0.942	0.931
Rural					0.959	0.85***
Country						
France						(Base)
Belgium						0.41***
Netherlands						0.323***
Germany						0.376***

(continued)

Table 2 (continued)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Italy						0.417***
Luxembourg						0.588***
Denmark						0.18***
Ireland						0.222***
UK						0.274***
Greece						0.267***
Spain						0.247***
Portugal						0.292***
Finland						0.189***
Sweden						0.228***
Austria						0.535***
Cyprus						0.173***
Czech Republic						0.336***
Estonia						0.218***
Hungary						0.335***
Latvia						0.259***
Lithuania						0.222***
Malta						0.64***
Poland						0.451***
Slovakia						0.348***
Slovenia						0.537***
Bulgaria						0.175***
Romania						0.309***
Croatia						0.284***
_cons	0.78**	0.788**	0.38***	0.563***	0.586***	2.06***
r2_p	0.00761	0.00763	0.0222	0.0255	0.0255	0.0508
N	25,482	25,482	25,160	25,160	25,050	25,050
ll	−17,400	−17,400	−16,919	−16,861	−16,787	−16,350
chi2	267	268	768	883	877	1,751

Source: Eurobarometer Flash Survey No. 256
Note: Sample sizes vary in response to missing values on some variables: 25, 482 to 25,050. While this 1.69 % decline is unlikely to influence the coefficients greatly, we did rerun the six models using just the sample set used to construct model 6. A comparison of the results confirmed the stability of the odds ratios as none varied by more than 0.005.
*$p < 0.05$, **$p < 0.01$ and ***$p < 0.001$

on the age effects is threefold: the first is to widen the gap between the younger and middle age groups (as shown in panel c of Fig. 1). The second is to decrease the distance to the awareness of the older respondents, and the third is to raise the apparent level of awareness of those in their 50s and 60s causing a net shift of the plot upward to the right (compare panel a with c in Fig. 1).

We turn now to the second question asked of consumers, namely, the importance they attach to the product's impact on the environment. Just over one third of the sample assigned importance to the environmental impact of the purchases they made (mean = 0.374). In the uncontrolled case, the probability of recognising the imbalance of environmental impact rises steadily with age, reaching a maximum among those in their early 70s; see Fig. 2, panel a.[8]

Unlike Fig. 1, including covariates made remarkably little difference to the way responses to the important question varied by age. In Fig. 2 only the increased negative effect of being male stood out. There was virtually no difference between the age effects of panels a and c (and hence b and d). An inspection of the

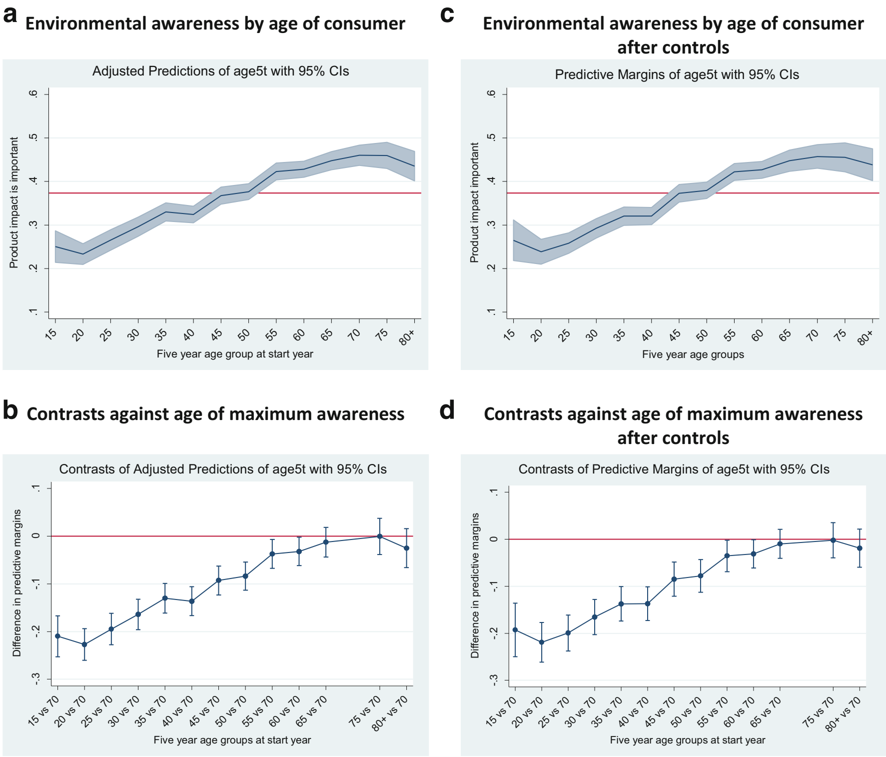

Fig. 2 The probability of regarding product impact on the environment as important (Europe 2009)

[8]It may appear that when it comes to assigning importance, it is no longer those under 20 who are the least engaged; rather it is those in their early 20s. However this difference is not statistically significant.

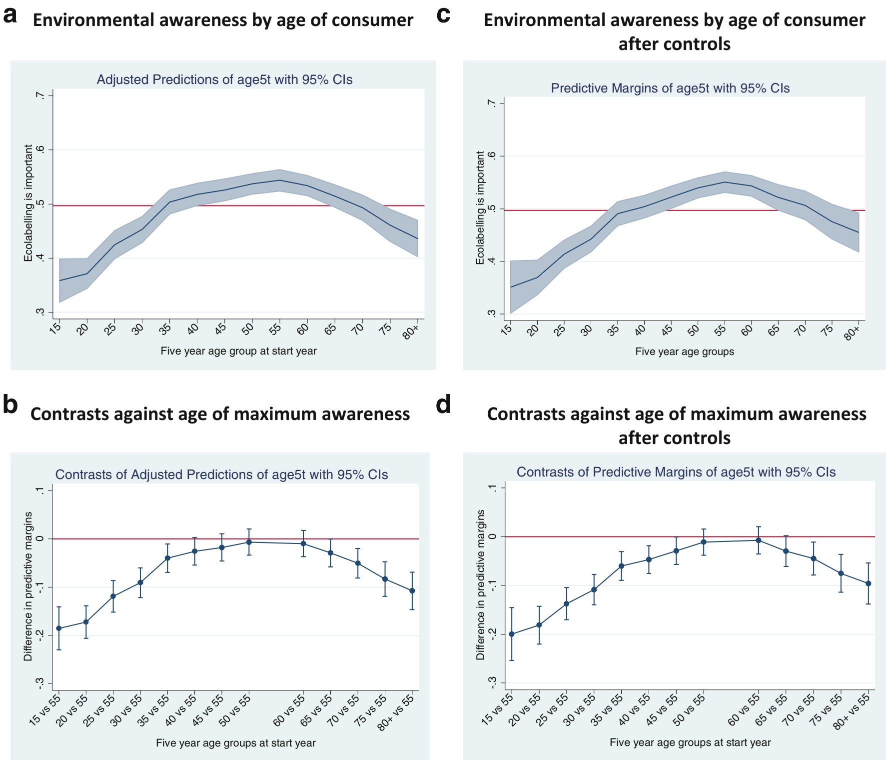

Fig. 3 The probability that eco-labelling plays an important part in the purchasing decision (Europe 2009)

corresponding estimate table (available on request) shows a markedly reduced effect of education and occupational differences when it came to attaching importance to environmental effects, as opposed to simply being aware of them. Similarly with country fixed effects, while marked contrasts between countries remain, numerically there were relatively fewer.

When it comes to the role eco-labelling plays in purchase decisions, almost half the sample said eco-labelling played an important part in their purchasing decisions (0.497) as shown in Fig. 3, panels a and c. The strong inverse U shape apparent in Fig. 1 reappears here in Fig. 3 as well. Eco-labelling is most likely to assume importance among the older middle aged, those in their 55 <60 age group, and this positioning remained even after controls were entered. The only shift we see in the age profile occurs at the far right of the graph where controls diminish the negative effect of those in their 70s and 80s. Over most of the age distribution, controls made remarkably little difference to the way the importance of eco-labelling varied with age.

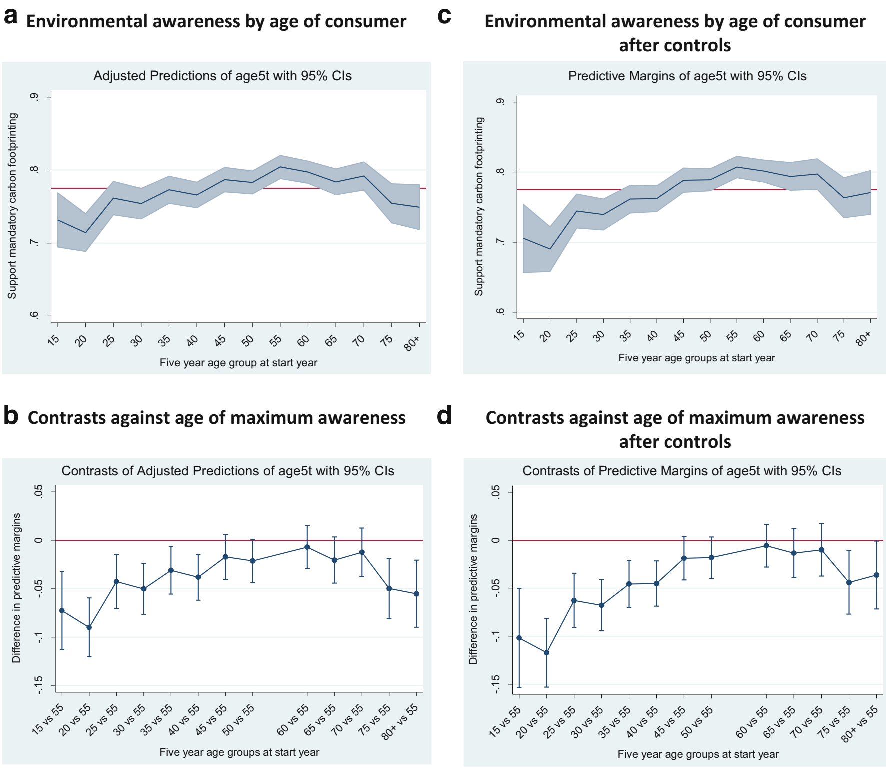

Fig. 4 The probability that consumers believe carbon footprint labelling should be mandatory (Europe 2009)

The final question we examine is whether eco-labelling should be mandatory or not. In this case over three quarters of the consumers believed products should carry a label showing its carbon footprint (0.776). While the age profile took a similar shape to that of the previous question, in Fig. 4 the differences between young, middle and older consumers were noticeably less marked, the range of average responses falling within the 0.7–0.8 range across the age groups. The most likely to favour mandatory carbon footprint labelling were those 55 <60 years, but there was no significant difference over the age span 45 through 70 years (as the difference in predictive margins shows, panel 4b).

The age profile remains largely intact when we enter controls, as a comparison of panels 4a and 4c shows. Comparing the predictive margins, 4b with 4d highlights the differences. The primary effect of controls is to lower the relative support for carbon labelling among the young. Inspection of the estimate table (not shown) reveals that the primary reason for this and the enhanced support at the oldest ages is the entry of country dummy variables. In other words, differences between countries tend to disguise the relatively much lower support the young offer mandatory carbon footprint labelling.

In summary, there is considerable empirical support in the Eurobarometer survey for 'middle-aged greenness' – the propensity of those in their 40s through 60s to exhibit the knowledge, purchasing behaviour and support for measures designed to encourage environmentally sustainable consumption. Although the actual age profiles in Figs. 1, 2, 3 and 4 differ slightly depending on the question asked, there remains a clear distinction between the responses of the young, middle- and older-aged consumers in each case.

6 Conclusions

Many people automatically assume that it will be the young who are most environmentally aware in part because the young grew up in an era of greater environmental consciousness. However our review of the literature revealed a distinct lack of consensus among scholars on how age effects pro-environmental consumption.

We began our study with no a priori assumption of the relationship between age and pro-environmental attitudes but soon uncovered a consistent peaking of pro-environmental attitudes among the middle-aged brackets – those in their 40s, 50s and 60s. The inverse U-shaped relationship we found between age and environmental consciousness held even after controlling for a range of other possible influences: gender, education occupation, settlement size and country of residence.

Of the four questions about environmental impact, we found that only one experienced a change in the age profile after controls were added – the level of knowledge consumers had about the environmental impact of the products they bought and consumed. Controlling for attributes that change with age raised the average age at which such awareness peaked, as well as lowering the relative level of awareness of the very young and reducing the effect of old age on awareness.

Our results on age are consistent with those of Laroche et al. (2001) who commented that prior to the early 1990s, it was common to find younger persons as being more environmentally concerned, but that this tendency has been reversed in the last two decades.

There are two theories that might explain the empirical support we find for the pro-environmental middle aged consumer. The first is that we are seeing a cohort effect (Samdhal and Robertson 1989; Gilg et al. 2005; Straughan and Roberts 1999; Roberts 1996b). The alternative is that the high level of pro-environmental consciousness we are witnessing in the middle-aged years reflects a life-stage age effect (Dychtwald and Gable 1990). The distinction is important because the former implies only a temporary shift in the age of the highest consciousness, whereas the latter implies persistence of the inverse U distribution over time. Further research on longitudinal or panel data would help discriminate between these two possibilities.

Of particular interest in this volume in honour of Professor Higano is the degree to which the relative importance of the arguments raised in the European case hold elsewhere. In Asia there is a concern that consumer's awareness of environmental degradation is still rather low despite high education levels (Chan 2000). Only a handful of studies have compared environmental attitudes across countries (Schultz and Zelezny 1999; Zelezny et al. 2000; Inglehart 1995; Alibeli and Johnson 2009; National Geographic 2010). Therefore and we support Schultz and Zelezny who '. . . . believe that a multinational understanding of the values and motives that underlie environmental concern and behavior is needed before we can move toward more effective environmental policies and social interventions designed to increase pro-environmental behavior' (1999: 264).

This same heterogeneity is likely to prevail across Asia, but we do not yet know the degree to which pro-environmental attitudes of Asian consumers will exhibit the same middle-aged bias that our European sample has revealed. This remains an intriguing question which a regional scientist may wish to explore.

Acknowledgements The literature review and initial empirical analysis were undertaken by Ben Beer of partial fulfilment of requirements for the Masters of Environmental Studies 90 point thesis presented to Victoria University of Wellington (Beer 2013). Ben Beer's supervisor, Professor Philip Morrison, reanalysed the data sometime later and drafted the chapter. Both authors acknowledge the use of the survey European Commission (2009). See http://ec.europa.eu/public_opinion/flash/fl_256_en.pdf.

Appendix 1: Survey Questions Analysed

These four questions constitute the dependent variables which relate to environmental consciousness and are listed as follows (as well as response options):

Question 1: In general, how much do you know about the environmental impact of the products you buy and use?

I am fully	4
I know about the most significant impacts	3
I know little about	2
I know nothing	1

Question 2: How important are the following aspects when making a decision on what products to buy? (a) The product's impact on the environment:

Very important	4
Rather important	3
Rather not important	2
Not at all important	1

Question 3: Some products have an eco-label which certifies that they are environmentally friendly. Which statement characterises you the best?

Eco-labelling plays an important part in my purchasing decisions	1
Eco-labelling does not play an important part in my purchasing decisions	2
I never read any labels	3

Question 5: Should a label indicating the carbon footprint of a product be mandatory in the future?

Yes	1
No, it should be done on a voluntary basis	2
The carbon footprint is of no interest to me	3

Source: Flash Eurobarometer Survey No. 256

Appendix 2: A Note on Weighting

The analysis in this paper has been undertaken without weighting. While there are subtle differences in the results with and without the survey's recommended weighting, the results at the level we are interested in remain essentially the same. We demonstrate this by rerunning the results in Fig. 1 as Fig. 5 here. The primary difference of course is the higher standard errors which are reflected here in the wider confidence intervals when comparing Fig. 5 to Fig. 1. There is also a one category shift to the right in age in this particular instance. However the essential difference between the young, middle and old remains the same.

The contrasts yield almost identical results as a comparison of Fig. 5b with Fig. 1b shows. Similar results hold for the weighted and unweighted cases after the addition of controls; compare Fig. 5c with Fig. 1c and Fig. 5d with Fig. 1d.

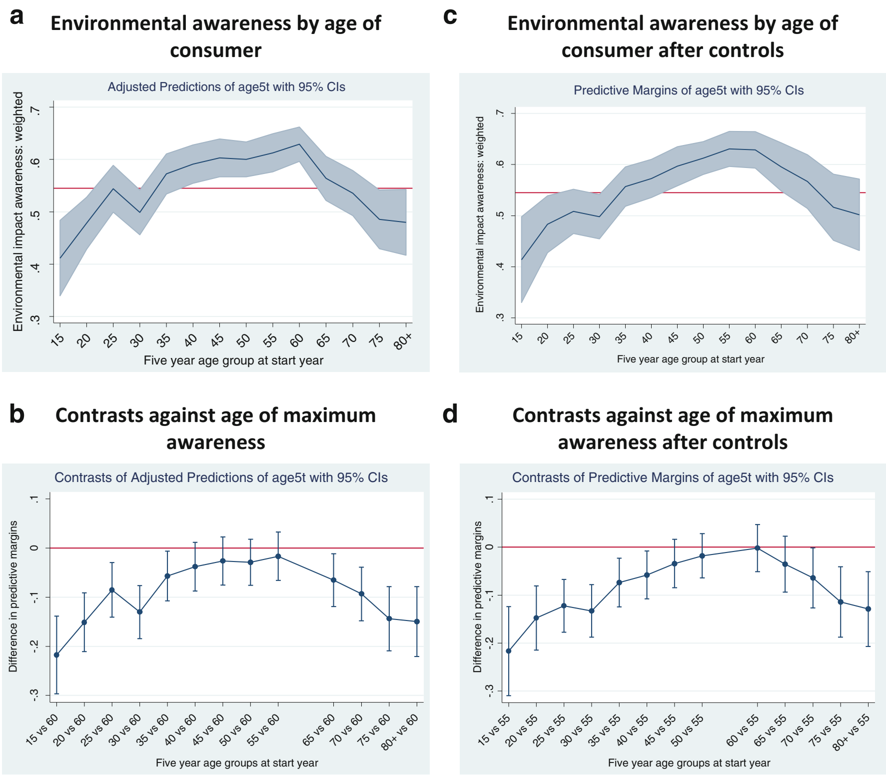

Fig. 5 Awareness of the environmental impact of consumer goods by age of consumer (Europe 2009)

References

Abeliotis K, Koniari C, Sardianou E (2010) The profile of the green consumer in Greece. Int J Consum Stud 34:153–160

Alibeli N, Johnson C (2009) Environmental concern: a cross national analysis. J Int Cross-Cult Stud 3(1):1–10

Anderson WT Jr, Cunningham WHC (1972) The socially conscious consumer. J Mark 36(3):23–31

Arcury TA, Christianson EH (1990) Environmental worldview in response to environmental problems: Kentucky 1984 and 1988 compared. Environ Behav 22:387–407

Balderjahn I (1988) Personality variables and environmental attitudes as predictors of ecologically responsible consumption patterns. J Bus Res 17:51–56

Beer B (2013) 'Mid-life greenness'. Environmental consciousness among European consumers (Masters of Environmental Studies). Victoria University of Wellington, Wellington

Berkowitz L, Lutterman KG (1968) The traditional socially responsible personality. Public Opin Q 32:169–185

Bodur M, Sarigollu E (2005) Environmental sensitivity in a developing country: consumer classification and implications. Environ Behav 37(4):487–510

Carlisle S, Hanlon P (2007) Well-being and consumer culture: a different kind of public health problem? Health Promot Int 22(3):261–268
Chan K (2000) Market segmentation of green consumers in Hong Kong. J Int Consum Mark 12(2):7–24
Datta S (2011) Pro-environmental concern influencing green buying: a study on Indian consumers. Int J Bus Manag 6(6):124–133
Diamantopoulos A, Schlegelmilch B, Sinkovics R, Bohlen G (2003) Can socio-demographics still play a role in profiling green consumers? A review of the evidence and an empirical investigation. J Bus Res 56:465–480
D'Souza C, Taghian M, Lamb P, Peretiatko R (2007) Green decisions: demographics and consumer understanding of environmental labels. Int J Consum Stud 31:371–376
Dychtwald K, Gable G (1990) Portrait of a changing consumer. Bus Horiz 33(1):62–73
European Commission (2009) European's attitude towards the issue of sustainable consumption and production. Analytical report. The Gallup Organisation, Hungary
Finisterra do Paco A, Raposo M (2010) Green consumer market segmentation: empirical findings from Portugal. Int J Consum Stud 34:429–436
Gilg S, Barr N, Ford N (2005) Green consumption or sustainable lifestyles? Identifying the sustainable consumer. Futures 37:481–504
Inglehart R (1995) Public support for environmental protection: objective problems and subjective values in 43 societies. Polit Sci Polit 28(1):57–72
Jain S.K., Kaur G (2004) Green marketing: an attitudinal and behavioural analysis of Indian consumers. Glob Bus Rev 5(2):187–205
Jain S.K., Kaur G (2008) Role of socio-demographics in segmenting and profiling green consumers. J Int Consum Mark 18(3):107–146
Kinnear T, Taylor J, Ahmed S (1974) Ecologically concerned consumers: who are they? J Mark 38(2):20–24
Laroche M, Bergeron J, Barbaro-Forleo G (2001) Targeting consumers who are willing to pay more for environmentally friendly products. J Consum Mark 18:503–520
Meffert H, Bruhn M (1996) Das Umweltbewußtsein von Konsumenten. Die Betriebswirtsch 56(5):621–648
National Geographic (2011) Greendex 2010: Consumer Choice and the Environment–A Worldwide Tracking Survey. http://environment.nationalgeographic.com/environment/greendex/ [Accessed 11 Dec 2011]
Peattie K (2001) Golden goose or wild goose? The hunt for the green consumer. Bus Strategy Environ 10:187–199
Pepper M, Jackson T, Uzzell D (2009) An examination of the values that motivate socially conscious and frugal consumer behaviours. Int J Consum Stud 33:126–136
Roberts JA (1996) Green consumers in the 1990s: profile and implications for advertising. J Bus Res 36(3):217–231
Robins N (1999) Making sustainability bite: transforming global consumption patterns. J Sustain Prod Des 10:7–16
Roos A, Nryud A (2008) Description of green versus environmentally indifferent consumers of wood products in Scandinavia: flooring and decking. J Wood Sci 54(5):402–407
Roper Organisation 1992 Environmental behaviour. North American: Canada, Mexico, United States Commissioned by S.C.Johnson and Son Ltd
Samdahl M, Robertson R (1989) Social determinants of environmental concern: specification and test of the model. Environ Behav 21(1):57–81
Saphores J, Nixon H, Ogunseitanc O, Shapirod A (2007) California households' willingness to pay for "Green" electronics. J Environ Plan Manag 50(1):113–133
Schaefer A, Crane A (2005) Addressing sustainability and consumption. J Macromark 25:76–92
Schor J (2005) Prices and quantities: unsustainable consumption and the global economy. Ecol Econ 55:309–320
Schultz P, Zelezny L (1999) Values as predictors of environmental attitudes: evidence for consistency across 14 countries. J Environ Psychol 19:255–265

Scott D, Willits K (1994) Environmental attitudes and behavior: a Pennsylvania survey. Environ Behav 26(2):239–260

Shrum L, McCarty J, Lowrey T (1995) Buyer characteristics of the green consumer and their implications for advertising strategy. J Advert 24(2):71–82

Sinnappan P, Rahman A (2011) Antecedents of green purchasing behavior among Malaysian consumers. Int Bus Manag 5(3):129–139

Soron D (2010) Sustainability self-identity and the sociology of consumption. Sustain Dev 18:172–181

Straughan R, Roberts J (1999) Environmental segmentation alternatives: a look at green consumer behavior in the new millennium. J Consum Mark 16(6):531–575

Tognacci N, Weigel R, Wideen F, Vernon D (1972) Environmental quality: how universal is public concern? Environ Behav 4(1):73–86

Van Liere K, Dunlap R (1980) Environmental concern: does it make a difference? How it is measured? Environ Behav 13(6):651–76

Webster E (1975) Determining the characteristics of the socially conscious consumer. J Consum Res 2:188–196

Xiao C, McCright A (2007) Environmental concern and sociodemographic variables: a study of statistical models. J Environ Educ 38(2):3–14

Zarnikau J (2003) Consumer demand for 'Green Power' and energy efficiency. Energy Policy 31:1661–1672

Zelezny L, Chua P, Aldrich C (2000) Elaborating on gender differences in environmentalism. J Soc Issues 56(3):443–457

Zimmer M, Stafford T, Stafford M (1994) Green issues: dimensions of environmental concern. J Bus Res 30(1):63–74

Cultural Capital and Local Development Nexus: Does the Local Environment Matter?

Roberta Capello and Giovanni Perucca

Abstract This chapter discusses the relationship between cultural capital and regional development. Our idea is that the culture/development nexus is mediated by the endowment of social, ethical, and behavioral values of places. Adopting an approach in which culture is shaped and defined by the socioeconomic elements present in an area, this work develops an operational definition of cultural capital and an empirical analysis pointing out that the cultural elements considered in the literature (heritage and the cultural industry) are not place-neutral. Instead, their economic effects arise only when they are embedded in particular cultural environments.

Keywords Culture and regional development • Nexus • Cultural environment

1 Introduction

In the past 20 years, the number of studies in the economic literature devoted to culture has greatly increased, also due to the wide debate generated by Throsby's work, which launched the idea of interpreting culture as an endogenous territorial asset like other forms of capital, such as natural or physical capital (Throsby 1999).

Following this approach, the European Spatial Development Perspective (ESDP, European Commission 1999), a major spatial vision and planning document of the EU, defined cultural variety as "... the characteristic territorial feature of the EU," which must "be retained in the face of integration" (ESDP, Sect. 1.1, point 1, p. 7).

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This definition is particularly important since it emphasizes the place-based nature of culture, which has been sometimes ignored in the literature on the role of cultural capital in economic development.

Within this literature, the large majority of studies have focused on two main elements of cultural capital. The first involves cultural heritage as a tourism attraction: Fainstein et al. (2003) pointed out that cultural heritage and the activities related to these physical assets are the main sources of attractiveness of places. The second element concerns the so-called “cultural industry” (Hesmondhalgh 2007). With this term, the literature refers to all industries producing culture-related goods and services, which in the decade before the economic downturn outperformed the more traditional sectors of the economy (Siwek 2002).

The literature has also recognized the existence of certain intangible cultural elements (such as religious behaviors, social norms, or ethnical values), which identify the cultural environment of local systems. There are studies that have analyzed the indirect effect of intangible forms of culture on local development, in that the cultural environment is not a source of economic development per se but rather an element which enhances the effect of other endogenous territorial capital assets on local development (Florida et al. 2008).

Surprisingly, however, very little is known about the effects of intangible forms of culture on the return from tangible ones. This issue is important for several reasons. First, the cultural environment may reflect different modes of culture supply. For example, the cultural industry may benefit from specific territorial conditions and cooperative behaviors among the actors involved in the cultural production process. Second, the consumption and production of cultural goods and services are expected not to be neutral to the cultural behaviors of individuals. For instance, the impact of cultural heritage on economic growth varies according to the individual cultural behaviors of different places.

For these reasons, an interesting field of analysis is the identification of the role played by the local cultural environment in fostering the economic impact of the tangible cultural assets. It is very likely that the richer the cultural environment, the greater the effects of cultural capital on local development.

In order to shed light on the role of intangible cultural elements in local development, there is a need to create some order in the large number of definitions that have been given to the term “cultural capital” in the literature (Sect. 2.1). Starting from the existing studies and their limits, an operational definition for the different cultural capital assets is proposed (Sects. 2.2 and 2.3) and applied in an empirical analysis of the role of the cultural environment in the development of local areas. In these studies, the empirical analysis is conducted on all 103 Italian provinces (NUTS3) (Sect. 3). Finally, the present work will investigate the impact of the tangible cultural assets on the recent economic performance of Italian provinces, and it will clarify whether the impact has been reinforced by the local cultural environment.

2 A Classification of Cultural Capital

2.1 Cultural Capital: A Multifaceted Concept

Despite the growing attention paid to the topic, the definition of cultural capital is rarely consistent across studies. Most of the time, it has been used interchangeably to indicate either tangible heritage or the mass-media industry or even social norms and cultural values.

Throsby (2010) claimed that the distinctive feature of cultural capital is its cultural value. Therefore, all the tangible assets and intangible practices, beliefs, and traditions which are important from a cultural perspective contribute to the cultural capital of a given place. Clearly, a classification of the components of cultural capital crucially depends on the interpretation of the term "culture."

According to Williams (1976), the term "culture" conveys two distinct meanings. On the one hand, it represents the society's overall way of life, traditions inherited from the past, current habits, and modes of action. On the other hand, it comprises the arts and letters giving tangible form to the shared values.

The differences among all the cultural elements mentioned by Williams and Throsby concern their degree of materiality. But this is not the only feature that has been mentioned to discriminate among cultural assets. Throsby (2001) claimed that cultural goods are characterized by different degrees of rivalry in their consumption. This is explained by the fact that, apart from their private consumption, cultural goods generate nonmarket benefits related to their nonuse value. These benefits often take the form of public goods. A monument, for instance, may have a nonuse value because of its symbolic and social importance. On the basis of this recognition, Throsby identified seven forms of the nonuse value of cultural goods leading to different degrees of rivalry in their consumption: aesthetic, spiritual, social, historic, symbolic, and authenticity values. The social, historic, and symbolic nonuse value of cultural goods is typically shared by all the members of a community, as in the case of religion or folklore, but also of the built heritage of a given place. Cultural goods possessing values of this kind are therefore rivalrous in their consumption and conceptually close to public goods. Aesthetics and authenticity benefits are more similar to club goods, since in this case preferences are usually diversified across individuals. Finally, as far as their use value is concerned, cultural assets may often be considered as private goods since their provision is regulated by market mechanisms.

The literature therefore seems to suggest two dimensions on which a distinction can be drawn among all elements pertaining to cultural capital: materiality, on the one hand, and rivalry, on the other. The same two dimensions have been applied to classify all territorial capital assets, these being defined as all the potential growth assets that an area may have (Camagni 2009). Their importance stems from the fact that tangible or intangible, as well as private or public, goods follows completely different laws of accumulation and depletion, in regard to which different normative suggestions have to be formulated. In the case of cultural assets, their sustainable consumption raises regulatory issues concerning the prevention of free riding and opportunistic behaviors.

Therefore, if taken together, the dimensions of materiality and rivalry constitute useful means with which to provide an operational definition of the multifaceted nature of cultural capital which can be easily applied in empirical investigation of its economic impact. The next sections present such an operational definition.

2.2 *Cultural Capital: Tangible Elements*

A definition of cultural capital assets is reported in Fig. 1, which presents the various elements that pertain to the multifaceted concept of cultural capital. They are organized around the two main dimensions mentioned above: materiality, on the one hand, and rivalry, on the other. Cultural assets are in general associated with tangible elements; the literature refers to cultural industry, as well as to historic monuments and cultural heritage. Their difference between these two kinds of cultural capital lies in the degree of rivalry that they have. The cultural industry represent private capital (and private investment) and therefore respond to market rules for its laws

Rivalry **(High)**	*Private goods*	***c*** Private Cultural Capital: stock of capital invested in the cultural industry	***i*** Private Mecenatism: Arts patronage, foundations and agencies aimed at the support of cultural activities	***f*** Cultural capital embedded in human beings: Human capital, individual cultural attitudes
↑	*Club goods, impure public goods*	***b*** Tangible Cultural Assets: monuments, museums, galleries	***h*** Cultural Cooperation Networks: Public/private partnerships in the provision of cultural goods and services	***e*** Cultural capital embedded in social relations: cultural networks
(Low)	*Public goods*	***a*** Public, Aggregate, Tangible Culture: landscapes, aggregate tangible heritage	***G*** Urbanization Economies: Types of agglomeration	***d*** Cultural values embedded in the society: Inherited cultural values shared within the community such as religion, folklore
		Tangible goods (hard)	*Mixed goods (hard + soft)*	*Intangible goods (soft)*
		Materiality **(High)**	**→**	**(Low)**

Fig. 1 A taxonomy of cultural capital elements (Source: adapted from Camagni 2009)

of accumulation; historic monuments and cultural heritage in general are typical public goods and therefore suffering from the "tragedy of commons," with risk of overexploitation and depletion in the long run if an appropriate public governance is not put in place.

More in detail, public, aggregate tangible culture (box *a* in Fig. 1) includes those assets close to public goods because they are non-excludable and characterized by a low level of rivalry. Examples are provided by cultural landscapes, aggregate tangible heritage, and other cultural assets spatially spread over wide areas. These resources possess multiple cultural values, from the aesthetic, to the social, to the historic and symbolic. The channel through which they generate economic value is mainly tourism attraction (Fainstein et al. 2003). Many studies have addressed this issue, pointing out that the economic benefits from tourism may take the form of new opportunities for local business and employment growth (Bonet 2011; Diedrich and Garcia-Buades 2008; McGehee and Andereck 2004).

Tangible cultural assets (box *b* in Fig. 1) comprise monuments, museums, and galleries. These represent cultural goods of an interesting type: they share most of the properties typical of public cultural capital described above, but they have a peculiarity, that of suffering from congestion effects. Their consumption is open to everybody, with no excludability mechanisms, but it is characterized by rivalry: two features typical of impure public goods that require specific normative interventions. Their presence generates both positive and negative economic spillovers to the local economy, and many studies in the literature measure the intensity of those spillovers. Plaza (2000) focused on the contribution to local tourism of the Guggenheim Museum in Bilbao, while Smith and von Krogh Strand (2011) analyzed the case of Oslo's new Opera House. In an era characterized by the conversion of many cities and regions from manufacturing activities to the service sector, with tourism as the main activity in that sector (Richard and Wilson 2006), this topic becomes particularly important.

Tangible private cultural capital (box *c* in Fig. 1) is defined by the stock of private capital invested in the cultural industry, which is highlighted in the literature as an important source of economic development. A broad set of definitions of the so-called "cultural industry" have been provided by previous studies. According to Hesmondhalgh (2007), the cultural industry can be defined as the industrial production of those objects and services whose artistic, aesthetic, and symbolic functions outweigh other dimensions. More generally, recalling the abovementioned types of cultural characteristics defined by Throsby (2001), cultural industries can be broadly defined as those industries whose output possesses some cultural value in addition to its commercial value. The issue of the impact of cultural industries on economic growth is relatively recent in the economic literature, for two main reasons: first, because a formal definition of cultural industries was introduced for the first time less than 30 years ago (Miege 1987), and second, because in recent decades cultural industries have outperformed other sectors of the economy (Siwek 2002), attracting the attention of both social scientists and policy makers.

2.3 Intangible Cultural Capital and the Cultural Environment of Places

As said, the cultural environment has a multidimensional nature which requires clear identification of its individual components. Figure 1 illustrates the various elements of intangible cultural capital. Moving along the right-hand side of the matrix, the degree of materiality associated with cultural elements decreases, highlighting the intangible side of cultural capital assets. When also the degree of rivalry is taken into consideration, six distinct elements emerge, which can be grouped into three categories.

The first category (boxes *d*, *e*, *f* in Fig. 1) consists of intangible cultural assets inherently embedded in human behaviors. Through their single, collective, or social behavior in regard to culture, human beings participate in the formation of an area's cultural environment. The cultural interests in museums, art galleries, and the historical cultural heritage embedded in single individuals, or the interest in setting up cultural associations and cultural networks, or the existence of cultural values – like religious values, folklore, and cultural symbols – embedded in the society are all nonmaterial elements that participate in the definition of intangible cultural elements.

Shared cultural values (box *d* in Fig. 1) closely relate to the concept of cultural capital developed by Bourdieu (1979). More precisely, cultural values can be linked to the embodied state of cultural capital. The latter (Bourdieu 1986) is the outcome of a process of assimilation of cultural norms, values, and knowledge by individuals. This component of cultural capital includes all the inherited habits and conventions arising from deep-rooted cultural values such as religion and folklore. Individuals assimilate these values almost unconsciously, as part of their cultural identity. This definition is consistent with the one employed by Guiso et al. (2006), who explicitly defined culture as the set of values which are "inherited by an individual from previous generations, rather than voluntarily accumulated" (p. 24).

Relational cultural capital (box *e* in Fig. 1) is characterized by an intermediate level of rivalry. It comprises the set of connections and linkages developed by groups of individuals on the basis of shared cultural interests and values. Compared with the elements just discussed, these cultural values are not widespread within the society; rather, they are shared by groups of people. Whereas shared cultural values represent the culture embedded in a social environment characterized by common norms and traditions, relational cultural capital involves the cultural traits of networks of individuals within a given society.

Individual cultural capital (box *f* in Fig. 1) again relates to the embodied form of cultural capital defined by Bourdieu (1979). Nevertheless, compared with box *d*, in this case the cultural elements have the characteristics of a private good, because they are not collectively shared by the society. Put differently, individual cultural capital represents the result of a (conscious or otherwise) process of learning and training exclusive to the single individual. As pointed out by Bourdieu (1986), this form of cultural capital is formalized in the economic literature under the concept of human capital (Lucas 1988). In the context of this paper, this component of cultural capital does not refer to formal education but, instead, to the cultural behaviors of individuals (such as cinema and theater attendance, reading of books and newspapers, etc.) not explicitly rewarded with an economic payoff on the job market.

The second category (boxes *i* and *h* in Fig. 1) does not refer to individual values and behaviors but, instead, to institutional behaviors, i.e., models of governance in the provision of cultural goods and services.

Cooperation networks in the cultural sector (box *h* in Fig. 1) comprise those goods and services supplied through public/private partnerships. These partnerships are often adopted in the cultural sector, for instance, in the strategic planning of cultural events (Bramwell 1997) or in urban regeneration projects (Boyle 1989). As claimed by Camagni (2009), the building of relational networks between public bodies and private firms makes it possible to foster private profitability and public efficiency in the investment phase.

Private support for culture (box *i* in Fig. 1) concerns those situations in which cooperation agreements occur between private agents. Examples in the cultural sector are provided by the private financing of cultural initiatives, associations, and artists. Arts patronage and cultural foundations support the supply of cultural assets through financial aid to the providers of those goods and services. Hence, they contribute to the stock of private capital invested in the cultural sector. These investments are not primarily aimed at generating profits but rather at achieving public outcomes (Dubach and Sacco 2013).

Finally, a last category of intangible cultural capital important for identification of a cultural environment is embedded in the presence in the area of urbanization economies (box *g* in Fig. 1). With respect to previous intangible elements, this aspect does not exclusively define a cultural environment, but it is a general characteristic of an urban area. Despite its influence on all industries of the economy, agglomeration plays an important role in the definition of a cultural environment for a number of reasons. Agglomeration guarantees proximity of potential customers to cultural capital assets; in fact, despite the decline of transport costs, proximity to cultural heritage is still one of the main determinants of private demand for culture. Moreover, agglomeration identifies areas with the most intense concentration of cultural goods and services (Lazzeretti et al. 2008). Finally, cities of different size are also qualitatively different in their modes of consumption and production of cultural goods and services (Rekers 2012); agglomeration affects the market for culture, favoring processes of both production and consumption of cultural goods.

2.4 Cultural Assets and Local Development: Testable Assumptions

The impact on economic growth of all the abovementioned types of tangible cultural assets has already been measured in previous works (Bowitz and Ibenholt 2009; Throsby 2004). Nevertheless, the existing empirical studies are either developed on the basis of qualitative empirical analyses on single case study areas or focused on subsets of cultural elements. The first empirical step forward in the empirical exercise presented here is to develop a cross-section analysis of a high number of differentiated areas, in order to grasp an average effect of private and public tangible cultural assets on economic growth. Therefore, our first assumption is *that tangible elements of cultural capital play a role in the definition of local development patterns*, *as in general highlighted by the literature*.

However, this is not all. Some studies have also questioned, mostly in an implicit way, whether the nexus between (tangible) cultural assets and local development strengthens in specific cultural environments. Russo (2002), for instance, discussed the significance of monuments and art galleries for local development, highlighting the strategic importance of wise governance to prevent the negative economic effects stemming from an overexploitation of the cultural heritage. As far as the cultural industry is concerned, Bryan et al. (2000) emphasized the different degree of embeddedness that characterizes the cultural industries compared with other industries, indirectly highlighting the strong linkage between the cultural industry and the local economy. Leslie and Rantisi (2011) stressed the importance of synergies with the local environment for emergence and affirmation on the global markets of cultural industries.

All these studies directly or indirectly theorize that the nexus between cultural assets and local development is not place-neutral. Specific local conditions favor this nexus more than others. However, this contention requires more in-depth reflection and empirical verification, which are the concerns of this study. As regards conceptual reflection, a more precise definition of what is meant by local cultural environment is required. Our impression is that intangible capital assets – like social cultural values, individual cultural attitudes, and a sense of identification with cultural symbols – all participate in the definition of a place's cultural environment, and they play a role in reinforcing the role of tangible cultural elements in economic growth.

Given the different nature of tangible and intangible cultural capital, we expect specific tangible elements to have a stronger impact on economic growth when they are located in a specific cultural environment. The cultural industry is expected to play a greater role in local growth when it is located in an environment characterized by a large market of cultural goods. The cultural heritage, in its turn, is expected to generate higher economic effects in cultural environments rich with cultural values and with efficient institutional rules for their governance. Therefore, our second assumption is *that the role of tangible elements of cultural capital on economic growth is reinforced when they are embedded in specific cultural environments*. In particular, we expect private tangible assets to play a greater role in local growth when they are located in cultural environments with large markets for cultural goods. By contrast, public tangible assets are expected to have an impact on local growth in cultural environments rich with efficient institutional rules for their governance.

These assumptions are verified on a sample of 103 Italian NUTS3 provinces.

3 Cultural Environments in Italian NUTS3 Regions

The crucial role of the cultural environment as a mediator of the nexus between culture and local growth requires sound identification of an area's cultural environment. To achieve this aim, a rich dataset was built on all intangible cultural assets presented in Fig. 1. This dataset was used to run a cluster analysis to identify groups of provinces with homogeneous cultural environments. Urbanization economies (box *g* in Fig. 1) were excluded since, as discussed in Sect. 2, they do not represent a territorial element confined to the cultural field; in fact, they do not identify the cultural characteristics of a given place but highlight an indirect support that the territory can provide to cultural assets.

Table 1 describes the proxies for each intangible cultural capital employed in the analysis for the year 2004.[1]

The results of the cluster analysis show a classification of the Italian territory into three distinct kinds of cultural environment, consistently with the theoretical framework that envisaged similarities in groups of intangible cultural assets (Table 2).[2] The first cluster, in fact, includes those areas characterized by a higher endowment, with respect to the others, of individual and relational cultural capital; for this reason, it can be labeled *an area endowed with intangible cultural assets embedded in individual behaviors*.

The second cluster is marked by the high amount of investments in public-private partnerships in the private support to culture. Due to its peculiarities, this group can be labeled *an area endowed with intangible cultural assets embedded in institutional behaviors*. Finally, the last group of areas is characterized by the lack of any intangible cultural asset, i.e., *an area poor in intangible cultural assets*.

To be noted is that urbanization economies do not significantly differ across different cultural environments (last row of Table 2). This result highlights that urbanization economies are not correlated with any of the cultural environment

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[1]This part of the empirical analysis made use of model-based clustering, where data are assumed to originate from a mixture of probability distributions (Fraley and Raftery 2002). The main advantage of model clustering is that it makes it possible to test several parameterizations with a variety of distributions (spherical, diagonal, and ellipsoidal) with variable shape and volume.

[2]The results were obtained through an analysis of variance based on Bonferroni, Scheffe, and Sidak (Savin 1980) multiple comparison tests, performed in order to show the main differences across clusters.

Table 1 Components of cultural capital: data and sources

Name	Description	Source
Intangible cultural assets embedded in individual behaviors		
Box *d* – cultural values embedded in the society	Share of religious marriages in the total	ISTAT
Box *e* – cultural capital embedded in social relations	Number of volunteers regularly offering their labor and competencies in voluntary cultural associations	ISTAT
Box *f* – cultural capital embedded in human beings	Per capita number of newspapers (sport newspapers excluded) sold in a year	ADS – Accertamenti Diffusione Stampa
Intangible cultural assets embedded in institutional behaviors		
Box *h* – cultural cooperation networks	Per capita investments in public-private partnerships (PPP) on cultural projects	National observatory on project financing
Box *i* – private patronage	Per capita number of foundations operating in the cultural sector	ISTAT
Urbanization economies		
Box *g* – urbanization economies	Resident population per square kilometer	ISTAT

Table 2 One-way analysis of variance across clusters

			Pairwise comparison	
Variable	F test	Significance	+	−
Cultural values embedded in the society	98.5	***	Poor CB	Inst.CB, Ind.CB
Cultural capital embedded in social relations	3.01	**	Ind.CB	Poor CB
Cultural capital embedded in human beings	62.71	***	Ind.CB	Inst.CB, Poor CB
Cultural cooperation networks	7.23	***	Inst.CB	Ind.CB, Poor CB
Private patronage	35.23	***	Inst.CB	Ind.CB, Poor CB
Urbanization economies	0.61	n.s.		

Ind. CB: areas endowed with intangible cultural assets embedded in individual behaviors
Inst. CB: areas endowed with intangible cultural assets embedded in institutional behaviors
Poor CB: areas poor in intangible cultural assets

groups identified through the cluster analysis. Since they act on all types of cultural assets, it is advisable to separate them with respect to the other intangible cultural assets.

Figure 2 presents the three cultural environments in Italy. The most striking result is the concentration of areas with limited propensity to cultural behaviors in the South of Italy; all provinces, except one (Messina, in Sicily), in fact, belong to this cluster. The northern and central parts of the country, instead, are split between the other two groups, with the individual cultural behavior area being more scattered in northern and central provinces, while the institutional cultural behavior area is more concentrated in the central part in both Tuscany and Marche, as well as in the northeastern part of the country.

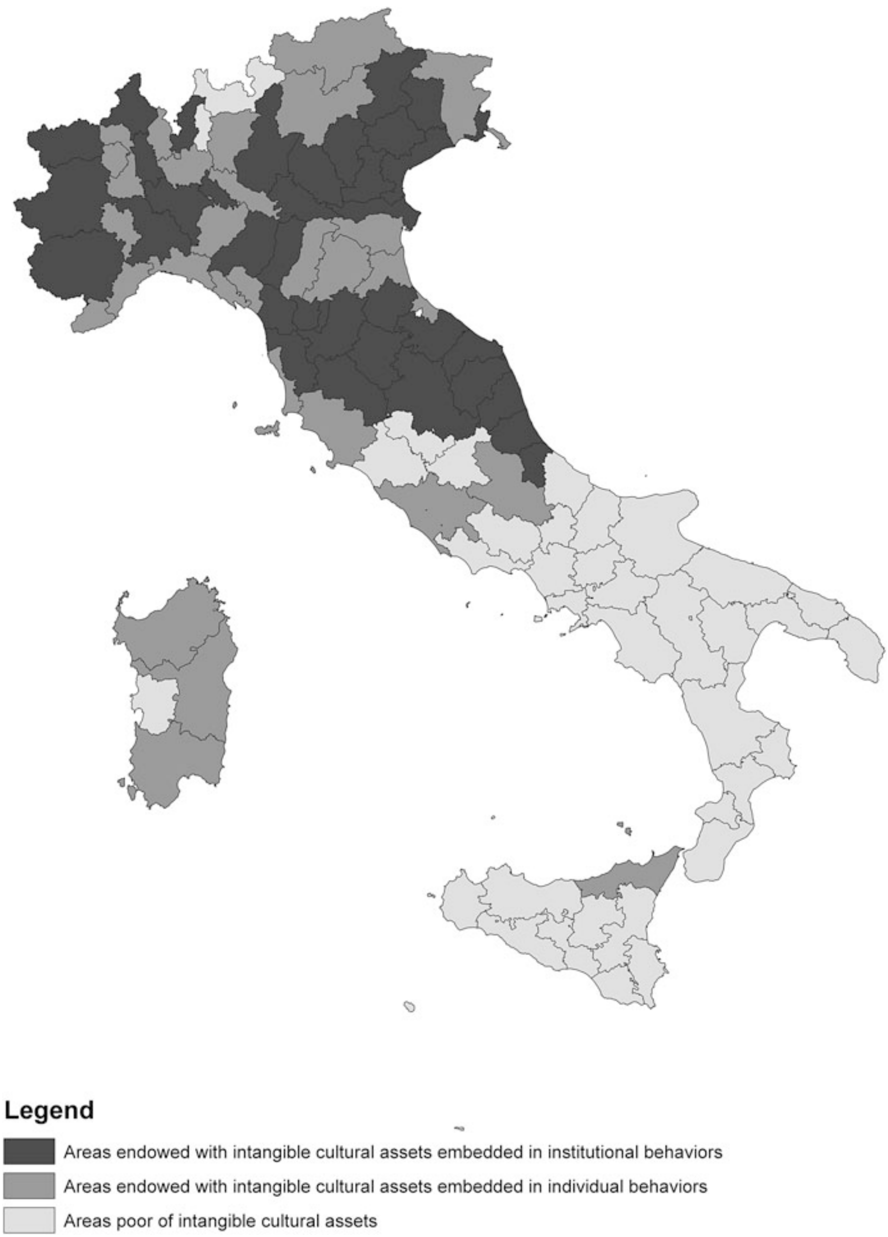

Fig. 2 A map of cultural environments in Italy

4 Tangible Cultural Elements and Economic Growth: The Effect of the Cultural Environment

4.1 The Growth Model

This section analyzes the role of tangible cultural elements in the economic growth of NUTS3 Italian regions, controlling for other relevant sources of growth.

Cultural elements, in fact, are certainly not the only factors that foster economic prosperity. Modern regional development models show that the determinants of regional economic growth no longer rely on traditional elements such as labor and capital, because these are today highly mobile. Instead, competitiveness is increasingly based on other place-based resources, namely, innovation capacity, competences, or, more in general, knowledge (Camagni and Capello 2008).

The accumulation of knowledge is fostered by certain tangible and intangible factors. Among the former, specialization in advanced value functions has a direct impact on knowledge creation (Capello et al. 2011). Other tangible elements, like physical accessibility, have an indirect effect on economic growth by enhancing knowledge spillovers and transmission. As regards the intangible territorial elements, the role of human capital in innovation (Lucas 1988) is well recognized in the literature (Dakhli and De Clercq 2004). Among the intangible territorial assets indirectly enabling knowledge accumulation to take place, a long stream of research has focused on the role of social capital (Putnam 1993). Moreover, urbanization economies facilitate learning and knowledge exchanges (Rosenthal and Strange 2004).

More in detail, our dependent variable is real regional GDP growth between 2004 and 2008. This period was chosen since, from 2008 onwards, the impact of the economic crisis resulted in a generalized slowdown of EU economies. In the presence of an exogenous shock, the traditional mechanisms of endogenous growth cannot be assumed to operate as expected in the literature (Martin 2012).[3]

Based on what was said above, the set of regressors can be classified as follows (Table 3):

– control variables identified according to a modern approach to regional growth. From this perspective, the creation of knowledge and innovation is the main driver of economic development. A large body of literature has assessed the role of human capital (Lucas 1988), while more recently some studies have emphasized the relationship between labor productivity and technological progress in terms of information and communication technology (ICT) availability and

[3]Nevertheless, as a consistency check of our findings, the same analysis has been conducted on the ARIMA estimates of regional GDP growth between 2004 and 2011, following the same approach as adopted by Capello and Lenzi (2015). The results were consistent with the findings reported here.

Table 3 Independent variables: source and description

Name	Description	Source
Initial per capita GDP	Per capita GDP	ISTAT[a]
Innovation		
Patents	Per capita number of patent applications	ISTAT
Assets facilitating innovation creation		
High-value functions	Share of workers employed in ISCO category 1 and 2 (managers and professionals)	Labour Force Survey
Physical accessibility	Multimodal potential accessibility	ESPON
Social capital (lack of)	Per capita number of murders	ISTAT
Urbanization economies	Population per square km; this variable is aimed at capturing the effect of agglomeration economies on all economic activities and (through interactions) on the tangible cultural elements	ISTAT
Tangible cultural assets		
Public tangible cultural capital	Per capita number of historic buildings (churches, palaces, bridges, fountains, etc.), museums, and galleries	Ministry of Cultural Heritage and Activities (Risk Map database)
Private tangible cultural capital	Per capita number of firms (local units) operating in the cultural sector. The ATECO (classification of economic activities) branches included in the cultural sector were listed by Santagata (2009). Compared with this classification, the present work focuses only on the conception and production of cultural goods and services. The supply of input to the cultural industry and the distribution of cultural commodities are excluded since official statistics do not allow discrimination between cultural and noncultural firms	ISTAT
Cultural environments		
Areas endowed with intangible cultural assets embedded in individual behaviors	Taxonomy of regions based on their endowment of intangible cultural elements	Authors' own elaborations
Areas endowed with intangible cultural assets embedded in institutional behaviors		
Areas poor in intangible cultural assets		

[a]National Statistical Institute

diffusion (Becchetti and Adriani 2005). The per capita number of patents captures the innovation produced within each region (Bottazzi and Peri 2003).

- A second group of independent variables comprising those territorial assets which facilitate and mediate the processes of knowledge and innovation creation. The endowment of physical infrastructures increases the accessibility of knowledge from outside the region's borders (Andersson and Karlsson 2007; Caragliu et al. 2011). Urbanization economies foster knowledge creation and knowledge diffusion (Parr 2002). Specialization in high-value functions is captured by the share of workers employed as managers and professionals according to the ISCED classification. Social capital is proxied by the inverse number of per capita murders, strongly associated in the literature with low levels of trust (Kennedy et al. 1998). Finally, population density measures the externalities generated by the proximity of other economic agents, as discussed in Sect. 2.3.
- A group of variables for the tangible and intangible cultural assets and a set of dummies for the kind of cultural environment. Tangible public elements are measured by the per capita number of monuments in NUTS3 regions. Material private assets are captured by the per capita number of firms (local units) operating in the cultural sector. A set of dummies for the three cultural environments previously identified is included to verify whether the different combinations of intangible cultural elements are divergent in their economic performance.
- A further control is introduced to account for the growth patterns of regions at different stages of development, through the initial per capita GDP level.

The empirical model takes the following form:

$$\begin{aligned}\Delta\text{GPD}_r =& \beta_0 + \beta_1\text{per capita GDP}_r + \beta_2\text{physical access}_r + \beta_3\text{high functions}_r \\ &+ \beta_4\text{patents}_r + \beta_5\text{social capital}_r + \beta_6\text{population dens}_r \\ &+ \beta_7\text{public tangible } CC_r + \beta_8\text{private tangible } CC_r \\ &+ \beta_9\text{cultural environment}_r + u_r \end{aligned} \tag{1}$$

where $r = 1, \ldots, 103$ indicates each of the Italian provinces and CC stands for the endowment of cultural capital.

Interactions between tangible cultural elements and both the set of dummies for the cultural environments and the urbanization economies make it possible to test the assumptions discussed in Sect. 2.4. As far as the tangible cultural assets are concerned, equation [1] becomes:

$$\begin{aligned}\Delta\text{GPD}_r = \textstyle\sum_{i=0}^{9}\beta_i X_i + \beta_{10}\text{public tangible } CC_r + \beta_{11}\text{public tangible } CC_r\cdot \\ \text{cultural environment}_r + \beta_{12}\text{public tangible } CC_r\cdot\text{population dens}_r + u_r\end{aligned} \tag{2}$$

where X_i is the set of control variables presented in Eq. (1). The same applies to the private tangible cultural assets:

Table 4 Results of the spatial autocorrelation tests

Inverse distance matrix				
	Model (1)	*Model (2)*	*Model (3)*	*Model (4)*
Spatial error				
Moran's I	−0.460	−0.358	−0.613	−0.158
Lagrange multiplier	0.672	0.643	1.164	0.457
Robust Lagrange multiplier	1.248	0.400	0.010	0.843
Spatial lag				
Lagrange multiplier	1.868	1.201	1.241	1.075
Robust Lagrange multiplier	2.444	0.958	0.087	1.461
Binary neighbors matrix				
	Model (1)	*Model (2)*	*Model (3)*	*Model (4)*
Spatial error				
Moran's I	−0.369	−0.243	−0.543	−0.005
Lagrange multiplier	0.547	0.486	1.003	0.283
Robust Lagrange multiplier	1.262	0.475	0.001	1.041
Spatial lag				
Lagrange multiplier	1.678	1.014	1.117	0.852
Robust Lagrange multiplier	2.394	1.004	0.115	1.611

$$\Delta \mathrm{GPD}_r = \sum\nolimits_{i=0}^{9} \beta_i X_i + +\beta_{10}\mathrm{priv.tangible}\ CC_r + \beta_{11}\mathrm{priv.tangible}\ CC_r \cdot \mathrm{cultural\ environment}_r + \beta_{12}\mathrm{priv.tangible}\ CC_r \cdot \mathrm{population\ dens}_r + u_r \tag{3}$$

4.2 *Empirical Results*

The empirical analysis was conducted in order to take three potential issues into account. The first concerned multicollinearity since, in principle, the measurements of the regional cultural elements might have been empirically associated with other territorial factors included as predictors. This issue was addressed by separately adding in the estimated model the different groups of regressors described in Table 3. The stability of the regression results across models suggested that the simultaneous inclusions of the variables of our data set and their interactions are not likely to have raised multicollinearity issues.

The second problem concerned spatial autocorrelation. We tested all the regression results for spatial dependence, allowing the spatial weight matrix to take different forms (continuous and binary distance). The results of the tests are reported in Table 4. As shown by these findings, spatial autocorrelation was not likely to occur.

Finally, the third issue referred to the potential endogeneity of the tangible cultural elements. We are inclined to reject this possibility for the following reasons. First, all regressors were one-year lagged with respect to the dependent variable. Second, tangible heritage is the outcome of historical processes of accumulation.

Southern regions, for instance, are endowed with a broad variety of monuments and historic buildings inherited from the Roman era, but at the same time, they are the less developed areas of the country. As regards the cultural industry, one objection could be that cultural goods and services may be considered as superior goods and that, therefore, their production could take place more intensively in richer societies. To account for this potential issue, the activities of distribution and retail supply were excluded from the empirical measurement of the regional specialization in the cultural industry. Third, empirical tests employing instrumental variables rejected the hypothesis of endogeneity for the two indicators of tangible cultural capital.

The regression results are reported in Table 5. Model (1) includes those factors which are assumed to affect regional growth through knowledge creation. As expected, the higher the degree of innovation activity, the greater the local growth. High-value functions are also statistically significant, and their relationship with the economic growth of Italian NUTS3 regions between 2004 and 2008 is positive. By contrast, accessibility turned out to be negatively associated with local growth; this counterintuitive result is common in the literature (Casi and Resmini 2014; Capello et al. 2008) and explained by the fact that accessibility captures congestion situations present in the less dynamic, and richest, areas of Europe.

Model (2) introduces the variables measuring the tangible elements of cultural capital and the set of dummies for the cultural environments (*areas poor in intangible cultural assets* are taken as reference). None of these variables is statistically significant. Therefore, neither the pure amount of heritage nor the regional endowment of firms operating in the cultural sectors led to a better economic performance. In the same way, cultural environments per se are not associated with different rates of growth. This evidence bears out our first assumption, providing a result in contrast with what is generally highlighted in the literature.

Nevertheless, this result is not surprising, given the discussion in the second section. In fact, we expected tangible cultural resources not to be neutral to the cultural environment in which they are embedded. To verify this hypothesis, we separately added to the model specification the interactions between the tangible cultural assets and the cultural environments for both the public elements (model 3) and the private ones (model 4), as shown, respectively, by Eqs. (2) and (3) in the previous section. The empirical results seem to confirm our hypothesis.

Model 3 takes the public cultural resources into account. The findings set out in Table 5 show that the relationship between economic growth and this specific dimension of cultural capital is highly differentiated across different cultural environments. Public tangible cultural capital is a growing factor in those *areas endowed with intangible cultural elements embedded in institutional behaviors*. In other cultural environments, cultural heritage proves to have either a nonsignificant effect (as shown by the interaction term between public tangible cultural capital and the dummy for the areas with cultural assets embedded in individual behaviors) or even a negative one, in the case of *areas poor in intangible cultural assets*. This result once again highlights the importance of the good, wise, and efficient governance of public monuments and cultural goods in general for their efficient exploitation.

Table 5 Regression results for the local growth model

	Model (1)	Model (2)	Model (3)	Model (4)
Per capita GDP	−0.004	−0.006	−0.007	−0.005
	(0.007)	(0.007)	(0.007)	(0.007)
Patents	0.021**	0.020*	0.021*	0.021*
	(0.011)	(0.012)	(0.012)	(0.012)
High-value functions	1.013***	1.023***	0.965***	0.978***
	(0.285)	(0.347)	(0.350)	(0.356)
Physical accessibility	−0.043*	−0.047**	−0.038	−0.057**
	(0.022)	(0.023)	(0.027)	(0.025)
Social capital	0.002	0.002	0.005	0.003
	(0.003)	(0.004)	(0.004)	(0.004)
Urbanization economies	0.000	0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Public tangible cultural capital		−0.010	−0.117**	0.003
		(0.020)	(0.053)	(0.023)
Private tangible cultural capital		−0.000	−0.000	0.000
		(0.000)	(0.000)	(0.002)
Institutional cultural behaviors		0.009	−0.034	0.020
		(0.018)	(0.024)	(0.029)
Individual cultural behaviors		0.023	−0.004	0.019
		(0.016)	(0.018)	(0.034)
Public tangible cultural capital* Areas with cultural assets embedded in individual behaviors			0.103** (0.046)	
Public tangible cultural capital* Areas with cultural assets embedded in institutional behaviors			0.148*** (0.055)	
Public tangible cultural capital* Urbanization economies			0.000* (0.000)	
Private tangible cultural capital* Areas with cultural assets embedded in individual behaviors				0.000 (0.002)
Private tangible cultural capital* Urbanization economies				0.000*
				(0.000)
Constant	0.605	0.670	0.540	0.846*
	(0.414)	(0.438)	(0.512)	(0.467)
Observations	103	103	103	103
R-squared	0.217	0.257	0.293	0.275

Dependent variable: annual GDP growth rate in the period 2004–2008 at NUTS3 level
Robust standard errors in parentheses. $***p<0.01$, $**p<0.05$, $*p<0.1$
The cluster *areas poor in intangible cultural assets* is taken as reference

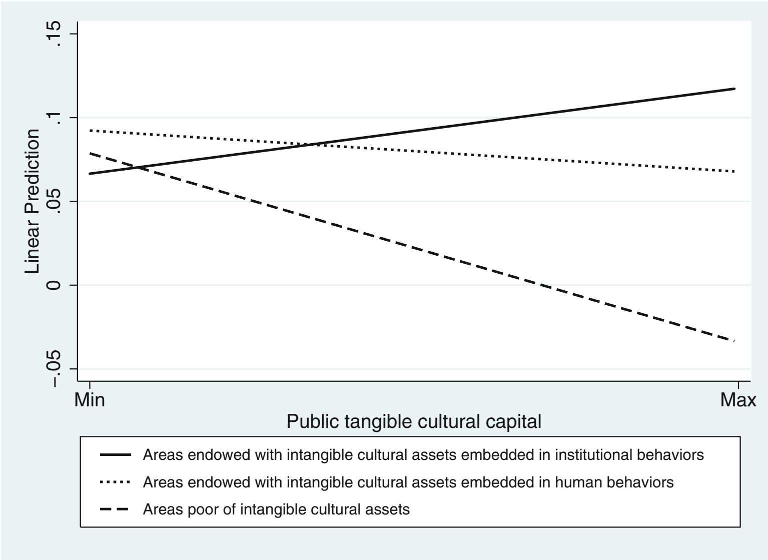

Fig. 3 Marginal effect of public tangible heritage on GDP growth in the three types of cultural environment

The same result can be read in a graph. Figure 3 shows the relationship between public tangible cultural capital and local growth predicted by the model in the three cultural environments. *Areas poor in intangible cultural assets* are unable to generate an economic return from their endowment of cultural heritage, and this negative relationship increases with the endowments of public cultural capital (dotted line in Fig. 3). The opposite holds for the *areas endowed with intangible cultural elements embedded in institutional behaviors*; in these areas, the marginal effect of public tangible capital on economic growth is positively related to the endowment of public tangible cultural capital, showing that the attention of institutions to cultural heritage increases the impact of these resources on economic growth.

Finally, also urbanization economies are associated with a higher return from public tangible cultural assets. Tangible cultural assets embedded in urban environments and densely populated areas generate positive spillovers on economic growth through tourism attraction (Kourtit et al. 2013).

Model (4) includes the interactions between the cultural environment and the private tangible cultural elements (cultural industry). In this case, the solely statistically significant joint effect concerns agglomeration economies. As shown in Fig. 4, densely populated areas exhibit a higher marginal effect of the cultural industry on local growth; conversely, small and less densely populated areas have a limited positive effect on local growth. This result demonstrates that the economic impact of the cultural industry is reinforced by the market-oriented elements represented by the agglomeration of both cultural and noncultural activities, consistently with the assumptions discussed in Sect. 2 and with the previous literature on the topic (Pratt 2008).

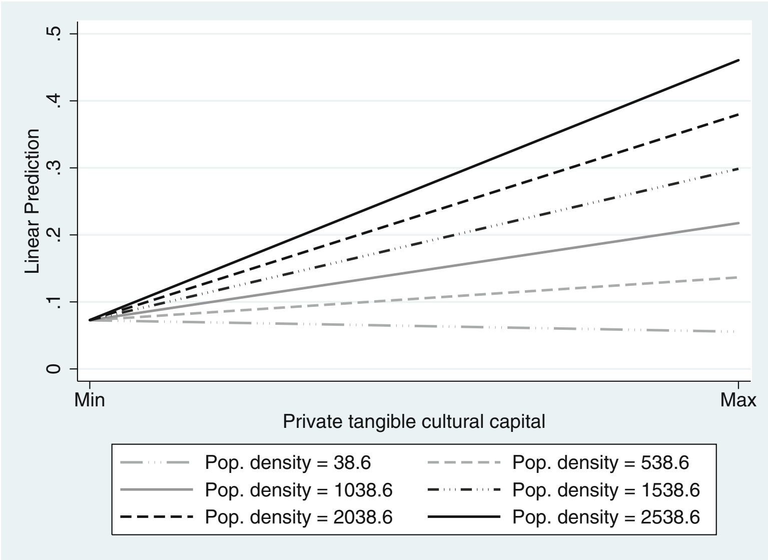

Fig. 4 Interactions between private tangible cultural capital and urbanization economies

Taken together, the output reported in the last two columns of Table 5 bears out our second assumption: tangible cultural assets are not place-neutral. Their impact on economic growth is mediated by the specific intangible cultural elements in which they are embedded.

5 Concluding Remarks

This chapter has studied the impact of tangible cultural elements, namely, physical cultural heritage and the cultural industry, on the economic growth of Italian NUTS3 regions. The empirical findings have important policy implications.

First, none of the tangible assets can be assumed to foster economic growth without certain territorial conditions. The latter are represented by the cultural environment in which the tangible elements are embedded. Cities are the main places of creation and consumption of culture, and this result is in line with those of previous studies. Urbanization economies, however, are not the only elements mediating the effect of culture on growth. Also, the aggregate of individual cultural behaviors and the modes of governance of culture play a major role, especially in the return from the exploitation of cultural heritage.

This consideration leads to the second policy prescription, which is particularly important at a time when the creation and restoration of cultural spaces is a well-documented strategy of municipalities and regional authorities to enhance the attractiveness and branding of their cities and regions (Evans 2003). Without appropriate local conditions, investments in tangible public cultural elements do not necessarily have an economic return; in order for them to be efficient, they must be coupled with policies enhancing and preserving the sociocultural environment in which cultural heritage and industries are located.

References

Andersson M, Karlsson C (2007) Knowledge in regional economic growth – the role of knowledge accessibility. Ind Innov 14(2):129–149

Becchetti L, Adriani F (2005) Does the digital divide matter? The role of information and communication technology in cross-country level and growth estimates. Econ Innov New Technol 14(6):435–453

Bonet L (2011) Cultural tourism. In: Towse R (ed) Handbook of cultural economics. Edward Elgar Publishing, Cheltenham, pp 166–171

Bottazzi L, Peri G (2003) Innovation and spillovers in regions: evidence from European patent data. Eur Econ Rev 47(4):687–710

Bourdieu P (1979) Les trois états du capital culturel. Actes Rech Sci Soc 30(1):3–6

Bourdieu P (1986) The forms of capital. In: Richardson JG (ed) Handbook of theory and research for the sociology of education. Greenwood, New York, pp 241–258

Bowitz E, Ibenholt K (2009) Economic impacts of cultural heritage-research and perspectives. J Cult Herit 10(1):1–8

Boyle R (1989) Partnership in practice – an assessment of public-private collaboration in urban regeneration – a case study of Glasgow action. Local Gov Stud 15(2):17–28

Bramwell B (1997) Strategic planning before and after a mega-event. Tour Manag 18(3):167–176

Bryan J, Hill S, Munday M, Roberts A (2000) Assessing the role of the arts and cultural industries in a local economy. Environ Plan A 32(8):1391–1408

Camagni R (2009) Territorial capital and regional development. In: Capello R, Nijkamp P (eds) Handbook of regional growth and development theories. Edward Elgar, Cheltenham, pp 118–132

Camagni R, Capello R (2008) Knowledge-based economy and knowledge creation: the role of space. In: Fratesi U, Senn L (eds) Growth and competitiveness in innovative regions: balancing internal and external connections. Springer, Berlin, pp 145–166

Capello R and Lenzi C (2015) Relevance and utility of EU RTDI policies for a smart growth. Environ Plan C, forthcoming

Capello R, Camagni R, Fratesi U, Chizzolini B (2008) Modelling regional scenarios for an enlarged Europe. Springer, Berlin

Capello R, Caragliu A, Nijkamp P (2011) Territorial capital and regional growth: increasing returns in knowledge use. Tijdchr Econ Soc Geogr 102(4):385–405

Caragliu A, Del Bo C, Nijkamp P (2011) Smart cities in Europe. J Urban Technol 18(2):65–82

Casi L, Resmini L (2014) Spatial complexity and interactions in the FDI attractiveness of regions. Pap Reg Sci 93(S1):S51–S78

Dakhli M, De Clercq D (2004) Human capital, social capital, and innovation: a multi-country study. Enterp Reg Dev 16(2):107–128

Diedrich A, Garcia-Buades E (2008) Local perceptions of tourism as indicators of destination decline. Tour Manag 30(4):512–521

Dubach EB, Sacco PL (2013) From arts patronage to cultural philanthropy: collaborating with granting foundations. In: Bruni L, Zamagni R (eds) Handbook on the economics of reciprocity and social enterprise. Edward Elgar, Cheltenham, pp 163–178

European Commission (1999) ESDP-European Spatial Development Perspective: towards balanced and sustainable development of the territory of the European Union. Office for Official Publications of the European Communities, Luxembourg
Evans G (2003) Hard-branding the cultural city – from Prado to Prada. Int J Urban Reg Res 27(2):417–440
Fainstein SS, Hoffman L, Judd DR (2003) Making theoretical sense of tourism. In: Fainstein SS, Hoffman LM, Judd DR (eds) Cities and visitors: regulating people, markets and city space. Blackwell, Oxford, pp 239–253
Florida R, Mellander C, Stolarick K (2008) Inside the black box of regional development – human capital, the creative class and tolerance. J Econ Geogr 8(5):615–649
Fraley G, Raftery AE (2002) Model-based clustering, discriminant analysis, and density estimation. J Stat Assoc 97:611–631
Guiso L, Sapienza P, Zingales L (2006) Does culture affect economic outcomes? J Econ Perspect 20(2):23–48
Hesmondhalgh D (2007) The cultural industries, 2nd edn. Sage, London
Kennedy BP, Kawachi I, Prothrow-Stith D, Lochner K, Gupta V (1998) Social capital, income inequality, and firearm violent crime. Soc Sci Med 47(1):7–17
Kourtit K, Nijkamp P, Partridge MD (2013) The new urban world. Eur Plan Stud 21(3):285–290
Lazzeretti L, Boix R, Capone F (2008) Do creative industries cluster? Mapping creative local production systems in Italy and Spain. Ind Innov 15(5):549–567
Leslie D, Rantisi NM (2011) Creativity and place in the evolution of a cultural industry the case of Cirque du Soleil. Urban Stud 48(9):1771–1787
Lucas RE (1988) On the mechanics of economic development. J Monet Econ 22(1):3–42
Martin R (2012) Regional economic resilience, hysteresis and recessionary shocks. J Econ Geogr 12(1):1–32
McGehee NG, Andereck KL (2004) Factors predicting rural residents' support of tourism. J Travel Res 43(2):131–140
Miege B (1987) The logics at work in the new cultural industries. Media Cult Soc 9(3):273–289
Parr JB (2002) Agglomeration economies: ambiguities and confusions. Environ Plann A 34(4):717–732
Plaza B (2000) Evaluating the influence of a large cultural artifact in the attraction of tourism the Guggenheim Museum Bilbao Case. Urban Aff Rev 36(2):264–274
Pratt AC (2008) Creative cities: the cultural industries and the creative class. Geogr Ann Ser B Hum Geogr 90(2):107–117
Putnam DR (1993) The prosperous community: social capital and public life. Am Prospect 4(13):11–18
Rekers JV (2012) We're number two! Beta cities and the cultural economy. Environ Plan A 44(8):1912–1929
Richard G, Wilson J (2006) Developing creativity in tourist experiences: a solution to the serial reproduction of culture? Tour Manag 27(6):1209–1223
Rosenthal SS, Strange WC (2004) Evidence on the nature and sources of agglomeration economies. Handb Reg Urban Econ 4:2119–2171
Russo AP (2002) The "vicious cycle" of tourism development in heritage cities. Ann Tour Res 29(1):165–182
Savin NE (1980) The Bonferroni and the Scheffé multiple comparison procedures. Rev Econ Stud 47(1):255–273
Siwek S (2002) Copyright industries in the US economy: the 2002 report. The International Intellectual Property Agency, Washington, DC
Smith A, von Strand Krogh I (2011) Oslo's new Opera House: cultural flagship, regeneration tool or destination icon? Eur Urban Reg Stud 18(1):93–110
Throsby D (1999) Cultural capital. J Cult Econ 23(1):3–12
Throsby D (2001) Economics and culture. Cambridge University Press, Cambridge

Throsby D (2004) Assessing the impacts of a cultural industry. J Arts Manag Law Soc 34(3):188–204

Throsby D (2010) The economics of cultural policy. Cambridge University Press, Cambridge

Williams R (1976) Keywords – a vocabulary of culture and society. Oxford University Press, New York

Who Wants More Open Space? Study of Willingness to Be Taxed to Preserve Open Space in an Urban Environment

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Abstract The presence of open space is often regarded as one of the considerations that enhance the quality of the living experience of populations in urban regions and cities and that enhance the long-term sustainability of urban environments. However, the provision of open space comes at a price. This chapter examines people's willingness to support tax increases for the preservation of open space in a fast-growing urban area where pressure to marketize land to its highest and best use is high. In particular, we study how a respondent's socioeconomic characteristics influence their willingness to pay in the city of Charlotte, United States. We use and analyze detailed survey data at the household level collected from a phone interview survey conducted in the Charlotte, North Carolina, area. The econometric models allow us to identify a systematic response bias which arises from protest zeros and respondents' tendency to underreport their willingness. Results show that a respondent's willingness is affected by the respondent's gender, age, ethnicity, and level of educational attainment. An individual is more willing to support if the individual is younger, Caucasian, and has reached a higher level of education. Individual behaviors are aggregated to obtain the regional level of willingness. Finally, results reveal that respondents have a well-marked tendency to underreport their willingness to support and report protest zeros in the survey.

Keywords Open space • Discrete choice • Willingness • Taxes • Response bias

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1 Introduction

The protection of public open space is an important environmental issue of our time, and it will remain central to the public debate as urban areas continue to expand at a fast pace. The benefit of open space has been widely acknowledged by the public and extensively documented in the literature. Most studies find that the net benefit to preserving most types of open-space land uses is positive, although the dollar values may vary substantially on a case-by-case basis (Bullock 2008; Cho et al. 2008; Irwin 2002; Kang and Cervero 2009; Panduro and Veie 2013; Tyrväinen and Väänänen 1998).[1] Many jurisdictions at the state, county, and local levels have held open-space referenda in the United States (Kotchen and Powers 2006; Balsdon 2012). As preservation efforts need public support to thrive, the preferences of individual citizens and of communities at the regional level need to be well understood by decision makers.

This research provides an empirical investigation of the factors that influence and shape residents' willingness to support tax increases to fund more open space by using a unique dataset collected through an interview survey conducted in the Charlotte, North Carolina, area in the fall of 2008. In the survey, respondents were asked to vote on a number of policy options (including higher taxes) with the explicit purpose of preserving land for open space. In order to tailor effective public policies and implement land-use plans in a fast-growing metropolitan area like Charlotte, many issues concerning the relationship between the residents' willingness to protect natural resources and the environment and their support for growth management policies have to be addressed explicitly. This paper uses this dataset to examine how residents differ in their preferences for policy options aimed at preserving open-space land use within their own communities.

Surveys of citizens and population canvassing have become well-established approaches to identify, prioritize, and craft urban public policies that reflect the sensitivities and sentiment of the citizens. In particular, contingent valuation methods have been used in many earlier quantitative studies aimed at valuing nonmarket resources, such as environmental amenities, pollution, conservation programs, and biodiversity (Breffle et al. 1998; Dziegielewska and Mendelsohn 2007; Howie et al. 2010; Tienhaara et al. 2015; Treiman and Gartner 2006). Prior research on the demand for open space and individuals' willingness to pay for open space in rural and urban areas is particularly abundant. Contingent valuation studies have established the effects of income, respondents' age, level of education attainment, home ownership, and other socioeconomic variables (Beasley et al. 1986; Bergstrom et al. 1985; Bowker and Didychuk 1994; Breffle et al. 1998; Halstead 1984; Johnston et al. 2001; Lant and Roberts 1990; Lindsey and Knaap 1999; Pate and

[1]In a recent meta-analysis, Brander and Koetse (2011) conclude that estimated values of open space are also influenced by methodological differences in study design.

Loomis 1997). Another line of research of relevance to our work considers the demand for open space by using actual behavior data such as land area of open space (Bates and Santerre 2001) and voter referenda for open space (Howell-Moroney 2004; Kotchen and Powers 2006; Romero and Liserio 2002; Schmidt and Paulsen 2009; Solecki et al. 2004). The geographical scale of analysis of these studies is usually rather coarse, that is, at the municipality or county level.

When participants in a stated preference survey are prompted to express a preference for, or act on a specific commodity or environmental good, it is frequently observed that a sizeable proportion of responses are zeros, in contradiction with otherwise reported intents. These so-called protest zeros are motivated by the rejection of the principle of economic contingent valuation, strategic posturing on the part of the respondent, or a lack of understanding of the valuation task at hand (Boyle 2003). They are more likely to happen when tax payments are used as vehicles for payment, especially in US-based studies (McConnell and Walls 2005). On the other hand, the existence of overreported values has also been documented in nonmarket valuation studies (Harrison and Rutström 2008). One major reason for this bias would be that the respondent does not actually have to pay for the good in question and therefore more freely overstates their willingness to pay, while an overreported value may also increase the chance of its provision in the future. Protest zeros and protest bias have rarely been explicitly modeled in studies of willingness to pay for open space.

The presence of protest zeros brings obstacles to analyzing survey data and understanding true preferences of the respondents because the valuation data themselves are biased. To deal with it, one approach taken by researchers is asking every respondent who gives a zero value several additional follow-up questions as to why they choose to do so. Then, based on the reasons stated by those respondents, protest zeros are identified and deleted from the sample for further analysis (Freeman 2003). While it is straightforward and may appear valid at first glance, this treatment could possibly lead to biased estimates for multiple reasons (Dziegielewska and Mendelsohn 2007). Some valid zeros may be deleted by mistake, while some protest zeros are unduly kept. Furthermore, some respondents may wish to not reveal the true reason for their zero vote. Also, other types of protest votes than protest zeros exist (Meyerhoff and Liebe 2006). For example, a respondent with true preference for much higher taxes may report slightly higher taxes instead of their true preference. These situations should also be taken into account in the analysis. A second approach to dealing with the problem of protest zeros focuses on statistical techniques and econometric models that allow for both valid zeros and potential protest zeros and correct for the bias introduced by the latter. See, for example, Brouwer and Martín-Ortega (2012), Dalmau-Matarrodona (2001), Strazzera et al. (2003), and Werner (1999). However, other types of protest votes receive little attention in the framework of this second approach.

In this chapter, we examine the factors that affect respondents' willingness to support (much or slightly) higher taxes for preserving land for open space, while controlling for protest zeros econometrically.[2] To this end, two related discrete choice models are estimated in this research. As a benchmark, the first is the conventional random utility model (McFadden 1974). The second model is similar to the one-sided response bias model proposed by Hsiao and Sun (1999). The latter focuses on the situation where the systematic response bias arises from the respondents wanting to underreport their willingness to support higher taxes in the survey. The quantitative analysis in this study considers negative response bias in which protest zeros are a special case. In the econometric specification of the second model, there is a positive probability of observing underreported response. The estimated results allow us to test whether there is a negative response bias in the survey when respondents are asked about their willingness to support higher taxes for the provision of open space. The motivation for making the assumption that there is a positive probability of observing underreported response in this model is grounded in the paper by Jorgensen and Syme (2000), who find that respondents who accept to bid also exhibit protest attitudes. This differs from most studies of contingent valuation which assume implicitly that protest beliefs are unique to respondents who reject a bid.

As a point of departure from prior research, this chapter makes two major contributions to the literature. First, we analyze detailed data at the household level to understand how an individual's willingness to support tax increases for land preservation is affected by socioeconomic factors. Individual behaviors are aggregated to obtain the regional level of willingness to support higher taxes for more public open space. Second, we determine the response bias in the survey data arising from protest zeros and respondents' tendency to underreport their willingness to support higher taxes. While the discrete choice models described in this chapter focus on individual behavior, land-use planning officials and policy makers are more interested in aggregate behaviors in the community. Thus, we also aggregate the disaggregated model estimates to obtain a measure of the regional level of willingness to support land preservation through higher taxes.

The remainder of the chapter is organized as follows. Data description is provided in Sect. 2. Section 3 introduces the econometric models employed in this study with a focus on the response bias model. We report the results of the regression estimations in Sect. 4. Based on these results, discussions on the aggregation issue and the relationship between residents' attitudes and their socioeconomic status are then provided. We also discuss policy implications of the results of the research. Conclusions are drawn in the final section of the chapter.

[2]It is possible that respondents might overreport their willingness to pay in the survey. A slight modification of our econometric model (i.e., reversing the order of the three options of tax increases in the estimation process) allows us to easily test if there is such overreporting in our data sample. The results suggest that the chances that a respondent who actually prefers slightly higher taxes would select much higher taxes or slightly higher taxes are zero. The chance of a respondent choosing slightly higher taxes while their intended choice is the status quo is also zero.

2 Data Description

Data are collected from the Charlotte-Mecklenburg Annual Survey conducted by the Urban Institute of the University of North Carolina at Charlotte. The sample involved 861 residents in Mecklenburg County, North Carolina, interviewed during the fall of 2008.[3] The county contains Charlotte, the largest city in North Carolina. The questionnaire is not designed for the sole purpose of the present study, but the survey provides useful information for answering our main research questions. Respondents were asked about their willingness to support certain policy options for the preservation of open space in the area. Open space in the survey can be regarded as land that is not presently developed and will remain so for the foreseeable future. To avoid errors imputable to a misunderstanding of the voting task, the interviewers read the statement that "As the region continues to grow, open space are being threatened" before asking any of the valuation-related questions. In the survey, four policy options are presented sequentially: purchasing land to be set aside for open space, using zoning to restrict what can be built on undeveloped land, requiring developers to set aside land for open space, and dedicating tax revenue to the preservation of land as open space. Respondents are asked to vote "yes" or "no" on each of the first three options. As to the policy of tax increase, respondents were asked to choose among "much higher taxes," "slightly higher taxes," and "no tax increase." The "do not know" responses and refusal to vote are treated as "no tax increase" votes instead of dropping them from the sample.[4]

Table 1 provides summary statistics on the respondents' attitudes and their socioeconomic characteristics. Independent variables for the empirical analyses include those collected in the interviews such as respondents' age, gender, educational attainment, home ownership, marital status, ethnicity, and so on. Observations that have missing values on the independent variables are dropped from the sample. Doing this reduces the sample from 861 observations to 840. While a question on family income was part of the interview, 19.4 % of the respondents refused to answer it. This high refusal rate on income questions is typical of public opinion surveys.[5]

To assess the specificity of respondents' preferences over the four alternative policy options to preserving open space, each cell in Table 2 reports test results for the null hypotheses that respondents are indifferent between pairs of policies. No

[3]To conduct the survey, a random digit dial sample of residential telephone numbers was purchased from a private survey sampling firm. The random sample ensures that each household telephone in the county has an equal possibility of being called. Within each household, one adult (18 years or older) was designated by a random procedure to be respondent for the survey. This random selection procedure was designed to ensure that respondents of all ages and both genders were included in the survey process.

[4]We also estimated the models by dropping them from the data sample. The results from this alternative analysis are almost the same and are available from the authors.

[5]In the empirical analyses reported in section "Empirical Results," given the high number of missing data, the income variable is approximated by home ownership dummy and the dummies on the levels of educational attainment.

Table 1 Summary statistics

Variable	Categories	Percentage
Age	18–24	4.76
	25–34	12.50
	35–44	22.86
	45–54	20.48
	55–64	20.60
	65+	18.81
Gender	Male	51.07
Education	0–11 years	2.86
	12 years	13.33
	13–15 years	25.12
	16 years	36.31
	17+ years	22.38
Ethnicity	Caucasian	66.90
Home ownership	Own	81.19
Employment status	Employed	62.02
Marital status	Married	55.71
"Which of the following actions would you support?"		
Purchase land to be set aside for open space	Yes	81.55
	No	15.00
	Do not know	3.33
	Refused	0.12
Using zoning to restrict what can be built on undeveloped land	Yes	86.67
	No	9.76
	Do not know	3.57
	Refused	0.00
Require developers to set aside land for open space	Yes	88.33
	No	9.64
	Do not know	1.90
	Refused	0.12
"Would you be willing to pay ... taxes for the preservation?"	Much higher	3.33
	Slightly higher	48.33
	No increase	47.38
	Do not know	0.83
	Refused	0.12
Number of respondents: 840		

preference for either policy options considered pairwise is found to be statistically significant different, except for the comparison between using zoning to restrict what can be built on land and requiring developers to set aside land for open space. For example, we reject the null hypothesis that there is no significant difference between the options of higher taxes and purchasing land, and the level of significance of such test is at 0.000. We note that there is a possibility that the

Table 2 Nonparametric test results for reported preferences over policy options

	Zoning	Require developers to set aside land	Higher taxes
Purchase land	12.342 (0.004)	12.086 (0.000)	210.277 (0.000)
Zoning	–	5.471 (0.146)	303.442 (0.000)
Require developers to set aside land	–	–	298.067 (0.000)

Notes: Numbers in the upper triangle are Pearson χ^2 and the associated *p*-values in parentheses

order of the policy options presented in the survey instrument may bring bias in the test results. However, because the significance/insignificance of the test results in Table 2 is at a high level, we believe that the above inferences are reasonable. We cannot test if such order bias actually exists in our sample due to data limitation.

The following analyses focus on the respondents' willingness to support higher taxes. In our survey sample, 48.33 % of the respondents choose not to increase taxes for more open space in their community. On the other hand, the sample includes 51.67 % of respondents whose stated choice is for slightly higher or much higher taxes to fund more open space. It should be pointed out that the rate of support for higher taxes in this area is lower than the average of 61 % of the electorate voting positively in 968 referenda for open-space conservation that occurred in the United States between 1998 and 2003 (Kotchen and Powers 2006).

3 Econometric Model

We start with a conventional random utility model (McFadden 1974). Let the set $\{0, 1, ..., M\}$ denote the set of mutually exclusive and collectively exhaustive choice alternatives faced by individuals participating in the survey. In this paper, the choice set contains the three different hypothesized levels of future taxation that were presented to the respondents during the phone interview. Let U_{jn} be the indirect utility associated with the jth choice (i.e., the jth level of higher taxes in the present paper) for respondent n,

$$U_{jn} = x_n \beta_j + \varepsilon_{jn}, \tag{1}$$

where x_n is the vector of independent variables[6] measuring socioeconomic characteristics of respondent n and ε_{jn} is an error term. Given the possible incidence of respondents' protest vote, a distinction needs to be made between the stated and intended choice of each respondent. While the former has been recorded during the

[6]There are no choice-specific independent variables in our data sample. The discrete choice models presented in this chapter can be extended to consider such variables.

survey, the latter has not and needs to be imputed. The intended choice is motivated by the true motivations and preferences of the respondent. It is given by

$$y^*_{jn} = \begin{cases} 1 & \text{if } U_{jn} = \max\left(U_{0n}, U_{1n}, \ldots, U_{Mn}\right), \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

Then the probability of respondent n choosing the jth level of higher taxes in the survey (i.e., $y^*_{jn} = 1$) is $\text{prob}\left(y^*_{jn} = 1\right) = F_j\left(x_n\beta_0, x_n\beta_1, \ldots, x_n\beta_M\right) \equiv F_{jn}$, where $F_j(\cdot)$ is a distribution function derived from the density function of the error term ε_{jn}. For example, the multinomial logit model (McFadden 1974; Maddala 1983) gives that when ε_{jn} is independently and identically distributed across j and n according to a Type I extreme-value density function,

$$\text{prob}\left(y^*_{jn} = 1\right) = \frac{e^{x_n\beta_j}}{\sum_{l=0}^{M} e^{x_n\beta_l}} = \frac{e^{x_n\alpha_j}}{1 + \sum_{l=1}^{M} e^{x_n\alpha_l}} = F_{jn}, \tag{3}$$

where $\alpha_l = \beta_l - \beta_0$.

Note that a respondent's intended choice can be systematically different from their stated choice in our data sample, in that the latter may be affected by a protest bias. Let y_{jn} denote the respondent's choice as stated during the survey interview,

$$y_{jn} = \begin{cases} 1 & \text{if the } j\text{th alternative is chosen by respondent } n, \\ 0 & \text{otherwise.} \end{cases} \tag{4}$$

If the respondents happen to state their intended choice in the survey, we have the conventional random utility model since

$$\text{prob}\left(y_{jn} = 1\right) = \text{prob}\left(y^*_{jn} = 1\right). \tag{5}$$

As discussed earlier, respondents tend to underreport their willingness to support higher taxes for preserving open space. Following Hsiao and Sun (1999) who model positive response bias in a product marketing research, we assume that there is a one-sided negative response bias in the data collected from the survey. Respondents whose intended choice is a specific level of taxation for open space tend to declare a preference for a lower level of taxation and thus present a negative response bias. To model such bias, we introduce an indicator w_{jn} with probability $\pi_{jn} \in [0, 1]$ that $w_{jn} = 1$ and probability $1 - \pi_{jn}$ that $w_{jn} = 0$. The alternatives are indexed so that larger j denotes a higher level of tax increases. Because of the tendency to underreport their willingness to support higher taxes, a respondent will choose the level j only in the following two cases: First, the intended choice is level j, and she/he does not report a lower level than that in the phone interview (i.e., $y^*_{jn} = 1$ and $w_{j'n} = 0$ for all $j' \leq j$). Second, the intended choice is a level of taxation higher than j, but she/he reports j in the interview (i.e., $w_{jn} = 1$ and $y^*_{j'n} = 1$ for all $j' > j$).

Formally, the probability of any respondent n choosing level $j \in \{1, 2, \ldots, M-1\}$ can be written as

$$\begin{aligned}
\text{prob}\left(y_{jn}=1\right) &= \text{prob}[(y_{jn}^{*}=1 \quad \text{and} \quad w_{j'n}=0 \quad \text{for} \quad j' \leq j) \\
&\qquad \text{or} \quad (w_{jn}=1 \quad \text{and} \quad y_{j'n}^{*}=1 \quad \text{for} \quad j' > j)] \\
&= \left[1-\sum_{i=0}^{j-1}\pi_{in}\right]F_{jn}+\pi_{jn}\sum_{i=j+1}^{M}F_{in}, \\
\text{prob}\left(y_{Mn}=1\right) &= \left[1-\sum_{i=0}^{M-1}\pi_{in}\right]F_{Mn},
\end{aligned} \tag{6}$$

and

$$\text{prob}\left(y_{0n}=1\right)=1-\sum_{j=1}^{M}\text{prob}\left(y_{jn}=1\right). \tag{7}$$

In this model, only the respondents whose intended choice is alternative j' could have positive chances to choose alternative j for $j \leq j'$ in the interview. There is no chance that a respondent with intended choice j will choose any higher level j'' ($j''>j$). It follows from (7) that $\text{prob}\left(y_{0n}=1\right) > \text{prob}\left(y_{0n}^{*}=1\right)$, which denotes a protest zero bias in our response bias model. This suggests that the probability of observing that a respondent reports no tax increase is greater than the probability that the intended choice is no increase. The model setup also indicates that $\text{prob}\left(y_{Mn}=1\right) < \text{prob}\left(y_{Mn}^{*}=1\right)$. However, the sign of the difference between $\text{prob}\left(y_{jn}=1\right)$ and $\text{prob}\left(y_{jn}^{*}=1\right)$ for $M>j>0$ could be nonpositive or nonnegative.

The models can be estimated by maximizing the following log-likelihood function

$$\log L=\sum_{n=1}^{N}\sum_{j=0}^{M}y_{jn}\log\left[\text{prob}\left(y_{jn}=1\right)\right], \tag{8}$$

where $\text{prob}\left(y_{jn}=1\right)$ is defined by (2) in the random utility model and by (7) in the response bias model. Sun (1995) shows that the MLE estimator for the response bias model is consistent and asymptotically normally distributed with the asymptotic covariance matrix equal to the inverse of the negative of the information matrix.

To get a more flexible version of the response bias model, one can further let $\pi_{jn} = G_j\left(\eta_j' x_n\right)$ where $G_j(\cdot)$ is a probability function. For more information on this setup, see Hsiao and Sun (1999). This extended setup may allow one to link the characteristics of a respondent with the chance of underreporting. The links are described by the coefficients $\eta_j^{'}$ s. To estimate, a format for distribution function $G_j(\cdot)$ should be assumed. Given that survey respondents are very likely to underreport their willingness to support tax increases, we estimate the response bias model with the assumption that $\pi_{jn} = \pi_j$ for any n and $j = 1,2$.

4 Empirical Results

This section reports the econometric results of applying the abovementioned random utility model and response bias model to the 2008 Charlotte-Mecklenburg survey data. Both models take logit specifications. The results on response bias are reported first, followed by those on the socioeconomic factors that affect respondents' willingness to support higher taxes for the preservation of open space. Individual preferences are also aggregated to obtain a regional level of willingness to support open-space expansion.

4.1 Overall Model Estimation

Table 3 reports estimation results from the random utility model with logit specification (multinomial logit model) and from the response bias model when there are three choices for the respondents—much higher taxes, slightly higher taxes, and no tax increase. The base category for the estimation is no tax increase. It is found that both model selection criteria—Akaike Information Criterion (Akaike 1973) and the percentage of correct prediction—favor the response bias model in Table 3.

We note that there are no explicit boundaries assigned for "much higher taxes" or "slightly higher taxes" in the phone survey instrument. Respondents may have their own interpretations of these two alternatives, which could possibly make our discrimination between the two choice alternatives inappropriate. Accordingly, to evaluate this possibility, we recode the response variable by collapsing the options of "much higher taxes" and "slightly higher taxes" into one single category—"higher taxes." Estimation results for the reclassified response variable of higher taxes are reported in Table 4 where the base category is again no increase in taxes. Even with the reclassification, it is found that the response bias model performs better than the random utility model according to the two criteria for model selection.

Table 5 is a detailed prediction success table for the models. The first two panels are for the models with three alternatives—much higher taxes, slightly higher taxes, and no tax increase. Each column corresponds to a predicted alternative and each row corresponds to a stated choice. For example, the number 22 in the first row of the table is the number of persons who chose "much higher taxes" and are predicted to choose "slightly higher taxes." We report the percentage of correct prediction for each category. For the "slightly higher taxes" alternative in the response bias model, 72.66 % of choices are predicted correctly. The figures suggest that it is easier to predict slightly higher taxes than to predict no tax increase in both models.

Table 3 Estimates of the willingness to support slightly and much higher taxes

Variable	Descriptions	Random utility model		Response bias model	
		Slightly	Much higher	Slightly	Much higher
Intercept		−0.39	−2.25**	−4.26	−0.76
		(0.37)	(0.91)	(2.68)	(0.87)
Age	25–34	−0.65	−1.92*	−4.30**	−0.76
		(0.40)	(1.09)	(1.98)	(0.91)
	35–44	−0.35	−1.07	−0.41	−0.27
		(0.38)	(0.90)	(1.43)	(0.93)
	45–54	−0.75**	−0.83	−3.15*	−0.59
		(0.38)	(0.88)	(1.76)	(0.90)
	55–64	−0.51	−2.08**	0.63	−1.99**
		(0.38)	(1.01)	(1.55)	(1.00)
	65+	−1.36***	−2.35**	−1.28	−2.87***
		(0.39)	(1.00)	(1.47)	(1.01)
Gender	Male	0.07	−0.81*	6.31**	−1.45***
		(0.15)	(0.42)	(2.73)	(0.55)
Education	13–15 years	0.32	−0.11	−1.44	1.55***
		(0.24)	(0.79)	(1.18)	(0.51)
	16 years	0.68***	0.59	2.15**	1.29***
		(0.23)	(0.71)	(0.94)	(0.48)
	17+ years	0.98***	1.74**	−1.38	3.26***
		(0.25)	(0.71)	(2.05)	(0.79)
Ethnicity	Caucasian	0.73***	0.93**	−1.34	2.40***
		(0.16)	(0.47)	(1.12)	(0.59)
Response bias	Probability of respondents choosing slightly higher taxes				0.6633***
					(0.04)
	Probability of respondents choosing no tax increase			0.2709***	
				(0.04)	
−log$L$		642.24		621.77	
Correct prediction		59.88 %		62.74 %	

Notes: Number of observations is 840. Standard errors are in parentheses
**, **, and * indicate significance at 1 %, 5 %, and 10 %, respectively

The response bias model is much better than the random utility model when we want to predict slightly higher taxes. Neither the random utility model nor the response bias model can correctly predict "much higher taxes," and we note that the response bias model has lower percentages of correctly predicting "no tax increases." The source of the difference may be ascribed to the negative response bias found to exist in the Charlotte survey and established by the response bias models. This bias makes the response bias model predict that fewer respondents choose "no taxes increases" and that more respondents choose "slightly higher

Table 4 Estimates of the willingness to support higher taxes

Variable	Descriptions	Random utility model	Response bias model
Intercept		−0.27	0.56
		(0.37)	(0.92)
Age	25–34	−0.72*	−1.68*
		(0.39)	(1.02)
	35–44	−0.39	−0.75
		(0.37)	(1.01)
	45–54	−0.74**	−1.80*
		(0.37)	(1.01)
	55–64	−0.59	−1.51
		(0.37)	(1.02)
	65+	−1.42***	−3.07***
		(0.38)	(1.11)
Gender	Male	0.02	0.67
		(0.15)	(0.46)
Education	13–15 years	0.30	0.75*
		(0.23)	(0.45)
	16 years	0.68***	1.45***
		(0.22)	(0.50)
	17+ years	1.03***	2.51**
		(0.24)	(1.01)
Ethnicity	Caucasian	0.73***	1.59***
		(0.16)	(0.48)
Response bias	Probability of respondents choosing no tax increase		0.3210***
			(0.05)
$-\log L$		545.95	543.48
Correct prediction		61.90 %	62.86 %

Notes: Number of observations is 840. Standard errors are in parentheses
**, **, and * indicate significance at 1 %, 5 %, and 10 %, respectively

taxes." That is true for each of the three groups who actually choose different levels of tax increases in the survey. Most notably, the prediction results in Table 5 show that 41 more respondents are correctly predicted to choose "slight higher taxes" in the response bias model than in the corresponding random utility model, although 17 fewer respondents are correctly predicted to choose "no tax increases" by the response bias model. In spite of the latter results, figures of correctly predicting "no tax increases" (i.e., 57.14 % for the data with three categories and 46.31 % for the recategorized data with two categories) suggest that the response bias models perform fairly well for predicting the "no tax increases" alternative in our cross-section data. Overall, as shown in Tables 3 and 4, the response bias models have better prediction performance based on the (overall) percentages of correct

Table 5 Prediction success table

Predicted alternatives					
	Actual alternatives	Much higher	Slightly higher	No increase	Observed total
Response bias model	Much higher taxes	0	22	6	28
	Slightly higher taxes	0	295	111	406
	No increase	0	174	232	406
	Percent correct (%)	0.00	72.66	57.14	
Random utility model	Much higher	0	16	12	28
	Slightly higher	0	254	152	406
	No increase	0	157	249	406
	Percent correct (%)	0.00	62.56	61.33	
			Higher taxes	No increase	Observed total
Response bias model	Higher taxes		340	94	434
	No increase		218	188	406
	Percent correct (%)		78.34	46.31	
Response bias model	Higher taxes		311	123	434
	No increase		197	209	406
	Percent correct (%)		71.66	51.48	

prediction. The tables also indicate that the response bias models are preferred according to the Akaike Information Criterion.

We also estimate a response bias model with ordered logit specification for the data with three choice alternatives since the three choice options represent decreasing orders of magnitude in taxation. Both criteria still favor the response bias model with an unordered logit specification.[7]

We conduct several additional robustness checks. It is found that our main results are insensitive to the inclusion of some other independent variables (e.g., home ownership, employment status, marital status) and the exclusion of some independent variables (e.g., variables of age, education, or gender) in the regressions. Estimated coefficients for the independent variables are qualitatively the same as reported in Tables 3 and 4. Estimated response biases are also of similar magnitude.

[7]Results from the ordered logit model are available from the authors upon request. As for the response bias estimated from the response bias model with ordered logit specification, it is found that the respondents whose intended choices are much higher taxes have about a 63.34 % chance to select slightly higher taxes during the phone interview. A respondent will have 31.22 % chance of choosing no tax increases while their intended choice is much higher taxes or slightly higher taxes.

4.2 Size of the Response Bias

Table 3 suggests that there is statistically significant response bias in the data sample when the respondents face three options with respect to raising taxes for the preservation of open space. We find that respondents tend to underreport their willingness to support higher taxes and that they are inclined to declare a preference for no tax increase. The respondents who actually prefer much higher taxes have about a 66.33 % chance to select slightly higher taxes during the phone interview. A respondent will have 27.09 % chance of choosing no tax increases while their intended choice is much higher taxes or slightly higher taxes.

In the regressions for the reclassified response variables—one single "higher taxes" versus no tax increase—reported in Table 4, results indicate that there is about a 32.10 % chance that an individual will choose no tax increases while she/he actually favors higher taxes.

While the abovementioned estimated chances of protest zero come from a specific econometric model on our data, some idea about the plausibility of these results can be obtained by looking at empirical evidence reported in the literature concerning the percentage of protest zeros in the valuation studies on other types of environmental goods. Dziegielewska and Mendelsohn (2007) identify 27 % of an air pollution data sample from Poland as protesters. Halstead et al. (1992) examine survey responses to a study of wildlife valuation in New England and determine that the share of protesters in the data sample is 32 %. In a case study involving endangered species, Kotchen and Reiling (2000) find that 19 % of the data sample collected in Maine are protest responses. Hence, our own analysis is by and large in line with other studies of protest vote in environmental goods valuation. When comparing the estimated chances of protest zeros in this paper to the results from previous studies, we should keep in mind that a much wider range of chances has been reported in the literature.

4.3 Socioeconomic Influences on Individual's Willingness

We explain how an individual's socioeconomic characteristics influence their true willingness to support higher taxes for the express purpose of preserving open space. Though the empirical models present varying estimated coefficients, some general observations can be made.

Estimated coefficients for some of the age categories are found statistically significant in Tables 3 and 4. The estimates for the response bias model reported in Table 3 indicate that the older individuals (aged 55 and above) are more likely to actually want to veto much higher taxes than other groups aged between 25 and 54. It is shown in Table 4 that respondents aged 65 and above are more reluctant to actually support tax increases for the preservation of open space. Younger respondents aged 18–24 have higher probability of wanting higher taxes than other age groups.

The response bias model in Table 3 suggests that male respondents are more likely to choose slightly higher taxes and they are more likely to veto much higher taxes than female respondents. The random utility model presents qualitatively similar results. However, the coefficient in the choice of slightly higher taxes in the random utility model is not significant, and it is much less than that obtained from the response bias model. When the two alternatives of higher taxes are reclassified in Table 4, the estimated coefficient for male variable in both models is positive, but the effect is not statistically significant.

Except for the choice of slightly higher taxes in the response bias model, the coefficient of the ethnic variable is positive and significant. Both the random utility models and the response bias models in Tables 3 and 4 generate results suggesting that Caucasians are more willing to support higher taxes for the preservation of open space than other ethnic groups.

Generally speaking, our empirical analysis finds that the higher the level of educational attainment a person has, the more she/he will favor higher taxes for more open space. This result holds in most cases that are reported in Tables 3 and 4, and it may reflect a preference for the provision of environmental good by the educated people (Kahn and Matsusaka 1997) and/or reflect the correlation between income (which correlated positively to education) and the demand for open space. The two possible sources cannot be quantified because no income variable is included in the analysis. Also, it is possible that the estimated significances of the age cohorts are partially indicative of actual income and potential lifelong earnings and the ability to pay higher taxes. Due to a large amount of nonresponse on income information from the survey, we cannot test the linkages. The previous results on ethnicity may also practically indicate the effects of income. According to the Census data, Caucasians' average income is greater than the average income for non-Caucasians in the study area.

We control other independent variables in the regression exercises. House ownership, employment status, and marital status have no significant roles in determining one's attitudes toward paying higher taxes for the preservation of open space.[8]

The location of a household and land-use patterns around it may also have effects on their attitudes. We try to control such effects. Locations of the respondents are identified through their residential zip codes revealed by themselves in the interview. Each zip code area's distance to the Central Business District (CBD) of the city of Charlotte is measured in road miles. The availability of surrounding public open space may affect an individual's attitudes; we consider the percentage of land within 0.5 mile of each area in public open space. Data on the location and land acreage of public open space (i.e., public parks and recreational facilities) in December 2008 come from the Division of Nature Preserves & Natural Resources, Mecklenburg County Park and Recreation. The estimated coefficient for the distance to the CBD is not different from zero. Also, the estimated coefficient for the percentage of

[8]Results are available upon request from the authors.

public open-space land within 0.5 mile of each zone is not statistically different from zero. One possible explanation for this result is the balance between Tiebout sorting and the substitution effect of existing open space. The former effect can increase a respondent's willingness to support more open-space conservation, while the latter effect decreases it. One also expects that the respondents' preferences for higher taxes are also influenced by the availability of private open space because it can serve as a substitute for public open space. Due to data limitation, the effects of private open space cannot be quantified.

The above estimated coefficients can be used to estimate an individual's actual preferences for each choice, prob $\left(y_j^* = 1 \middle| x\right)$. As an example, from Table 1, we define a "median" individual as the one with each variable equal to its median value. That is, a median respondent has the following characteristics: aged between 45 and 54, male, 16 years of education, and Caucasian. We note first that this "median" individual is selected from our sample and used a straw man to show the effects of changes in his characteristics on willingness to support higher taxes. He may have characteristics differing from the true median individual. Later in this paper, we will analyze the regional willingness using more statistical information for the whole region. Calculation using the estimates for the response bias model shows that there is a 58.30 % probability that a median individual actually prefers much higher taxes and the probabilities for slightly higher taxes and no increases are 17.78 % and 23.92 %, respectively. In contrast, the random utility model suggests that there is 40.10 % probability that a median respondent is willing to see that there is no tax increase. And the probability for much higher taxes is only 3.77 % for a median individual. When the two levels of higher taxes are grouped into one single variable, the response bias model found that the median respondent has a 92.21 % probability that he actually favors tax increases. The corresponding number from the random utility model is 60.39 %. The differences between estimated probabilities from the response bias model and the random utility model can be imputed to the large chances of systematically negative response bias. We can also calculate the probabilities for individuals with other socioeconomic characteristics by using the estimated coefficients. Now consider a respondent who has the above characteristics except that he has a high school diploma. The response bias models show that there is 38.09 % probability that he actually prefers much higher taxes, while the probability for slightly higher taxes is 4.93 %. In contrast, the probabilities estimated from the random utility model are 2.94 % and 40.33 %, respectively. More examples are illustrated in Fig. 1.

We are also interested in examining the effect on the willingness to support of each independent variable. To estimate the effect of a change in one variable, we need to specify the values of other variables. The "marginal" effects of each independent variable on an individual's true willingness can be quantified. Figure 1 shows the effects of age and the level of educational attainment. The probabilities are calculated by using estimates from the response bias model and the associated level of age or educational attainment, while other characteristics are set equal to those of the median respondent. As above, the probabilities of supporting "much higher taxes" and "slightly higher taxes" are obtained from the models with three choices and that on "higher taxes" from the models with two choices.

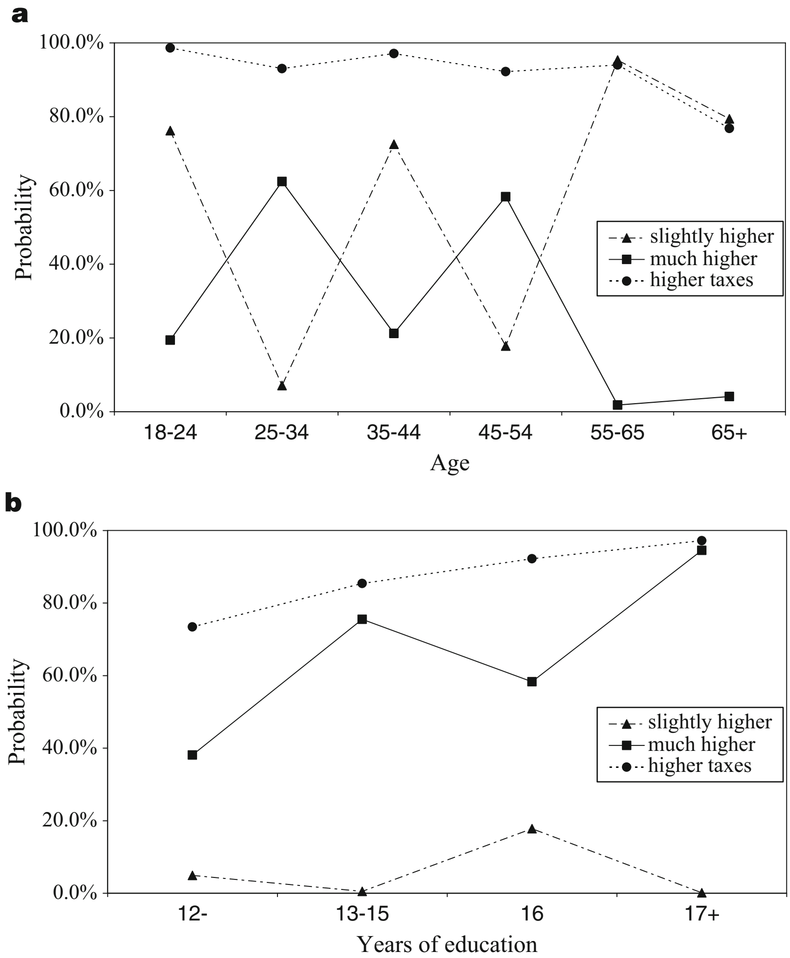

Fig. 1 Age, years of education, and the estimated probabilities. (**a**) Age and the estimated probability of support. (**b**) Years of education and estimated probabilities of support

4.4 The Regional Level of Willingness

The discrete choice models discussed above focus on individual preferences of the respondents, while land-use planning officials and policy makers are more interested in aggregate preferences and behaviors. Accordingly, we calculate a regional level of willingness to support higher taxes by aggregating the disaggregated model to the whole city.

We note that Caucasians are overrepresented in our data sample from the survey. According to the 2008 American Community Survey, 60.35 % of Mecklenburg County residents are Caucasian. Accordingly, we need to weight our data sample to calculate an unbiased sample of the regional level of willingness for the whole county. Also, seniors are overrepresented in our data sample. To correct the overrepresentation or underrepresentation of particular groups and calculate the regional level of willingness, we follow a widely used weighting method (Hsiao and Sun 1999) and statistical information from the US Census Bureau. For age cohort i of the ethnic groups, g, the aggregate proportion of choosing the jth option is approximated by

$$\hat{P}(j)_{gi} = \frac{1}{N_{gi}} \sum_{n=1}^{N} \text{prob}\left(y_j^* = 1 \middle| x_n\right), \quad g = 1, 2; \quad i = 1, \ldots, 6, \tag{9}$$

where N_{gi} is the number of respondents of age i with ethnicity g in the data sample. Then the regional level of willingness is calculated by

$$\hat{P}(j) = \sum_{g=1}^{2} \sum_{i=1}^{6} s_{gi} \hat{P}(j)_{gi}, \tag{10}$$

where s_{gi} is the share of population of age cohort i with ethnicity g in the County's whole population over the age of 18. The shares are obtained from the 2008 American Community Survey published by US Census Bureau.

Table 6 presents the estimated results of the willingness to support tax increases from the random utility model and the response bias model at the regional level. For comparison purposes, the weighted reported level of willingness is also presented. The first set of results in Table 6 uses two categories of higher taxes (i.e., slightly higher and much higher). If the weighted data is well representative of the whole population of the County, the response bias model finds that the regional willingness to support much higher taxes is 52.02 %, which is much greater than the percentage of support in the survey and than that from the random utility model. It gives 19.88 % of regional willingness to support slightly higher taxes which is much lower than the level indicated by the random utility model. The source for those differences is the large chance of systematically negative response bias. The second set of aggregate results is based on the reclassified single "higher taxes" response variable. Results

Table 6 Estimated regional willingness to support higher taxes

	Reported level (%)	Random utility model (%)	Response bias model (%)
Much higher taxes	3.45	3.54	52.02
Slightly higher taxes	49.14	48.96	19.88
No tax increases	47.42	47.50	28.10
Higher taxes (reclassified category)	52.58	52.50	77.28
No tax increases	47.42	47.50	22.72

show that the regional level of true willingness is 77.28 %. In contrast, the random utility model suggests that the regional level of willingness is only 52.50 %.

4.5 Policy Implications

The findings of this paper point to significant policy implications. Results underscore the significant variability of support for land preservation in the population on the basis of demographic and socioeconomic profiles. Land-use plans encompassing a component of land safeguarding from future development in a region should be responsive to the changes in variables such as age structure, ethnic composition of population, and level of educational attainment across the region. While it is easier to conceive, the "one size fits all" approach to building liveable communities through land preservation is disconnected from the aspirations of residents and is likely to miss the mark in some communities. Land-use planning strategies will be on a politically and financially sustainable course only if they are crafted with the full recognition that communities differ by their aspirations, visions, and priorities.

When public opinion surveys are referenced in public debates on raising taxes for open-space preservation, it is important to note that the public's true preference cannot be fully understood without considering possible biases in people's reported willingness to support higher taxes for the stated purpose. For this case study of the Charlotte/Mecklenburg, North Carolina, area, we found no evidence of tendency to overstate their approval of higher taxes. On the contrary, empirical results strongly demonstrate that there is a sizeable amount of underreported willingness to pay through higher taxes for more open space protected from development. The literal reading of survey results is misleading to policy makers and public officials in that it may be interpreted as lack of support for open-space preservation within the urban fabric. The hidden truth is that a broad base of support exists for more liveable communities.

Though the corrected regional level of willingness may call for raising taxes for the preservation of open space, some individuals may actually be worse off if an increased tax is levied on their income or property. Policy intervention is optimal only if it considers individual heterogeneity in socioeconomic characteristics. Empirical results from this research can be used to identify who really wants more taxes for open-space conservation and who does not.

5 Conclusions

This paper examines how an individual's socioeconomic characteristics affect their willingness to support tax increases for the preservation of open space in a fast-expanding urban area. We control and estimate potential response bias in the data sample obtained from a survey conducted in the Charlotte, North Carolina, area.

Individual decisions are also aggregated across the region to get a measure of the regional level of willingness to support.

Empirical results show that an individual's attitudes toward paying higher taxes for more open space are affected by the individual's age, gender, ethnicity, and the level of educational attainment. It is found that respondents tend to grossly underreport their willingness to support higher taxes for the preservation of open space in the survey. They exhibit positive tendency to choose no increase in taxes in the survey, although they actually prefer an increase over no increase. Because the estimation framework used in the paper allows for protest zero bias and negative response bias, we established that support for environment preservation policies in the urban region of Charlotte, North Carolina, is much more widespread than raw survey results could suggest. It can also be extended to analyze survey data with positive bias identified by many studies on the willingness to pay (WTP) for environmental goods in the contingent valuation literature (see, e.g., Cummings and Taylor 1999). Future research will examine residents' WTP for the preservation of open space by using a specially designed survey questionnaire and controlling systematic response bias in the analyses. Specific attention will also be devoted to exploring the existence and magnitude of neighborhood effects that may permeate personal attitudes with respect to environmental preservation and other quality of life issues of relevance to urban communities. Finally, a socioeconomic analysis of protest votes will provide important insights into the hidden dimensions of the land preservation debate and, by extension, inform policy makers on the depth of social endorsement of other policy tools of the urban sustainability movement.

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References

Akaike H (1973) Information theory and extension of the maximum likelihood principle. In: Petrov BN, Csaski F (eds) Proceedings of the 2nd international symposium on information theory. Akadémiai Kiadó, Budapest, pp 267–281

Balsdon EM (2012) Property value capitalization and municipal open space referenda. Land Econ 88:201–232

Bates LJ, Santerre RE (2001) The public demand for open space: the case of Connecticut communities. J Urban Econ 50:97–111

Beasley S, Workman W, Williams N (1986) Estimating amenity values of urban fringe farmland: a contingent valuation approach. Growth Chang 17:70–78

Bergstrom J, Dillman B, Stoll J (1985) Public environmental amenity benefits of private land: the case of prime agricultural land. South J Agric Econ 17:139–149

Bowker JM, Didychuk D (1994) Estimation of the nonmarket benefits of agricultural land retention in eastern Canada. Agric Resour Econ Rev 23:218–255

Boyle KJ (2003) Contingent valuation in practice. In: Champ PA, Boyle KJ, Brown TC (eds) A primer on nonmarket valuation. Kluwer Academic Publishers, Dordrecht, pp 111–169

Brander LM, Koetse MJ (2011) The value of urban open space: meta-analyses of contingent valuation and hedonic pricing results. J Environ Manage 92:2767–2773
Breffle WS, Morey ER, Lodder TS (1998) Using contingent valuation to estimate a neighbourhood's willingness to pay to preserve undeveloped urban land. Urban Stud 35:715–727
Brouwer R, Martín-Ortega J (2012) Modeling self-censoring of polluter pays protest votes in stated preference research to support resource damage estimations in environmental liability. Ecol Econ 34:151–166
Bullock CH (2008) Valuing urban green space: hypothetical alternatives and the status quo. J Environ Plan Manag 51:15–35
Cho SH, Poudyal NC, Roberts RK (2008) Spatial analysis of the amenity value of green open space. Ecol Econ 66:403–416
Cummings RG, Taylor LO (1999) Unbiased value estimates for environmental goods: a cheap talk design for the contingent valuation method. Am Econ Rev 89:649–665
Dalmau-Matarrodona E (2001) Alternative approaches to obtain optimal bid values in contingent valuation studies and to model protest zeros. Estimating the determinants of Individuals' willingness to pay for home care services in day case surgery. Health Econ 10:101–118
Dziegielewska DA, Mendelsohn R (2007) Does 'No' mean 'No'? A protest methodology. Environ Resour Econ 38:71–87
Freeman AM (2003) The measurement of environmental and resource values: theory and methods. Resources for the Future, Washington, DC
Halstead JM (1984) Measuring the nonmarket value of Massachusetts agricultural land: a case study. J Northeast Agric Econ Counc 13:12–19
Halstead JM, Luloff AE, Stevens T (1992) Protest bidders in contingent valuation. Northeast J Agric Resour Econ 21:160–169
Harrison GW, Rutström EE (2008) Experimental evidence on the existence of hypothetical bias in value elicitation methods. In: Plott C, Smith VL (eds) Handbook of experimental economics results. Elsevier, New York
Howell-Moroney M (2004) Community characteristics, open space preservation and regionalism: is there a connection? J Urban Aff 26:109–118
Howie P, Murphy SM, Wicks J (2010) An application of a stated preference method to value urban amenities. Urban Stud 47:235–256
Hsiao C, Sun B-H (1999) Modeling response bias-with an analysis of the demand for an advanced electronic device. J Econom 89:15–39
Irwin EG (2002) The effects of open space on residential property values. Land Econ 78:465–481
Johnston R, Opaluch J, Grigalunas T, Mazzotta M (2001) Estimating amenity benefits of coastal farmland. Growth Chang 32:305–325
Jorgensen BS, Syme GJ (2000) Protest responses and willingness to pay: attitude toward paying for storm water pollution abatement. Ecol Econ 33:251–265
Kahn ME, Matsusaka JG (1997) Demand for environmental goods: evidence from voting patterns on California initiatives. J Law Econ 40:137–173
Kang CD, Cervero R (2009) From elevated freeway to urban greenway: land value impacts of the CGC project in Seoul. Korea Urban Stud 46:2771–2794
Kotchen MJ, Powers SM (2006) Explaining the appearance and success of voter referenda for open-space conservation. J Environ Econ Manag 52:373–390
Kotchen MJ, Reiling SD (2000) Environmental attitudes. Motivations, and contingent valuation of non-use values: a case study involving endangered species. Ecol Econ 32:93–107
Lant CL, Roberts RS (1990) Greenbelts in the cornbelt: riparian wetlands, intrinsic values and market failure. Environ Plan A 22:1375–1388
Lindsey G, Knaap G (1999) Willingness to pay for urban greenway projects. J Am Plann Assoc 65:297–313
McConnell V, Walls M (2005) The value of open space: evidence from studies of nonmarket benefits, working paper. Resources for the Future, Washington, DC
Maddala GS (1983) Limited-dependent and qualitative variables in econometrics. Cambridge University Press, New York

McFadden D (1974) Conditional logit analysis of qualitative choice behavior. In: Zarembka P (ed) Frontiers in econometrics. Academic, New York

Meyerhoff J, Liebe U (2006) Protest beliefs in contingent valuation: explaining their motivation. Ecol Econ 57:583–594

Panduro TE, Veie KL (2013) Classification and valuation of urban green spaces—a hedonic house price valuation. Landsc Urban Plan 120:119–128

Pate J, Loomis J (1997) The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. Ecol Econ 20:199–207

Romero F, Liserio A (2002) Saving open spaces: determinants of 1998 and 1999 “Antisprawl” ballot measures. Soc Sci Q 83:341–352

Schmidt S, Paulsen K (2009) Is open space preservation a form of exclusionary zoning? The evolution of municipal open space policies in New Jersey. Urban Aff Rev 45:92–118

Solecki WD, Mason RJ, Martin S (2004) The geography of support for open-space initiatives: a case study of New Jersey’s 1988 ballot measure. Soc Sci Q 85:624–638

Sun B-H (1995) Econometric analysis of survey response bias-with an application to the demand for an advanced electronic device, Ph.D Dissertation, University of Southern California, Los Angeles

Strazzera E, Scarpa R, Calia P, Garrod GD, Willis KG (2003) Modelling zero values and protest responses in contingent valuation surveys. Appl Econ 35:133–138

Tienhaara A, Ahtiainen H, Pouta E (2015) Consumer and citizen roles and motives in the valuation of agricultural genetic resources in Finland. Ecol Econ 75:37–44

Treiman T, Gartner J (2006) Are residents willing to pay for their community forests? Results of a contingent valuation survey in Missouri, USA. Urban Stud 43:1537–1547

Tyrväinen L, Väänänen H (1998) The economic value of urban forest: an application of the contingent valuation method. Landsc Urban Plan 43:105–118

Werner M (1999) Allowing for zeros in Dichotomous choice contingent valuation models. J Bus Econ Stat 17:479–486

On Capital Taxation and Economic Growth and Welfare in a Creative Region

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Abstract We follow Donovan and Batabyal (Int Rev Econ Financ, 38:67–72, 2015) and study the effects of physical capital or investment income taxation on economic growth and welfare in a region that is creative in the sense of Richard Florida. This region possesses physical and creative capital. Our analysis leads to six findings. First, we demonstrate the effect of the investment income tax ζ on steady-state consumption and physical capital per effective creative capital unit, denoted by c and k, respectively. Second, we show how the economy of our creative region responds to the implementation of ζ. Third, we compare c and k on the new balanced-growth path (BGP) with c and k on the old or pretax BGP. Fourth, we study the effect of ζ in an aggregate economy consisting of many creative regions. Fifth, we analyze whether a policy of subsidizing investment and raising the revenue for this subsidy with lump-sum taxes increases welfare in our creative region. Finally, we study the impacts in our creative region when, instead of rebating the revenue from ζ to the creative class households, the taxing authority (TA) in this region makes purchases.

Keywords Creative capital • Creative region • Economic growth • Investment income • Taxation

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1 Introduction

Regional scientists and urban economists are now very familiar with the twin notions of the *creative class* and *creative capital*. According to Florida (2002, p. 68), the creative class "consists of people who add economic value through their creativity." This class is made up of professionals such as doctors, lawyers, scientists, engineers, university professors, and, notably, bohemians such as artists, musicians, and sculptors. These individuals are significant because they possess creative capital which is defined to be the "intrinsically human ability to create new ideas, new technologies, new business models, new cultural forms, and whole new industries that really [matter]" (Florida 2005, p. 32). Florida emphasizes that the creative class is salient because this group gives rise to ideas, information, and technology, outputs that are important for the growth of cities and regions. Therefore, cities and regions that want to succeed in the global arena need to do all they can to draw in members of this creative class because this class, we are told, is the main driver of economic growth.

A variety of perspectives have been used by researchers thus far to examine the two concepts of creative capital and the creative class. Nathan (2007) finds little evidence for the existence of a creative class in a number of British cities. McGranahan and Wojan (2007) concentrate on rural counties in the United States of America (USA) and find support for Florida's creative class thesis. Florida et al. (2008) show that the creative class idea outperforms conventional educational attainment measures in accounting for regional labor productivity measured with *wages*. However, conventional educational attainment measures are a better predictor of regional *income* than the creative class idea.

The subject of economic growth in creative regions has been looked at by several researchers. For instance, Batabyal and Nijkamp (2010) focus on a two-sector trading regional economy and provide the first formal analysis of the creative capital accumulation decision faced by individuals in this regional economy. More recently, Batabyal and Nijkamp (2011) have analyzed different questions within the setting of a two-sector model of a trading creative regional economy. They show that whether or not faster productivity growth in the tradable sector leads to the exit of creative people from this sector to the non-tradable sector is independent of whether this faster productivity growth is neutral or non-neutral. Finally, Usman and Batabyal (2014) analyze the impact that learning by doing—arising as a side effect of the production of final goods—has on economic growth in a creative region.

Next, consider the topic of *investment* in creative regions. In this regard, Forte et al. (2005) have noted the importance of what they call "innovative investment developments" in advancing the strategic development of creative urban systems. Malecki (2007) contends that because investment is mobile, policy makers in the most competitive cities and regions need to understand the vital role of knowledge and the nature of what he calls "place competition." Similarly, in his call for the endogenous development of city-regions, Friedmann (2007) advocates for investments in seven clusters of tangible regional assets such as a region's intellectual and creative assets.

Comunian (2011) points out that for a city to be genuinely creative, investments need to be made not only in regeneration projects but also in a city's cultural development. Finally, in the *only* theoretical paper that we are aware of on the subject of investment income in creative regions, Donovan and Batabyal (2015) analyze the impact that the taxation of investment income has on the equilibrium growth rate of consumption in a creative region. Even though researchers now comprehend the salient role played by investment in promoting the working of creative regions, with the exception of the Donovan and Batabyal (2015) paper, there is *no* theoretical research on either investment in a creative region or on the impact of investment income taxation on the functioning of a creative region.

Given this lacuna in the literature, the basic objective of our chapter is to follow Donovan and Batabyal (2015) and analyze hitherto unstudied questions about the effects of physical capital or investment income taxation[1] on economic growth and welfare in a region that is creative *a la* Richard Florida. This region possesses both physical and creative capital. Our analysis leads to six findings delineated in Sects. 3, 4, 5, 6, 7, and 8 below. Section 2 describes the theoretical framework which is adapted from Barro et al. (1995) and Romer (2012, pp. 49–75). Section 3 demonstrates the effect of the investment income tax ζ on steady-state consumption and physical capital per effective creative capital unit, denoted by c and k, respectively. Section 4 shows how the economy of our creative region responds to the implementation of ζ. Section 5 compares c and k on the new balanced-growth path (BGP) with c and k on the old or pretax BGP. Section 6 studies the effect of ζ in an aggregate economy consisting of multiple creative regions. Section 7 analyzes whether a policy of subsidizing investment and raising the revenue for this subsidy through lump-sum taxes, increases welfare in the creative region under study. Section 8 studies the impacts in our creative region when, instead of rebating the revenue from ζ to the creative class households, the taxing authority (TA) in this region makes purchases. Finally, Sect. 9 concludes and then suggests two ways in which the research described in this chapter might be extended.

2 The Theoretical Framework

Consider a stylized creative region whose economy can be described by the prominent Ramsey-Cass-Koopmans model and that is on its balanced-growth path (BGP). This model is well known to researchers because it has been and is used routinely to study a variety of research questions in economic growth and macroeconomics more generally. Hence, in the remainder of this section, we shall

[1]In the remainder of this chapter, we shall use the terms "physical capital tax," "capital tax," and "investment income tax" interchangeably.

be relatively brief in our discussion of this model. Readers interested in a more expansive discussion of this model should consult a standard textbook such as Romer (2012, pp. 49–75).

There are a large number of identical firms in the creative region under study. Each of these firms has a production function $F(\cdot,\cdot)$ given by

$$Q = F\,(K, AR) \tag{1}$$

where Q is output, K is the physical capital input, R is the creative capital input, and A is knowledge or, alternately, the effectiveness of the creative capital input. Let q, c, and k denote output per effective creative capital unit, consumption per effective creative capital unit, and physical capital per effective creative capital unit, respectively. The firms hire the physical and the creative capital inputs in competitive markets and sell their output in a competitive output market. These firms take knowledge A as given and the growth of knowledge is given by the differential equation

$$\frac{dA(t)}{dt} = \dot{A}(t) = gA(t),\ g > 0 \tag{2}$$

The creative region under study is populated by infinitely lived creative class households. The size of each household grows at rate $h > 0$. Each household rents the physical capital it owns to firms. The initial (time $t = 0$) physical capital holding of a household is $K(0)/H$, where $K(0)$ is the initial quantity of physical capital in our creative region and H denotes the number of creative class households. The utility function of a creative class household is given by

$$U = \int_{t=0}^{\infty} e^{-\rho t} \left\{ \frac{C(t)^{1-\theta}}{1-\theta} \right\} \frac{R(t)}{H} dt \tag{3}$$

where $\rho > 0$ is the time discount rate, $C(t)$ is the consumption of each member of a creative class household at time t, and $\theta > 0$ is the coefficient of relative risk aversion, and we assume that $\rho - h - (1-\theta)g > 0$. The expression inside the curly brackets in Eq. (3) can be thought of as a creative class household's instantaneous utility function.

The competitive firms in our creative region hire the available stocks of physical and creative capital, they pay these two inputs their marginal products, and they sell the resulting output. The marginal product of physical capital or $\partial F\,(K, AR)\,/\partial K = f'(k)$, where $f(\cdot)$ is the intensive form of the production function given in Eq. (1).[2] Because markets in our creative region are competitive and because there is no depreciation, the real interest rate $r(t)$ is given by

$$f'\,\{k(t)\} = r(t). \tag{4}$$

[2]See Romer (2012, p. 11) for more details on this point.

If we denote the real return to creative capital or the wage by $W(t)$, then straightforward computations show that the marginal product of creative capital in terms of the function $f(\cdot)$ at any time t is given by

$$A(t)\left[f\{k(t)\} - k(t)f'\{k(t)\}\right] = W(t), \tag{5}$$

and the wage per unit of effective creative capital can be expressed as

$$f\{k(t)\} - k(t)f'\{k(t)\} = w(t). \tag{6}$$

This completes the description of our theoretical framework. Our next task is to show the impact of the investment income tax ζ on steady-state consumption per effective creative capital unit or c and physical capital per effective creative capital unit or k.

3 Two Impacts of the Investment Income Tax

We begin by supposing that at some time, say time $t = 0$, the taxing authority (TA) in our creative region decides to tax investment income at rate ζ. Because of the existence of this tax, the real interest rate is now not given by Eq. (4) but instead by

$$(1-\zeta)f'\{k(t)\} = r(t). \tag{7}$$

In this section, we assume that the TA returns the tax revenue it collects via lump-sum transfers to the various creative class households. Also, we suppose that the TA's tax policy is unanticipated in our creative region.

In order to describe the apposite steady-state effects of ζ, we will need to determine how ζ influences the $dc(t)/dt = \dot{c}$ and the $dk(t)/dt = \dot{k}$ loci. Given Eq. (7), the solution to the representative creative class household's maximization problem gives[3]

$$\frac{\dot{c}(t)}{c(t)} = \frac{(1-\zeta)f'\{k(t)\} - \rho - \theta g}{\theta}. \tag{8}$$

From Eq. (8), setting $\dot{c} = 0$ gives us

$$(1-\zeta)f'\{k(t)\} = \rho + \theta g. \tag{9}$$

In words, Eq. (9) says that the after-tax rate of return must equal the sum of the time discount rate ρ and the product of the coefficient of relative risk aversion θ and the growth rate of knowledge g. Compared to the case with no tax on physical capital,

[3] See Romer (2012, p. 56) for additional details.

the pretax return on physical capital or $f'\{k(t)\}$ must now be *higher*, and hence, k must be *lower* in order for $\dot{c} = 0$ to hold.

If we were to plot the $\dot{c} = 0$ locus in a graph with k on the horizontal axis and c on the vertical axis, then we would get a vertical line which touches the horizontal axis at $k = k^*$ where k^* satisfies Eq. (9). Given the discussion in the preceding paragraph, we conclude that relative to the old or pretax $\dot{c} = 0$ locus, the new or after-tax $\dot{c} = 0$ locus would shift to the *left*.

Adapting equation 2.25 in Romer (2012, p. 59) to our problem, we infer that the equation of motion for k or $\dot{k}$ in the "no investment income tax" scenario is given by

$$\dot{k} = f\{k(t)\} - c(t) - (h + g)\,k(t). \tag{10}$$

Now, observe that for any given k, the level of c that implies $\dot{k} = 0$ is given by

$$c(t) = f\{k(t)\} - (h + g)\,k(t). \tag{11}$$

In the scenario studied in this section, the investment income tax proceeds are returned to the creative class households in our region by the TA using lump-sum transfers. This tells us that the pretax $\dot{k} = 0$ locus is *unaffected* by the TA's tax. We now proceed to highlight the manner in which the economy of our creative region responds to the implementation of the investment income tax ζ.

4 Response of Creative Region to the Investment Income Tax

Recall that at time $t = 0$, when the investment income tax ζ is put in place, the value of the stock of physical capital per effective creative capital unit or k is given by the *history* of the economy of our creative region. This means that the value of k *cannot* change discontinuously and, as discussed in Sect. 3, it remains equal to $k = k^*$ on the old or pretax BGP.

In contrast to this, the consumption of a creative class household, in effective units of creative capital or c, can move higher at the time the investment income tax ζ is implemented. The reader should note that this moving up of c is possible because the TA's investment income tax is *unanticipated*. Now, in order for the economy of our creative region to reach the new BGP, the events described below need to occur and these are illustrated in Fig. 1. With k on the horizontal axis and c on the vertical axis, Fig. 1 plots the $dk(t)/dt = \dot{k} = 0$ and the $dc/dt = \dot{c} = 0$ loci in the same diagram.

When ζ is implemented by the TA at time $t = 0$, c moves up as shown by the arrow pointing upward from point E until point A is reached. Put differently, the economy under study is now on the new saddle path. When this happens, the return to saving and accumulating physical capital in our creative region is *lower* than before, and hence, households move away from saving and into consumption. In terms of Fig. 1, this means that the economy gradually moves down along the new

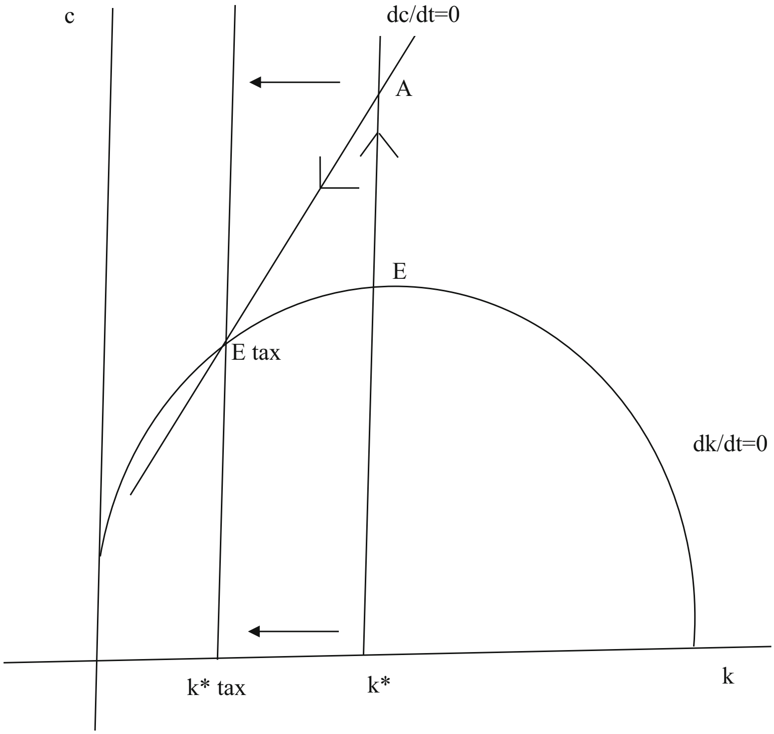

Fig. 1 Effects of the investment income tax

saddle path from point A until it ultimately reaches the new BGP equilibrium point marked E_{tax}. Our next task in this paper is to compare c and k on the new BGP with c and k on the old or pretax BGP.

5 A Comparison of Two BGPs

Remember that all taxes including the TA's investment income tax ζ are distortionary in nature. As a result, from the discussion in Sect. 4, it is clear that on the new BGP at point E_{tax}, the distortionary ζ gives rise to two results that are shown in Fig. 1. First, the economy of our creative region has a *lower* level of physical capital per effective creative capital unit, and this is shown by the point marked k^*_{tax} in the figure. Second, inspection of Fig. 1 reveals that the economy under study also has a *lower* level of consumption per effective creative capital unit. Let us now analyze the effect of the investment income tax ζ in an aggregate economy consisting of multiple creative regions.

6 Investment Income Taxation in an Aggregate Economy

6.1 Relationship Between the Saving Rate and the Investment Income Tax

In this section, we focus on an aggregate economy that consists of many creative regions of the sort that we have been studying thus far in Sects. 2, 3, 4, and 5. The preferences of the creative class households are identical in each region, but we allow the investment income tax rates across the different regions to vary. In addition, we suppose that each of the different creative regions is situated on its own BGP.

In this setting, the first question we want to study is the BGP relationship between the saving rate in each creative region and the investment income tax ζ in this region. Specifically, we claim that the BGP saving rate or $(q^* - c^*)/q^*$ is *decreasing* in the tax ζ. Now, from the analysis in Sects. 2, 3, 4, and 5, we know that, ceteris paribus, the higher the ζ, the lower will be the BGP level of k^*. An additional implication of our analysis thus far is that the higher the ζ, the more the $\dot{c} = 0$ locus shifts to the *left*, and therefore, the greater is the *decline* in k^*. Put differently, we have $\partial k^*/\partial\zeta < 0$.

Using the intensive version of the production function or $f(\cdot)$, on the BGP, the proportion of output that is saved and invested or the saving rate is given by $\{f(k^*) - c^*\}/f(k^*)$. Because the relevant k is constant, $\dot{k} = 0$ on the BGP. Using Eq. (10), we get $f(k^*) - c^* = (h+g)k^*$. Using this last result, we can express the proportion of output that is saved or s on the BGP as

$$s = \frac{(h = g)\,k^*}{f(k^*)} \tag{12}$$

We now use Eq. (12) to find an expression for the derivative $\partial s/\partial\zeta$. After some steps of algebra, we get

$$\frac{\partial s}{\partial \zeta} = \frac{(h+g)\,(\partial k^*/\partial\zeta)f(k^*) - (h+g)\,k^* f'(k^*)\,(\partial k^*/\partial\zeta)}{f(k^*)^2} \tag{13}$$

Simplifying Eq. (13) further gives us

$$\frac{\partial s}{\partial \zeta} = \frac{(h+g)}{f(k^*)}\frac{\partial k^*}{\partial \zeta}\left[1 - \frac{k^* f'(k^*)}{f(k^*)}\right] \tag{14}$$

Let us define $\beta_K(k^*) \equiv k^* f'(k^*)/f(k^*)$ to be physical capital's share of income in our creative region before the implementation of the investment income tax ζ. It is clear that $\beta_K(k^*) < 1$. We have already pointed out that $\partial k^*/\partial\zeta < 0$. Evaluating Eq. (14) in light of these last two pieces of information, we infer that

$$\frac{\partial s}{\partial \zeta} = \frac{(h+g)}{f(k^*)} \frac{\partial k^*}{\partial \zeta} \left[1 - \beta_K \left(k^*\right)\right] < 0. \tag{15}$$

This verifies our claim that the saving rate on the BGP in our creative region is *decreasing* in the investment income tax ζ. Do creative class household residents in regions with a high saving rate have any incentive to invest in regions with a low saving rate? We now answer this question.

6.2 Investment Interaction Between High- and Low-Saving Creative Regions

Creative regions with a high-saving rate have a low ζ and a high k^*. To answer the question posed at the end of the preceding paragraph, note from the analysis in Sect. 6.1 that the condition we need for $\dot{c} = 0$ is that $(1-\zeta)f'(k) = \rho + \theta g$. This tells us that the after-tax rate of return must be equal to the sum of the time discount rate ρ and the product of the coefficient of relative risk aversion θ and the growth rate of knowledge g.

Given that household preferences and firm technologies are identical across the different creative regions, it must be the case that ρ, θ, and g are also the same across these same regions. In turn, this means that the after-tax rate of return will be the *same* across the different creative regions. Because the after-tax rate of return is the same in all the creative regions, irrespective of whether it is a high- or low-saving region, there is *no* incentive to shift saving from a high-saving to a low-saving creative region.

Our analysis in Sect. 5 yielded two results about the economy of our creative region. First, we showed that this region had a *lower* level of physical capital per effective creative capital unit. Second, we pointed out that the economy under study also had a *lower* level of consumption per effective creative capital unit. Given these two negative findings, will welfare in our creative region rise if the TA in this region *subsidizes* investment, i.e., sets $\zeta < 0$, and raises the revenue for this subsidy via lump-sum taxes? We now turn to this question.

7 The Effect of Subsidizing Investment

It is clear that if the TA in our creative region were to subsidize investment, then the Sect. 5 results would be overturned. In particular, our creative region would now have a *higher* level of physical capital per effective creative capital unit and a *higher* level of consumption per effective creative capital unit. Will this raise welfare? To answer this question, observe that the original or pretax market equilibrium in our creative region is a competitive equilibrium. Then, from the first theorem of welfare

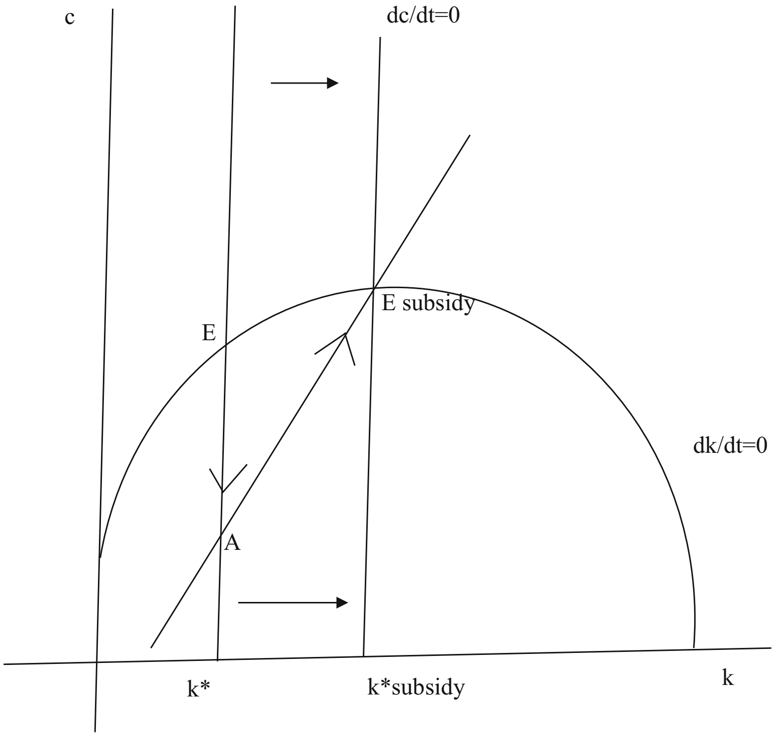

Fig. 2 The effects of investment subsidization

economics and the discussion in Romer (2012, pp. 63–64), it follows that the above mentioned market equilibrium is Pareto optimal, and hence, welfare in our creative region *cannot* be raised by attempting to improve upon the market equilibrium.

To grasp this point diagrammatically, see Fig. 2. The initial market equilibrium is at point E in the figure. The implementation of the subsidy results in a short-run drop in consumption per effective creative capital unit or c to the point marked A in the figure. However, over time, the economy of our creative region moves up the saddle path as shown by the arrow and then settles at the new equilibrium marked $E_{subsidy}$. Now, the important point to comprehend is the following. The present value of the utility lost in our creative region from the short-run decline in c *exceeds* the present value of the utility gain in the long run, and this is why subsidizing investment in the creative region under study is *not* a good idea. Our final task in this chapter is to ask how our analysis in Sects. 3 and 4 changes when instead of rebating the revenue from ζ to the creative class households, the TA in this creative region makes purchases.

8 The Impact of Purchases by the TA

Let $TA(t)$ denote the TA's purchases per effective creative capital unit. Then, the intertemporal behavior of k is now no longer given by Eq. (10) but instead by the following equation:

$$\dot{k} = f\{k(t)\} - c(t) - TA(t) - (h+g)\,k(t). \tag{16}$$

The purchases made by the TA do *not* add to the stock of physical capital in our creative region. As a result, the $\dot{k} = 0$ locus shifts down as shown in Fig. 3. Once the investment income tax ζ has been put in place, two things happen that are also shown in Fig. 3. First, the $\dot{c} = 0$ locus shifts to the *left*. Second, k^* *declines* to k^*_{tax}. Note that both these effects are identical to what happened in the case where the TA rebated the tax proceeds to the creative class households through lump-sum transfers.

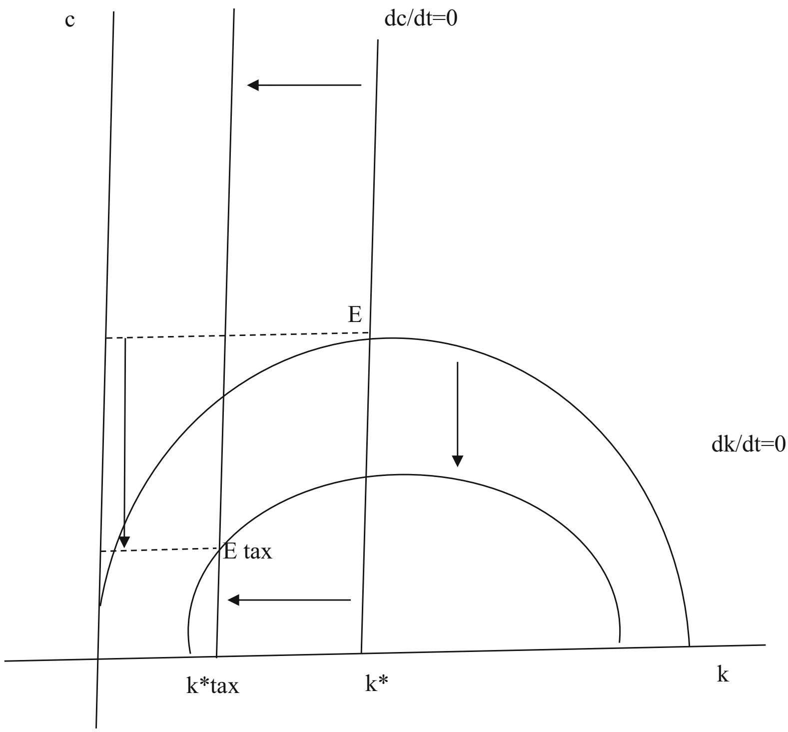

Fig. 3 The effects of purchases by the TA

On the new BGP at the point marked E_{tax} in Fig. 3, consumption per effective creative capital unit is *lower* than in the case where the investment income tax proceeds are rebated to the different creative class households by the TA. In this regard, note that the magnitude of the TA's purchases is given by $\zeta f'(k)k$. Finally, there is the technical matter about whether the initial level of c shoots up or down. The answer here depends on whether the posttax saddle path passes above or below the original BGP point denoted by E in Fig. 3. This completes our detailed study of the effects of investment income taxation on economic growth and welfare in a creative region.

9 Conclusions

In this chapter, we studied the effects of capital taxation on economic growth and welfare in a region that was creative in the sense of Richard Florida. This region possessed both creative and physical capital. Our analysis led to six findings. First, we demonstrated the effect of the investment income tax ζ on steady-state consumption and physical capital per effective creative capital unit, denoted by c and k, respectively. Second, we showed how the economy of our creative region responded to the implementation of ζ. Third, we compared c and k on the new BGP with c and k on the old or pretax BGP. Fourth, we studied the effect of ζ in an aggregate economy consisting of many creative regions. Fifth, we analyzed whether a policy of subsidizing investment and raising the revenue for this subsidy with lump-sum taxes increased welfare in our creative region. Finally, we studied the impacts in our creative region when, instead of rebating the revenue from ζ to the creative class households, the taxing authority (TA) in this region made purchases.

The analysis in this chapter can be extended in a number of different directions. In what follows, we suggest two possible extensions. First, instead of announcing and implementing the investment income tax ζ at time $t = 0$, the TA could announce at time $t = 0$ that it will implement the tax ζ at some later time, say, $t = t_1$. It would be instructive to use phase diagrams of the sort utilized in this chapter to shed light on the economic growth and welfare effects of this kind of *anticipated* taxation. Second, and once again in contrast with the analysis undertaken in this chapter, it would be helpful to analyze the working of a creative region when the TA's actions affect a creative class household's *utility* from private consumption. Studies that analyze these aspects of the underlying problem will provide additional insights into the nexuses between investment income taxation and the economic growth and welfare of creative regions.

References

Barro RJ, Mankiw NG, Sala-i-Martin X (1995) Capital mobility in neoclassical models of growth. Am Econ Rev 85:103–115

Batabyal AA, Nijkamp P (2010) Richard Florida's creative capital in a trading regional economy: a theoretical investigation. Ann Reg Sci 44:241–250

Batabyal AA, Nijkamp P (2011) The impact of neutral and non-neutral productivity growth on creative capital in a trading regional economy. Geogr Anal 43:61–77

Comunian R (2011) Rethinking the creative city: the role of complexity, networks, and interactions in the urban creative economy. Urban Stud 48:1157–1179

Donovan PJ, Batabyal AA (2015) On economic growth and investment income taxation in a creative region. Int Rev Econ Financ 38:67–72

Florida R (2002) The rise of the creative class. Basic Books, New York

Florida R (2005) The flight of the creative class. Harper Business, New York

Florida R, Mellander C, Stolarick K (2008) Inside the black box of regional development—human capital, the creative class, and tolerance. J Econ Geogr 8:615–649

Forte F, Girard LF, Nijkamp P (2005) Smart policy, creative strategy, and urban development. Stud Reg Sci 35:947–963

Friedmann J (2007) The wealth of cities: towards an assets-based development of newly urbanizing regions. Dev Chang 38:987–998

Malecki EJ (2007) Cities and regions competing in the global economy: knowledge and local development policies. Environ Plan C 25:638–654

McGranahan D, Wojan T (2007) Recasting the creative class to examine growth processes in rural and urban counties. Reg Stud 41:197–216

Nathan M (2007) The wrong stuff? Creative class theory and economic performance in UK cities. Can J Reg Sci 30:433–449

Romer D (2012) Advanced macroeconomics, 4th edn. McGraw-Hill Irwin, New York

Usman U, Batabyal AA (2014) Goods production, learning by doing, and growth in a region with creative and physical capital. Int Rev Econ Financ 33:92–99

Some Extensions to Interregional Commodity-Flow Models

Kieran P. Donaghy

Abstract Some interregional commodity-flow models, developed in the tradition of interregional input-output modeling, take on detailed characterizations of transportation networks to extend their explanatory reach, whereas others, developed in the tradition of spatial-interaction modeling, assume detailed characterizations of production. This chapter demonstrates how features of models within each of these two traditions can be integrated in two new specifications: a partial-equilibrium static formulation and a dynamic formulation of location, production, and interaction. This chapter also introduces several extensions to extant commodity-flow models, including explicit treatment of trade in intermediate goods, so-called *new economic geography* behavioral foundations for production and interindustry and interregional trade, and endogenous determination of capital investment and employment. These extensions enable commodity-flow models to be used to analyze the impacts of recent structural changes.

Keywords Interregional commodity-flow models • New economic geography behavioral foundations • Differential games

1 Introduction

Interregional commodity-flow models have played an important role in the development of regional science in characterizing flows of goods and services within and between regional economies. They have reflected not only changing patterns of economic geography on the ground, so to speak, but also the interregional and intraregional trade and transport activity needed to bring about and sustain those patterns. As such, commodity-flow models have integrated models of production,

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distribution, and transportation and have moreover served, when embedded in programming models, to support planning analyses of infrastructure investments or industrial and other policies.

Particular commodity-flow models have been developed to meet the needs for the analysis of particular problems at particular times, and the models have reflected the state of theoretical model development at those times (See Batten and Boyce (1986) for an early review of the literature.). One can identify several 'family trees' in commodity-flow modeling. There are models that would seem to derive from interregional input-output parentage (e.g., Leontief and Strout 1963; Moses 1960; Kohno et al. 1994), which go on to introduce more detail of transport networks, and those which derive from spatial-interaction parentage (e.g., Wilson 1970; Kim et al. 1983; Batten and Boyce 1986; Boyce 2002; Ham et al. 2005), which go on to introduce more detail about production.[1] Given the array of models that are now in the literature, what is taken to be a commodity-flow model, versus something else, may be to a certain extent in the eye of the beholder.

This chapter—really, more of a "research note"—demonstrates how features of models in these two families can be integrated in two new specifications: a partial-equilibrium static formulation and a dynamic formulation of location, production, and interaction. It also introduces several extensions to extant commodity-flow models: explicit treatment of trade in intermediate goods, so-called *new economic geography* behavioral foundations for production and interindustry and interregional trade, and endogenous determination of capital investment and employment.[2] These extensions enable commodity-flow models to be used to analyze the impacts of such structural changes associated with globalization as the fragmentation of production, the lengthening of supply chains, and the clustering of industrial activities to enable exploitation of economies of scale and scope.

2 Extensions to a Static Partial-Equilibrium Model

In their 1986 review of spatial-interaction, transportation, and interregional commodity-flow models, Batten and Boyce demonstrate how a static model which simultaneously deals with the location of goods production and assignment of commodity flows can be derived from the spatial-interaction principles embodied in the model formulated by Wilson in 1970. The solution to the model, which minimizes shipments in ton-miles (or the equivalent) that satisfy demands for intermediate and final goods, is conditioned on a formalization of entropy, to accommodate cross-hauling of goods, and allows for flow-dependent costs. Boyce (2002) would go on to modify the specification of this model and estimate its

[1]One could also include multimodal freight network models with production detail (e.g., Southworth and Peterson 2000).

[2]Some of these extensions have been suggested in Donaghy (2009).

parameters statistically. Ham et al. (2005) would further exploit this model to characterize multimodal shipping patterns in the United States. There are several extensions that can be made to this class of models that would increase their flexibility and coverage of analytical problems. For one, the Leontief input-output technology can be replaced by a technology that allows for both substitution of inputs in production, in response to changes in factor price ratios, and economies of scale. A second extension is that delivered prices of intermediate goods can be introduced both to gain insight into how shipment patterns would respond to changes in such prices and to support explicit modeling of trade in intermediate goods. We introduce both changes in this section.

We shall adopt the following notation to characterize network flows. Nodes of the network through which goods are shipped are indexed by l and m. Links joining such nodes are indexed by a and routes comprising contiguous links are indexed by r. The length of some link a connecting two nodes for some mode of transport v is denoted by d_a^v.[3] If link a is part of route r connecting nodes l and m for mode v, an indicator variable δ_{lmr}^{av} assumes the value 1.0. It is 0 otherwise. The length of a given route from some node l to another node m for mode v, D_{lmr}, is given by the sum of link distances along the route, that is:

Length of Route r from Node l to Node m for Mode v

$$D_{lmr}^{v} \equiv \sum_{a} d_a^v \delta_{lmr}^{av}, \forall l, \forall m, \forall r, \forall v. \tag{1}$$

Turning to quantities shipped through the network, we index sectors engaged in production in the spatial economy by i and j. We will not differentiate between different types of final demand—e.g., consumption, government spending, investment, or exports. Let X_l^i denote the total output (in dollars) of sector i produced at node l, x_{lm}^{ij} denote interindustry sales from sector i at location l to sector j at location m, and FD_{lm}^i denote final demand at location m for sector i's product at location l. The physical flow of sector i's product from l to m along route r by mode v is h_{lmr}^{iv}. This quantity is obtained by converting the value flow along route r from dollars to tons

[3]Other studies—e.g., Ham et al. (2005)—attempt to accommodate the impact on "effective" distance of a link that congestion may have, in a sense making imputed transport cost *flow dependent*, by employing the Bureau of Public Roads link congestion function, $d_a = d_a^o\left[1 + 0.15(f_a/k_a)^4\right]$, in which d_a^o is the physical distance covered by link a, f_a is the physical flow of commodities along the link (to be defined below), and k_a is the periodic flow capacity of the link. Because of computational challenges introduced by model specification changes discussed below, we will not follow suit but will retain link capacity constraints in the formulation of the model.

by means of the ratio of total annual interregional economic flow to total annual physical flow, q_x^i. The total physical flow of all commodities shipped on a link a via all routes using the link is given by

$$f_a^v \equiv \sum_i \sum_{lmr} h_{lmr}^{iv} \delta_{lmr}^{av} + TT_a^v, \forall a, \forall v, \tag{2}$$

in which TT_a denotes the physical flow of commodities associated with through traffic.

Conditions that the network must satisfy at any point in time are as follows.

Material Balance Constraint

$$X_l^i = \sum_m \sum_j x_{lm}^{ij} + \sum_m FD_{lm}^i, \forall i, \forall l; \tag{3}$$

Conservation of Flow Constraint

$$\sum_r h_{lmr}^{iv} = \wp^{iv} \sum_j x_{lmt}^{ij}/q_x^i + \wp^{iv} FD_{lm}^i/q_x^i, \forall i, \forall l, \forall m, \forall v; \tag{4}$$

where $\wp^{iv}$ denotes the probability that good i will be shipped via mode v and, following Ham et al. (2005), is taken to be a random utility function of average distance ($\overline{\text{dist}_i}$) and average value ($\overline{\text{val}_i}$) of shipment of good i by available modes v—i.e.,

$$\wp^{iv} = e^{\beta_1^{iv}\overline{\text{val}_i} + \beta_2^{iv}\overline{\text{dist}_i}} / \sum_v e^{\beta_1^{iv}\overline{\text{val}_i} + \beta_2^{iv}\overline{\text{dist}_i}}, \forall v.$$

Link Capacity Constraint

$$f_a^v \le k_a^v, \forall a, \forall v; \tag{5}$$

Nonnegativity and Feasibility Conditions

$$f_a^v \ge 0, \forall a, \forall v; h_{lmr}^{iv} \ge 0, \forall i, \forall l, \forall m, \forall r, \forall v; x_{lm}^{ij} > 0, \forall i, \forall j, \forall l, \forall m. \tag{6}$$

Equation 3 ensures that shipments from industry i in location l do not exceed production by the industry in that location, while Eq. (4) reconciles physical and value flows. Inequality (5) imposes physical limitations on flows over links, and the conditions given in (6) ensure that the distribution of goods throughout the network is feasible.

Because observations on FD^i_{lm}, final demand at location m for sector i's goods produced at location l, are generally not available and cannot be easily derived, we shall replace the summation of FD^i_{lm} terms in Eq. (3) with the aggregate quantity $\overline{\mathrm{FD}}{}^i_l$, which is a measure of all of industry i's product at location l that is shipped to all sources of final demand at all locations in the network. This quantity can be determined by remainder when Eq. (3) is rewritten as:

Modified Material Balance Equation

$$\overline{\mathrm{FD}}{}^i_l \left(\equiv \sum_m \mathrm{FD}^i_{lm} \right) = X^i_l - \sum_m \sum_j x^{ij}_{lm}, \forall i, \forall l. \tag{3'}$$

The part of industry i's product at location l that is shipped to all sources of final demand in just location m, $\overline{\mathrm{FD}}{}^i_{\underset{\sim}{lm}}$, can be approximated by employing a gravity model formulation in which $\overline{\mathrm{FD}}{}^i_l$, the aggregate amount of the output from industry i at location l to be distributed to all locations, is allocated to each location m according to its relative share of total industrial output and the impedance of distance:

$$\overline{\mathrm{FD}}{}^i_{\underset{\sim}{lm}} = \overline{\mathrm{FD}}{}^i_l \cdot \frac{\sum_j X^j_m D^{*-1}_{lm}}{\sum_m \sum_j X^j_m D^{*-1}_{lm}}, \forall i, \forall l, \forall m. \tag{7}$$

In this expression, D^{*-1}_{lm} is the inverse of the distance of the shortest route between locations l and m by any mode v. Employing this expression, Eq. (4) can now be rewritten as:

Modified Conservation of Flow Constraint

$$\sum_r h^{iv}_{lmr} = \wp^{iv} \sum_j x^{ij}_{lm} / q^i_x + \wp^{iv} \overline{\mathrm{FD}}{}^i_{\underset{\sim}{lm}} / q^i_x, \forall i, \forall l, \forall m, \forall v. \tag{4'}$$

We assume that production of good j at location m at time t can be represented by a two-stage production function with constant elasticity of substitution (CES) and the possibility of increasing returns to scale, hence the possibility of imperfect competition. Output, X^j_m, is a function of aggregates of inputs i shipped from other locations l and location m, c^{ij}_m, and local labor and capital in the industry, L^j_m and K^j_m. The production function and input aggregator functions are written as:

Production Function

$$X^j_m = \left[\sum_i \alpha^{ij}_m c^{ij-\rho^j_m}_m + \alpha^{L_j}_m L^{j-\rho^j_m}_m + \alpha^{K_j}_m K^{j-\rho^j_m}_m\right]^{-\kappa^j_m/\rho^j_m}, \forall j, \forall m, \tag{8}$$

and

Input Aggregator Function

$$c^{ij}_m = \vartheta^{ij}_m \prod_l x^{ij\varepsilon^{ij}_{lm}}_{lm}, \forall i, \forall j, \forall m. \tag{9}$$

In (8) the α^{ij}_m parameters are factor intensity parameters, ρ^j_m is the substitution parameter, and κ^j_m is the economies-of-scale parameter for industry j in location m. In (9), ϑ^{ij}_m is the scale parameter for the aggregator of inputs i in the production of good j, and the ε^{ij}_{lm} parameters are share parameters.

We know from microeconomic theory that in equilibrium the product of the Lagrange multiplier associated with a cost minimization problem and the partial derivative of X^j_m taken with respect to any input x^{ij}_{lmt} will be offset by the input price, which in this case will be the effective delivered price, $p^i_{lm\cdot}$. Assuming imperfect competition, hence, taking the Lagrange multiplier to be the average cost of production and to equal to the output price, P^j_m, divided by a markup, π, the equilibrium condition can be expressed as

$$p^i_{lm\cdot} = \frac{P^j_m}{\pi} \cdot \frac{\partial X^j_m}{\partial x^{ij}_{lm}} = \frac{P^j_m}{\pi} \cdot \frac{\partial X^j_m}{\partial c^{ij}_m} \cdot \frac{\partial c^{ij}_m}{\partial x^{ij}_{lm}}. \tag{10}$$

The partial derivative of X^j_m with respect to x^{ij}_{lm} can be obtained by first rewriting (8) in mathematically equivalent form as

$$X^{j-\rho^j_m/\kappa^j_m}_m = \left[\sum_i \alpha^{ij}_m c^{ij-\rho^j_m}_m + \alpha^{L_j}_m L^{j-\rho^j_m}_m + \alpha^{K_j}_m K^{j-\rho^j_m}_m\right], \forall j, \forall m, \tag{11}$$

and differentiating both sides with respect to c_m^{ij} to obtain

$$-\rho_m^j/\kappa_m^j \cdot X_m^{j-\rho_m^j/\kappa_m^j-1} \cdot \frac{\partial X_m^j}{\partial c_m^{ij}} = -\rho_m^j \alpha_{lm}^{ij} c_m^{ij-\rho_m^j-1}, \forall i, \forall j, \forall m. \quad (12)$$

Isolating the partial derivative in (12) yields

$$\frac{\partial X_m^j}{\partial c_m^{ij}} = \kappa_m^j \alpha_{lm}^{ij} X_m^{j\left(\rho_m^j+\kappa_m^j\right)/\kappa_m^j} c_m^{-\rho-1}, \forall i, \forall j, \forall m. \quad (13)$$

The partial derivative of the input aggregator function taken with respect to x_{lm}^{ij} is just

$$\frac{\partial c_m^{ij}}{\partial x_{lm}^{ij}} = \varepsilon_{lm}^{ij} \frac{c_m^{ij}}{x_{lm}^{ij}}, \forall i, \forall j, \forall l, \forall m. \quad (14)$$

Substituting from (13) and (14) into (10) and rearranging terms, one obtains the partial-equilibrium expression for x_{lm}^{ij}, which is the input demand equation:

Input Demand Equation

$$x_{lm}^{ij} = \frac{\varepsilon_{lm}^{ij} \kappa_m^j \alpha_m^{ij}}{\pi} \cdot \frac{P_m^j}{p_{lm\cdot}^i} \cdot X_m^{j\left(\rho_m^j+\kappa_m^j\right)/\kappa_m^j} c_m^{ij-\rho_m^j}, \forall i, \forall j, \forall l, \forall m. \quad (15)$$

In Eq. (15), the *effective delivered price* at location m of input i shipped from location l, $p_{lm\cdot}^i$, will be a weighted average of the delivered prices of this input arriving via different modes v and routes r. That is,

$$p_{lm\cdot}^i = \sum_{rv} \left[\frac{h_{lmr}^{iv}}{\sum_{rv} h_{lmr}^{iv}} \cdot p_{lmr}^{iv} \right]. \quad (16)$$

In this static formulation, we take industrial outputs (expected demand levels) and output (f.o.b.) prices to be exogenously given. Delivered (c.i.f.) prices (for particular routes and modes) are a function of output prices, modal shipping costs per ton-mile, p^v, distances of shipment, D_{lmr}^v, and value to weight ratios, q_x^i. That is,

$$p_{lmr}^{iv} = P_l^i + p^v \cdot D_{lmr}^v / q_x^i. \quad (17)$$

The optimization problem is to choose input demands x_{lm}^{ij} and shipments h_{lmr}^{iv} so as to minimize the total cost of shipments.[4] The objective function may be written as:

Objective Function

$$\min Z(x,h) = \sum_{i}\sum_{lmrv} h_{lmr}^{iv} D_{lmr}^{v} p^{v}. \tag{18}$$

Note that, unlike commodity-flow models in the tradition of spatial-interaction modeling following from Wilson (1970) and discussed by Batten and Boyce (1986), we do *not* include an entropy expression, either as a condition the solution of the model must satisfy or as part of the objective function, because cross-hauling of commodities (as intermediate inputs) is explicitly modeled by Eq. (6).

The model can be solved as a mixed-complementarity problem. Noting that the input demand Eq. (15) already represents (has been derived from) a first-order condition for minimizing costs of production and that the modified material balance Eq. (3') and the gravity allocation of final demand Eq. (7) have been used to substitute into the modified conservation of flow constraint (4'), then using identity (2) to substitute for f_a^v, the relevant Lagrangian expression may be written as

$$\begin{aligned} L(x,h) &= \sum_{i}\sum_{lmrv} h_{lmr}^{iv} D_{lmr}^{v} p^{v} + \sum_{i}\sum_{lmv} \beta_{lm}^{iv} \left(\sum_{j} \wp^{iv} x_{lm}^{ij} / q_x^i + \wp^{iv} \overline{FD}_{\underset{\sim}{lm}}^{i} / q_x^i - \sum_{r} h_{lmr}^{iv} \right) \\ &+ \sum_{ij}\sum_{lm} \phi_{lm}^{ij} \left(\frac{\varepsilon_{lm}^{ij} \kappa_m^j \alpha_m^{ij}}{\pi} \cdot \frac{P_m^j}{p_{lm\cdot}^i} \cdot X_m^{j\left(\rho_m^j + \kappa_m^j\right)/\kappa_m^j} c_m^{ij - \rho_m^j} - x_{lm}^{ij} \right) \\ &+ \sum_{av} \psi_a^v \left(k_a^v - \sum_{i}\sum_{lmrv} h_{lmr}^{iv} \delta_{lmr}^{av} + TT_a^v \right), \end{aligned} \tag{19}$$

where c_m^{ij}, $\wp^{iv}$, p_{lmr}^{iv}, $p_{lm\cdot}^{i}$, and $\overline{FD}_{\underset{\sim}{lm}}^{i}$ are as defined above and β_{lm}^{iv}, ϕ_{lm}^{ij}, and ψ_a^v are the Lagrange multipliers associated with the modified conservation of flow constraints, the input demand equations, and the capacity flow constraints.

[4] Essentially, this is a problem of "traffic assignment" for carriers, given the demands for goods by firms and households at the nodes of the networks. But the influence of carriers' routing choices of commodity flows on delivered prices affects at least firms' demands for intermediate goods; so the problem may be viewed as a static cooperative game.

The Karush-Kuhn-Tucker conditions defining the saddle-point cost-minimizing solution are as follows:

$$\partial L/\partial h_{lmr}^{iv} = D_{lmr}^{v} p_{lmr}^{iv} - \beta_{lm}^{iv} + \phi_{lm}^{ij} x_{lm}^{ij}/p_{lm\cdot}^{i} \left[p_{lmr}^{iv} \left(\sum_{vr} h_{lmr}^{iv} - h_{lmr}^{iv} \right) \Big/ \left(\sum_{vr} h_{lmr}^{iv} \right)^{2} \right] - \psi_{a}^{v} \delta_{lmr}^{av} \geq 0, \quad \forall i, \forall l, \forall m, \forall r, \forall v. \tag{20}$$

$$\partial L/\partial x_{lm}^{ij} = \sum_{v} \left(\beta_{lm}^{iv} \left(\wp^{iv}/q_{x}^{i} \right) \left(1 - \sum_{j} X_{m}^{j} D_{lm}^{*-1} \Big/ \sum_{m} \sum_{j} X_{m}^{j} D_{lm}^{*-1} \right) \right) - \phi_{lm}^{ij} \left(\frac{\rho_{m}^{j} \left(\varepsilon_{lm}^{ij} \right)^{2} \kappa_{m}^{j} \alpha_{m}^{ij}}{\pi} \cdot \frac{P_{m}^{j}}{p_{lm\cdot}^{i}} \cdot X_{m}^{j\left(\rho_{m}^{j}+\kappa_{m}^{j}\right)/\kappa_{m}^{j}} c_{m}^{ij-\rho_{m}^{j}} / x_{lm}^{ij} + 1 \right) \geq 0, \quad \forall i, \forall j, \forall l, \forall m. \tag{21}$$

$$h_{lmr}^{iv} \left(\partial L/\partial h_{lmrt}^{i} \right) = 0, \forall i, \forall v, \forall l, \forall m, \forall r, \tag{22}$$

$$x_{lm}^{ij} \left(\partial L/\partial x_{lm}^{ij} \right) = 0, \forall i, \forall j, \forall l, \forall m, \tag{23}$$

$$h_{lmr}^{iv} \geq 0, \forall i, \forall l, \forall m, \forall r, \forall v; x_{lm}^{ij} \geq 0, \forall i, \forall j, \forall l, \forall m. \tag{24}$$

$$\partial L/\partial \beta_{lm}^{iv} = \sum_{j} \wp^{iv} x_{lm}^{ij}/q_{x}^{i} + \wp^{iv} \overline{FD}_{\underset{\sim}{lm}}^{i}/q_{x}^{i} - \sum_{r} h_{lmr}^{iv} \leq 0, \forall i, \forall j, \forall l, \forall m, \tag{25}$$

$$\partial L/\partial \phi_{lm}^{ij} = \frac{\varepsilon_{lm}^{ij} \kappa_{m}^{j} \alpha_{m}^{ij}}{\pi} \cdot \frac{P_{m}^{j}}{p_{lm\cdot}^{i}} \cdot X_{m}^{j\left(\rho_{m}^{j}+\kappa_{m}^{j}\right)/\kappa_{m}^{j}} c_{m}^{ij-\rho_{m}^{j}} - x_{lm}^{ij} \leq 0, \forall i, \forall j, \forall l, \forall m, \tag{26}$$

$$\partial L/\partial \psi_{a}^{v} = k_{a}^{v} - \sum_{i} \sum_{lmr} h_{lmr}^{iv} \delta_{lmr}^{av} + TT_{a}^{v} \leq 0, \forall a, \forall v, \tag{27}$$

$$\beta_{lm}^{iv} \left(\partial L/\partial \beta_{lm}^{iv} \right) = 0, \forall i, \forall j, \forall l, \forall m, \tag{28}$$

$$\phi_{lm}^{ij} \left(\partial L/\partial \phi_{lm}^{ij} \right) = 0, \forall i, \forall j, \forall l, \forall m, \tag{29}$$

$$\psi_{a}^{v} \left(\partial L/\partial \psi_{a}^{v} \right) = 0, \forall a, \forall v, \tag{30}$$

$$\beta_{lm}^{iv} \geq 0, \forall i, \forall l, \forall m, \forall v; \phi_{lm}^{ij} \geq 0, \forall i, \forall j, \forall l, \forall m; \psi_{a}^{v} \geq 0, \forall a, \forall v. \tag{31}$$

The model, which can be solved by the PATH algorithm of Dirkse and Ferris (1995), comprises conditions (20–31).

3 Extensions to a Dynamic Model of Location, Production, and Interaction

Batten and Boyce (1986) discuss under "new developments and prospects" for spatial-interaction and commodity-flow models the integration of location, production, and interaction behavior (or LPI), noting that such modeling work is jointly concerned with location of physical capital stock, productive activities occurring with this stock, and flows generated by these activities. An example of LPI modeling is provided by Kohno et al. (1994)—henceforth KHM (1994)—who constructed a dynamic (multi-period) input-output programming model to measure socioeconomic effects of the (then) proposed Asian Expressway Network. The model not only explicitly incorporates industrial capital goods but also infrastructural facilities and incorporates the concept of interregional input-output programming of Moses (1960). Also embodied in the model is the computational technique of "simulation of traffic assignment on the network" (or STAN). The model can be employed to answer the question of what facilities should be invested in, when, where, and by how much in order to maximize aggregate regional income. The authors employed the model to derive an investment criterion and conduct a feasibility study based on anticipated traffic volume.

The static commodity-flow model developed in the previous section can be modified to embody some of the features of the KHM model—i.e., its dynamic formulation and endogenous determination of industrial capital stocks—as well as endogenous determination of labor employed and industrial output. In this latter formulation, the behavior of representative firms in each industry and location can be characterized by reaction functions, according to which firms adjust the capital stock, labor employed, intermediate input purchases, and output to their respective partial-equilibrium levels. In the case of output, the partial-equilibrium level is taken to be expected demand, $\tilde{X}^j_m$.[5] These levels are—in most cases—themselves functions

[5]We are assuming for the sake of convenience that forecasts of expected demand can be obtained (by survey or time-series forecasting) or projected by means of a forcing function of time. The formation of demand expectations can be endogenized, however, as in many macroeconometric studies, and the expectation variable eliminated by introducing a higher-order differential equation and substituting for this variable an expression written solely in terms of observable quantities and parameter estimates. See, e.g., Donaghy (1993), for a demonstration.

of prices set by firms (f.o.b. prices) or carriers (c.i.f. prices) or determined in other markets (e.g., markets for labor and transport services). The reaction functions are as follows:

$$\dot{x}^{ij}_{lm} = \gamma^{xij}_{lm}\left(x^{ij}_{lm}* - x^{ij}_{lm}\right), \forall i, \forall j, \forall l, \forall m,$$
$$\text{where } x^{ij}_{lm}* = \frac{\varepsilon^{ij}_{lm}\kappa^{j}_{m}\alpha^{ij}_{m}}{\pi} \cdot \frac{P^{j}_{m}}{p^{i}_{lm\cdot}} \cdot X^{j\left(\rho^{j}_{m}+\kappa^{j}_{m}\right)/\kappa^{j}_{m}}_{m} c^{ij-\rho^{j}_{m}}_{m}, \tag{32}$$

$$\dot{L}^{j}_{m} = \gamma^{Lj}_{m}\left(L^{j}_{m}* - L^{j}_{m}\right), \forall j, \forall m,$$
$$\text{where } L^{j}_{m}* = \left[\frac{\kappa^{j}_{m}}{\pi} \cdot \alpha^{Lj}_{m} \cdot \frac{P^{j}_{m}}{w^{j}_{m}}\right]^{1/\left(1+\rho^{j}_{m}\right)} \left(X^{j}_{m}\right)^{\left(\kappa^{j}_{m}+\rho^{j}_{m}\right)/\left(\kappa^{j}_{m}+\kappa^{j}_{m}\rho^{j}_{m}\right)}, \tag{33}$$

$$\dot{K}^{j}_{m} = \gamma^{Kj}_{m}\left(K^{j}_{m}* - K^{j}_{m}\right), \forall j, \forall m,$$
$$\text{where } K^{j}_{m}* = \left[\frac{\kappa^{j}_{m}}{\pi} \cdot \alpha^{Kj}_{m} \cdot \frac{P^{j}_{m}}{ucc^{j}_{m}}\right]^{1/\left(1+\rho^{j}_{m}\right)} \left(X^{j}_{m}\right)^{\left(\kappa^{j}_{m}+\rho^{j}_{m}\right)/\left(\kappa^{j}_{m}+\kappa^{j}_{m}\rho^{j}_{m}\right)}, \tag{34}$$

$$\dot{X}^{j}_{m} = \gamma^{Xj}_{m}\left(\tilde{X}^{j}_{m} - X^{j}_{m}\right). \tag{35}$$

The γ parameters appearing in Eqs. (32), (33), (34), and (35) are disequilibrium adjustment parameters. The partial-equilibrium level to which intermediate input demand, $x^{ij}_{lm}*$, adjusts is just the level derived in the static model above. The partial-equilibrium levels to which the capital stock and labor employed adjust, $L^{j}_{m}*$ and $K^{j}_{m}*$, are derived in a manner similar to that of intermediate input demand. In the expressions for these quantities, w^{j}_{m} is the prevailing wage paid in industry j in location m, and ucc^{j}_{m} is the analogous user cost of capital. Expected sectoral output/demand is assumed to adjust to actual output/demand according to a process of adaptive expectations.

Given the reaction functions of representative firms (shippers), link capacities, and relevant prices, and the zero-order equations characterizing network flows in the static model, we can formulate a cooperative differential game between shippers and carriers in which the joint objective is to minimize the present value of shipping costs over a relevant planning horizon. The objective functional of this game would be

$$J = \min_{\{x,h\}} \int_{t_0}^{t_1} e^{-\lambda_c t} \sum_{i} \sum_{lmrv} h^{iv}_{lmr} D^{v}_{lmr} p^{v}\, dt. \tag{36}$$

Following Kamien and Schwartz (1981), the intertemporal Lagrangian function for this optimization problem can be formulated as

$$L = e^{-\lambda_c t}\sum_{i}\sum_{lmvr} h^{iv}_{lmr}D^{v}_{lmr}p^{v} + \sum_{ij}\sum_{lm}\mu^{xij}_{lm}e^{-\lambda_c t}\left[\gamma^{xij}_{lm}\left(x^{ij}_{lm}* - x^{ij}_{lm}\right) - \dot{x}^{ij}_{lm}\right]$$
$$+\sum_{j}\sum_{m}\mu^{Lj}_{m}e^{-\lambda_c t}\left[\gamma^{L_j}_{m}\left(L^{j}_{m}* - L^{j}_{m}\right) - \dot{L}^{j}_{m}\right] + \sum_{j}\sum_{m}\mu^{Kj}_{m}e^{-\lambda_c t}$$
$$\times\left[\gamma^{K_j}_{m}\left(K^{j}_{m}* - K^{j}_{m}\right) - \dot{K}^{j}_{m}\right] + \sum_{j}\sum_{m}\mu^{\tilde{X}j}_{m}e^{-\lambda_c t}\left[\gamma^{\tilde{X}j}_{m}\left(X^{j}_{m} - \tilde{X}^{j}_{m}\right) - \dot{\tilde{X}}^{j}_{m}\right]$$
$$+\sum_{i}\sum_{lmv}\zeta^{icon}_{lmv}e^{-\lambda_c t}\left(\sum_{j}\wp^{iv}x^{ij}_{lm}/q^{i}_{x} + \wp^{iv}\overline{\text{FD}}^{\,i}_{\underset{\sim}{lm}}/q^{i}_{x} - \sum_{r}h^{iv}_{lmr}\right) + \sum_{a}\sum_{v}\zeta^{flo}_{av}e^{-\lambda_c t}$$
$$\times\left(\sum_{i}\sum_{lmr}h^{iv}_{lmr}\delta^{av}_{lmr} + TT^{v}_{a} - f^{v}_{a}\right) + \sum_{a}\sum_{v}\zeta^{cap}_{av}e^{-\lambda_c t}\left(k^{v}_{a} - f^{v}_{a}\right)$$
$$+\sum_{a}\sum_{v}\zeta^{f}_{av}e^{-\lambda_c t}f^{v}_{a} + \sum_{i}\sum_{lmrv}\zeta^{hiv}_{lmr}e^{-\lambda_c t}h^{iv}_{lmr} + \sum_{ij}\sum_{lm}\zeta^{xij}_{lm}e^{-\lambda_c t}x^{ij}_{lm}. \tag{37}$$

In this expression the μ variables are costate (or adjoint) variables, whereas the ζ variables are intertemporal Lagrange multipliers.

In addition to initial values given for the state variables, the state Eqs. (32), (33), (34), and (35), and zero-order conservation of flows Eq. (4'), the first-order necessary conditions for an optimal solution to the dynamic optimization problem are as follows.

$$\partial L/\partial x^{ij}_{lm} = -\mu^{xij}_{lm}e^{-\lambda_c t}\gamma^{xij}_{lm} + \zeta^{icon}_{lmv}e^{-\lambda_c t}\left(\wp^{iv}/q^{i}_{x}\right)\left(1 + X^{j}_{m}D^{*-1}_{lm}/\sum_{m}\sum_{j}X^{j}_{m}D^{*-1}_{lm}\right) + \zeta^{xij}_{lm}$$
$$= -\dot{\mu}^{xij}_{lm}e^{-\lambda_c t} + \lambda_c\mu^{xij}_{lm}e^{-\lambda_c t}, \forall i, \forall j, \forall l, \forall m, \tag{38}$$

$$\partial L/\partial L^{j}_{m} = -\mu^{Lj}_{m}e^{-\lambda_c t}\gamma^{Lj}_{m} = -\dot{\mu}^{Lj}_{m}e^{-\lambda_c t} + \lambda_c\mu^{Lj}_{m}e^{-\lambda_c t}, \forall j, \forall m, \tag{39}$$

$$\partial L/\partial K^{j}_{m} = -\mu^{Kj}_{m}e^{-\lambda_c t}\gamma^{Kj}_{m} = \dot{\mu}^{Kj}_{m}e^{-\lambda_c t} + \lambda_c\mu^{Kj}_{m}e^{-\lambda_c t}, \forall j, \forall m, \tag{40}$$

$$\partial L/\partial X_m^j = \mu_{lm}^{xij} e^{-\lambda_c t} \gamma_{lm}^{xij} \left[\left(\rho_m^j + \kappa_m^j\right)/\kappa_m^j\right] x_{lm}^{ij} * /X_m^j + \mu_m^{Lj} e^{-\lambda_c t} \gamma_m^{Lj}$$
$$\times \left[\left(\kappa_m^j + \rho_m^j\right)/\left(\kappa_m^j + \kappa_m^j \rho_m^j\right)\right] L_m^j * /X_m^j + \mu_m^{Kj} e^{-\lambda_c t} \gamma_m^{Kj} \left[\left(\kappa_m^j + \rho_m^j\right)/\left(\kappa_m^j + \kappa_m^j \rho_m^j\right)\right]$$
$$\times K_m^j * /X_m^j + \mu_m^{Xj} e^{-\lambda_c t} \gamma_m^{Xj} + \zeta_{lv}^{icon} e^{-\lambda_c t} \wp^{iv} \left(\partial \overline{FD}_{\underset{\sim}{lm}}^i / \partial X_m^j\right)/q_x^i$$
$$= -\dot{\mu}_m^{Xj} e^{-\lambda_c t} + \lambda_c \mu_m^{Xj} e^{-\lambda_c t}, \ \forall \text{j}, \forall \text{m},$$
$$\text{where } \ \partial \overline{\text{FD}}_{\underset{\sim}{lm}}^i / \partial X_m^j = \frac{1}{\sum_m \sum_j X_m^j} \left\{ \left(X_l^i - \sum_m \sum_j X_m^j \right) D_{lmr}^{*-1} - \overline{\text{FD}}_{\underset{\sim}{lm}}^i \right\}, \tag{41}$$

$$\partial L/\partial h_{lmr}^{iv} = e^{-\lambda_c t} D_{lmr}^v p_{lmr}^{iv} + \mu_{lm}^{pi} e^{-\lambda_c t} \gamma_{lm}^{pi} \left[p_{lmr}^{iv} \left(\sum_{vr} h_{lmr}^{iv} - h_{lmr}^{iv} \right) \Big/ \left(\sum_{vr} h_{lmr}^{iv} \right)^2 \right]$$
$$- \psi_{lmr}^{ij} \delta_{lmr}^{av} + \zeta_{lmr}^{hiv} = 0, \forall i, \forall j, \forall l, \forall m, \tag{42}$$

$$\zeta_{av}^{cap} e^{-\lambda_c t} \left(k_a^v - f_a^v\right) = 0, \zeta_{av}^{cap} e^{-\lambda_c t} f_a^v = 0, \forall a, \forall v, \tag{43}$$

$$\zeta_{lmr}^{hiv} e^{-\lambda_c t} h_{lmr}^{iv} = 0, \forall i, \forall l, \forall m, \forall r, \forall v, \tag{44}$$

$$\zeta_{lm}^{xij} e^{-\lambda_c t} x_{lm}^{ij} = 0, \forall i, \forall j, \forall l, \forall m. \tag{45}$$

The transversality conditions that must be satisfied at every data point are as follows.

$$\begin{aligned} &\lim_{t\to\infty} \mu_{lm}^{xij} e^{-\lambda_c t} x_{lm}^{ij} = 0, \ \forall i, \forall j, \forall l, \forall m, \ \lim_{t\to\infty} \mu_m^{Lj} e^{-\lambda_c t} L_m^j = 0, \ \forall j, \forall m, \\ &\lim_{t\to\infty} \mu_m^{Kj} e^{-\lambda_c t} K_m^j = 0, \ \forall j, \forall m, \ \lim_{t\to\infty} \mu_m^{Xj} e^{-\lambda_c t} X_m^j = 0, \ \forall j, \forall m. \end{aligned} \tag{46}$$

The first-order necessary conditions can be solved by a variable-step, variable-order Adams method, as in the case of the dynamic network model of Donaghy and Schintler (1998). Discretized conditions can be solved by the PATH algorithm of Dirkse and Ferris (1995).

In this dynamic model, firms (shippers) react over time to prices and economies of scale and scope that can be realized by industrial location, thereby affecting the economic geography through their location decisions, while carriers react to shipping costs and firms' and households' demands for intermediate and final goods to adjust shipments between locations.[6]

[6]In Donaghy et al. (2005), changes in network (link) capacity are also considered in a dynamic optimization framework.

4 Conclusion

In this chapter we have demonstrated how features of models in two distinct lineages of commodity-flow models—those of spatial-interaction parentage and those of interregional input-output parentage—can be integrated in two new specifications that embody recent theoretical developments and extensions that permit examination of different classes of contemporary problems that are beyond the explanatory reach of previous models. The parameters of the models here presented have been estimated with time-series data from 1977 to 2007 on commodity flows derived from a regional econometric input-output model for 13 industrial sectors and 13 states and the rest of the United States (Brown-Steiner et al. 2015). The models are presently being employed in research on the impacts on air quality of increased freight movement.

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References

Batten DF, Boyce D (1986) Spatial interaction, transportation, and interregional commodity flow models. In: Nijkamp P (ed) Handbook of regional and urban economics, vol I. North-Holland, Amsterdam, pp 357–406

Boyce D (2002) Combined model of interregional commodity flows on a transportation network. In: Hewings GJD, Sonis M, Boyce D (eds) Trade, networks, and hierarchies: modeling regional and interregional economies. Springer, Berlin, pp 29–40

Brown-Steiner B, Chen J, Donaghy K (2015) The evolution of freight movement and associated non-point-source emissions in the midwest-northeast transportation corridor of the United States, 1977–2007. In: Batabyal A, Nijkamp P (eds) The region and trade. World Scientific, London, pp 177–204

Dirkse SP, Ferris MC (1995) The PATH solver: a non-monotone stabilization scheme for mixed complementarity problems. Optim Methods Softw 5:123–156

Donaghy KP (1993) A continuous-time model of the United States economy. In: Gandolfo G (ed) Continuous time econometrics: theory and applications. Chapman and Hall, London, pp 151–194

Donaghy K (2009) Modeling the economy as an evolving space of flows. In: Reggiani A, Nijkamp P (eds) Complexity and spatial networks. Springer, Berlin, pp 151–164

Donaghy KP, Schintler LA (1998) Managing congestion, pollution, and infrastructure in a dynamic transportation network model. Transp Res D 3:59–80

Donaghy K, Vial JF, Hewings GJD, Balta N (2005) A sketch and simulation of an integrated modeling framework for the study of interdependent infrastructure-based networked systems. In: Reggiani A, Schintler LA (eds) Methods and models in transport communications: cross Atlantic perspectives. Springer, Berlin, pp 93–117

Ham H, Kim TJ, Boyce D (2005) Implementation and estimation of a combined model of interregional, multimodal commodity shipments and transportation network flows. Transp Res B 39:65–79

Kamien, Schwartz (1981) Dynamic optimization: the calculus of variations and optimal control in economics and management. North Holland, New York

Kim TJ, Boyce DE, Hewings GJD (1983) Combined input-output and commodity flow models for interregional development planning: insights from a Korean application. Geogr Anal 15:330–342

Kohno H, Higano Y, Matsumura Y (1994) Dynamic takeoff-accelerating effects and the feasibility of the Asian expressway network on China. Paper presented at the 41st North American meetings of the RSAI, Niagara Falls, Ontario, Canada, November

Leontief WW, Strout A (1963) Multiregional input-output analysis. In: Barna T (ed) Structural interdependence and economic development. St. Martin's Press, New York, pp 119–150

Moses L (1960) A general equilibrium model of production, interregional trade, and location of industry. Rev Econ Stat 42:373–397

Southworth F, Peterson BE (2000) Intermodal and international freight network modeling. Transp Res C 8:147–166

Wilson AG (1970) Interregional commodity flows: entropy maximizing procedures. Geogr Anal 2:255–282

Evaluation of Ecosystem Services Through Revealed Policy Preferences: Exchange Rates Between Scientific Currencies

Tomaz Ponce Dentinho

Abstract Rational public choices imply that total marginal values of alternative decisions should be the same along all those decisions. Concerning the environment, those values are related to production services, regulating services, cultural services and supporting services. The total value of the environment must take into account all these services. Nevertheless, the various scientific disciplines that influence decision-making are not equally specialised in the evaluation of the various services. Ecologists evaluate the ecosystems' sustainability and analyse the environment capacity to recycle emissions and have a better understanding of the regulation services. Economists evaluate and valuate costs and benefits looking for alternative policies but are more sensible to environmental production services. In the end each discipline tends to evaluate the environment based on its own frame of reference. Decision support systems combine all these evaluations in order to recommend the best solutions taking into account all the interests involved. But only when the decisions are taken and implemented it is possible to say that all these different evaluations of facts are transformed into values associated with acts, impacts and effects.

The objective of this essay is not to propose an alternative decision support system able to recommend best solutions for policymakers. The purpose is to introduce a methodology able to estimate the decision rules revealed by public choices. It is assumed that different disciplinary evaluations can be designed to complement each other rather than to compete with each other. It is also presupposed that each one of these evaluations could be allocated to the same spatial and temporal referential of decision-making. Finally, it is alleged that rational public choices should be consistent so that the trade-off between disciplinary evaluations of alternative decisions should be similar along all the decisional boundaries, where one decision must have the same marginal value as the alternative solution.

The methodology is exemplified for three types of decisions: the design of a protected area, the design of a land use plan for the protection of water springs and the management plan of a marine ecosystem. The results include not only the

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estimates of the decision rules revealed by former public choices but also the design of consistent plans implicit in the revealed decision rules and an assessment of the total value of each plan that combines the ecological, environmental, social and economic valuations through the revealed decision rules.

Keywords Ecosystem services • Valuation • Land use • Land use planning • Marine spatial planning • Coastal management • Cost benefit analysis

1 Introduction

A wide range of studies have been undertaken so far to evaluate ecosystems. Many of these studies try to evaluate some or multiple functions and uses of ecosystems (Costanza et al. 1997; Turner 1997; EEA 2002), but only a few show explicit marginal values for alternative scenarios that are consistent with conventional decision-making tools such as cost-benefit analysis (Turner et al. 2003; Randall 2002; Hanley and Shogren 2002). Nevertheless cost-benefit analysis does not usually cover the total value of the ecosystem (Turner et al. 2001), leaving behind the value of the ecosystems' sustainability and the associated supporting services or the environment capacity to recycle emissions commonly identified with regulation services somehow related to the ecologic evaluation.

The evaluations achieved by these disciplinary methodologies can be quite different, and the features of the environment measured by the various studies are often poorly defined. Some studies assess the value of particular species to humans, others refer goods and services provided by the environment and some others deal with the value of biodiversity in itself (Nunes and Van Den Bergh 2001). Furthermore, as pointed out by many authors (de Groot et al. 2002; Farber et al. 2002; Limburg et al. 2002), there is a lack of a systematic typology to integrate the increasing number of publications that try to value the benefits of natural ecosystems to the human society.

What seems to happen is that each scientific paradigm tends to devise its own valuation system. Ecologists design maps with ecological values assuming the relevance for the sustainability of the ecosystem or with environmental impacts that reveal the recycling capacity of the environment related to existence of planned pollution sources. On the other hand, economists prefer to assess the costs and the benefits easily evaluated for production services but harder to estimate for regulation and supporting services. And the question stays open. How to combine the different disciplinary perspectives in a consistent decision support methodology?

There have been various attempts to overcome the gap between disciplinary evaluations of ecosystems, rooted in the environment interpretations of diverse scientific paradigms, and on the marginal values, implicitly revealed by decisions or acts. One approach to overcome such gap is to adopt first the cost-benefit analysis but complement the study with multicriteria analysis in order to include equity and environmental issues (European Commission 2002). Another strategy is to apply only multicriteria analysis with all sorts of possible methods to aggregate the various criteria (Qureshi et al. 1999; De Marchi et al. 2000), considering not only the economic and environmental evaluations but also the political judgements. Nevertheless many things are far from being resolved: the gap between ecosystem evaluation and valuation, the contradictions between the rules of the market behaviour and the rules that govern ecosystems (Gowdy and Carbonell 1999) and the conflicting patterns perceived or assumed by society.

The debate continues between those two aggregation methodologies usually named as monetary and nonmonetary evaluations (Turner 1997). There have been some comparative examinations of the two approaches (Munda et al. 1995) and also other attempts to overcome the gap between disciplinary evaluation and policy valuation. One line of research adopts an interdisciplinary approach to systems modelling and tries to include the interactions between human activities and the environment and vice versa, which pose both conceptual and empirical research challenges (Turner 1997; Turner et al. 2003; Fabbri 1998). Another solution is to understand the construction of values through the study of institutional arrangements and stakeholder analysis to identify and conceptualise conflicts and understand the institutional mechanisms by which costs and benefits are appropriated (Langford et al. 1999; Brouwer 2000; de Marchi et al. 2000; Kontogianni et al. 2001). And some others appeal for the mutual respect between sciences based on the idea that the assumptions of one branch of science should accept facts revealed by other branches (Wilson 1998).

Meanwhile, all sorts of decision support systems are being implemented (Zhu et al. 1996, 1998; Runner and Starkl 2004), either pressured by the need to decide taking into account a multitude of factors and effects or stimulated by the creative generation of decision tools able to include all sorts of data, theories and interests.

Notwithstanding all this, one point seems to be missed. The point is that only when choices are made and implemented, all the disciplinary evaluations can be transformed into policy values. Actually, it seems clear that ecological sustainability, environmental resilience, economic efficiency and social dynamics can only be evaluated by the scientific paradigms that somehow create or adopt those evaluation concepts. Yet, only when or where there is a choice between alternative solutions, it is possible to assess the marginal value of those decisions and have an estimate of the total value of the ecosystem. In the end all choices, individual or collective, can be seen as value statements.

The purpose of this paper is to introduce a methodology not only to estimate the decision rules revealed by public choices but also to assess the marginal value of the decisions and, at the same time, have an insight about the total value of the ecosystem. It is assumed that the economic, ecological, environmental and social evaluations can be designed to complement each other rather than compete with each other. It is also supposed that each one of these evaluations could be allocated to the same spatial and temporal referential of decision-making. Finally, it is alleged that rational public choices should be consistent so that the trade-off between disciplinary evaluations for alternative decisions should be similar along all the decisional boundaries, where one decision must have the same total value as the alternative solution.

The methodology is applied for three types of decisions: the design of a protected area, the design of a land use plan for the protection of water springs and the management plan of a marine ecosystem. The results include not only the estimates of the decision rules revealed by former public choices but also the design of consistent plans implicit in the revealed decision rules and an assessment of the total value of each plan that combines the environmental and economic valuations through the revealed decision.

In the next section the methods used for economic and environmental valuation methodologies are synthesised. In the third point the environmental decision support system revealed by public choices is explained and justified. Then, the proposed methodology is applied for three types of decisions: the design of a terrestrial protected area where the only trade-off is between spatially defined ecological and economic values, the design of a land use plan for the protection of water springs where the explicit management conflict is between spatially defined economic values and environmental values of water flows and, finally, the design of marine protected areas where there are strong spatial diffusion effects from human intervention. The paper concludes in point 5.

2 Valuation Methods

As long as we are forced to make choices, we are doing valuation (Costanza et al. 1997). And because choices are important and have value, quite often each discipline designs and improves specific valuation tools which are requested and used by policymakers, mainly when conflicts can be represented by politicians, on one side, and disciplinary experts, on the other side. Economic valuation is quite useful to support decision-making when there are trade-offs between private and public goods. Sociocultural valuation has been used to establish protection schemes for particular cultural heritage sites. Environmental valuation schemes, such as environment impact assessment, become a common method to minimise environmental impacts of projects. And ecological valuation is quite common in the design of natural protected areas.

2.1 Economic Valuation

There are three main assumptions for economic valuation. One is that societal welfare is the sum of individual welfare. A second one assumes that individual welfare can be measured. And, finally, it is presumed that individuals maximise welfare by choosing the best combination of goods and services that yields the maximum net benefit. From this perspective, the legitimacy of a policy is assured whenever the interpersonal sum of benefits exceeds costs (Randall 1987). Therefore, from the economic perspective, the valuation problem is to assess the net benefits

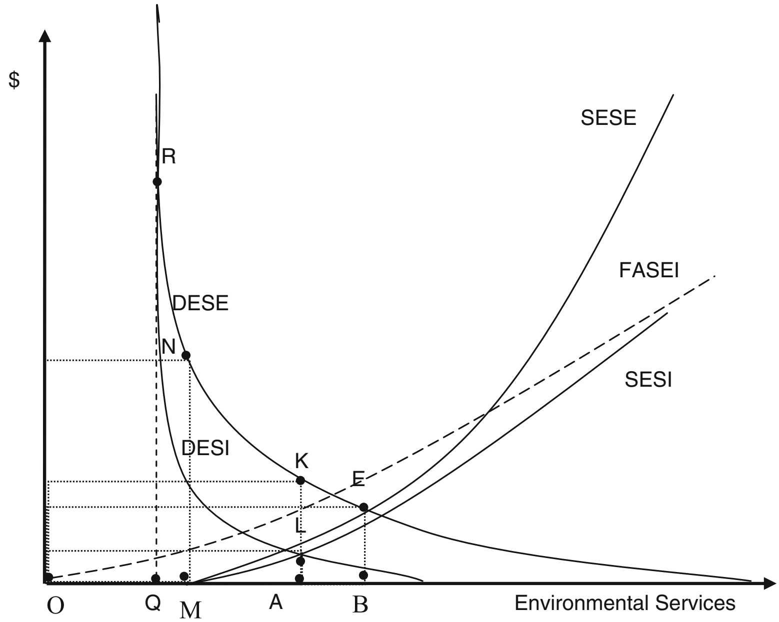

Fig. 1 Supply and demand of environmental services

by estimating the value the beneficiaries would be willing to pay and appraising the costs that the losers are able to accept, either by allowing it voluntarily or by promoting its implementation.

The objective of the economic valuation is to value alternative managements of the environmental services. To clarify the main concepts of economic valuation of environmental services, let us look at their demand and supply in Fig. 1 (Pearce et al. 2006), where x line stands for the amount of environmental services (ES), y line represents their marginal values and marginal costs ($), DESI is the monetary demand for environmental services, DESE is the total demand for environmental services internalising all external benefits, SESI is the monetary supply of environmental services, SESE is the total supply of environmental services internalising all external costs and FASEI is the free access supply for environmental services, being the x line the free access demand for environmental services.

Figure 1 shows five levels of environmental services: $O =$ the equilibrium that results from free access to environmental services, $Q =$ a minimum threshold of environmental services to support present and future human beings, $M =$ the equilibrium that maximises the monetary value for direct users of environmental services, $A =$ the actual equilibrium where direct users are constrained by regulatory policies and $B =$ the optimal equilibrium. Except for equilibrium (O), where the total economic value tends to zero, for all the other levels of environmental services, the total economic value, assessable by the area below the demand function for environmental services, tends to infinity. This explains the differences between the two main approaches to the economic valuation of the environment. On the one hand, those (I), like Robert Costanza et al. (1997) and Rudolph de Groot et al. (2002), try to estimate the total actual values of the various environmental services in order to highlight the importance of marine biodiversity and to complement detailed qualitative environmental descriptions (Beaumont et al. 2007). Somehow these authors perceive that the more likely outcome in Fig. 1 is some level of environmental services between *O* and *Q*, and they attempt to show policymakers the enormous amount of total economic value that could be lost if that happens. On the other hand those (II) aim to support decisions on alternative policies with marginal effects on environmental services (Randall 1987). These approaches assess marginal values of alternative managements of environmental services, resulting from different projects, policies or scenarios on emissions. Looking at Fig. 1 the main task of this second approach is to compare the values of different levels of environmental services: the value of *Q* taken as *q*, the value of $M = q +$ [QMRN], the value of $A = q +$ [QMLKRN] and the value of $B = q +$ [QMIEKRN]. The difference between the value of environmental service levels *A* and *B* is the area of the polygon [LEK], and this is the only value that is important to advice policymakers the choice between *A* and *B*. To some extent both perspectives complement each other. The total value approach (I) highlights the importance of environmental services provided by marine biodiversity which is crucial when those services are exploited with free access. The approach that focuses on the marginal value of alternatives (II) aims to support decision-making over alternative policies which is important to maximise the value of environmental services without free access. Notice that both perspectives (I and II) use similar methods to value the various environmental services.

There are several methods suitable to assess environmental values. First are approaches that use market values of goods and services such as changes in productivity, cost of illness and opportunity cost (Willis et al. 1988; Montegonery et al. 1984) Norton Griffiths 1994; Howard 1995; Houghton and Mendelson 1997). Second are cost-side methods that use the value of preventive expenditures, replacement costs, relocation costs and shadow projects (Pagiola 1996). Third are surrogate market techniques such as travel cost methods and hedonic methods where prices of market goods are taken as environmental surrogates (Bockstael et al. 1987; Balkan and Khan 1988; Englin and Mendelson 1991; Pendleton 1993; Read-Sturgess and Associates 1994). A fourth group is the contingent valuation methods using bidding games, take-it-or-leave-it experiments, trade-off games, costless choice and Delphi techniques (Wilson and Carpenter 1999). The limits of CBA can be mainly seen in the non-substitutability of essential goods, irreversibility, long-term effects and intergenerational fairness.

Table 1 presents the list of environmental services, the type of values that they entail (direct use and option value, indirect use and no use) and the various methods that could assess them. The only method that covers all values is the contingent valuation (CV) or choice modelling (CM). Nevertheless, it is based on stated preferences instead of preferences revealed by actual behaviour of environmental

Table 1 Environmental goods and services and valuation methods

	Values										
Environmental Services	Direct Use Values				Indirect Use Values						Non-use, bequest and existence
	Without consumer surplus	With consumer surplus									
Food Provision	X			X							
Raw Materials	X			X							
Leisure and Recreation	X	X	X	X							
Cultural heritage and identity	X			X	X						
Cognitive Values	X			X							
Resilience and resistance								X	X	X	
Nutrient cycling							X	X	X	X	
Gas and climate regulation						X		X	X	X	
Bioremediation of waste							X	X	X	X	
Biologically mediated habitat						X				X	
Disturbance prevention						X		X		X	
Non-use, bequest & existence											X
Methods	Market	Hedonic	Travel Cost	Contingent Val.& Choice Modelling	Hedonic	Avoidance	Replacement	Mortality	Cost of Illness	Contingent Val.& Choice Modelling	Contingent Val.& Choice Modelling

Option values that assess the value of the information secured by postponing irreversible decisions were not included

service users, and although there have been strong improvements in this valuation methodology, there are huge problems with the analysis of many alternatives which are often implicit in environmental decisions differentiated across the dimensions of space and time.

2.2 *Ecological Valuation*

Ecological evaluation involves usually two phases. First is the definition and the determination of measures for ecological value and, then, the choice and the application of methods able to aggregate those measures (Cardoso 2015) into 12 types of measures of ecological values: (i) *Species richness* is the most applied measure of biodiversity. (ii) *Rarefaction* techniques try to determine the number of species that would have been recorded in each considered area if effort was the same for all recorded areas. (iii) *Surrogates* for species richness are more widely available or more easily acquired. (iv) *Ecologic diversity*, based on the information theory, tries to combine the number of species and the evenness of their. (v) *Rarity*, which many times is considered as a synonym to endemism, is usually associated with species that are restricted in space, has low numbers of individuals or presents narrow habitat requirements. (vi) *Threat status* classifies species into different categories (extinct, critical, endangered, vulnerable, lower risk and data deficient) based on species rarity, immediacy of threat, habitat trends, fragmentation, negative interactions with introduced species, recovery potential, taxonomic distinctiveness and conflict of species recovery with human interests. (vii) *Taxonomic distinctiveness* is the degree to which species differ from one another, from which it is possible to derive trees of evolution and their geographical patterns. (viii) *Functional diversity*, somehow related with keystone species, seeks to preserve not only species but also natural ecosystem processes such as nutrient flux and recycling, primary productivity, metapopulation dynamics, gene flow or natural selection and evolution. (ix) Umbrella species have such large area and habitat requirements that other species are supposedly protected through conservation actions primarily intended for the umbrella. (x) *Irreplaceability* was firstly as a practical measure of the potential contribution of a site towards a reservation goal. It can be defined as the proportion of fully representative sets of sites at a given combination size where any site under consideration occurs. (xi) *Biological integrity* was defined as the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organisation comparable to that of the natural habitat of the region. (xii) *Vulnerability* of sites can be seen as a non-scientific but political measure for conservation practice, since it is not a measure based on any ecological principles.

Pedro Cardoso (2015) also summarises that there are three types of aggregation methods: (a) The *scoring approaches* simply rank sites according to the values from one measure but are extensively used in bibliography related to prioritisation of sites for conservation or in the prioritisation of large biogeographical areas. (b) *Iterative approaches* aggregate different measures and attribute weights or priorities to each measure in order to obtain the final value. It starts from the selection of one site and adds the other ones assessing the aggregated value, since many regions have already all iterative approaches that can take previously protected areas and species into account, trying to fill the gaps in the existing network, in what is called gap analysis. (c) *Optimal approaches* include methods such as integer linear programming for the problem of minimising the number of sites that represent all specified objectives.

3 Methodology Explanation, Justification and Demonstration

The decisions selected by these different valuation methodologies are necessarily different. Some studies assess the value of particular species to humans, others refer goods and services provided by the environment and some others deal with the value of biodiversity in itself (Nunes and Van Den Bergh 2001). In the same line of criticism (de Groot et al. 2002), along with other authors (Farber et al. 2002;

Limburg et al. 2002), highlights the lack of a systematic typology to integrate the increasing number of valuations that try to value the benefits of natural ecosystems to the human society.

What seems to happen is that each scientific paradigm tends to devise its own valuation system. Ecologists design maps with environmental values assuming the relevance for the sustainability of the ecosystem. Environmentalists estimate impacts from alternative projects. Sociocultural scientists value things according to their role in the society along space and time. Finally, economists, as mentioned above, prefer cost-benefit analysis where everything can be translated into money. And the question stays open. How to combine the different disciplinary valuations in a consistent decision support methodology?

3.1 Methodological Explanation

The objective of the methodology proposed is to combine different environmental valuation systems in a consistent way. The method is based on three assumptions.

First, ecological, environmental, sociocultural and economic values do not overlap. Being so, it is possible to add the productive values of each use of the natural resources to the ecological, environmental and sociocultural values associated to each one of those uses. Even if the ecological, environmental and sociocultural values were not expressed in monetary terms, it is possible to make the addition between the various valuations if some "exchange rate" between the various valuations can be defined.

Second, ecological, environmental, sociocultural and economic values should be allocated to connectable regulatory dimensions, even if the effects of those values are felt elsewhere. Let us take an example of the valuation of different land use policies. The economic value of land use can be allocated to a particular spatial grid, but its effects are captured along the logistic value chains. On the other hand, the environmental value of water associated with a particular land use is assessed in the water spring but felt by the water consumers. Finally, although being often perceived by aliens, ecological and sociocultural values of landscape are, respectively, assessed by some lump sum measures of biodiversity or by some type of sociocultural ranking, both of them quite often associated with map images.

Finally, public decisions are, or at least should be, consistent so that the trade-off between similar values must be the same along all the decision – making space of competences. Therefore in every point of the boundary (f) that limits alternative uses of the environment, the total value for one use (Vfa) must be exactly the same as the total value for the alternative use (Vfb):

$$Vfa = Vfb \tag{1}$$

Nevertheless, each total value (*Vfa*, *Vfb*) results from adding together the economic values (*Vfea*, *Vfeb*), the ecological values (*Vfba*, *Vfbb*), the environmental values (*Vfna*, *Vfnb*) and the sociocultural values (*Vfca*, *Vfcb*), each one of them multiplied by an exchange rate function. The exchange rate function (ρ) relates the economic value to the ecological value. The exchange rate function (θ) relates the economic value to the sociocultural value. The exchange rate function (σ) relates the economic value to the sociocultural value:

$$Vfa = Vfea + Vfba \times \rho + Vfna \times \theta + Vfca \times \sigma \tag{2}$$

$$Vfb = Vfeb + Vfbb \times \rho + Vfnb \times \theta + Vfcb \times \sigma \tag{3}$$

In the boundary the value associated to alternative uses (*a*, *b*) is equal. Therefore:

$$(Vfea - Vfeb) = (Vfbb - Vfba) \times \rho + (Vfnb - Vfna) \times \theta + (Vfcb - Vfca) \times \sigma \tag{4}$$

Notice that the boundary line has many points. Assuming that it is possible to obtain the economic, sociocultural, environmental and ecological values for different alternatives (*a*, *b*), then it is also possible to estimate the functions (θ), (ρ) and (σ). If these functions are just simple parameters, then they can be considered as "exchange rates between different disciplinary valuations": on the one hand, between economists and ecologists (ρ), between economists and environmentalists (θ) and between economists and historians (σ). On the other hand, it is possible to calculate the exchange rates between ecologists and environmentalists (θ/ρ), between ecologists and historians (ρ/σ) and between environmentalists and historians (θ/σ).

In Fig. 2 we demonstrate graphically the concept of the exchange rate between disciplinary valuations. Assume that there is only a conflict between values assessed by economic methods and values appraised by ecological methods. Admit that there are two alternative uses for land (*L*), forest (*f*) and pasture (*p*), whose economic marginal values are expressed by the lines *Ep* and *Ef* and whose ecological marginal values are represented by the lines *Bp* and *Bf*, on the left. An economic land use plan will allocate Lep to pasture and Lef to forest. On the other hand an ecologic land use plan will attribute *Lbp* to pasture and *Lbf* to forest. Nevertheless, once the conflict between forest and pasture is solve in line *E* on the right, it is possible to say that the marginal economic and ecological value for pasture is equal to the marginal economic and ecological value for forest: $Vfep + \rho Vfbp = Vfef + \rho Vfbf$, where ρ = exchange rate between economic and ecological valuations revealed by decision *R*. And because the regulatory boundary *E* occurs in many points, then it is possible to estimate the value of the exchange rate: $\rho = (Vfea – Vfeb) / (Vfbb - Vfba)$.

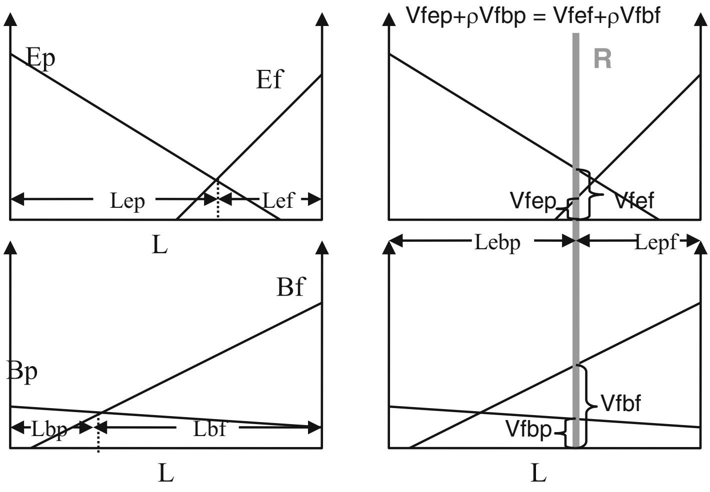

Fig. 2 Explanation of the exchange rate mechanism

3.2 Methodological Justification

There are some doubts related to the concept of the exchange rate between disciplinary valuations. The first doubt, usually put forward by economists, is that the a priori regulatory boundaries (*R*) which are the base to estimate the exchange rates between disciplinary valuations, do not reveal the sum of all individual values on the decision and therefore could not be taken as an efficient decision. The second criticism, more in tune with noneconomists, is that the regulatory boundaries redesigned with consistent exchange rates along the decisional space will not guarantee the defence of cultural, environmental and ecological sustainability. A third doubt, coming from both economists and noneconomists, refers to the unconsistency of collective decision-making. Finally the doubt related to the inability to value to the various policy alternatives according to the different valuation methodologies.

To address these doubts, let us consider a simple formal model that somehow in common to any decision-maker. The decision-maker faces (*i*) types of instrumental variables (*Rik*) that can appear in different (*k*) places or periods and (*j*) types of dependent variables (*Yjk*) that also materialise in (*k*) places and periods. They characterise the reality and are related through a set of functions *Yj*(*Rik*, *Yjk*) that try to explain the functioning of that reality. The problem is to maximise an objective function *Z*(*Xik*, *Yjk*) subject to the functioning of the real world:

$$\text{Max } Z\,(Rik, Yjk) \tag{5}$$

$$\text{st. } Yjk = Yj\,(Rik, Yjk)\ \text{for all } jk \tag{6}$$

Two questions arise. One is to formulate and calibrate models with the functions $Yj(Rik, Yjk)$ that try to address the functioning of the economic, cultural, environmental and ecological systems. A second question is to agree upon an objective function $Z(Rik, Yjk)$ suitable to take in account the various aspects of sustainable development. These questions are very difficult to answer because, as stressed by Robert Costanza et al. (1997), they involve the collaborative construction of dynamic, evolutionary models of linked ecological, environmental, economic and cultural systems that adequately address long-term responses and uncertainties.

Notwithstanding these difficulties, decisions must be taken. The common practice has been to divide decisions by disciplines (j), and the decision problem is simplified in the following way:

$$\text{Max}\ \ Za\,(Rik, Yak) \tag{7}$$

$$\text{st.}\ \ Yak = Ya\,(Rik, Yak) \tag{8}$$

where Za is the objective function selected for discipline (a), Yak are the dependent variables associated with discipline (a) that can appear in different (k) places or periods and Rik are the instrumental variables in places and periods (k). According to this approach, each discipline chooses dependent variables, objective functions and models of the reality from its own perspective.

A more interdisciplinary approach is to consider all the disciplinary valuations and weight them in the objective function with the weights (wj). The formalised problem result is expressions (9) and (10):

$$\text{Max}\ \ Z = \Sigma_j\ \ Zj\,(Rjk, Yjk)\,wj \tag{9}$$

$$\text{st.}\ \ Yjk = Yj\,(Rjk, Yjk)\ \text{for all}\ jk \tag{10}$$

The exchange rate approach proposed in this paper selects, initially, one of the disciplinary valuations for the objective function and considers the other disciplinary valuations as constraints:

$$\text{Max}\ Za\,(Rjk, Yak) \tag{11}$$

$$\text{st.}\ \ Yjk = Yj\,(Rjk, Yjk)\ \text{for all}\ jk \tag{12}$$

$$Z'jk = Zj\,(Rjk, Yjk)\ \text{for all}\ jk \neq ak \tag{13}$$

In this case the consistency of the solution is guaranteed when the shadow prices of $Z'jk$ constraints are the same for all (k). Being so it is possible to rewrite the problem through the incorporation of $Z'jk$ constraints in the objective function multiplied by the shadow prices vj. These shadow prices are the exchange rates between disciplinary valuations that must be the same for all (k) places or periods:

$$\text{Max } Za\,(Rjk, Yak) + \Sigma_{jk \neq ak} Zj\,(Rjk, Yjk)\,vj \tag{14}$$

$$\text{st. } Yjk = Yj\,(Rjk, Yjk) \text{ for all } jk \tag{15}$$

Based on this formalisation, it is now possible to analyse the doubts presented above. Related to the first doubt, it is true that consistent regulatory boundaries are not a sufficient condition to maximise the sum of individual welfare. Nevertheless, the requirement of consistency along the regulatory boundary is a necessary condition to maximise welfare. Furthermore, consistency is often the better we can get from public decisions, in which concerns the second criticism, it is not true that regulatory boundaries do not guarantee the defence of cultural, environmental and ecological sustainability. Actually that sustainability can be secured by the disciplinary valuations $Zj(Rjk,Yjk)$ that are explicit in the objective function. The only thing the method requires is a clear hierarchy of the outcomes of different policies. Third, collective decision-making can be un-consistent; the issue is that through the exchange rate mechanism, it is possible to design consistent policies. Finally, there is certainly some inability to value policies from various disciplinary perspectives. However, to consider these valuations in the exchange rate mechanism seems to be a look at the multiple effects of policymaking.

3.3 Methodological Demonstration

The exchange rate mechanism can be explained using linear programming models. Figure 3 presents three types of problems.

In scheme A spatial cells do not interrelate with each other, which can be used for the design of a protected area. In scheme B cells related with each other along the water flows, which can be a useful tool for the protection of water sources.

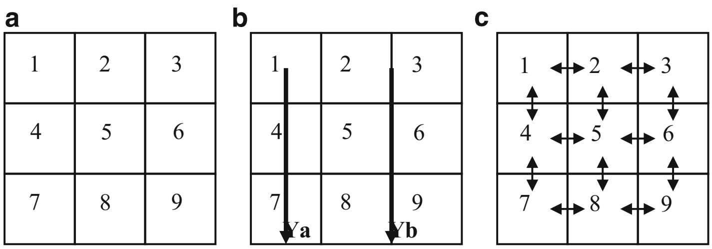

Fig. 3 Three types of problems

And in scheme C spatial cells relate with the neighbourhood cells which are more applicable to marine areas.

The optimisation model for situation A can be limited to the objective function presented below in (16), where Xjk = the land uses (j) for each cell (k), $Zejk$ = the economic value of use (j) for each cell (k), $Zajk$ = the ecological value of use (j) for each cell (k) and va = the exchange rate between economic and ecologic values:

$$\text{Max } Z = \Sigma_{j=1-J;k=1-9}\, Zejk(Xjk) + \Sigma_{j=1-J;k=1-9} Zajk(Xjk)va \tag{16}$$

Notice that model (16) can be presented with an objective function with economic values and one restriction ($B'a$) with ecological values, with the respective shadow price (va):

$$\text{Max Z} = \Sigma_{j=1-J;k=1-9}\, Zejk(Xjk) \tag{17}$$

$$\Sigma_{j=1-J;k=1-9} Zajk(Xjk) <= B'a \tag{18}$$

Nevertheless, if ecological restrictions are established by cell, then the model has nine ecological restrictions. The only thing it required, for the exchange rate mechanism, is that the shadow prices of these restrictions (vka) should be the same (va):

$$\text{Max } Z = \Sigma_{j=1-J;k=1-9}\, Zejk(Xjk) \tag{19}$$

$$\Sigma_{j=1-J;} Zajk(Xjk) <= B'ka \text{ for } k = 1..9 \tag{20}$$

The optimisation model for situation B has an objective function presented in (21) where Xjk= the land uses (j) for each cell (k), Zejk = the economic value of use (j) for each cell (k), Ya,Yb = the environmental variables in points a and b and va, vb = the exchange rates between economic and environmental valuations in points a and b. Notice that if the points a and b are not connected, then va and vb can be different and seen as shadow prices related to environmental standards $Y'a$ and $Y'b$. Nevertheless, if a and b are connected, for instance, through a water supply system, then va and vb should be the same:

$$\text{Max } Z = \Sigma_{j=1-J;k=1-9}\, Zejk(Xjk) - Ya.va - Yb.vb \tag{21}$$

$$\Sigma_{j=1-J;k=1,4,7} Ejk(Xjk) - Ya = 0 \tag{22}$$

$$\Sigma_{j=1-J;k=2,3,5,6,8,9} Ejk(Xjk) - Yb = 0 \tag{23}$$

The optimisation model for situation C has an objective function presented in (24) where Xjk = the land uses (j) for each cell (k), $Zejk$ = the economic value of use (j) for each cell (k), Zajk = the ecological value of use (j) for each cell (k) and va = the exchange rate between economic and ecologic values. Furthermore, there are spatial interactions between variables (Xjk) that are expressed by nine restrictions (25) where $Fjkq$ represent the spatial interactions between Xjk and Xjk:

$$\text{Max } Z = \Sigma_{j=1-J;k=1-9}\, Zejk\,(Xjk) + \Sigma_{j=1-J;k=1-9} Zajk(Xjk)va \tag{24}$$

$$\Sigma_{j=1-J;q=1..9} Fjkq(Xjk) = 0 \text{ for } k = 1..9 \tag{25}$$

4 Case Studies

In this point, the methodology is applied for three cases: the design of a protected area, the elaboration of land use plans for the protection of water springs and the management plan of a marine ecosystem. Each one of these cases assumes a different interrelation between spatial cells. In the design of the protected area, spatial cells do not interrelate with each other as in scheme A of Fig. 2. In the elaboration of land use plans for the protection of water springs, cells relate with each other along the water flow as in scheme B of Fig. 2. Finally in the design of marine protected areas, there are strong spatial diffusion effects as in scheme C of Fig. 2.

4.1 Contributions to the Spatial Plan of Morro Alto Protected Area

The Natura 2000 site of Morro Alto is located in the highlands of Flores Island. Flores Island is the western island of the Azorean Archipelago, with 142 km^2, height of 900 m and 4000 inhabitants. The study area was divided into square parcels of 1 ha each, and it was assumed that each spatial cell does not interact with the others. Each one of these small areas is classified into 12 territorial classes according to the altitude, the slope, the accessibility and the soil. Furthermore, for each pair (land use/territorial class), there is a private economic value related to the forest and pasture value added, a public economic value associated with the quantity and quality of water generated, and an ecological value that takes into account the relevance for the preservation of species and habitats of Natura 2000 (Dias 2004).

On the other hand the boundaries of Natura 2000 sites are the result of a discussion between experts and politicians. In each one of the parcels belonging to this boundary, it will be expected that the ecological and economic values associated with the inclusion in a Natura 2000 site will be exactly the same as the value of being out of that protected area. Therefore, taking into consideration the land uses allowed or forbidden on the parcels on the boundary, and based on their respective ecological

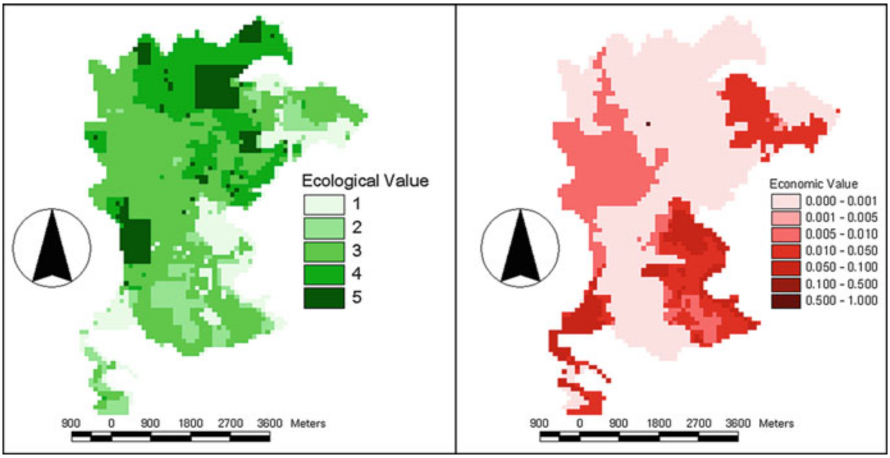

Fig. 4 Ecological values and economic values for the present land use in "Morro Alto", Flores Island

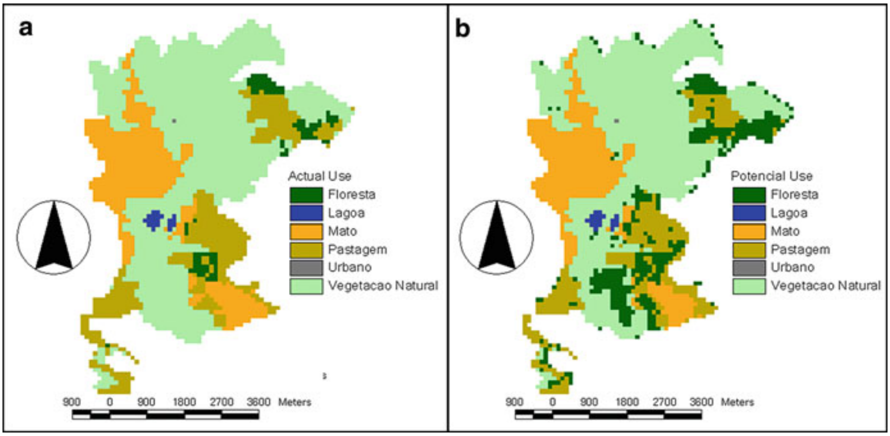

Fig. 5 (**a**) Actual land use. (**b**) Optimised land use [$\rho = 0.036$]

and economic values (Fig. 4), it is possible to obtain the estimates for the exchange rate coefficient [$\rho = 0.036$].

Knowing the exchange rate, it is then possible to generate various interesting outcomes: First, it is possible to obtain the best land use map (Fig. 5b) and compare it with the present land use (Fig. 5a), by choosing for each parcel the land use that leads to the maximum total value among all the other alternatives. From the observation of the two maps, it is clear that there are many similarities although some of the pasture area is potentially better used by forest.

Second, for a lower exchange rate [$\rho = 0.018$], it is possible to obtain another consistent land use map that represents a less conservationist solution (Fig. 6).

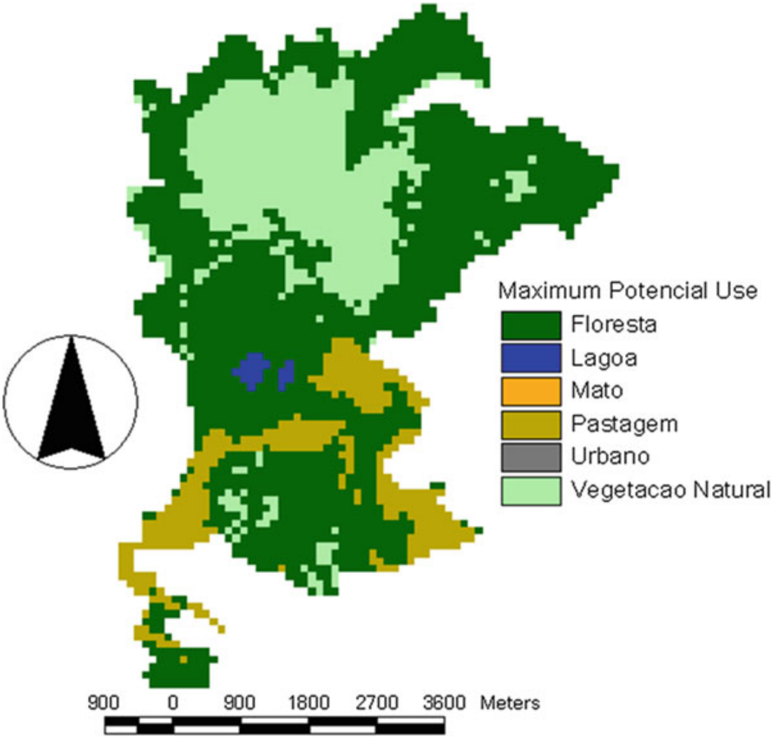

Fig. 6 Optimised land use [$\rho = 0.018$]

In this solution the area of natural vegetation and degraded vegetation will decrease living space to forest land.

The results seem quite interesting. First, there is a method to monetarise nonmonetary values. Second, this method is also suitable to value non-use values better informed by noneconomists. Finally the exchange rate between disciplines can also be used to assess the internal consistency of land use plans or to design different plans according to various exchange rates.

4.2 Elaboration of Land Use Plans for the Protection of Water Sources

To develop the land use plan for the protection of two water springs in São Miguel Island (Fig. 7), we used a linear programming model for Azores for different types of soils and managements and in phosphorous emissions. The model used now adds to the model of Dentinho (2002), the emissions of coliforms from the different areas

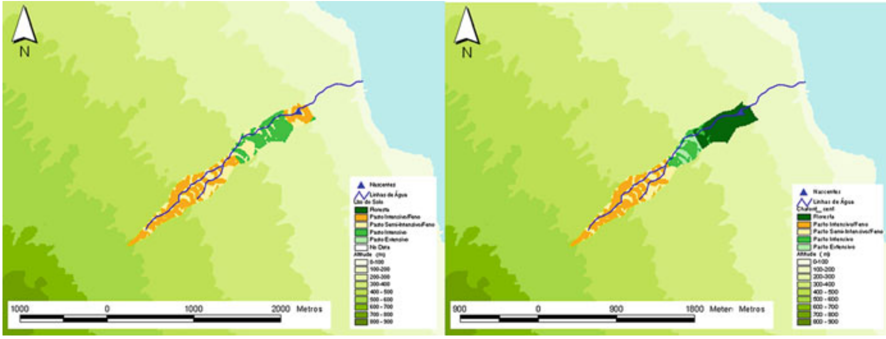

Fig. 7 (**a**) Actual land use [$\rho = 0$]. (**b**) Optimised land use [$\rho = 2986$]

of the basin taking into account the land use, the soil type and the distance to the water spring.

The basin of the water spring of Couto is located in Santa Bárbara village in the northwest of island of São Miguel, Azores. It has 5720 ha and an average precipitation of 1123 mm por ano. The soil derives mainly from volcanic ashes. Figure 6a reveals the actual land use and corresponds to the simulation of the linear programming model when the exchange rate between economic value for the farmers and the environmental value for the water consumers, assessed by CFUs per millilitre (colonial formation units), is zero. Figure 6b presents the proposed land use and corresponds to the simulation of the linear programming model when the exchange rate between the economic value for the farmers and the environmental value for the water consumers is 2986 euros. This exchange rate guarantees that the CFUs per millilitre in the water spring is less than 50. Based on the model it is also possible to estimate that the compliance with the regulation of 50 CFUs/ml will lead to a reduction in income of 27 % and a decrease in employment of 32 %.

4.3 Design of Marine Protected Areas

The Faial-Pico Channel contains habitats (reefs, shallow inlets and bays and submerged and semi-submerge marine cave) and marine species (fishes, sea turtles and dolphins) with relevant ecologic, scientific and economic values. A few areas (Monte da Guia, Baixa do Sul and Ilhéus da Madalena) have been designated as Sites of Community Importance (SCIs) and are part of the Natura 2000 European network of protected areas: Tempera et al. (2001) recommended the creation of a marine park that comprised the whole channel between the islands of Faial and Pico, because the designated SCIs are (i) too small to ensure the conservation of the resources they are supposed to protect and (ii) relatively close to each other and in a well-defined and ecologically coherent area between the islands of Pico and Faial.

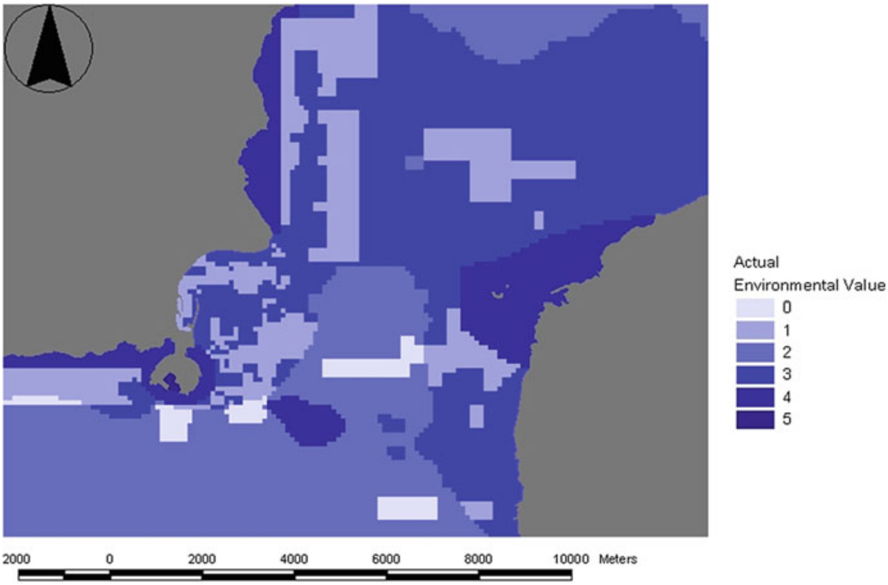

Fig. 8 Environmental values for the actual use in the Faial-Pico Channel

The application exchange rate between disciplinary valuations for the Faial-Pico Channel is based on a geographical information system (GIS). The study area was divided into square parcels of 100 × 100 m. Each one of these small areas was valuated in environmental terms based on the type of the bottom and the bathymetry taking into account their relevance for the ecosystem (Fig. 8). Shallow areas were valuated higher than deeper areas for they concentrate higher biomasses and biodiversity. Rocky bottoms were considered more valuable than soft bottoms as they concentrate most of the conspicuous biodiversity and fishery resources. Areas designated for conservation and harvest refugia (namely, under Natura 2000 sites and no-take areas for limpets) received a higher environmental. This approach results in infra littoral (<50 m deep) rocky bottoms within designated areas being given the highest value.

On the other hand, according to sea use allowed by regulatory measures, each one of these small areas is attached an economic value which was related to the employment supported by each one of those areas in different activities: fisheries, tourism and harbour logistics (Fig. 9).

Regulatory boundaries are the result of discussions between experts, stakeholders and politicians. In each one of the parcels belonging to these boundaries, it can be expected that the environmental and economic value associated with the inclusion within the regulatory restriction is exactly the same as the value of being out of that rule. Therefore, taking into consideration the sea uses allowed or forbidden on the different parcels of the regulatory boundaries, and based on the environmental

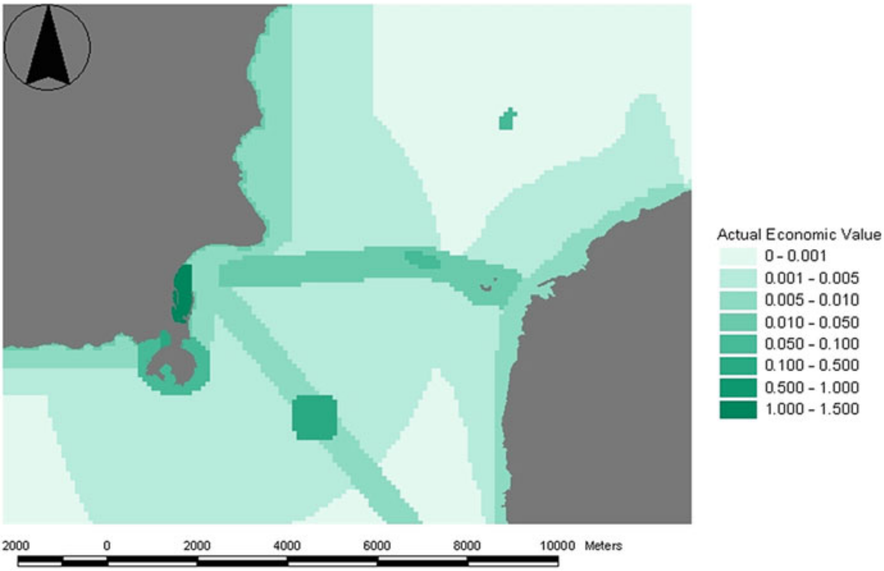

Fig. 9 Economic values for the actual use in the Faial-Pico Channel

and economic values of being in or out, it is possible to have estimates for (ρ) in expression (4).

In the Faial-Pico Channel, there are only three regulatory boundaries from which it is possible to derive exchange rates between disciplinary valuations. Table 2 presents these cases taking into account the values of being in or out of the regulatory boundary for the small areas where those boundaries are defined.

Notice that, instead of being an estimate from existent regulations, the exchange rate can be just a coefficient that relates a change in economic value associated with a change in the ecological value. Such coefficient can help planners to design efficient and consistent sea use plans, at least taking into account the available information on economic, ecological and social-cultural values for alternative sea uses. The only data needed is a quantified ecological impact associated with alternative uses by humans whose economic value is known.

Having (ρ), it is then possible to generate various interesting outcomes:

First, it is possible to obtain the best sea regulatory map (Figs. 10 and 11), by choosing for each parcel the rule that leads to the maximum total value among all the other regulatory alternatives. From the observation of Figs. 10 and 11, it is clear that, for all the estimated exchange rates ($\rho = 0.033$; $\rho = 0.087$), the optimisation of regulation will lead to a consistent sea use map that represents a more conservationist solution than the present one. In this solution all the channels with exception for the Horta Port, Madalena Port and Porto Pim Bay will be a natural park as is proposed by Tempera et al. (2001).

Table 2 Exchange rates between ecological and economic values in regulatory boundaries of the Faial-Pico Channel

	Economic value						Ecological value		Exchange rate
	Fish in	Fish out	Tour in	Tour out	Total in	Total out	In	Out	$\rho = [Vfe\,(\text{in}) - Vfe\,(\text{out})] \,/\, [Vf\text{b}\,(\text{out}) - Vfb\,(\text{in})]$
Regulation on limpets (50 % of coastal area)	0.0110	0.0165	0.0340	0.0060	0.0450	0.0225	3	2	$\rho = 0.023$
Regulation that forbids tourism and fisheries in "Monte da Guia"	0.000	0.030	0.000	0.057	0.000	0.087	5	3	$\rho = 0.087$
Regulation that forbids 50 % of fisheries in "Baixa do Sul"	0.1322	0.1983	0.0510	0.0382	0.1832	0.2366	4	3	$\rho = 0.053$

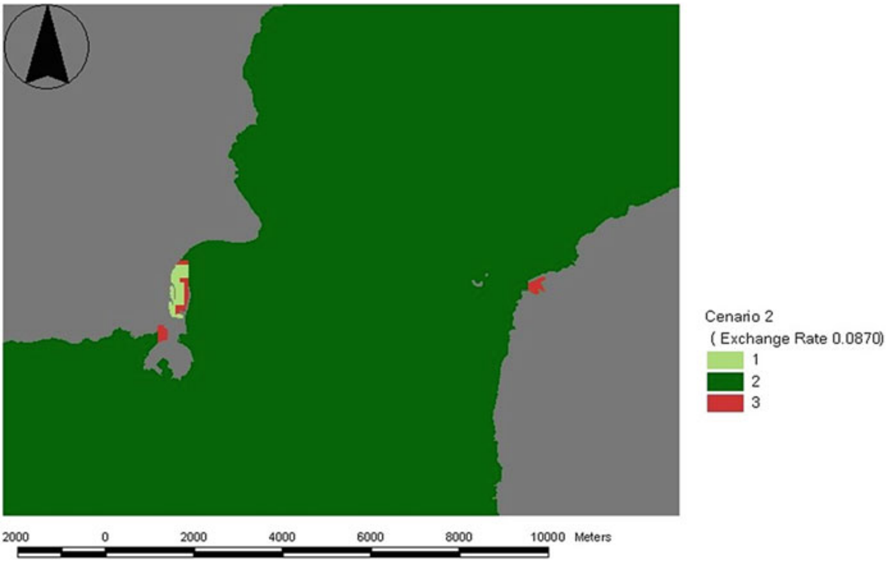

Fig. 10 Optimal regulation [$\rho = 0.087$]

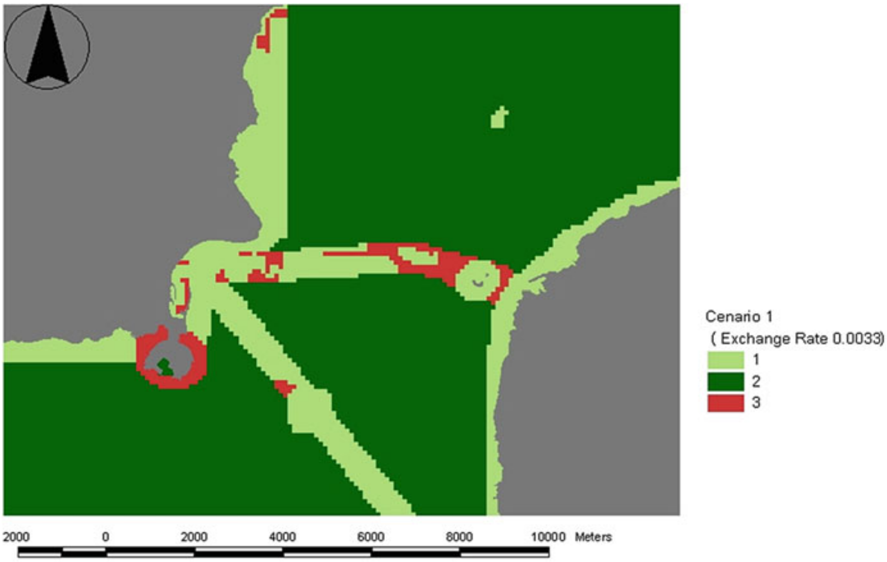

Fig. 11 Optimised regulation [$\rho = -0.0033$]

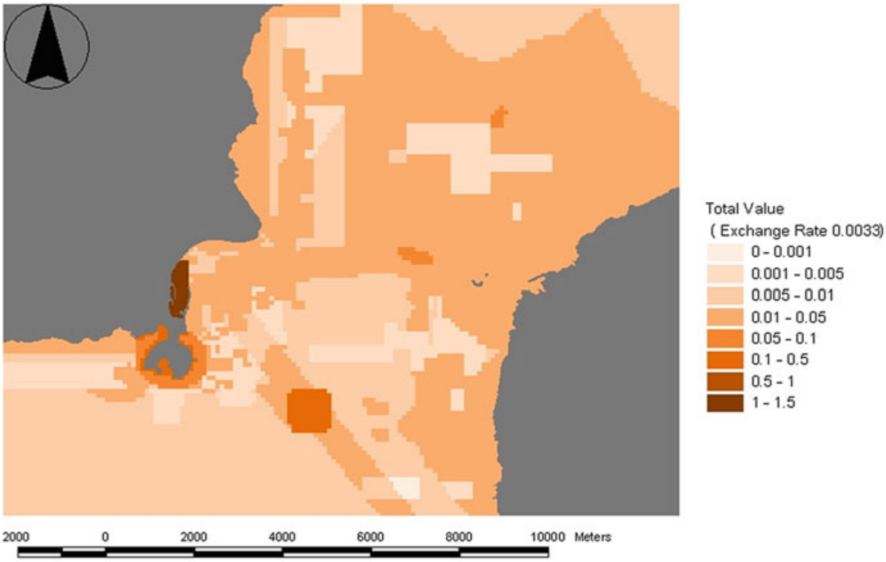

Fig. 12 Total value [$\rho = 0.0033$]

Second, for a lower exchange rate ($\rho = 0.0033$), it is possible to obtain another consistent sea use map that represents a less conservationist solution (in Fig. 11). In this alternative there will be maintenance of the present rules for most the area under pressure (type 1) except close to Monte da Guia where the increase in the human pressure, namely, related with fisheries, seems advisable (type 3).

Finally, it is possible to design the maps of total sea use values for each one of the exchange rates and their respective plans (Figs. 12 and 13). When the exchange rate is [$\rho = -0.00033$], the total value of the channel is equivalent to 3770 employments. When the exchange rate is [$\rho = -0.087$], the total value of the channel is equivalent to 267 employments.

5 Conclusions

The challenge was to combine the different disciplinary perspectives in a consistent decision support methodology. It was assumed that the economic, ecological and cultural valuations complement each other rather than being substitutes. It was also supposed that each one of these valuations can be linked to some dimensional referential or map. Finally, it was believed that public decisions should be consistent so that the trade-off between similar values must be the same along all the decisions. Based on that, the idea of an exchange rate between disciplinary valuations was explained and applied to three different case studies.

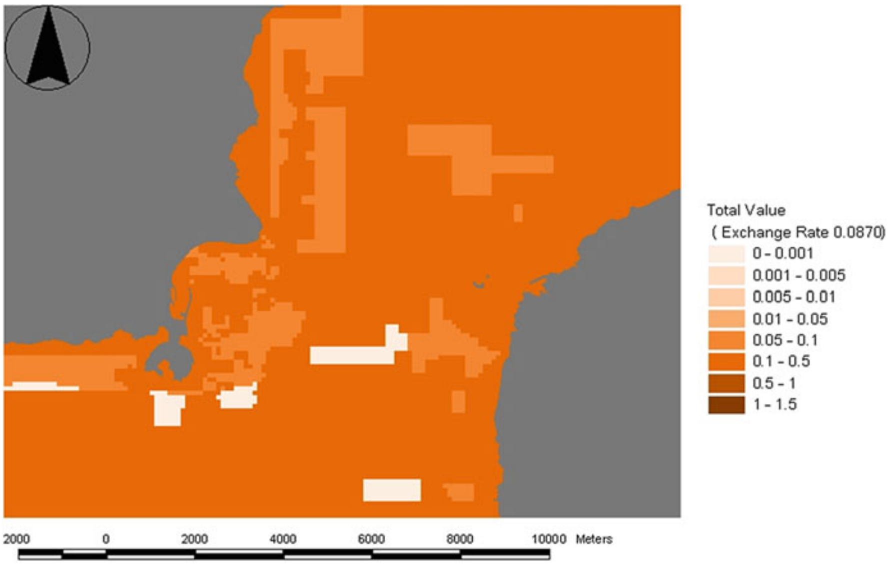

Fig. 13 Total value [$\rho = 0.087$]

The results seem quite interesting. First, there is a method to connect monetary and nonmonetary valuations. Second, this method is also suitable to address non-use values informed by noneconomists. Finally the exchange rate between disciplines can also be used to assess the internal consistency of sea use and land use plans or to design different plans according to various exchange rates.

References

Balkan E, Khan JR (1988) The value of changes in deer hunting quality. Appl Econ 20:533–539

Beaumont NJ, Austen MC, Atkins JP, Burdon D, Degraer S, Dentinho TP, Derous S, Holm P, Horton T, van Ierland E, Marboe AH, Starkey DJ, Townsend M, Zarzycki T (2007) Identification, definition and quantification of goods and services provided by marine biodiversity: implications for the ecosystem approach. Mar Pollut Bull 54(3):253–265

Bockstael NE, Hanemann WM, Kling CL (1987) Estimating the value of water quality improvements in a recreational demand framework. Water Resour Res 23(5):951–960

Brouwer R (2000) Environmental value transfer: state of the art and future prospects. Ecol Econ 32:137–152

Cardoso P (2015) The use of arachnids (Class Arachnida) in biodiversity evaluation and monitoring of natural areas. Universidade de Lisboa (Faculdade de Ciências de Lisboa)

Costanza R, D'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Naeem S, Limburg K, Paruelo J, O'Neill RV, Raskin R, Sutton P, van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260

De Groot R, Wilson M, Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ 41:393–408

De Marchi B, Funtiwicz SO, Lo Cascio S, Munda G (2000) Combining participative and institutional approaches with multicriteria evaluation. An empirical study for water issues in Troina, Sicily. Ecol Econ 34(2000):267–282
Dentinho T (2002) Modelo Agro-Ambiental para a Bacia das Sete Cidades. Plano de Ordenamento da Bacia das Sete Cidades. Direcção Regional dos Recursos Hídricos e Ordenamento, Açores
Dias E (2004) Plano da Rede Natura 2000 nos Açores. Direcção Regional do Ambiente, Açores
EEA (2002) Integrating marine science in Europe. Marine Board
Englin J, Mendelson R (1991) A hedonic travel cost analysis for valuation of multiple components of site quality: the recreation value of forest management. J Environ Econ Manag 21:275–290
European Commission (2002) Guide to cost-benefit analysis of investment projects. Evaluation unit of DR regional policy, European Commission
Fabbri KP (1998) A methodology for supporting decision making in integrated coastal zone management. Ocean Coast Manag 39:51–62
Farber S, Costanza R, Wilson M (2002) Economic and ecological concepts of valuing ecosystem services. Ecol Econ 41:375–392
Gowdy JM, Carbonell AF (1999) Toward consilience between biology and economics: the contribution of ecological economics. Ecol Econ 29(1999):337–348
Hanley N, Shogren JF (2002) Awkward choices: economics and nature conservation. In: Bromley DW, Paavola J (eds) Economics, ethics and environmental policy: contested choices. Blackwell Publishing, Oxford
Houghton K, Mendelson R (1997) A economic analysis of multiple-use forestry in Nepal. Ambio 25(3):156–159
Howard P (1995) The economics of protected areas in Uganda: costs, benefits and policy issues. A Dissertation for the University of Edinburgh
Kontogianni A, Skourtos MS, Langford IH, Bateman IJ, Georgiou S (2001) Integrating stakeholder analysis in non-market valuation of environmental assets. Ecol Econ 37(1):123–138
Langford IH, Georgiou S, Day RJ, Bateman IJ (1999) Comparing perceptions of risk and quality with willingness to pay: a mixed methodological study of public preferences for reducing health risks from polluted coastal bathing waters. Risk Decis Policy 4(3):201–220
Limburg KE, O'Neil RV, Costanza R, Farber S (2002) Complex systems and valuation. Ecol Econ 41:409–420
Montegonery CA, Brown GM, Adams DM (1984) The marginal cost of species preservation. J Environ Econ Manag 26:111–128
Munda G, Nijkamp P, Rietvield P (1995) Monetary and non-monetary evaluation methods in sustainable development planning. Econ Appl XLVII(2):143–160
Norton Griffths M (1994) Biodiversity conservation in Kenya. Dissertation submitted to University College London, UK
Nunes P, Van Den Bergh JCJM (2001) Economic valuation of biodiversity: sense or nonsense? Ecol Econ 39(2):203–222
Pagiola S (1996) Republic of Croatia coastal forest reconstruction and protection project. Annex 1 economic analysis. The World Bank, Washington, DC
Pearce D, Atkinson G, Mourato S (2006) Cost-benefit analysis and the environment. OECD Publishing, Paris
Pendleton L (1993) Adding it all up: the economic valuation of a tropical marine park. Presented at the Environmental Economics and Policy Analysis Workshop. HIID, USA
Qureshi ME, Harrison SR, Wegener MK (1999) Validation of multicriteria analysis models. Agric Syst 62:105–116
Randall A (1987) Economic theory, total economic value as a basis for policy. Trans Am Fish Soc 116:325–335
Randall A (2002) Benefit cost considerations should be decisive when there is nothing more important at stake. In: Bromley DW, Paavola J (eds) Economics, ethics and environmental policy: contested choices. Blackwell Publishing, Oxford

Read Sturgess and Associates (1994) The economic significance of Grampians National Park: for Department of Conservation and Natural Resources. Read Sturgess and associates, Kew, Vic

Runner N, Starkl M (2004) Decision aid systems for evaluating sustainability: a critical survey. Environ Impact Assess Rev 24(2004):441–449

Tempera F, Afonse P, Morato T, Gubbay S, Dentinho T, Silva M, Prieto R, Cardigos F, Pitta MJ, Serrão Santos R (2001) Proposta Técnico- Científica de Gestão dos Sítios de Interesse Comunitário do Canal Faial-Pico. Departamento de Oceanografia e Pescas da Universidade dos Açores. Arquivos do DOP. Série Relatórios Internos, n° 8/2001, viii+76 pp

Turner RK (1997) Georgescu-Roegen versus Solow/Stiglitz: a pluralistic and interdisciplinary perspective. Ecol Econ 22:299–302

Turner RK, Bateman IJ, Adger WN (2001) Ecological economics and coastal zone ecosystems' values: an overview. In: Turner RK, Bateman IJ, Adger WN (eds) Economics of coastal and water resources: valuing environmental functions. Kluwer Academic Publishers, Dordrecht/Boston/London

Turner RK, Paavola J, Cooper P, Farber S, Jessamy V, Georgiou S (2003) Valuing nature: lessons learned and future research directions. Ecol Econ 46:493–510

Willis KG, Benson JF, Saunders C (1988) The impact of agricultural policy on the cost of nature conservation. Land Econ 64(2):147–157

Wilson EO (1998) Consilience. Alfred Knopf, New York

Wilson MA, Carpenter SR (1999) Economic valuation of freshwater ecosystem services in the United States 1971–1997. Ecol Appl 9(3):772–783

Zhu X, Aspinall RJ, Healey R (1996) ILUDSS: a knowledge-based spatial decision support system for strategic land-use planning. Comput Electron Agric 15:279–301

Zhu X, Healey RG, Aspinall RJ (1998) A knowledge-based systems approach to design of spatial decision support systems for environmental management. Environ Manag 22:35–48

Optimal International Investment Policy for the Sea Environment in East Asia: Case Study of the Sea of Japan

Katsuhiro Sakurai

Abstract In this paper, we quantify emissions of land-based water pollutants created by socioeconomic activity in the coastal areas of the Sea of Japan. We also create a multiregional socioeconomic-environmental system model to perform a dynamic optimization simulation analysis. This analysis will focus on parts of Japan, China, South Korea, and Russia, and for each region it will solve the maximization problem of optimizing regional production under constraints on COD emissions resulting from that region's economic activity. In terms of results, the maximum COD reduction achieved was 6 % compared to 1995, the maximum average reduction rate over the 25-year period was 2.6 %, and the average GDP growth rate over the 25-year period was 4.6 %. We also successfully quantified the effect on the Sea of Japan.

Keywords International investment policy • Sea environment • Optimization problem • Dynamic simulation • Sea of Japan

1 Introduction

In recent years, as the international socioenvironmental situation has changed, there has been increasingly active exchange and socioeconomic activity in the area around the Sea of Japan (i.e., the Northeast Asian region). In the 1980s, the Northeast Asian economic zone began to engage in various cooperative regional activities, including community involvement and joint research. Ongoing factional Cold War structures at this time surrounded the USA, the Soviet Union, and their allies, but there was a trend toward cooperation and exchange on the municipal and regional level (Nakato 1999). Actual cooperation in the form of partner cities, sister cities, and other municipal relationships took place between, for example, Hokkaido and Niigata Prefecture and the Chinese province of Heilongjiang, as well as between Toyama Prefecture and Liaoning province, among other examples. In the 1990s, a variety

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of policies and projects began to be examined in each region as potential ways of responding to the global environmental problem. Agenda 21, adopted in 1992, discusses global warming caused by environmental pollution and also mentions water pollution. Particularly with regard to the issues related to marine, Chap. 17 “Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas and coastal areas and the protection rational use and development of their living resources” (United Nations Secretariat 1993) has been described as it should to promote the use and integrated management and sustainable development. These issues must be recognized as extremely important problems.

Perhaps due to these influences, the region surrounding the Sea of Japan has also begun to pursue specific action. Representative of this activity is the Northeast Asian Conference on Environmental Cooperation held in the city of Niigata in 1992 and the Northwest Pacific Region Environmental Cooperation Center which opened in Toyama in 1997. Internationally, the Northwest Pacific Action Plan (NOWPAP) was formulated to focus on the area surrounding the Sea of Japan. This plan constitutes a part of the United Nations Environment Programme’s (UNEP) initiative on environmental conservation in highly enclosed marine regions and the Regional Seas Programme (RSP), which targets 18 regions around the globe, including the Northwest Pacific, the Mediterranean, the Caribbean, and the Black Sea. This therefore indicates that the Sea of Japan is considered to be an important international focus of environmental conservation efforts.

In the present, research on the causes and processes of environmental problems must naturally be continued, with ongoing monitoring of the oceanic environment and other areas. However, we have reached the stage at which it is necessary to propose a concrete program for environmental conservation and preservation that is socially effective and broken down into specifics. Moreover, the borderless nature of environmental problems requires that all of the world’s countries in all regions recognize a common need to work together toward solutions.

According to the United Nations, 70 % of marine pollution is due to activity on land, and the reduction of pollutant flows from land activity is an important issue. Hence, in 1995 the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities was adopted at the UN. Additionally, Article 197 of the United Nations Convention on the Law of the Sea stipulates cooperation on a regional basis, and on these grounds there is a need for neighboring countries to pursue cooperative efforts on marine environmental conservation. However, this is not a question resolved just by agreements or decisions, as each region must pursue policy after quantitatively establishing the effects on economic and environmental burdens, remaining mindful of an economic level achievable for that region. Hence, constructing and testing such models will likely prove beneficial to each country’s efforts to implement concrete environmental policy.

The objective of the present research is to build a system model that links water pollutant emissions and socioeconomic activity in the Northeast Asian region to clarify the interdependent relationship therein. Through this, this research will take a broad look at how flows of pollutants into the Sea of Japan will change with the ongoing progress of socioeconomic activity in Japan and the rest of the region, as well as examine whether this contamination can be restrained. This research will also examine the effects of a hypothetical investment strategy in which Japan (or another nation) contributes antipollution investment to countries in the Northeast Asian region specifically to stop water pollution. The important perspective of this research is the consideration of the possibility of integrated management of the international marine region around the Sea of Japan, wherein such consideration is centered on environmental effects from the land and the fiscal dimension of the surrounding region. Specifically, we solve the maximization problem of optimizing regional GDP given constraints in the form of regional financial policy and inflows of water pollutants from human activity in the Northeast Asia coastal region. The feasible solutions thereby derived contain indicators that can be analyzed to evaluate policy effects.

2 Current State of the Northeast Asian Region

2.1 Overview of the Sea of Japan

The Sea of Japan, shown in Fig. 1, is a marginal sea surrounded by the Eurasian continent and the Japanese archipelago. (A "marginal sea" is located on the outer edge of a continent and incompletely separated from the ocean by islands and/or peninsulas.)

Two currents meet in the Sea of Japan, the Liman Current from the north (cold) and the Tsushima Current from the south (warm), and this point of intersection is a rich fishing zone. Although the seasonal winds coming from the continent are dry in the winter, they pick up a great deal of moisture over the Sea of Japan, forming an area of heavy snowfall in Japan's Hokuriku region where the winds strike land. In this way and others, the Sea of Japan has a major effect on its surrounding coastal regions. The sea has also recently been a focus of national and international attention; for example, South Korea and North Korea voiced objections to the sea's name at the 6th United Nations Conference on the Standardization of Geographical Names in 1992.

The Sea of Japan has a surface area of 1,059,000 km^2 (2.8 times the land area of Japan), a mean depth of 1588 m, and an estimated volume of 1,682,000 km^3 (Table 1). At the beginning of the 1930s, a pioneering study by Uda (1934) discovered that for depths beyond a few hundred meters, the Sea of Japan is comprised of water pockets in which physiochemical properties are uniform. In particular, at depths below 500 m, the water is 0–1 °C and has a salt content of around 34.07 psu. This is called "Japan Sea Proper Water."

According to Kondo (2003), the maximum depth of the Sea of Japan is 3650 m and its basin is deep relative to its surface area. Another geographical characteristic of the sea is that entrances to the sea are shallow, resulting in sluggish exchange with external waters and a lower water-exchange ratio than other seas. Residence

Fig. 1 Location of the Sea of Japan (Source: Northwest Power & Conservation Council)

Table 1 Overview of the Sea of Japan (From Naganuma (1993))

Depth (m)	Area (10^6 km^2)	Volume (10^6 km^3)
0	1.059	0.185
200	0.787	0.229
500	0.740	0.340
1000	0.620	0.287
1500	0.526	0.238
2000	0.427	0.189
2500	0.329	0.142
3000	0.239	0.072
Over 3000		
Total volume (10^6 km^3)		1.682
Avg. depth (10^3 m)		1.588

time in the Sea of Japan is estimated at around 100 years (Gamo and Horibe 1983; Chen et al. 1995; Watanabe et al. 1991; Tsunogai et al. 1993).

At the 6th Meeting of the Subcommittee on National Biodiversity Strategy, held by the Japanese Ministry of Environment on February 15, 2014, the Subcommittee's strategy proposal stated that, due to the aforementioned characteristics, the Sea of Japan displayed a highly closed nature, and as a result the land-based activities of a great many countries were responsible for contributing inflows of pollutants into the sea. Moreover, the environmental state of the environment in the Sea of Japan was feared to continue to worsen in the future due to increasing population and economic growth in these countries. Once polluted, therefore, the sea will not be quick to recover and it is instead structurally weak against pollution. There is thus the possibility that this water pollution problem will become very grave in the future due to environmental burdens from a variety of sources.

According to Kim et al. (2002), there are reports of recent major changes in the vertical distribution of dissolved oxygen in the Sea of Japan. Although the OMZ (oxygen minimum zone) was 800 m deep in the late 1960s, it was found to be over 1500 m deep in the late 1990s, and moreover with lower oxygen concentrations. In other words, it is conceivable that water pollution is progressing via changes in dissolved oxygen such as this. There are many theories regarding the causes of this, either viewing it as part of a natural phenomenon also witnessed in the past (Broecker et al. 1999; Stocker 1998, etc.) or attributing it to human activities (Manabe and Stouffer 1993; Stocker and Schmittner 1997, etc.). However, the true cause is not currently known with certainty.

In any case, it is a fact that water quality is actually changing due to a variety of factors. If it is assumed that inflows of pollutants from socioeconomic activities and other land-based human behavior are indeed affecting the Sea of Japan, then surely the relevant countries must cooperate to restrain this pollution and promote an environmentally sustainable regional economy.

2.2 *Overview of the Regions in Northeast Asia*

The focus of the present research is coastal regions in Japan, China, South Korea, and Russia, primarily around the Sea of Japan (Fig. 2).

As shown in Table 2, a total of 14 regions were created: Japanese prefectures on the Sea of Japan; in China, the provinces of Jilin and Heilongjiang; in South Korea, Busan, Gangwon Province, North Gyeongsang Province, and South Gyeongsang Province; and in Russia, coastal regions, the Khabarovsk region, and Sakhalin Oblast. North Korea has been removed from consideration in this study due to data collection problems.

Populations in Table 2 were calculated from sources including Japanese regional data in Kaya (2003), Murakami (1999), and Statistics Japan (2000); for Korea, from the Ministry of Construction and Transportation (1996); for China, from Imura and Katsuhara (1995); and for Russia, from the United Nations (1996) and Nakato (1999). For GRP (regional GDP), sources used included, for Japan, Yano Tsuneta Kinenkai (1999b); for South Korea, the Ministry of Construction and Transportation (1996) and Yano Tsuneta Kinenkai (1999a); for China, the Association for the Promotion of International Trade, Japan (1999); and for Russia, the Economic Research Institute of the Far Eastern branch of the Russian Academy of Sciences (1994) and Nakato (1999).

Fig. 2 Sea of Japan and target regions

3 Method

3.1 Framework of the Model

This paper builds a system model that describes socioeconomic activity and water pollutant dynamics for the purpose of evaluating international investment policies in regions around the Sea of Japan and determining the specific economic level and pollution controls feasible. This socioeconomic-environmental system model describing regional population change, socioeconomic activity, and the link between these and water pollutant emissions is used to perform dynamic simulation analysis under hypothesized international investment policies (investment for the removal of water pollution) in order to quantitatively evaluate policy effects. If it is possible to solve the simulation model's maximization problem of optimizing GDP under constraints on finances and water pollutant emissions, then it will be possible to

Table 2 Classification of study area

Country	Index	Prefecture	Area (10^4 km^2)	Population (thousand) (1995)	GRP (billion $) (1995)
Japan	1	Hokkaido	7.8	5719	208.9
	2	Aomori, Akita, Yamagata	3.1	4000	129.5
	3	Niigata, Nagano, Toyama	3	5820	229.1
	4	Ishikawa, Fukui, Gifu	1.9	4108	155.8
	5	Kyoto, Hyogo	1.3	7960	318.6
	6	Yamaguchi, Shimane, Tottori	1.6	2957	105.6
	7	Fukuoka, Saga, Nagasaki	1.1	7345	260.1
South Korea	8	Gangwon-do, Gyeongsangbuk-do	3.6	4308	4.4
	9	Busan, Gyeongsangnam-do	1.1	7843	8.7
China	10	Ji Lin	18.7	25,920	13.5
	11	Heilongjiang	45.5	37,010	24.1
Russia	12	Khabarovsk Krai	82.4	1608	4.3
	13	Primorsky Krai	16.6	2287	3.5
	14	Sakhalinskaya Oblast	8.7	699	1.7

specify the optimal investment size and budget distribution, which will enable us to determine feasible economic levels and water pollutant reduction rates. This paper presents a multiregional socioeconomic system model as but a single method of evaluating integrated-management policy for marine regions, and the Sea of Japan and the surrounding regions are taken to be a test case. Additionally, analysis of the resulting solution to this model will enable us to acquire a guideline for specific policy proposals and programs in this region in the near future.

The analytical method used in this paper is based on the approach of Higano (1995), wherein environment and economic activity are comprehensively viewed as systems, and a model dependent on mass balance and value balance is built to derive an optimal solution with additional consideration for environmental burden. Past empirical research that applies this approach includes papers by Mizunoya and Higano (2000) and Sakurai et al. (2003), which discuss atmospheric pollution, and Mizunoya et al. (2001) and Sakurai et al. (2004), which discuss closed marine regions and water pollution.

This series of research clarifies the interaction between economic activity and environmental burden and analyzes environmental policy effects through simulation.

This paper expands the single-country or regional models of previous studies and builds a multiregional environmental-economic system model for the Northeast Asian region (around the Sea of Japan). This model hypothesizes international environmental investment policy efficient from an integrated-management perspective to evaluate the effects of such policy, for the purpose of sustainable regional economic development and controlling land-based water pollutants flowing into the Sea of Japan.

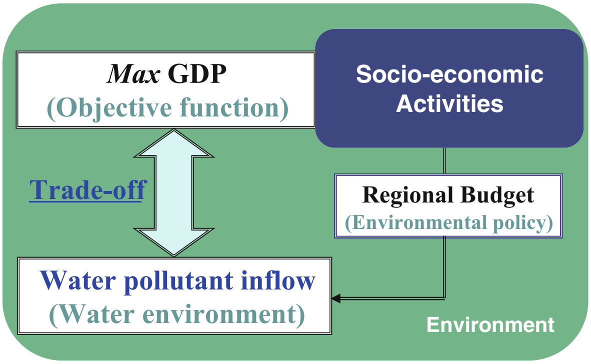

Fig. 3 Model framework

The framework of the model is contained in Fig. 3.

3.2 *Water Quality Estimation Model for the Sea of Japan*

As stated in Sect. 2.1, the sea can be viewed as a highly closed marine region. In this section, a box model is used to estimate water quality in the Sea of Japan with consideration for the burden effects of land-based pollution.

With the box model, the target region is divided into appropriately sized boxes, and on the basis of the condition of continuity for seawater and indicator substances (in this model, COD is used), it is possible to examine changes over time in oceanographic elements within or between boxes. In this paper, the box model is applied such that the entire Northeast Asian region (around the Sea of Japan) is taken to be a single box, regarding which the impact of land-based COD inflows is evaluated.

Taking the Sea of Japan as a single box, the water quality thereof is expressed as follows:

$$V_1 \frac{dC_1}{dt} = Q_{21}C_2 - Q_{12}C_1 + G \tag{1}$$

$$Q_{12} - Q_{21} = Q_R \tag{2}$$

where

V_1: Volume of the Sea of Japan (m^3)
C_1: Average concentration of the Sea of Japan (g/m^3)
C_2: Average concentration of neighboring waters (g/m^3)
Q_{21}: Inflows of water from neighboring waters to the Sea of Japan (m^3/day)
Q_{12}: Outflows of water from the Sea of Japan to neighboring waters (m^3/day)
Q_R: Supply of freshwater to the Sea of Japan (m^3/day)
G: Land-based pollution to the Sea of Japan (ton/day)

Here, the steady state is assumed to be $\left(\frac{dC_1}{dt} = 0\right)$ to obtain Eq. (3) from (1) and (2).

$$C_1 = \frac{Q_{21}}{Q_{21} + Q_R} C_2 + \frac{G}{Q_{21} + Q_R} \tag{3}$$

In Eq. (3), Q_R (31×10^{10} m^3/year (Takayama 1990, the supply of freshwater from the Amur River, which contributes the most inflows to the Sea of Japan) is a miniscule value compared to Q_{21} (8199×10^{10} m^3/year, inflows of seawater from the Tsushima Current (Research Institute for Applied Mechanics, Kyushu University (1999)). For this reason, it is assumed that $Q_R = 0$.

This results in Eq. (4) below.

$$C_1 = C_2 + \frac{G}{Q_{21}} \tag{4}$$

Because $Q_{21} = \frac{V_1}{D}$, it is possible to derive the following:

$$C_1 = C_2 + \frac{G \cdot D}{V_1} \tag{5}$$

where

V_1 D: Residence time of the Sea of Japan (days)

Therefore, it is possible using Eq. (5) to evaluate the change in concentrations in the Sea of Japan due to land-based pollutants (G) using the relationship between the volume of the Sea of Japan (V_1) and its residence time (D).

3.3 Multiregional Economic-Environmental System Simulation Model

3.3.1 Inflows of Land-Based Pollutants into the Sea of Japan

Total inflows of water pollutants to the Sea of Japan are emitted by every region and the value for this is taken to be a sum of all inflowing pollutants.

$$WP^h(t) = \sum_j wp_j^h(t) \tag{6}$$

where

WP^h (t): Total quantity of water pollutants h that flows into the Sea of Japan in period t.

$wp_j^h(t)$: Total quantity of water pollutants h that flow into the Sea of Japan from region j in period t.

3.3.2 Quantity of Pollutants Flowing into the Sea of Japan from Each Region

The quantity of pollutants flowing into the Sea of Japan from each region is determined by each region's lifestyle-pollutant emissions, industrial pollutant emissions, and the quantity of reductions in pollutants due to industrial pollution-removal investment.

$$wp_j^h(t) = fh_j^h E^h \cdot z_j^u(t) + fi_j^h \left\{ P^h x_j(t) - Rk_j^A(t) \right\} \tag{7}$$

where

fh_j^h: Pollutant runoff coefficient for lifestyle pollutants h in region j

E^h: Lifestyle emission coefficient vector for water pollutants h

z_j^u: Processing type-specific (subscript u) population vector in region j

fi_j^h: Pollutant runoff coefficient for industrial pollutants h in region j

P^h: Industrial emission coefficient vector for water pollutants h

R: Pollution-reduction coefficient

$k_j^A(t)$: Capital accumulation of the reduction of industrial pollutants in region j for period t

(Subscript $u = 1$, sewers; $u = 2$, agricultural village emissions; $u = 3$, community wastewater treatment plants; $u = 4$, flush toilet wastewater treatment tanks; $u = 5$, human excreta treatment plants)

3.3.3 Capital Accumulation of the Reduction of Industrial Pollutants

The capital accumulation of the reduction of industrial water pollution for each region was calculated through the following equation:

$$k_j^A(t+1) = k_j^A(t) + i_j^A(t) - \delta_j^A \cdot k_j^A(t) \tag{8}$$

where

$k_j^A(t+1)$: The capital accumulation of the reduction of industrial pollutants in region j for period $(t+1)$

$i_j^A(t)$: Investment to industry to reduce water pollution in region j for period t

δ_j^A: Capital depreciation coefficient

3.3.4 Environmental Investment

Environmental investment in each region (i.e., the total amount of investment toward reducing water pollution) is taken as the sum of pollution-reduction investment from of both industrial and lifestyle types.

$$i_j^C(t) = i_j^A(t) + i_j^S(t) \tag{9}$$

$$i_j^S(t) = \sum_{u=1}^{6} i_j^u(t) \tag{10}$$

where

$i_j^C(t)$: Total water pollution-reduction investment in region j for period t
$i_j^S(t)$: Pollution-reduction investment from lifestyle sources in region j for period t
$i_j^u(t)$: Investment into processing facilities for lifestyle emissions

3.3.5 Population

Total population in each region for period $(t+1)$ changes depending on the natural growth (reduction) rate in each region.

$$z_j(t+1) = z_j(t) + \Delta z_j(t) \tag{11}$$

$$\Delta z_j(t) = \lambda_j z_j(t) \tag{12}$$

where

$z_j(t)$: Total population in region j for period t
$\Delta z_j(t)$: Change in population in region j for period t
λ_j: Natural population growth (reduction) rate in region j

3.3.6 Populations for Lifestyle-Pollutant Processing Types

The sum total population for each processing type in each region was equal to the total population of each region. Additionally, the growth of populations using sewers, populations using agricultural village drainage, populations using flush toilet wastewater treatment tanks, and populations using human excreta treatment plants was determined by the investment in each. In the same way, the growth of populations using community wastewater treatment plants is also dependent upon investment in such treatment plants.

$$z_j(t) = \sum_{u=1}^{6} z_j^u(t) \tag{13}$$

$$z_j^u(t+1) = z_j^u(t) + \Delta z_j^u(t) \tag{14}$$

3.3.7 Flow Conditions for the Product Market

Regional production in each industry adheres to the flow conditions for the product market.

1. **Japan** ($j \leq 7$)

$$x_j(t) = Ax_j(t) + c_j(t) + Di_j^C(t) + i_j^p(t) + y_j(t) + EX_j(t) - IM_j(t) \tag{15}$$

where,

$x_j(t)$: Production vector for each industry in region j for period t
A: Input-output coefficient matrix
$c_j(t)$: Consumption vector in region j for period t
D: Input coefficient vector for environmental investment
$i_j^p(t)$: Production investment vector in region j for period t
$y_j(t)$: Vector of environmental investment received by region j for period t
$EX_j(t)$: Exports for region j in period t
$IM_j(t)$: Imports for region j for period t

2. **Korea**, **China**, **and Russia** ($j \geq 8$)

$$x_j(t) + y_j(t) = Ax_j(t) + c_j(t) + Di_j^C(t) + i_j^p(t) + EX_j(t) - IM_j(t) \tag{16}$$

3.3.8 Environmental Investment Constraints

The total investment in reduction of water pollution received by each region was taken to be less than or equal to the total investment in pollution reduction.

$$i_j^C(t) \geq y_j(t) \tag{17}$$

3.3.9 Production Function

The production function here was assumed to be a Harrod-Domar model fixed-coefficient production function.

$$x_j(t) \leq \omega_j k_j^p(t) \tag{18}$$

where,

ω_j: Capital output ratio
$k_j^p(t)$: Productive capital accumulation in region j for period t

3.3.10 Productive Capital Accumulation

Productive capital accumulation in each region is determined by productive investment and fixed capital depreciation.

$$k_j^p(t+1) = k_j^p(t) + i_j^p(t) - \delta_j^p \cdot k_j^p(t) \tag{19}$$

where,

δ_j^p: Coefficient of fixed capital depreciation

3.3.11 Consumption Constraints

Consumption in each region is determined by the consumption coefficient and the population of that region

$$c_j(t) \leq k_j z_j(t) \tag{20}$$

where,

k_j: Consumption coefficient vector

3.3.12 GRP in Each Region (Regional CDP)

The GRP in each region is determined by the value-added ratio and production in each region.

$$GRP_j(t) = V_j x_j(t) \tag{21}$$

where

$GRP_j\ (t)$: Production in region j for period t
V_j: Value-added ratio vector for region j

3.3.13 GDP

The GDP of the larger region overall was taken to be the sum total of each smaller region's GRP.

$$GDP(t) = \sum_{j=1}^{14} GRP_j(t) \quad (22)$$

where

$GDP(t)$: Total production in region j

3.3.14 International Environmental Investment Policy

The amount of international environmental investment from Japan to other regions for the purpose of reducing pollution is taken to be within a fixed percentage of Japan's overall GDP.

$$y_J^T(t) \leq \gamma GDP_J^T(t) \quad (23)$$

where

γ: Environmental investment ratio
$GDP_J^T(t)$: Overall GDP for Japan in period t

3.3.15 Environmental Investment Funds for the Reduction of Water Pollution

1. **Target regions within Japan** ($j \leq 7$)
   The amount of environmental investment toward a given region in Japan is taken to be a fixed percentage of Japanese funds overall.

$$y_J^T(t) = \sum_{j=1}^{7} y_j(t)/\mu \quad (24)$$

where

μ: Percentage of environmental investment that does toward a given Japanese region

2. **Target regions outside of Japan** ($j \geq 8$)
   The amount of international environmental investment from Japan is equal to the sum total of the environmental investments received by the target regions in each country.

$$y_J^T(t) = \sum_{j=8}^{14} y_j(t) \tag{25}$$

3.3.16 Objective Function

The objective function is total GDP in the final period ($T = 6$) for the target region, and it is defined as the maximization problem shown in Eq. (27) of optimizing GDP given constraints on land-based water pollutants flowing into the Sea of Japan.

$$\max GDP(T) \tag{26}$$

subject to Eqs. (6)–(25) and

$$WP^h(t) \leq \overline{WP^h(t)} \tag{27}$$

where

$\overline{WP^h(t)}$: Constraint value for water pollutant h

4 Simulation

4.1 Setting Parameters

This section will prepare the various data that will constitute the initial conditions for the simulation. The data displayed in Table 2 will be utilized for population and GRP. Table 3 reconstitutes population and GRP data from Table 2.

The water pollutants, industries, and classifications of lifestyle emission processing are each, respectively, displayed in Tables 4, 5, and 6.

The data in Table 6 are estimates based on Kaya (2003), Murakami (1999), the Suido Sangyo Shinbun (2000), Imura and Katsuhara (1995), etc.

Quantity of COD inflows is displayed in Table 7. These values utilize 1995 figures as a baseline. The data was calculated from sources including the World Bank (1999), Kunimatsu and Muraoka (1989), and Wada (1990).

All values utilize 1995 levels as a baseline in an attempt to set for data of the same period, where such data was obtainable.

Table 3 Population and GRP standard values for each region

Region	Population (1000s)	GRP (millions USD)
1	5719	208,860
2	4000	129,458
3	5820	229,126
4	4108	155,803
5	7960	318,599
6	2957	105,606
7	7345	260,052
8	4308	44,025
9	7843	86,718
10	25,920	13,523
11	37,010	24,126
12	1608	8099
13	2287	9790
14	699	4378
Total	117,584	1,598,163

Table 4 Target water pollutant

Index	Water pollutant
1	COD (chemical oxygen demand)

Table 5 Classifications of lifestyle emission processing types and the population using each (1000s, 1995)

Index	Industry based
1	Agriculture
2	Manufacturing
3	Construction
4	Communications/transport
5	Commercial/food and drink
6	Others

Table 6 Industry classifications

Index	Lifestyle based	Japan	South Korea	China	Russia
1	Sewers	24,819	4637	12,598	689
2	Agricultural village emission processing	1115	0	0	0
3	Community wastewater treatment plants	3231	0	0	0
4	Flush toilet wastewater treatment tanks (incl. unprocessed)	8496	0	0	0
5	Human excreta treatment plants (incl. unprocessed)	248	0	0	0
6	Unprocessed	0	6403	50,332	3905
Total		37,909	11,040	62,930	4594

Table 7 COD reference values (tons)

Region	Household emissions	Industrial emissions	Total emissions
1	5882	6209	12,092
2	13,048	3849	16,897
3	18,694	6812	25,506
4	13,635	4632	18,267
5	12,021	9472	21,493
6	8,971	3140	12,111
7	12,316	7732	20,047
8	26,572	2577	29,149
9	27,393	4841	32,234
10	207,620	453	208,074
11	296,455	809	297,264
12	13,660	498	14,158
13	19,425	602	20,028
14	6970	269	7240
Total	682,662	51,895	734,560

Table 8 Simulation case

Case	COD reduction rates (compared with 1995)
Case00	0 %
Case01	1 %
Case02	2 %
Case03	3 %
Case04	4 %
Case05	5 %
Case06	6 %
Case07	7 %

4.2 Simulation Case

This simulation is a dynamic model with six periods and 12 years. The objective function is displayed in Eqs. (26) and (27), defined as a maximization problem in which GDP is optimized given constraints on total inflows of land-based pollutants (COD) from the target region into the Sea of Japan.

Table 8 displays the various cases set for each COD reduction in the final simulation year. For example, Case05 means that the COD reduction rate of the final period is 5 %. That is, 5 % of COD inflow will be reduced after 25 years, based on the amount of COD inflow in 1995.

Calculations were performed using LINGO Version 8.0, a general-purpose optimization program by LINDO Systems.

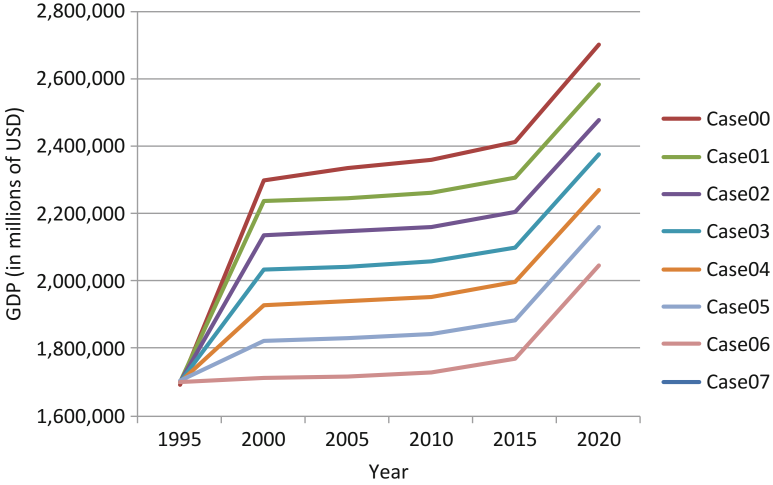

Fig. 4 Changes in objective function values (GDP) (in millions of USD)

4.3 Results and Analysis

4.3.1 Objective Function

Displayed in Fig. 4 are changes in the objective function value (GDP) that were calculated through this simulation. It can be seen that GDP levels change differently in response to the COD constraints in each case. In Case00, the average growth rate of GDP is 36 %, but gradually drops off in each subsequent case. Case06 shows an average GDP growth rate of 4.6 %. In Case07, the case set for 7 % pollution reduction, there were no feasible solutions to the maximization problem. Therefore, the system model used in this paper demonstrates that the maximum possible reduction rate of the COD pollutant is 6 %.

4.3.2 Land-Based Pollutants

In this simulation, COD inflows serve as a constraint imposed on the GDP maximization problem. For example, "Case05" indicates that by the final period, there will be a 5 % reduction in pollutants compared to 1995 levels. In this case, while there is a 5 % reduction by the final period, constraints are placed such that each year prior preceding the final period produces lower COD emissions levels than the one preceding it in order to avoid high COD emissions in those years. Figure 5 displays changes in COD inflows calculated via the simulation. As stated, the maximum reduction rate was found to be 6 %.

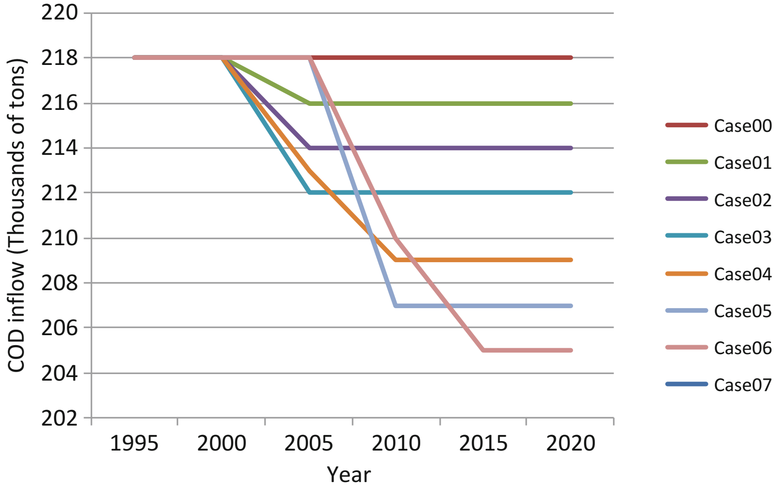

Fig. 5 COD inflows (Thousands of tons)

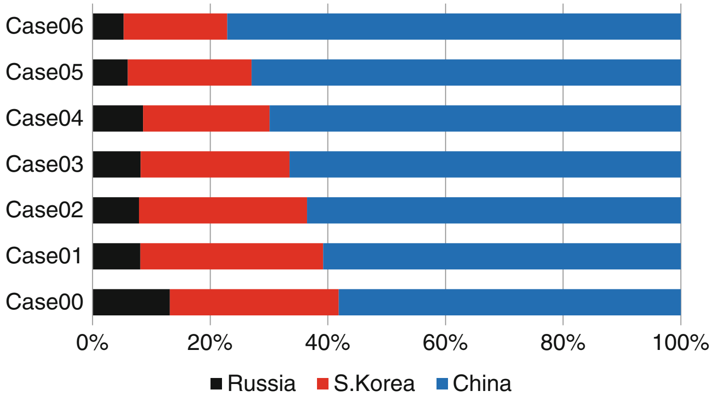

Fig. 6 Environmental investment distribution from Japan to S. Korea, China, and Russia

4.3.3 Distribution of Environmental Investment

The international environmental investment policies hypothesized in this paper are investment policies that reduce industrial water pollution so that regions surrounding the Sea of Japan can manage the sea in an integrated manner. Due to differences in economic levels, in reality this takes the form of environmental investment from Japan to the regions of other countries. Figure 6 presents the proportions of environmental investment sent to each South Korea, China, and Russia. The most investment goes to China in every case; moreover its proportion of investment increases as the COD reduction rate increases. Meanwhile, South Korea and Russia receive a smaller share of the environmental investment as COD reduction rates

Table 9 Impact of land-based water pollutants on the Sea of Japan

Water-exchange time	100 years	16 years
Impact on water quality	0.013 mg/L	0.002 mg/L

increase. In other words, it was found that as environmental constraints become tighter, higher investment is allocated to contain Chinese emissions.

4.3.4 Impact of Land-Based Water Pollutants on the Sea of Japan

The impact of land-based inflows of water pollutant COD on the Sea of Japan can be calculated using the results of this simulation and the box model presented in Sect. 3.2.

In these calculations, residence time in the Sea of Japan was taken to be 100 years, as in Gamo and Horibe (1983), Chen et al. (1995), Watanabe et al. (1991), and Tsunogai et al. (1993). However, other sources report overall water-exchange times in the Sea of Japan to be 16 years, and additional tests were done under this assumption for reference purposes. The results are presented in Table 9.

5 Conclusion

The research in this paper examined both the environment and the economy in a macro model. The Sea of Japan was used as an example to build a multiregional environmental-economic system model with environmental investment, for the purpose of attempting a quantitative evaluation of an efficient integrated-management system for an ocean environment (by nature an international problem). The analysis in this simulation found that COD could be reduced by a maximum of 6 % compared to 1995 levels, the maximum average reduction rate was 2.6 % over 12 years, and average GDP growth for those 25 years was estimated at 4.6 %.

One important aspect of this paper is to not only discuss individual countries' actions but to use environmental problems to help break down barriers between countries and regions and to consider a framework for integrated regional policy on the environment and the economy. Hence this study was not general or conceptual, but instead assessed water pollution and economic activity in quantitative terms, setting environmental investment that was regionally integrated, efficient, and comprehensively raised the potential of the entire region. A dynamic optimization model was then used to derive the optimal investment solution, i.e., the theoretically most efficient distribution of environmental investment across the Northeast Asian region and the associated specific levels of regional economic progress and COD inflows. The hypothesized international environmental investment was aimed at reducing industrial water pollution, and by eliminating economic borders between target regions for the purpose of delivering efficient concentrated aid, it attempted to raise the economic potential of the region while simultaneously achieving a borderless reduction of environmental burdens. In other words, this can be taken as one policy option for an international system that managed to achieve both economic efficiency and environmental management of a marine environment shared by the diverse regions involved.

In any case, cooperative systems are especially necessary for oceanic regions. Policy should not be left to the individual regulations of each region, but rather a comprehensive perspective should be taken and economic incentives utilized to increase the potential of the entire region while checking environmental burdens in an optimal fashion. Such a system is urgently needed. It is to discover a specific policy program that this paper presents this model for environmental investment and its empirical quantitative analysis. It is absolutely necessary that policy evaluation using systems and empirical analysis like this one be used to create more useful policy proposals and that new development of such methods be encouraged.

This paper dealt with land-based water pollution represented by COD as a chief source of environmental burden. A number of problems have been raised regarding aspects of COD such as its validity as a water pollution indicator and the methods by which it is measured. From this perspective, there is a need for discussion regarding the appropriateness of COD in the evaluation of water pollution. However, in a macro model like the one used in this paper that uses diverse data from a wide region, the top priority is the existence of data, its acquisition, and its ability to be used across the board. In that sense, the datasets used for this paper were the best currently available. In the future, we hope to include other indicators of water pollution such as a total nitrogen and total phosphorus to build a comprehensive model that also introduces constraints on atmospheric pollutants and others. Finally, there also remains the problem of North Korea, which, though located in the region, was excluded from this analysis due to data collection problems.

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References

Broecker WS, Sutherland S, Peng T-H (1999) A possible 20th-century slowdown of southern ocean deep water formation. Science 286:1132–1135

Chen CTA, Wang S-L, Bychkov AS (1995) Carbonate chemistry of the Sea of Japan. J Geophys Res 100:13737–13745

Economic Research Institute of the Far Eastern branch of the Russian Academy of Sciences (1994) The Russian far east: economic handbook. Toyo Keizai

Gamo T, Horibe Y (1983) Abyssal circulation in the Japan Sea. J Oceanogr Soc Jpn 39:220–230

Higano Y (1995) Distribution of the value added to the input of the environmental goods based on the materials balance principle. Stud Reg Sci 26(1):181–187

Imura H, Katsuhara K (1995) Chuugoku no kankyou mondai. Toyo Keizai Inc.

Kaya Y (ed) (2003) Chronological Environmental Tables 2004/2005. Ohm-sha

Kim KY, Kim G, Kang DJ, Volko YN, Yoon JH, Takematsu M (2002) The changes in the east/Japan Sea found by CREAMS. Oceanogr Soc Jpn 11(3):419–429

Kondo J (ed) (2003) Japan environmental council white paper 2003. Northwest Pacific Region Environmental Cooperation Center

Kunimatsu T, Muraoka K (ed) (1989) Kasen odaku no moderu kaiseki. Gihodo Shuppan Co., Ltd

Manabe S, Stouffer RJ (1993) Century-scale effects of increased atmospheric CO_2 on the ocean-atmosphere system. Nature 364:215–217

Mizunoya T, Higano Y (2000) A dynamic analysis of the economic policy to reduce the air pollutants emission in Japan. Stud Reg Sci 31(3):79–106

Mizunoya T, Morioka R, Higano Y (2001) A study on optimal environmental policy measures related to the introduction of new technologies to improve the water quality of lake kasumigaura. Stud Reg Sci 32(3):83–106

Murakami M (1999) Is water revived?: drinking water and water environment. Power-sha

Naganuma M (1993) Characteristics of the Sea of Japan (I). Jpn Sea Nat Fish Res Inst Fish Res Agency 364:4–8

Nakato Y (1999) The economy of the ring of the Sea of Japan. Daimei-do

Research Institute for Applied Mechanics, Kyushu University (1999) Dynamics Simulation Research Center News, No. 2, 1999.4.30

Sakurai K, Mizunoya T, Kobayashi S, Higano Y (2003) The impact of environmental tax on the Japanese economy as a policy measure for the global warming: an analysis through environmental economic system simulation. Stud Reg Sci 33(3):49–66

Sakurai K, Mizunoya T, Kobayashi S, Higano Y (2004) A water environmental policy to improve the water quality of lake kasumigaura incorporating residents' preferences in the basin. Stud Reg Sci 34(1):219–245

South Korean Ministry of Construction and Transportation (1996) Annual report of construction and transportation statistics (construction sector) 1996

Statistics Japan (2000) Statistics of Japan 2000

Stocker TF (1998) Climate change: the seesaw effect. Science 282:61–62

Stocker TF, Schmittner A (1997) Influence of CO_2 emission rates on the stability of the thermohaline circulation. Nature 388:862–865

Suido Sangyo Shinbunsha (2000) Almanac of sewer drain 2000

Takayama S (1990) Rivers. In: Ichikawa M (ed) Hydrology 8. Asakura Publishing Co.

The Association for the Promotion of International Trade, Japan (1999) Chinese economic data 2000

Tsunogai S, Watanabe YW, Harada K, Watanabe S, Saito S, Nakajima M (1993) Dynamics of the Japan sea deep water studied with chemical and radiochemical tracers. In: Teramoto T (ed) Deep ocean circulation, physical and chemical aspects. Elsevier Science Publishers, B. V., pp 105–119

Uda M (1934) The hydrographic conditions of the Sea of Japan and its adjacent marine area. Rep Fish Exp Station 5:57–190

United Nations (1996) World population monitoring 1996

United Nations Secretariat (ed) (1993) Japanese trans. by the Japanese Ministry of the Environment and Ministry of Foreign Affairs. Agenda 21, Sustainable Development. Overseas Environmental Cooperation Center, Japan

Wada Y (1990) Model analysis of non-point source. Gihodo Shuppan Co., Ltd., Tokyo

Watanabe YW, Watanabe S, Tsunogai S (1991) Tritium in the Japan Sea and the renewal time of the Japan Sea deep water. Mar Chem 34:97–108

World Bank (1999) World development indicators. Toyo Shorin Co., Ltd., Tokyo

Yano Tsuneta Kinenkai/Kokusei-sha ed. (1999a) World economic census 1999/2000. Yano Tsuneta Kinenkai

Yano Tsuneta Kinenkai/Kokusei-sha ed. (1999b) Prefectural economic census of Japan 2000. Yano Tsuneta Kinenkai

Part II
Asia-Pacific Perspectives

Spatial Impacts of Endogenously Determined Infrastructure Investment

William Cochrane, Arthur Grimes, Philip McCann, and Jacques Poot

Abstract We address three questions: Do infrastructure investments impact on local incomes, population and land values? Do these effects spill over into neighbouring regions? Is infrastructure investment a response to local developments? We outline a theoretical framework and estimate a simultaneous equation growth model of infrastructure investment, real incomes, population and land values. The model, estimated by spatial three-stage least squares, uses New Zealand functional labour market panel data. We find that infrastructure investment increases population and incomes, but is itself endogenously determined and subject to positive spatial spillovers. Thus a self-reinforcing cycle exists between local incomes and infrastructure investment.

Keywords Infrastructure • Economic growth • Migration • Land values

1 Introduction

In this chapter we address three interrelated questions that are crucial to understanding the economic effects of infrastructure investment. First, do infrastructure investments impact on local incomes, population and land values? Second, do these effects spill over into neighbouring regions and, if so, are the spillovers positive or negative? Third, is local infrastructure investment primarily a response to local

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developments? The interrelationships between these three questions require that empirical tests of any of the three questions take the simultaneity and spatial issues relating to all three questions into account.

We address these questions initially by outlining a theoretical framework based on the concept of adjustment to spatial equilibrium. We then estimate a model of public infrastructure investment, real incomes, population and land values. The resulting simultaneous equation growth model, estimated by spatial three-stage least squares, uses panel data relating to New Zealand functional labour market areas. We find that local infrastructure investment increases population and real incomes, but is itself endogenously determined, in part by local developments, and is subject to positive spatial spillovers. The finding of positive two-way causation between local incomes and local infrastructure investment indicates that a self-reinforcing cycle exists between low (high) incomes causing low (high) infrastructure investments in turn causing low (high) income growth. The existence of this self-reinforcing cycle implies that there may be a significant role for central government support for local infrastructure funding in those regions least able to fund required infrastructure additions.

Public infrastructure investment has been widely used as a tool for regional economic development motivated by the view that such infrastructure is an intermediate public good that plays an active role in the production process. Increasing the stock of public infrastructure in a region may improve the productivity of existing firms and induce new firms to locate in the region (Gibbons et al. 2012). Amenity-enhancing infrastructure is a direct drawcard for workers, so further enhancing the productive capacity of a region. Consequently, productivity and/or amenity-enhancing infrastructure investment is expected to cause regional output and employment to grow (Lall 2007). Endogenous growth theory suggests that it is even possible that the region's long-run growth rate will increase. Given the magnitude of infrastructure investments and the policy emphasis on them as tools for regional development, the role of infrastructure in economic growth has been the subject of considerable research dating back to Nurske (1953) and Hirschman (1958).

Empirical work in recent decades has taken its lead from the work of Aschauer (1989) in which infrastructure enters as an input in an aggregate production function. Early studies in this tradition (e.g. Biehl 1986; Deno 1988; Reich 1991) found a strong productive effect of public infrastructure. However, while meta-analyses of the empirical research indicate that public expenditure on infrastructure generally raises national and regional economic growth (Nijkamp and Poot 2004; Bom and Ligthart 2009), subsequent research has raised concerns around the robustness of some empirical results.

A key issue that must be dealt with in empirical work is that most infrastructure expenditure is itself endogenously determined and so responds to (as well as potentially causing) economic and population growth. Accounting for this simultaneity is crucial, and doing so generally reduces the estimated impact of infrastructure investments on private sector output (Hulten and Schwab 1991; Garcia-Mila and McGuire 1992; Holtz-Eakin 1994; Sturm et al. 1998). Nevertheless, carefully conducted studies of the impacts of clearly exogenous infrastructure developments mostly find some causally related impacts of new infrastructure on local economic outcomes. For instance, Gibbons et al. (2012) find that (exogenously driven) road improvements in the UK have a positive effect on local employment and also lift plant-level productivity, value added and wages. Similarly, Duflo and Pande (2007) find a positive downstream productivity impact of new dam developments in India that contrasts with a lack of significant impacts upstream.

When the spatial context in which public infrastructural investment occurs is taken explicitly into account, the magnitude and significance of the estimated effect of infrastructure investment may again decrease (Kelejian and Robinson 1997). A number of possible avenues exist by which public investment at one location can influence productivity and output at neighbouring locations. Public infrastructural investment in one region may induce mobile production factors to move to that region to avail themselves of the improved infrastructure endowments. This mechanism suggests that the output of a region depends positively on its own stock of infrastructure and negatively on the stock of infrastructure in the surrounding regions. Conversely, public infrastructure – especially that related to transportation – may have a positive impact not only in the region where it is located but also on neighbouring regions due to the network characteristics of some infrastructure, in which any piece is complementary to the entire network. For example, the building or expansion of a port or airport in one region may allow producers in neighbouring regions greater access to markets. Thus the spatial impact of infrastructure investment on neighbouring regions is theoretically indeterminate and, in empirical work, may depend critically on the definition of 'region' within the dataset.

One framework for measuring the spatially varying impacts of infrastructure is the spatial equilibrium approach suggested by Haughwout (2002). This approach uses changes in land values (a fixed resource) as a summary measure of the present discounted value of benefits attributed to a change in infrastructure provision.[1] It recognises that changes in land values are an endogenous response to new infrastructure. Local authority incomes derived from property taxes may depend on land values, so land values themselves, as well as local incomes, may affect the financial ability of local authorities to invest in infrastructure. Our approach is novel in accounting for the endogenous interactions between infrastructure investment, land values, population and incomes, hence treating these four variables as a simultaneous system while also explicitly accounting for spatial interactions. We do so choosing, as our regional definition, functional labour market areas (LMAs) rather than administratively defined regions. This paper is therefore in the tradition of the macro-level impact studies cited above, but with the innovations of explicitly identifying the drivers of local public investment and of using a spatial simultaneous equations econometric methodology to measure interregional spillover effects.

[1]Grimes and Liang (2010) and Grimes and Young (2013) use this approach, respectively, to measure the net benefits of a motorway extension and an urban rail upgrade within New Zealand.

The chapter is structured as follows: Section 2 covers the theoretical framework, the specification of our model and the methodology used to perform the estimation. Section 3 discusses the data used in the chapter and outlines the rationale for the use of LMAs as the underlying spatial frame for the analysis. Section 4 reports the results of a standard three-stage least square (3SLS) procedure to estimate the parameters of our model and then compares these results with those of a recently developed spatial 3SLS procedure. Section 5 presents conclusions.

2 Model Specification and Methodology

Our approach is to embed the impact of local infrastructure investment in a model of spatial equilibrium as developed, inter alia, by Roback (1982), Haughwout (2002) and Moretti (2011). The specific theoretical model that we use to underpin our empirical work is the reduced form model of Overman et al. (2010) as extended by Grimes (2014) to include the impacts of infrastructure on population, incomes and land values. The first relationship in the model, reflecting the regional production function, is given by

$$W = w(L,\ I) \tag{1}$$

where W is the after-tax wage received by an individual in the region,[2] L is the region's labour force (assumed to be proportional to population) and I is the stock of infrastructure in the region. With diminishing (increasing) returns to scale, $W_L < 0$ (>0), while if an infrastructure investment has a benefit-cost ratio greater than (less than) one, $W_I > 0$ (<0).

The second relationship relates land (or house) prices (H) to the size of the labour force and to the infrastructure stock:

$$H = h(L,\ I) \tag{2}$$

where $H_L > 0$ since additional population increases demand for city land that is in limited supply. For an individual, $H_I < 0$ in the case where the new infrastructure enables improved access to land (e.g. where improved commuting options reduce the effective cost of housing), but for the value of land across the region as a whole, $H_I > 0$ provided the benefit-cost ratio of the infrastructure investment exceeds one (Coleman and Grimes 2010).

The third relationship relates amenity benefits for residents (A) to labour force and infrastructure provision:

$$A = a(L,\ I) \tag{3}$$

[2]Regional subscripts are suppressed throughout the paper for clarity.

where $A_L > 0$ in the case where residents benefit from a greater population (e.g. through the ability to have enhanced civic events with a larger population) and $A_L < 0$ where congestion effects outweigh the positive externalities of a larger population. We assume that new infrastructure (e.g. new cultural facilities) enhances the amenities of residents, so $A_I > 0$.

Amenity-adjusted wages (AW/H) are equalised over time across regions through population flows. The analysis in Grimes (2014) demonstrates formally that provided infrastructure is of net benefit to the population, then $dL/dI > 0$. Thus:

$$L = l(I) \tag{4}$$

with $L_I > 0$. Relationships (1), (2) and (4) provide the basis for our empirical model; amenities appear implicitly through (4).

To complete the model, we must add an equation for local government infrastructure provision to this framework. We assume that local infrastructure is endogenously determined and is congestible. Consequently, an increase in population leads to a lower quality of public services unless some infrastructure investment is undertaken. Population is therefore one determinant of infrastructure provision. Some of the infrastructure has to be paid for by local residents, and we assume that local governments face an inter-temporal balanced budget constraint. Local government raises its funds through a mix of property taxes and direct charges on residents (McLuskey et al. 2006), so the level of land values and local incomes influences available funding and hence influences the level of investment in local infrastructure. This leads to the final relationship in our model:

$$I = i\,(L,\ H,\ W) \tag{5}$$

with I_L, I_H, $I_W > 0$. Relationships (1), (2), (4) and (5) form the theoretical starting point for our empirical work to which a small number of extra exogenous variables are added to reflect theoretical considerations that are not taken into account explicitly in the spatial equilibrium model outlined above. Additional exogenous variables act as instruments in our estimation procedure. The resulting framework is a growth model comprising four equations for growth in public infrastructure capital, change in real income, population change and change in real land value. Each equation is estimated using data for 58 LMAs across two intercensal time periods (1996–2001 and 2001–2006). The equations each contain a constant and a period dummy (Period_dummy =0 in the first period and =1 in the second period) to control for broader national business cycle effects.

The first equation, for the growth rate of public infrastructure (Δ_Infrastructure) is expressed, as in (5), as a function of the percentage change in real median income (Δ_Income), the percentage change in the usually resident population (Δ_Population) and the percentage change in estimated real land value (Δ_Landvalue). We add the rate of initial home ownership as an additional variable since Roskruge et al. (2013) found that homeowners tend to hold local authorities to a stricter level of account than do renters. This may potentially lead to a higher or lower provision of services depending on how well local authorities' revenues are used when investing in public infrastructure. The homeownership variable (%_Homeownership_1996) is used to capture this effect with the value from the start of the period (1996) being used to avoid endogeneity problems.[3]

The equation for the change in real income per capita explains income growth, as in (1), in terms of the growth in public infrastructure capital (Δ_Infrastructure) and the percentage change in usually resident population (Δ_Population). We add the natural logarithm of median income at the start of the period (log_Income_1996) and the local unemployment rate (%_Unemployed_1996) as extra variables to this relationship. We expect a negative sign on the parameter estimate of the log of real income at the beginning of the period (log_Income_1996) (beta convergence) as the standard neoclassical growth model posits that income growth is inversely related to the initial level of income (Barro and Sala-i-Martin 1992). In addition, we hypothesise that there may be an Okun's law relationship between unemployment and real income growth (Lee 2000), so that real income growth is reduced as unemployment rises. We therefore expect a negative sign on the local unemployment rate (%_Unemployed_1996) parameter.

The population growth (Δ_Population) equation is expressed, as in (4), as a function of growth in public infrastructure capital (Δ_Infrastructure). To this basic specification, we add the change in overseas-born population (Δ_Overseas_Born),[4] an industry mix variable (Industry_Mix), the natural logarithm of the initial median real income (log_Income_1996) and the initial percentage unemployed (%_Unemployed_1996). Population growth through net migration is hypothesised to be associated with prevailing labour market conditions, with these flows being positively related to pre-existing real income levels (log_Income_1996) and employment opportunities created by nationally growing industries that are present in the local region (Industry_Mix) (Boyle et al. 1998; Greenwood 1997; Molho 1986; Poot 1986). Net migration may also be positively associated with the unemployment rate because of high labour turnover in such areas attracting migrants (Poot 1986).

The equation for the percentage change in real land value, as in (2), comprises variables for growth in public infrastructure capital (Δ_Infrastructure) and the percentage change in usually resident population (Δ_Population). The natural log of real land value at the start of the period (log_landvalue_1996) is included to reflect potential convergence processes for land prices. Spatial differences in amenities will lead to persistent spatial differences in the value of land. However, on the long-run growth path, there may be neoclassical convergence, in which case we expect a negative sign on the parameter estimate for the log of initial real land value (log_landvalue_1996).

[3]In equations where an initial (1996) level variable is included (in order to avoid endogeneity issues), we also include that variable interacted with the period dummy in order to allow its coefficient to differ in the first and second periods.

[4]International migration is proxied here by the five-year change in the percentage of overseas-born persons in an LMA.

These four equations represent our base model which we estimate using 3SLS to take account of simultaneity and contemporaneous correlation of the error terms within the equation system. Besides the exogenous variables included in the model, we utilise a number of exogenous instruments in the estimation. These include a spatial variable (distance to Auckland), a climate variable (rainfall) and a range of demographic and population characteristics variables: percentage with a degree, percentage of (indigenous) Maori, percentage in professional occupations, percentage of smokers, the dependency ratio and population density. All variables are defined in Table 1.

Table 1 Variable definitions

Variable		Definition
Endogenous	Δ_Income	Growth in real median income (percent)
	Δ_Infrastructure	Growth in infrastructure capital (percent)
	Δ_Landvalue	Growth in real land value (percent)
	Δ_Population	Growth in usually resident population (percent)
Exogenous	%_Homeownership_1996	Percent Home ownership in 1996
	%_Unemployed_1996	Percentage of labour force that is unemployed in 1996
	Industry_Mix	Industry mix effect
	log_Income_1996	Natural logarithm of real median income in 1996, $2006
	log_Landvalue_1996	Natural log of real land value in 1996, $2006
	Period*Homeown	Interaction of %_Homeownership and the period dummy
	Period*Income	Interaction of log_Income_1996 and the period dummy
	Period*Landvalue	Interaction of log_Landvalue_1996 and the period dummy
	Period*Unemployed	Interaction of %_Unemployed_1996 and the period dummy
	Period_dummy	0 = 1996–2001, 1 = 2001–2006
	Δ_Overseas_Born	Growth in overseas-born population (percent)
Instruments	%_Degree_Plus	Percentage with Bachelors degree or higher
	%_Maori	Percentage Maori
	%_Professionals	Percentage in professional occupations
	%_Smokers_1996	Percentage smokers in 1996
	Dependency_Ratio	Demographic dependency ratio ((0–14 plus 65+)/(15–64))
	Km_to_Auckland	Distance to Auckland (Km)
	Period*Population_Density	Interaction of Population_density and the period dummy
	Population_density	LMA population density (population per km^2)
	Rainfall	Rainfall (mm) largest urban area in LMA (20 year average)

Wu and Gopinath (2008) examined the causes of spatial disparities in economic development in the United States using a two-step procedure based on the approach of Kelejian and Prucha (2004). Firstly, a system of simultaneous equations, being structural equations of demand and supply in the labour and housing markets, is estimated using a 3SLS estimator, thus correcting for endogeneity and contemporaneous correlation. In the second step of the procedure, the residuals from the 3SLS estimation are tested for spatial autocorrelation. If spatial autocorrelation is identified in an equation, the 3SLS residuals are used to estimate the spatial correlation parameter (ρ) by means of the generalised moment estimator suggested by Kelejian and Prucha (1999). The data are then transformed using the matrix (I-ρW) where I is an NxN identity matrix, N being the number of observations and W a spatial weights matrix. Using the transformed data, each equation is then re-estimated using ordinary least squares (OLS).

In this chapter we face a similar problem, the estimation of a system of equations representing the growth path of regional economies in the potential presence of spatial autocorrelation. We adopt a somewhat different approach from Wu and Gopinath (2008). Initially the four-equation growth model is estimated using standard 3SLS.[5] The residuals of each of the estimated equations are then inspected for the presence of spatial autocorrelation. Where the residuals of a particular equation show a significant level of spatial autocorrelation, the spatial lag of the dependent variable is created. Next, the 3SLS system is re-estimated with the inclusion of the spatially lagged variables in the relevant equations. The inclusion of the spatially lagged dependent variables in the 3SLS system can be seen as analogous to the use of the spatial autoregressive (SAR) model in the single equation context (see LeSage and Pace 2009, 32–33).

The observations in all models are weighted by the LMA usually resident populations for the beginning of the relevant period. Given that many of the variables represent average outcomes for individuals and households within LMAs, a control for heteroscedasticity is introduced by means of analytical weights equal to the population size of each LMA.[6]

3 Data and Descriptives

Our data, covering the two periods 1996–2001 and 2001–2006, are drawn from a number of sources: the quinquennial New Zealand Census of Population and Dwellings, statistical profiles of individual councils available from New Zealand's Department of Internal Affairs (DIA), Motu Economic and Public Policy Research's

[5] All estimations were carried out in Stata 11 using either the reg3 command (3SLS), the spatreg command (invoking the spatial procedures provided by Maurizio Pisati) or the splagvar command of P. Wilner Jeanty.

[6] Analytical weights can be used with most Stata regression commands, but not with spatreg.

Quotable Value New Zealand (QVNZ) property sales and valuation database and Motu's Regional and Local Authorities Finance database.[7]

These data are aggregated to labour market areas (LMA) which are built up from the census area unit[8] (CAU) level. Functional economic areas are generally the most appropriate unit of analysis for examining regional economic activity, as administrative areas tend to have arbitrary boundaries in so far as they reflect economic relations (Stabler and Olfert 1996; ONS and Coombes 1998; Casado-Diaz 2000). Newell and Papps (2001) used travel-to-work data from the 1991 and 2001 censuses to define LMAs in New Zealand. This research yielded 140 LMAs for 1991 and 106 for 2001. This level of breakdown is too refined for linking to regional characteristics that come from sources other than the census. A level of disaggregation that permits the use of regional analysis with a wide range of regional indicators is that of 58 LMAs, with an average population of approximately 65,000 per LMA in 2001.

Total additions to public fixed capital in the LMA are calculated on the basis of reported territorial authority (TA) and regional council (RC) additions to infrastructure capital. Infrastructure investment includes local council expenditure on roading; storm water, sewerage, refuse and drainage; water treatment and supply; and parks and community facilities.[9] The values for these investment expenditures are apportioned to their constituent CAU on the basis of population and then aggregated to the LMA level.[10] Figures 1 and 2 show the spatial distribution of growth in infrastructural capital for the 1996–2001 and 2001–2006 periods, respectively. Moran's I statistics for both periods are positive and significant ($I = 0.156$, $p < 0.05$), indicating the clustering of similar values of infrastructure growth across LMAs. For the 1996–2001 period, infrastructure capital growth rates range from 1.5 to 28 %; the 2001–2006 range is similar, ranging from 1.7 % to 28 %. LMA infrastructure growth rates in the two periods are strongly correlated ($r = 0.65$, $p < 0.01$).

The percentage change in real median income (in NZ$2006) is calculated from the census meshblock database aggregated to LMA boundaries for the 1996, 2001 and 2006 censuses. For the first period, 1996–2001, percentage change in real

[7]The DIA data are available at www.localcouncils.govt.nz/lgip.nsf; for details on the two sets of Motu-sourced data, see: www.motu.org.nz/building-capacity/datasets.

[8]Census area units, as defined by Statistics New Zealand, usually contain between 3000 and 5000 persons.

[9]The nature of local council financial reporting means that some operational expenditures are included along with capital expenditures in this dataset, but no further distinction between capital and operating expenditure is possible within these categories. Clearly operational council expenditures (for instance, on council administration) are excluded from our data.

[10]Estimates of the existing stock of public infrastructure are not available. We assume that the observed growth in infrastructural capital was proportional to the investment ratio (I/Y*100). This ratio was calculated by dividing the sum of total additions to infrastructure capital (I) in the LMA by LMA aggregate income (Y). The latter was proxied by the mean personal income in the LMA multiplied by the usually resident population aged 15 years and over.

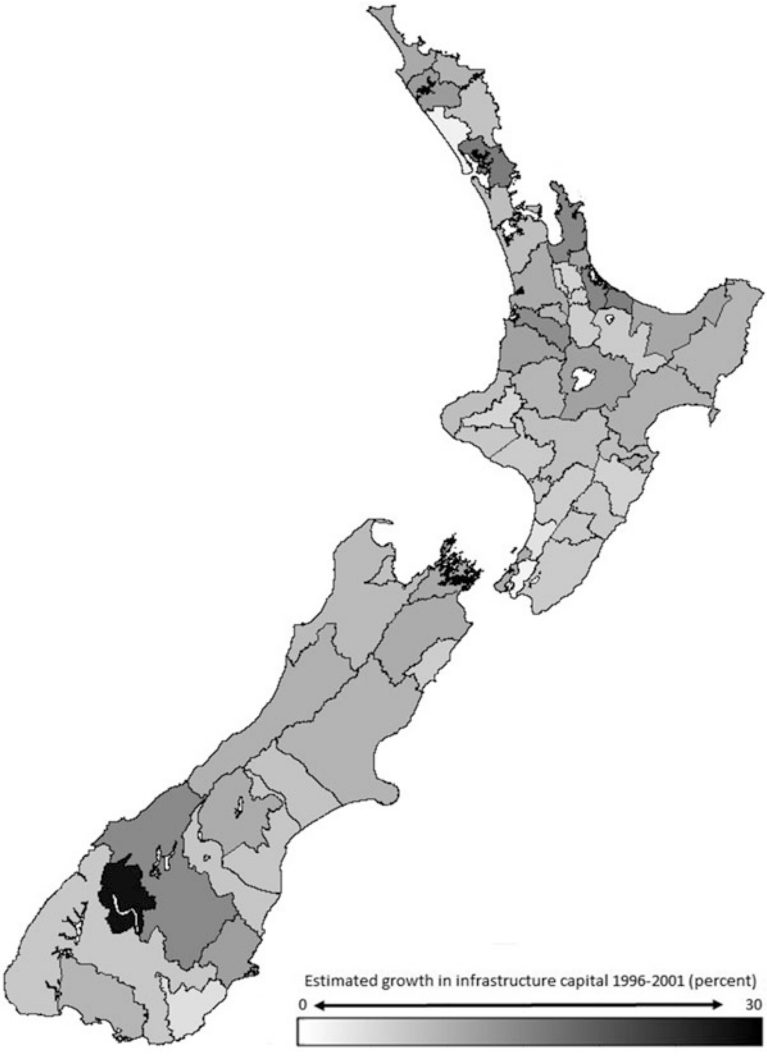

Fig. 1 Growth in infrastructure capital, 1996–2001

median income ranged from a decline of 1 % to an increase of 17 %, while in the second period, the percentage change in real median income ranged from 1 to 25 %. The correlation in the growth of median income between the two periods was insignificant. Moran's I for the period was significant and positive ($I = 0.168$, $p < 0.05$); however, for the second period I was not significant ($I = 0.079$, $p > 0.1$) indicating that in the latter period, growth in real median income was not geographically clustered.

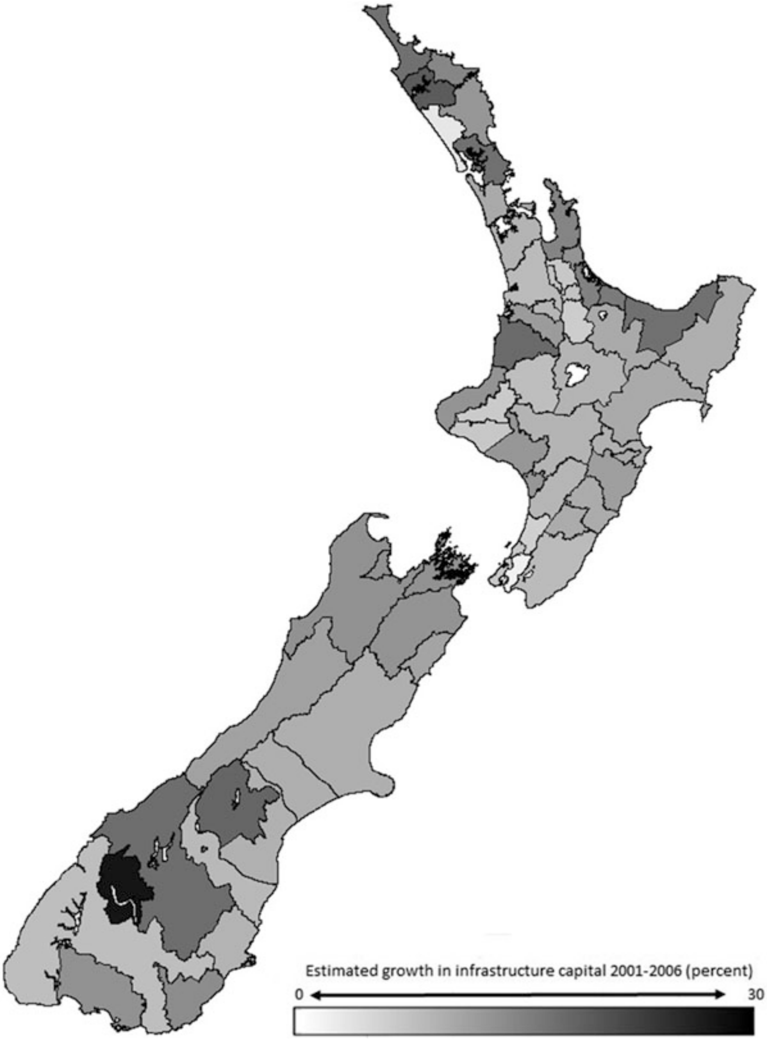

Fig. 2 Growth in infrastructure capital, 2001–2006

Percentage change in usually resident population is calculated on the basis of census counts aggregated to LMA boundaries for the two periods. Moran's I for both periods were significant and positive (1996–2001, $I = 0.212$, $p < 0.01$; 2001–2006, $I = 0.253$, $p < 0.001$). For the first period, population growth varied between a decline of 14 % and an increase of 16 %, with over half (35/58) of the LMAs experiencing population declines. In the second period, population growth ranged from a decline of 5 % to an increase of 30 % with a quarter of LMAs experiencing population declines. Population growth between the two periods was highly correlated ($r = 0.798$, $p < 0.05$).

To obtain the percentage change in estimated real land value, land values were estimated by multiplying the CAU mean sales price by the ratio of land valuation to capital valuation for each census year. The CAU estimates were then aggregated to LMA level, weighted by the number of dwellings in each CAU and converted to NZ$2006 dollars. The percentage change for the intercensal period was then calculated. In the first period, percentage change in real land values ranged from a decline of nearly 50 % to an increase of close to 100 % over the 5 years. There was a moderate negative correlation between the percentage change in estimated real land value in the first and second periods ($r = -0.416$, $p < 0.05$). In the second period, only one LMA had land that declined in value, while increases ranged up to nearly 380 % during a time of national and global property price boom. Moran's I for both periods is significant and positive (1996–2001, $I = 0.200$, $p < 0.01$; 2001–2006, $I = 0.129$, $p < 0.05$).

The industry mix variable is the industry mix effect calculated by the classical shift share technique (Cochrane and Poot 2008). Descriptive statistics for all variables used in the analysis are shown in Table 2.

Before turning to the estimation results, we consider the construction of the spatial weight matrix used to specify the spatial relation between LMAs. Although the selection of the spatial weight matrix is a crucial decision in spatial econometric analysis, there exists no clear-cut means of deciding on which approach to use (Griffith 1996; Getis and Aldstadt 2004; Conley and Topa 2002).[11] We construct the weight matrix on the basis of the reciprocal of squared travel time between the major urban centre of each LMA. The matrix takes a block diagonal form (i.e. LMAs in one time period do not interact with neighbours in a separate time period) and is row standardized.

4 Results

The results of the nonspatial 3SLS system are presented in Table 3.[12] In the equation for growth in public infrastructure capital (Δ_Infrastructure), two variables are significant at the 5 % level (with positive coefficients). The two variables are the

[11] Stetzer (1982) and Florax and Rey (1995) find that overspecification of the spatial weights matrix leads to a loss of statistical power, while under-specification induces an increase in power in the presence of positive spatial autocorrelation and a loss in power in the presence of negative spatial correlation. Both under- and overspecification produce an increase in the mean squared error for spatial econometric models (Griffith 1996, pp 66–67).

[12] In Tables 3, 5 and 7 rather than reporting the interaction terms directly, the parameter on the variable of interest in the latter period is reported to assist interpretation of results. For instance in the equation for the percentage change in real land value, rather than reporting the parameter on the interaction term for 1996 land value and the period dummy (period*landvalue), we report the parameter on land value in the 2001–2006 period obtained by adding the parameter estimate obtained for the first period to that of the interacted term.

Table 2 Descriptive statistics by period (population weighted)

Variable		Period beginning 1996				Period beginning 2001			
		Mean	S.d.	Min	Max	Mean	S.d.	Min	Max
Endogenous	Δ_Income	5.85	2.29	−0.71	16.94	11.59	3.02	0.75	24.52
	Δ_Infrastructure	8.21	2.59	1.45	28.05	9.69	3.01	1.70	27.54
	Δ_Landvalue	15.64	18.51	−47.61	96.32	95.91	43.11	−13.97	376.07
	Δ_Population	3.29	5.43	−13.52	16.44	7.78	5.21	−5.2	28.99
Exogenous	%_Homeownership_1996	70.54	3.33	51.97	79.24	70.51	3.28	51.97	79.24
	%_Unemployed_1996	7.81	1.89	2.37	18.87	7.80	1.86	2.37	18.87
	Industry_Mix	−0.06	1.84	−5.71	3.42	−0.07	2.52	−7.82	3.62
	log_Income_1996	9.94	0.11	9.47	10.15	9.94	0.11	9.47	10.15
	log_Landvalue_1996	11.03	0.68	8.89	12.00	11.06	0.67	8.89	12.00
	Δ_Overseas_Born	12.39	9.46	−10.9	38.73	24.53	9.39	−2.37	69.34
Instruments	%_Degree_Plus	9.44	4.79	3.21	21.46	11.59	5.3	3.83	23.8
	%_Maori	13.64	7.99	4.51	52.59	13.41	8.13	4.39	55.42
	%_Professionals	22.44	5.34	9.77	33.87	24.74	5.96	10.49	36.65
	%_Smokers_1996	23.83	3.12	20.5	37.05	23.75	3.08	20.5	37.05
	Dependency_Ratio	53.35	6.29	34.21	69.84	53.52	6.76	35.48	71.12
	Km_to_Auckland	474.13	482.5	0.00	1,638	461.05	479.06	0.00	1, 638
	Population_density	63.09	85.23	0.45	321.25	64.33	85.49	0.45	321.25
	Rainfall	1,123.02	293.89	360.00	2,430.00	1,124.78	289.7	360.00	2,430.00

Weighted by LMA usually resident population at commencement of period

Table 3 Nonspatial 3SLS

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Growth in infrastructure capital	116	6	2.81	0.051	52.44	.000
Growth in real median income	116	7	2.75	0.506	214.17	.000
Growth in population	116	8	2.14	0.861	800.87	.000
Growth in real land value	116	5	26.839	0.734	317.51	.000
Growth in infrastructure capital						
	Coef.	**Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
Δ_Income	0.628	0.125	5.010	0.000	0.383	0.873
Δ_Population	0.037	0.057	0.640	0.519	-0.075	0.149
Δ_Landvalue	0.026	0.011	2.290	0.022	0.004	0.048
%_1996 Homeownership, 1996-01 coeff	0.078	0.091	0.850	0.394	-0.101	0.256
%_1996 Homeownership, 2001-06 coeff	0.028	0.156	0.179	0.858	-0.278	0.333
Period_dummy	-0.807	8.914	-0.090	0.928	-18.278	16.664
Constant	-1.469	6.585	-0.220	0.823	-14.375	11.437
Growth in real median income						
Δ_Infrastructure	0.610	0.162	3.760	0.000	0.292	0.928
Δ_Population	0.137	0.064	2.130	0.033	0.012	0.262
log_Income_1996, 1996-01 coeff	2.031	3.593	0.570	0.572	-5.011	9.073
log_Income_2001, 2001-06 coeff	-3.500	5.645	-0.620	0.535	-14.564	7.564
%_Unemployed_1996, 1996-01 coeff	0.004	0.176	0.020	0.981	-0.341	0.349
%_Unemployed_1996, 2001-06 coeff	-0.196	0.300	-0.653	0.516	-0.784	0.392
Period_dummy	60.755	44.197	1.370	0.169	-25.870	147.380
Constant	-19.830	36.955	-0.540	0.592	-92.260	52.600
Growth in population						
Δ_Infrastructure	0.519	0.139	3.730	0.000	0.247	0.791
Δ_Overseas_Born	0.414	0.027	15.560	0.000	0.361	0.467
Industry_Mix	0.474	0.130	3.660	0.000	0.219	0.729
log_Income_1996, 1996-01 coeff	5.284	3.421	1.540	0.122	-1.421	11.989
log_Income_1996, 2001-06 coeff	18.403	5.247	3.508	0.000	8.120	28.686
%_Unemployed_1996, 1996-01 coeff	0.224	0.164	1.370	0.170	-0.097	0.545
%_Unemployed_1996, 2001-06 coeff	0.852	0.280	3.042	0.002	0.303	1.401
Period_dummy	-136.599	40.415	-3.380	0.001	-215.811	-57.387
Constant	-60.335	34.971	-1.730	0.084	-128.877	8.207
Growth in real land value						
Δ_Infrastructure	4.140	1.386	2.990	0.003	1.423	6.857
Δ_Population	-0.020	1.001	-0.020	0.984	-1.982	1.942
Log_Landvalue_1996, 1996-01 coeff	1.024	8.161	0.130	0.900	-14.971	17.019
Log_Landvalue_1996, 2001-06 coeff	-34.788	10.976	-3.169	0.002	-56.301	-13.275
Period_dummy	470.428	81.592	5.770	0.000	310.511	630.345
Constant	-29.593	90.221	-0.330	0.743	-206.423	147.237

NB: Grey shading indicates significance at 5 percent level. Parms is number of parameters in the equation.
Endogenous variables: Δ_Infrastructure, Δ_Income, Δ_Population, Δ_Landvalue
Exogenous variables: %_Homeownership _1996, Period*Homeown, Period_dummy, lag_log_Income_1996, log_Income_1996, Period*Income, %_Unemployed_1996 , Period*Unemployed, Industry mix effect, lag_log_Landvalue_1996, log_Landvalue_1996, Period*Landvalue, %_Maori Rainfall, %_Professionals, %_Degree_Plus, %_Smokers_1996, Km_to_Auckland, Population_density, Period*Population_Density, Dependency_Ratio, Δ_Overseas_Born

percentage change in median income (Δ_Income) and the percentage change in estimated real land value (Δ_Landvalue). The significance of these two variables is in line with the expected importance of access to funding for local authorities' infrastructural investment. Other variables are all statistically insignificant though of the expected sign.

In the growth in real income (Δ_Income) equation, population growth (Δ_Population) and the growth in public infrastructure capital (Δ_Infrastructure) are significant and positive. Infrastructure growth increases productivity and, consequently, real income, indicating (from the theory) that infrastructure investments have, on balance, had a benefit-cost ratio exceeding one. Moreover, population growth provides a boost to real income growth, consistent with increasing returns to scale (agglomeration externalities) in the regional production function on which equation (1) is based.

Regional population growth is positively affected by investment in public infrastructure (Δ_Infrastructure), international migration (Δ_Overseas_Born) and a favourable mix of industries (Industry_Mix). In addition, initial incomes and unemployment are significant in the second period.

Lastly, investment in public infrastructure (Δ_Infrastructure) is significant for the growth in the real value of land (Δ_Landvalue). In addition, the lagged log of real land value is significant and negative in the second period, indicating a process of land price convergence over those 5 years.

In the context of our theoretical model, the estimated system in Table 3 shows material interactions between all four variables of interest, even after instrumenting the endogenous variables through 3SLS estimation. As shown in Fig. 3, each of the dependent variables is explained significantly by at least one of the other endogenous variables, and each endogenous variable is significant for at least one other endogenous variable.

Table 4 presents Moran's *I* statistics for the residuals from the nonspatial 3SLS estimates. Moran's *I* statistics are positive and significant at the 5 % level for each variable other than population change, indicating that spatial autocorrelation is

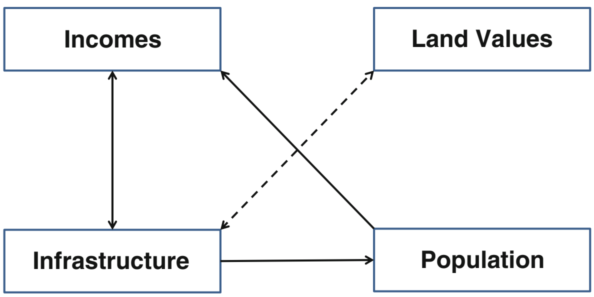

Fig. 3 Estimated system linkages (All linkages are significant at the 5 % level in the nonspatial estimates; the two-way linkages between infrastructure and land values are not significant at the 5 % level in the spatial estimates)

Table 4 Moran's I

Variables	I	E(I)	sd(I)	z	p-value*
Growth in infrastructure capital	0.107	-0.009	0.060	1.921	0.027
Growth in real median income	0.093	-0.009	0.061	1.663	0.048
Growth in population	0.061	-0.009	0.061	1.140	0.127
Growth in real land value	0.107	-0.009	0.060	1.908	0.028

present in these instances.[13] Accordingly, the 3SLS system is re-estimated including spatial lags on the dependent variables in the growth in public infrastructure capital (Δ_Infrastructure), growth in real income (Δ_Income) and growth in real value of land (Δ_Landvalue) equations.

The results of the spatial 3SLS model are shown in Table 5. Table 6 reports Moran's *I* statistics for the residuals of the spatial 3SLS estimation. The results indicate that the inclusion of the spatial lags in the growth in public infrastructure capital (Δ_Infrastructure), real income growth (Δ_Income) and real land value growth (Δ_Landvalue) equations has reduced the impact of spatial autocorrelation with none of Moran's *I* statistics for the 3SLS equations being significant at the 5 % level. Table 7 compares the results of the nonspatial and spatial 3SLS systems. Of the three spatial lag terms, only that for infrastructure (Spatial_Lag_Δ_Infrastructure) is significant at the 5 % level. The positive and significant coefficient on this variable indicates that growth in infrastructure spending in one region spills over positively into surrounding areas.

With the inclusion of the spatial lag terms, two variables, Δ_Landvalue in the infrastructure equation ($p = 0.154$) and Δ_Infrastructure in the land value equation ($p = 0.125$), are now no longer significant at the 5 % level. All other previously significant variables remain significant, and all previously significant variables remain of the same sign. Furthermore, the insignificant spatial lag term in the land value equation suggests that Table 5 (nonspatial) estimate for the coefficient on Δ_Infrastructure in the land value equation ($p = 0.003$) may be more appropriate than that in Table 7. Overall, we continue to see a material degree of interaction amongst the four variables. In particular, new infrastructure investment impacts positively on both population and income per head (and its positive effects spreads to other areas) with lesser support for a positive effect on land values.

5 Conclusions

We have estimated the impact of local authority infrastructure spending on key regional economic and demographic outcomes within New Zealand using a spatial 3SLS estimation methodology to account for simultaneity and spatial autocor-

[13]Cliff and Ord (1981, pp. 200–206) and Schabenberger and Gotway (2005, pp. 314–315) discuss issues of assessing spatial autocorrelation in regression residuals using Moran's *I*.

Table 5 Spatial 3SLS

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Growth in infrastructure capital	116	7	2.570	0.205	54.42	.000
Growth in real median income	116	8	2.547	0.577	210.24	.000
Growth in population	116	8	2.131	0.862	807.85	.000
Growth in real land value	116	6	26.772	0.735	312.51	.000

	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Growth in infrastructure capital						
Spatial_Lag_Δ_Infrastructure	0.415	0.128	3.250	0.001	0.164	0.666
Δ_Income	0.490	0.125	3.920	0.000	0.245	0.735
Δ_Landvalue	0.016	0.011	1.420	0.154	-0.006	0.038
Δ_Population	0.016	0.057	0.280	0.781	-0.096	0.128
%_1996 Homeownership, 1996-01coeff	0.024	0.094	0.250	0.800	-0.160	0.208
%_1996 Homeownership, 2001-06coeff	-0.005	0.161	-0.031	0.975	-0.321	0.311
Period_dummy	-1.540	9.125	-0.170	0.866	-19.425	16.345
Constant	0.065	6.703	0.010	0.992	-13.073	13.203
Growth in real median income						
Spatial_Lag_Δ_Income	0.076	0.141	0.540	0.590	-0.200	0.352
Δ_Infrastructure	0.430	0.163	2.630	0.009	0.111	0.749
Δ_Population	0.157	0.064	2.440	0.015	0.032	0.282
log_Income_1996,1996-01 coeff	2.504	3.697	0.680	0.498	-4.742	9.750
log_Income_2001, 2001-06 coeff	-4.867	5.790	-0.841	0.400	-16.215	6.481
%_Unemployed_1996, 1996-01 coeff	-0.019	0.182	-0.110	0.915	-0.376	0.338
%_Unemployed_1996, 2001-06 coeff	-0.224	0.312	-0.717	0.473	-0.836	0.388
Period_dummy	78.865	45.205	1.740	0.081	-9.735	167.465
Constant	-23.388	37.995	-0.620	0.538	-97.857	51.081
Growth in population						
Δ_Infrastructure	0.515	0.134	3.850	0.000	0.252	0.778
Δ_Overseas_Born	0.412	0.026	15.700	0.000	0.361	0.463
Industry_Mix	0.490	0.129	3.790	0.000	0.237	0.743
log_Income_1996,1996-01 coeff	5.440	3.390	1.600	0.109	-1.204	12.084
log_Income_1996, 2001-06 coeff	18.411	5.215	3.530	0.000	8.190	28.632
%_Unemployed_1996, 1996-01 coeff	0.217	0.163	1.330	0.183	-0.102	0.536
%_Unemployed_1996, 2001-06 coeff	0.846	0.279	3.036	0.002	0.300	1.392
Period_dummy	-135.114	40.273	-3.350	0.001	-214.048	-56.180
Constant	-61.764	34.639	-1.780	0.075	-129.655	6.127
Growth in real land value						
Spatial_Lag_Δ_Landvalue	0.064	0.115	0.550	0.579	-0.161	0.289
Δ_Infrastructure	2.179	1.418	1.540	0.125	-0.600	4.958
Δ_Population	0.426	1.020	0.677	0.677	-1.573	2.425
Log_Landvalue_1996, 1996-01 coeff	-0.498	8.502	-0.060	0.953	-17.162	16.166
Log_Landvalue_1996, 2001-06 coeff	-37.416	11.991	-3.120	0.002	-60.918	-13.914
Period_dummy	477.405	99.404	4.803	0.000	282.577	672.233
Constant	0.539	93.937	0.995	0.995	-183.574	184.652

NB: Grey shading indicates significance at 5 percent level. Parms is number of parameters in the equation.

Endogenous variables: Δ_Infrastructure, Δ_Income, Δ_Population, Δ_Landvalue

Exogenous variables: lag_infrastructure, %_Homeownership _1996, Period*Homeown, Period_dummy, lag_log_Income_1996, log_Income_1996, Period*Income , %_Unemployed_1996 Period*Unemployed, Industry mix effect, lag_log_Landvalue_1996, log_Landvalue_1996, Period*Landvalue , %_Maori, Rainfall, %_Professionals, %_Degree_Plus, %_Smokers_1996, Km_to_Auckland, Population_density, Period*Population_Density, Dependency_Ratio, Δ_Overseas_Born

Table 6 Moran's I

Variables	I	E(I)	sd(I)	z	*p*-value*
Growth in infrastructure capital	0.012	−0.009	0.06	0.337	0.368
Growth in real median income	0.070	−0.009	0.061	1.288	0.099
Growth in population	0.061	−0.009	0.061	1.136	0.128
Growth in real land value	0.083	−0.009	0.06	1.519	0.064

Table 7 Comparison of nonspatial and spatial 3SLS

	Non Spatial 3SLS		Spatial 3SLS	
Equation	**R-sq**	**P**	**R-sq**	**P**
Growth in infrastructure capital	0.051	0.000	0.205	0.000
Growth in real median income	0.506	0.000	0.577	0.000
Growth in population	0.861	0.000	0.862	0.000
Growth in real land value	0.734	0.000	0.735	0.000
Growth in infrastructure capital				
	Coef.	**P>z**	**Coef.**	**P>z**
Spatial_Lag_Δ_Infrastructure			0.415	0.001
Δ_Income	0.628	0.000	0.490	0.000
Δ_Landvalue	0.026	0.022	0.016	0.154
Δ_Population	0.037	0.519	0.016	0.781
%_1996 Homeownership 1996-01 coefficient	0.078	0.394	0.024	0.800
%_1996 Homeownership 2001-06	0.028	0.858	-0.005	0.975
Period_dummy	-0.807	0.928	-1.540	0.866
Constant	-1.469	0.823	0.065	0.992
Growth in real median income				
Spatial_Lag_Δ_Income			0.076	0.590
Δ_Infrastructure	0.610	0.000	0.430	0.009
Δ_Population	0.137	0.033	0.157	0.015
log_Income_1996 – 1996-01 coeff	2.031	0.572	2.504	0.498
log_Income_2001 – 2001-06 coeff	-3.500	0.535	-4.867	0.400
%_Unemployed_1996 – 1996-01 coeff	0.004	0.981	-0.019	0.915
%_Unemployed_1996 2001-06 coeff	-0.196	0.516	-0.224	0.473
Period_dummy	60.755	0.169	78.865	0.081
Constant	-19.830	0.592	-23.388	0.538
Growth in population				
Δ_Infrastructure	0.519	0.000	0.515	0.000
Δ_Overseas_Born	0.414	0.000	0.412	0.000
Industry_Mix	0.474	0.000	0.490	0.000
log_Income_1996 – 1996-01 coeff	5.284	0.122	5.440	0.109
log_Income_2001 – 2001-06 coeff	18.403	0.000	18.411	0.000
%_Unemployed_1996 – 1996-01 coeff	0.224	0.170	0.217	0.183
%_Unemployed_1996 2001-06 coeff	0.852	0.002	0.846	0.002
Period_dummy	-136.599	0.001	-135.114	0.001
Constant	-60.335	0.084	-61.764	0.075
Growth in real land value				
Spatial_Lag_Δ_Landvalue			0.064	0.579
Δ_Infrastructure	4.140	0.003	2.179	0.125
Δ_Population	-0.020	0.984	0.426	0.677
Log_Landvalue_1996, 1996-01 coeff	1.024	0.900	-0.498	0.953
Log_Landvalue_1996, 2001-06 coeff	-34.788	0.002	-37.416	0.002
Period_dummy	470.428	0.000	477.405	0.000
Constant	-29.593	0.743	0.539	0.995

NB: Grey shading indicates significance at 5 percent level relation. We show that there is significant spatial dependence in infrastructure investment with evidence that growth in infrastructural spending in one area spills over into surrounding regions. The results from both the spatial and nonspatial 3SLS estimators tell a similar story, albeit with more conservative findings when using the spatial estimates.

Both sets of results support the presence of a self-reinforcing growth process: real income growth is positively affected by both infrastructure growth and population growth, while real income growth itself contributes to growth in infrastructure spending. Infrastructure investment also has a positive impact on regional population growth, and increased infrastructure investment appears to be reflected positively in land values, although the effect is not statistically significant in the spatial model.

These findings are all in accordance with our theoretical model that incorporates endogenous infrastructure investment at the local level. The empirical findings confirm that positive two-way interactions exist between infrastructure investment and major regional economic and demographic outcomes. Accordingly, infrastructure investment cannot generally be treated as an exogenous variable in spatial analyses and must instead be treated as an endogenously determined variable driven, at least in part, by the local authority's funding ability.

From a policy perspective, the results confirm the importance of infrastructure investment for raising incomes within the local (and neighbouring) region and for supporting local population growth. An implication of this finding, as stressed by Durlauf (1996) and, in the New Zealand context, by McLuskey et al. (2006), is that if local funding ability is constrained by low incomes, then a self-reinforcing cycle of low incomes causing low infrastructure investment, in turn causing low incomes, may result. The existence of this self-reinforcing cycle implies that there may be a significant role for central government to play in supporting infrastructure investments, especially in regions least able to fund their own required additions to infrastructure.

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References

Aschauer D (1989) Is public expenditure productive? J Mon Econ 23(2):177–200

Barro RJ, Sala-i-Martin X (1992) Convergence. J Pol Econ 100(2):223–251

Biehl D (ed) (1986) The contribution of infrastructure to regional development final report of the infrastructure studies group to the Commission of the European Communities. Office for Official Publications of the European Communities, Luxembourg

Bom P, Ligthart J (2009) What have we learned from the three decades of research on the productivity of public capital? Working Paper, Tilburg University
Boyle P, Halfacree K, Robinson V (1998) Exploring contemporary migration. Longman, Harlow
Casado-Diaz JM (2000) Local labour market areas in Spain. Reg Stud 34(9):843–856
Cliff AD, Ord JK (1981) Spatial processes: models and applications. Pion, London
Cochrane W, Poot J (2008) Forces of change: a dynamic shift-share and spatial analysis of employment change in New Zealand labour markets areas. Stud Reg Sci 38(1):51–78
Coleman A, Grimes A (2010) Betterment taxes capital gains and benefit cost ratios. Econ Lett 109(1):54–56
Conley TG, Topa G (2002) Socio-economic distance and spatial patterns in unemployment. J Appl Econ 17(4):303–327
Deno KT (1988) The effect of public capital on US manufacturing activity: 1970 to 1978. South Econ J 55(1):400–411
Duflo E, Pande R (2007) Dams. Q J Econ 122(2):601–646
Durlauf SN (1996) A theory of persistent income inequality. J Econ Growth 1(1):75–93
Florax R, Rey S (1995) The impacts of misspecified spatial interaction in linear regression models new directions in spatial econometrics. In: Anselin L, Florax R (eds) New directions in spatial econometrics. Springer, Berlin, pp 111–135
Garcia-Mila T, McGuire TJ (1992) The contribution of publicly provided inputs to states' economies. Reg Sci Urban Econ 22(2):229–242
Getis A, Aldstadt J (2004) Constructing the spatial weights matrix using a local statistic. Geogr Anal 36(2):90–104
Gibbons S, Lyytikainen T, Overman H, Sanchis-Guarner R (2012) New road infrastructure: the effects on firms, SERC Discussion Paper 117. Spatial Economics Research Centre, London
Greenwood MJ (1997) Internal migration in developed countries. In: Rosenzweig MR, Stark O (eds) Handbook of population and family economics, vol 1. North Holland, Amsterdam, pp 647–720
Griffith D (1996) Some guidelines for specifying the geographic weights matrix contained in spatial statistical models. In: Arlinghaus S (ed) Practical handbook of spatial statistics. CRC Press, Boca Raton, pp 65–82
Grimes A (2014) Infrastructure and regional economic growth. In: Fischer M, Nijkamp P (eds) Handbook of regional science. Springer, Heidelberg, Chapter 28
Grimes A, Liang Y (2010) Bridge to somewhere: valuing Auckland's northern motorway extensions. J Transp Econ Pol 44(3):287–315
Grimes A, Young C (2013) Spatial effects of urban rail upgrades. J Transp Geogr 30:1–6
Haughwout A (2002) Public infrastructure investments productivity and welfare in fixed geographic areas. J Publ Econ 83(3):405–428
Hirschman A (1958) The strategy of economic development. Westview Press, Boulder
Holtz-Eakin D (1994) Public-sector capital and the productivity puzzle. Rev Econ Stat 76(1):12–21
Hulten CR, Schwab RM (1991) Public capital formation and the growth of regional manufacturing industries. Nat Tax J 44(4):121–134
Kelejian HH, Prucha IR (1999) A generalized moments estimator for the autoregressive parameter in a spatial model. Int Econ Rev 40:509–533
Kelejian HH, Prucha IR (2004) Estimation of simultaneous systems of spatially interrelated cross sectional equations. J Econ 118:27–50
Kelejian HH, Robinson DP (1997) Infrastructure productivity estimation and its underlying econometric specifications: a sensitivity analysis. Pap Reg Sci 76:115–131
Lall S (2007) Infrastructure and regional growth dynamics and policy relevance for India. Ann Reg Sc 41(3):581–599
Lee J (2000) The robustness of Okun's law: evidence from OECD countries. J Macroecon 22(2):331–356
LeSage JP, Pace RK (2009) Introduction to spatial econometrics. Chapman and Hall/CRC, Boca Raton

McLuskey W, Aitken A, Grimes A, Kerr S, Timmins J (2006) Rating systems in New Zealand: an empirical investigation into local choice. J Real Estate Lit 14(3):381–397

Molho I (1986) Theories of migration: a review. Scot J Pol Econ 33(4):396–419

Moretti E (2011) Local labor markets. In: Ashenfeiter O, Card D (eds) Handbook of labor economics, vol 4, Part B. North Holland, Amsterdam, pp 1237–1313

Newell JO, Papps KL (2001) Identifying functional labour market areas in New Zealand: a reconnaissance study using travel-to-work data, Occasional Paper Series No 2001/6. Department of Labour, Wellington

Nijkamp P, Poot J (2004) Meta-analysis of the impact of fiscal policies on long-run growth. Eur J Pol Econ 20(1):91–124

Nurske R (1953) Problems of capital formation in underdeveloped countries. Basil Blackwell, Oxford

ONS, Coombes MG (1998) 1991- travel to work areas. Office for National Statistics, London

Overman H, Rice P, Venables A (2010) Economic linkages across space. Reg Stud 44(1):17–33

Poot J (1986) A system approach to modelling the inter-urban exchange of workers in New Zealand. Scot J Pol Econ 33(3):249–274

Reich R (1991) The real economy. Atl Mon 267(2):35–52

Roback J (1982) Wages rents and the quality of life. J Pol Econ 90:1257–1278

Roskruge M, Grimes A, McCann P, Poot J (2013) Homeownership social capital and satisfaction with local government. Urban Stud 50(12):2517–2534

Schabenberger O, Gotway CA (2005) Statistical methods for spatial data analysis. CRC Press, Boca Raton

Stabler JC, Olfert MR (1996) Spatial labor markets and the rural labor force. Growth Chang 27(2):206–230

Stetzer F (1982) Specifying weights in spatial forecasting models: the results of some experiments. Environ Plan A 14:571–584

Sturm J-E, Kuper GH, De Haan J (1998) Modelling government investment and economic growth on a macro level: a review. In: Brakman S, Vanes H, Kuipers SK (eds) Market behaviour and macroeconomic modelling. Macmillan, London, pp 359–406

Wu JJ, Gopinath M (2008) What causes spatial variations in economic development in the United States? Am J Agric Econ 90(2):392–408

Migration Responses to a Loss in Regional Amenities: An Analysis with a Multiregional CGE Model

James A. Giesecke and John R. Madden

Abstract Amenities, both natural and urban, have long been considered to be a major factor in the choice of regional location by households. In this chapter, we examine demographic and economic effects of a relative decline in a region's amenities, where 'amenities' are taken to mean any features of a region outside purely economic ones. We have in mind such amenity changes as a heightened perception of pollution or an apparent change in regional weather patterns, possibly emanating from anthropogenic climate change. With regard to the latter, we imagine a change that makes a region's climate more uncomfortable without (at least for the period under consideration) having any effects on production functions. Our method of analysis is a dynamic multiregional computable general equilibrium (CGE) model with lagged (imperfect) migration responses. Each region's residents change their pattern of net interregional migration in response to relative changes in expected regional income and amenities. We undertake a simulation to explore the time path of adjustment in migration and regional economic variables in response to an amenity shock. A key component of the chapter is a careful interpretation of results, disentangling the effects resulting from the various mechanisms which link regions.

Keywords Computable general equilibrium • CGE • Interregional migration • Regional amenities

1 Introduction

There is a long literature on the role that amenities play in determining the regional location of households (e.g. Graves 1980; Evans 1990; Greenwood et al. 1991). In this chapter, we examine the economic effects of a change in a region's perceived amenities. In order to trace the time path of regional economic effects, we employ a dynamic multiregional computable general equilibrium (CGE) model featuring a

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lagged response to economic and non-economic drivers of migration. A major aim of this chapter is to explain the effects in terms of the key model mechanisms that determine the time path of results for key variables.

Our CGE model's theory is consistent with the use of the term 'amenities' in its widest sense. The regional science literature often refers to natural amenities and urban amenities (Kahsai et al. 2011). The latter may include cultural opportunities and the availability of health and recreational services and also the absence of dis-amenities, such as high crime rates and pollution levels.[1] In our CGE framework, we will take 'amenities' to mean any features of a region outside purely economic ones.

In this chapter, we explore the consequence of a change in a region's amenities for interregional migration, which then indirectly affects economic variables throughout the region's economy and across the nation's other regional economies. A change in regional amenities may be accompanied by some other economic shock(s) that also has ramifications for regional economies. For instance, a better transport system may raise the livability of a region (i.e. increased amenities), but achieving the better transport system requires construction activity, and once in place, the new system can result in agglomeration economies.[2] Similarly, while climate change may make a region uncomfortably hot (a reduction in amenities), it may also affect agricultural productivity and possibly the productivity of other industries in the region (Klaiber 2014). In this paper, however, we model the economic ramifications flowing from just the change in the region's attractiveness as a desirable place to live.

The amenity changes we have in mind in our modelling include a heightened perception of pollution or of the risk of a natural disaster or an apparent change in regional weather patterns emanating from anthropogenic climate change.[3] For the period under examination, we make the assumption that the amenity change, while making the region a less attractive place to live, does not impact on production functions.[4]

In the next section, we briefly describe our CGE model, the Victoria University Regional Model (VURM), before describing our migration theory in some detail.[5]

[1]We take our examples from Herzog and Schlottmann (1993, p. 145).

[2]See, for instance, Madden and Gwee (2010). Also, the creation of local public amenities generally needs public financing. Lecca et al. (2014) model the effects of this.

[3]Perceived effects can have important economic consequences. See, for instance, Giesecke et al. (2012).

[4]As noted by Li and Higano (2007), climate change will be a significant issue facing the world in the twenty-first century requiring measures to reduce greenhouse gas emissions. Emission targets agreed for the Copenhagen Accord in 2010 are unlikely to limit global warming to 2 °C (Rogelj et al. 2010), and thus, significant impacts on production functions are likely to occur in due course.

[5]For a recent review of CGE models, see Giesecke and Madden (2013). CGE models have been employed extensively in assessing the impacts of greenhouse gas reduction policies at the multi-country (e.g. McKibbin et al. 2010), national and regional (e.g. Adams and Parmenter 2013) and small region (e.g. Oladosu and Rose 2007) levels. Similarly, CGE models have been used extensively to assess the regional economic impacts of natural disasters (e.g. Shibusawa et al. 2009; Shibusawa and Miyata 2011).

Before putting our model to work simulating a loss in amenities, we set out in Sect. 3 a stylised ‘back-of-the-envelope’ (BOTE) version of VURM. In Sect. 4 we discuss the results from a CGE simulation of a 1 % fall in relative amenities in one region. With the aid of the BOTE model, we are able to provide a clear explanation of the time path of effects on regional economic variables consequent upon the loss of amenities.

2 The Victoria University Regional Model (VURM)

2.1 VURM Overview

VURM is a dynamic multiregional CGE model.[6] The operational Australian version of VURM explicitly models the behaviour of economic agents within each of Australia’s eight states and territories and features a large number of industries and commodities. For this exercise, however, we have for expository purposes reduced VURM’s number of regions to three (North, East and South) and the number of industries to eight.[7]

Neoclassical assumptions govern the behaviour of the model’s economic agents. Each of the eight representative industries operating within each of the three regions is assumed to minimise costs subject to constant-returns-to-scale production technologies and given input prices. A representative utility-maximising household resides in each of the model’s three regions. Investors allocate new capital to industries on the basis of expected rates of return. Units of new capital are assumed to be a cost-minimising combination of inputs sourced from each of the model’s four sources of supply (the three domestic regions plus imports). Imperfect substitutability between the imported and three domestic sources of supply for each commodity is modelled using the CES assumption of Armington. In general, markets are assumed to clear and to be competitive. Purchaser’s prices differ from basic prices by the value of indirect taxes and margin services. Taxes and margins can differ across commodity, user, region of source and region of destination. Foreign demands for each of the eight commodities from each of the three regions are modelled as inversely related to their foreign currency prices. The model includes details of the taxing, spending and transfer activities of two levels of government: a regional government operating within each region and a federal government operating Australia-wide. Intergovernmental transfer payments

[6]VURM stands for Victoria University Regional Model. Prior to 2014, it was known as the MMRF (or Monash Multi-Regional Forecasting) model.

[7]North comprises Western Australia, Northern Territory and Queensland. South comprises South Australia, Victoria and Tasmania. East comprises New South Wales and the Australian Capital Territory. The eight sectors are primary production, manufacturing, utilities, construction, private services, transport services, dwelling services and public services.

and personal transfer payments to households are also modelled. Dynamic equations describe stock-flow relationships, such as those between regional industry capital stocks and regional industry investment levels. Dynamic adjustment equations allow for the gradual movement of a number of variables towards their long-run values. For example, the national real wage is assumed to be sticky in the short run, adjusting over a period of about 5 years to return the level of national employment to its baseline level following an economic shock. Regional economic linkages arise from interregional trade, factor mobility, the taxing and spending activities of the federal government and long-run economy-wide employment and balance of trade constraints. The model also evaluates a full set of national and regional income accounts and associated deflators. The reader is referred to Adams et al. (2003) for a detailed discussion of the model and Naqvi and Peter (1996) for an overview of core equations. The model is solved with the GEMPACK economic modelling software (Harrison and Pearson 1996). In solving the model, we undertake two parallel model runs: a baseline simulation and a policy simulation. The baseline simulation is a business-as-usual forecast for the period 2015–2039. The policy simulation is identical to the baseline simulation in all respects other than the addition of the exogenous shocks describing the policy under investigation. We report model results as percentage deviations in the values of variables in each year of the policy simulation away from their baseline values.

2.2 Treatment of Interregional Migration

2.2.1 Approaches Taken in the Regional CGE Literature

Regional and multiregional models have taken a variety of approaches to the treatment of interregional migration. Some regional CGE models assume that labour is immobile across regions (e.g. Hirte 1998). This assumption is more likely to be the case when the study is just for the short run (e.g. Li and Rose 1995). Other studies take the opposite long-run approach and allow for endogenous interregional migration to equalise wages (e.g. Morgan et al. 1989) or utility (e.g. Groenewold et al. 2003). Many other regional CGE models, however, allow for imperfect interregional labour mobility.

Whalley and Trela (1986) were the first to incorporate imperfect interregional labour mobility into a regional CGE model.[8] Their migration theory was developed from their observation that individuals have ‘direct associations with specific regions’ (p. 74). They assume that there is a distribution of individuals within each region who differ only by their intensity of preference for remaining in the region. In making decisions about migration, individuals compare the utility they

[8] Their model is a multiregional CGE model of Canada. A description detailing the model’s migration theory can also be found in Jones and Whalley (1989).

would receive from residing in each of the regions. The marginal individual (i.e. the individual indifferent to migrating or remaining) is assumed to treat utility as just coming from income, and (as they are the marginal individual) the income receivable is the same for each region of residence.[9] All other individuals face a utility penalty from relocating, with the penalty increasing with the intensity of their location preference. If out-of-region income were to increase following some shock, outmigration would occur – until for the new marginal individual, home region income would just equal the income they could receive outside the region less the location penalty from shifting. That is, individuals trade off the extra income they would receive by migrating against location preference. Thus, in the new equilibrium, interregional wage differentials are consistent with zero migration.

The responsiveness of interregional migration to interregional income differentials depends on the parameterisation of location preferences. Jones and Whalley (1989, p. 386) point to difficulties in setting the value of this parameter to be consistent with econometrically estimated elasticities of outmigration. Other modellers use equations directly employing econometrically estimated parameters for net migration (e.g. Rickman 1992; McGregor et al. 1995, 1996; Rutherford and Törmä 2010). McGregor et al. (1995) model net migration to equalise a function of interregional differences in unemployment and wage rates, with gradual adjustment of regional wage rates to return populations to equilibrium (i.e. zero net migration).[10]

McGregor et al. (1996) simulate an improvement in amenities in Scotland and find it causes unfavourable shifts in both the real consumer wage rate and unemployment. The authors (p. 350) surmise that it would seem problematic to direct interventionist regional policy at regions which are ‘low wage, high unemployment’, as this description might simply mean the region is ‘amenity-rich’.

2.2.2 A Specification for Interregional Migration

We begin the development of our migration theory by assuming that gross interregional migration flows respond to movements in per capita regional income relativities. We call the measure of income that is relevant to the migration decision ‘migration income’. Equation (E1) defines migration income in region r as the expected wage per worker:

$$Y_r^{(M)} = W_r \times \mathrm{ER}_r \tag{E1}$$

[9] ‘Income’ is the sum of real incomes from labour, natural resource taxes and federal government transfers to the region.

[10] See also Gillespie et al. (2001).

where

$Y_r^{(M)}$ is migration income in region r.
W_r is the real consumer wage in region r.
ER_r is the employment rate (1 minus the unemployment rate) in region r.

We define movements in per capita migration income relativities via Eq. (E2):

$$\frac{Y_d^{(M)}}{Y_o^{(M)}} = Y_{o,d}^{(\mathrm{Diseq})} \cdot \frac{F_d^{(M)}}{F_o^{(M)}} \tag{E2}$$

where

$Y_r^{(M)}$ is migration income in region r.
$Y_{o,d}^{(\mathrm{Diseq})}$ is a measure of disequilibrium in migration income relativities between migration origin region o and migration destination region d.
$F_r^{(M)}$ is a shift variable used for calibrating migration income ratios.

A plausible initial parameterisation of the right-hand side of (E2) is

$$Y_{o,d}^{(\mathrm{Diseq})} = 1;\ \text{and}$$
$$F_r^{(M)} = Y_r^{(M)\mathrm{Initial}}$$

where $Y_r^{(M)\mathrm{Initial}}$ are the initial (base period) values for $Y_r^{(M)}$. As we shall see, with such a parameterisation of (E2), we have assumed that the base period migration income relativities ($Y_d^{(M)}/Y_o^{(M)}$) are consistent with trend regional gross emigration rates and that the initial migration income relativities provide information about relative regional amenity values through the structure of regional compensating migration income relativities ($F_d^{(M)}/F_o^{(M)}$).

In (E2), the values for $F_r^{(M)}$ are exogenous, while the values for $Y_r^{(M)}$ are determined by (E1) on the basis of labour market conditions in region r. Hence, (E2) determines $Y_{o,d}^{(\mathrm{Diseq})}$. We assume that a rise, say, in $Y_{o,d}^{(\mathrm{Diseq})}$ will generate a rise in the gross emigration rate from region o to region d ($\mathrm{GEMR}_{o,d}$) and a fall in the gross emigration rate from region d to region o ($\mathrm{GEMR}_{o,d}$). That is, a rise in $Y_{o,d}^{(\mathrm{Diseq})}$ will cause region d's net immigration rate to rise and region o's net immigration rate to fall.

We adopt an inverse logistic function, as illustrated in Fig. 1, to model the relationship between movements in $Y_{o,d}^{(\mathrm{Diseq})}$ and $\mathrm{GEMR}_{o,d}$.[11] For modelling a region's gross emigration rate, this function has three useful properties. First, by establishing a positive relationship between $\mathrm{GEMR}_{o,d}$ and $Y_{o,d}^{(\mathrm{Diseq})}$, the function reflects Whalley and Trela's insight that because individuals differ in terms of their preferences for residing within given regions, greater movements in relative regional wage rates are required to bring forth still higher levels of interregional migration.

[11]This function is also used in Dixon and Rimmer (2002: 190–193) to regulate net changes to another stock variable, namely, industry-specific capital stocks.

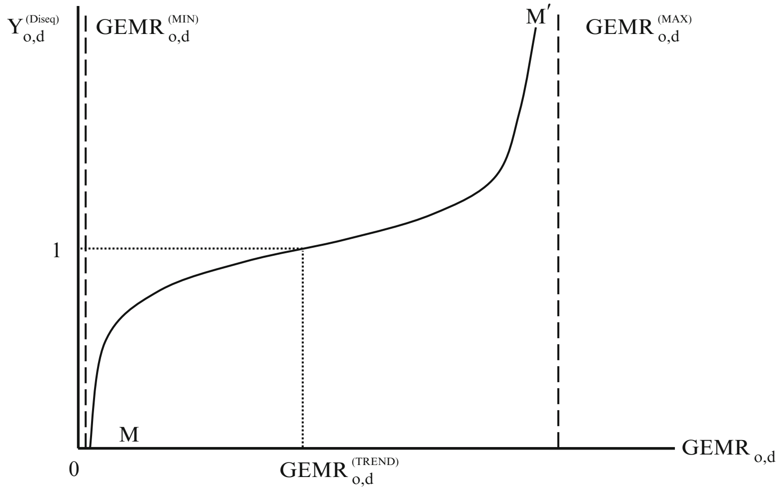

Fig. 1 Relationship between gross regional emigration rates and disequilibrium in regional migration income

Second, it allows us to model the autonomous component of interregional migration by establishing a trend value for $\text{GEMR}_{o,d}$ consistent with a value for $Y_{o,d}^{(\text{Diseq})}$ of 1. Third, it allows us to limit the minimum and maximum rates of gross emigration within historically observed bounds.[12] The equation describing Fig. 1 is

$$Y_{o,d}^{(\text{Diseq})} = 1 + F_{o,d} + (1/C_{o,d}) \times \left\{ \left[\ln\left(\text{GEMR}_{o,d} - \text{GEMR}_{o,d}^{(\text{MIN})}\right) - \ln\left(\text{GEMR}_{o,d}^{(\text{MAX})} - \text{GEMR}_{o,d}\right) \right] - \left[\ln\left(\text{GEMR}_{o,d}^{(\text{TREND})} - \text{GEMR}_{o,d}^{(\text{MIN})}\right) - \ln\left(\text{GEMR}_{o,d}^{(\text{MAX})} - \text{GEMR}_{o,d}^{(\text{TREND})}\right) \right] \right\} \tag{E3}$$

where

$F_{o,d}$ is a parameter governing the vertical position of the function MM′ in Fig. 1.
$C_{o,d}$ is a positive parameter, governing the sensitivity of the gross emigration rate from region o to region d to movements in disequilibrium in the migration income ratio between region o and d.[13]

[12] At the limit, the minimum and maximum gross emigration rates must be within the bounds 0 and 1, respectively. We choose minimum and maximum rates within these bounds by examining the historical data on region-specific emigration rates.

[13] We choose a value for $C_{o,d}$ that generates migration dynamics consistent with those described for Australia in Debelle and Vickery (1999). They find that net emigration from an Australian state following a relative downturn in its labour market occurs steadily over a number of years, with the bulk of the population adjustment having occurred by year 4 and the process largely complete by year 7.

$GEMR_{o,d}$ is the gross emigration rate from region *o* to region *d*, expressed as a proportion of region *o*'s population.
$GEMR_{o,d}^{(MIN)}$ is the historically observed minimum proportion of the region *o*'s population that emigrates to region *d* each year.
$GEMR_{o,d}^{(MAX)}$ is the historically observed maximum proportion of region *o*'s population that emigrates to region *d* each year.
$GEMR_{o,d}^{(TREND)}$ is the trend or normal rate of emigration from region *o* to region *d*.

To translate movements in $GEMR_{o,d}$ to movements in gross emigration numbers, we multiply the year *t* value of $GEMR_{o,d}$ by the year *t* population for region *o*. The resulting population flows affect start of year populations in year $t+1$. Movements in $GEMR_{o,d}$ can thus be interpreted as changes in planned emigration in year *t*, with an average 6-month lag before the population movement occurs at the beginning of year $t+1$.

2.2.3 A Specification for Short-Run Deviations in Regional Employment Rates

We allow for short-run stickiness in both regional populations and regional wage rates. As discussed in Sect. 2.2.2, regional populations adjust slowly, via interregional migration, to movements in regional migration income relativities. In our policy simulations, we allow for limited deviations in short-run regional wages away from their baseline values. With short-run regional populations also sticky, we allow short-run labour market pressures to be mainly manifested as short-run deviations in regional employment rates. More explicitly, we allow the path of regional wages in policy simulations to be governed by

$$\left(W_r^{(\text{Policy})}/W_r^{(\text{Baseline})} - 1\right) = \left(W_{(t-1),r}^{(\text{Policy})}/W_{(t-1),r}^{(\text{Baseline})} - 1\right) + \alpha\left(\text{ER}_r^{(\text{Policy})}/\text{ER}_r^{(\text{Baseline})} - 1\right) \qquad \text{(E4)}$$

where

$W_r^{(\text{Baseline})}$ and $W_r^{(\text{Policy})}$ are wage rates in region *r* in the baseline and policy simulations, respectively.
$W_{(t-1),r}^{(\text{Baseline})}$ and $W_{(t-1),r}^{(\text{Policy})}$ are the lagged values for regional wages in the baseline and policy simulations, respectively.
$\text{ER}_r^{(\text{Baseline})}$ and $\text{ER}_r^{(\text{Policy})}$ are regional employment rates (1 – the unemployment rate) in the baseline and policy simulations, respectively.
α is a positive parameter.

With (E4) activated in the policy simulation, the deviation in the regional wage grows (declines) as long as the regional employment rate remains above (below) its baseline level. A value for α is chosen that ensures the regional employment effects of a shock in year t are largely eliminated by year $t+5$. (E4) represents an implementation at the regional level of the national sticky wage adjustment mechanism described in Dixon and Rimmer (2002, p. 205).[14]

2.2.4 A General Theory of Regional Wage Rates and Employment Rates in the Short Run and the Long Run

Layard et al. (2005) outline a general theory for the determination of regional real wage rates and employment rates under the limiting cases of the short run (exogenous regional labour forces) and the long run (endogenous regional labour forces). We pause here to compare this general theory to the specific theory outlined in Sects. 2.2.2 and 2.2.3, before proceeding with our amenity experiment in Sect. 3.

Layard et al. begin by describing regional labour demand via a CES production function. In more general functional form, we describe their labour demand function via (E5)

$$W_r = \alpha_r f\left(\mathrm{ER}_r \cdot \mathrm{SL}_r\right) X \qquad (f' < 0) \tag{E5}$$

where W_r is the real wage, α_r is a measure of the productivity of labour in region r, ER_r is the regional employment rate, SL_r is the share of the national labour force in region r and X is an indicator of economy-wide labour productivity.

The regional wage process is described by (E6), a function they note that is consistent with theory describing bargaining outcomes, efficiency wages and/or a standard labour supply response.

$$W_r = \gamma_r f^{(2)}\left(\mathrm{ER}_r\right) X \qquad (f^{(2)\prime} > 0) \tag{E6}$$

where γ_r is a wage push indicator.

(E5) and (E6) are consistent with the theory of our CGE model. (E5) describes, in general functional form, the regional labour demand equations implicit in the standard implementation of VURM.[15] (E6) is consistent with (E4), with both describing a positive relationship between the regional wage rate and the regional employment rate.

[14](E4) follows the basic structure of the wage adjustment equation described by equation (24.2) in Dixon and Rimmer (2002: p. 205). The difference is that in (24.2), the national wage deviation rises (falls) so long as national employment in the policy case is above (below) its baseline level. In (E4), the regional wage deviation rises (falls) so long as the regional employment rate is above (below) its baseline level.

[15]In VURM, individual industries within each region are assumed to substitute between labour, capital and land in a cost-minimising fashion subject to a CES technology. Aggregating to the regional level, the resulting industry-specific cost-minimising labour demand equations generate region-wide labour demand functions that are consistent with (E5).

In the short run, Layard et al. assume that the distribution of the national labour force across regions is given. In terms of (E5) and (E6), SL_r is exogenous. Solving (E5) and (E6) for short-run values for ER_r and W_r, Layard et al. obtain

$$\mathrm{ER}_r = \underset{}{g^{(1)}} \left(\underset{-}{\gamma_r}, \underset{+}{\alpha_r}, \underset{-}{\mathrm{SL}_r}\right) \tag{E7}$$

$$W_r = g^{(2)} \left(\underset{+}{\alpha_r}, \underset{+}{\gamma_r}, \underset{-}{\mathrm{SL}_r}, \underset{+}{X}\right) \tag{E8}$$

Together, (E7) and (E8) imply that a short-run fall in region r's labour force (i.e. a fall in SL_r) will be associated with a rise in the regional employment rate and in the regional wage rate. As we shall find in Sect. 4, this is consistent with the short-run regional labour market dynamics exhibited by our CGE model with (E1)–(E4) operational.

In the long run, Layard et al. note that the process of interregional migration renders regional labour forces endogenous. They begin by describing region r's net in-migration rate (NMR_r):

$$\mathrm{NMR}_r = h\left(\frac{W_r \cdot \mathrm{ER}_r}{X\,(1 + c_r)}\right) \qquad \left(h' > 0\right) \tag{E9}$$

where c_r reflects, among other things, differences in regional amenity. (E9) is an effective summary of the joint operation of Eqs. (E1)–(E3).

Layard et al. assume that in equilibrium, NMR_r is zero. Solving (E9) for the expected regional real wage ($W_r \cdot \mathrm{ER}_r$) under the long-run assumption of $\mathrm{NMR}_r = 0$ gives

$$W_r \cdot \mathrm{ER}_r = j\,(X\,(1 + c_r)) \qquad \left(j' > 0\right) \tag{E10}$$

To solve for the long-run values for the regional real wage and the regional employment rate, Layard et al. combine (E6) and (E10), providing

$$W_r = k^{(1)} \left(\underset{(+)}{\gamma_r}, \underset{(+)}{X}, \underset{(+)}{c_r}\right) \tag{E11}$$

$$\mathrm{ER}_r = k^{(2)} \left(\underset{(-)}{\gamma_r / (1 + c_r)}\right) \tag{E12}$$

Via (E11) and (E12), Layard et al. conclude that relative unemployment rates and relative wage rates depend on long-run supply-side structural factors only. As we shall find in Sect. 4, the long-run behaviour of the regional labour market and migration theory described by (E1)–(E4) conforms with this conclusion.

3 Simulation and Interpretation of Multiregional Model Mechanisms

We use the VURM described in Sect. 2 to investigate the regional economic consequences of a change in the relative amenity value of one region, East. An important purpose of the section is to explain our results in a way that can be readily understood by readers unfamiliar with a CGE model. To do this, we explain our results in terms of a miniature model, BOTE, which is a stylised back-of-the-envelope representation of the regional macroeconomy as modelled in VURM. While BOTE is small and aggregated, it is sufficient to explain the major regional macroeconomic outcomes of the full-scale VURM. BOTE concentrates on the nature and direction of regional macroeconomic causation in the short run and long run.

3.1 A Stylised Back-of-the-Envelope Representation of Regional Macroeconomic Relationships

3.1.1 Equations of the BOTE Model

Equations B1–B22 (Table 1) describe a stylised representation of the key regional macroeconomic relationships relevant to the simulation we discuss in Sect. 4. We refer to these equations as the BOTE (back-of-the-envelope) model.[16]

(B1)–(B19) describe variables *within* any given year of a dynamic simulation. (B20) and (B21) describe how key regional stock variables, capital and population move through time. These equations hold *between* any two adjoining years of a dynamic simulation. (B22) describes the lagged adjustment of real regional wages in the policy simulation. This equation is relevant to the process of regional wage adjustment in policy simulations only. We describe these equations in turn.

Equation (B1) is gross regional expenditure (GRE) in constant price terms:

$$\mathrm{GRE}_r = C_r + I_r + G_r^{(S)} + G_r^{(F)} \tag{B1}$$

where C_r is real regional private consumption spending, I_r is real regional gross fixed capital formation, $G_r^{(S)}$ is real state government consumption spending in region r and $G_r^{(F)}$ is real federal government consumption spending in region r.

[16]In developing the BOTE model, we extend to the regional level distinctions used in the national macro BOTE model outlined in Giesecke and Schilling (2010) between equations that describe variables within any given year of a dynamic simulation, equations that hold between adjoining years of a dynamic simulation, equations describing adjustment of variables in the policy simulation and effective short-run and long-run closures.

Table 1 BOTE: a back-of-the-envelope representation of the main macroeconomic relationships of a MRCGE model (Bold denotes exogenous variables)

	'Effective' short-run closure	'Effective' long-run closure
Equations holding within any given year of the year-on-year baseline and policy simulations		
(B1)	$\text{GRE}_r = C_r + I_r + G_r^{(S)} + G_r^{(F)}$	$\text{GRE}_r = C_r + I_r + G_r^{(S)} + G_r^{(F)}$
(B2)	$Y_r = \text{GRE}_r + \left(X_r^{(*)} - M_r^{(*)}\right) + \left(X_r^{(R)} - M_r^{(R)}\right)$	$Y_r = \text{GRE}_r + \left(X_r^{(*)} - M_r^{(*)}\right) + \left(X_r^{(R)} - M_r^{(R)}\right)$
(B3)	$Y_r = [1/\mathbf{A_r}]f(L_r, \mathbf{K_r})$	$Y_r = [1/\mathbf{A_r}]f(L_r, K_r)$
(B4)	$\mathbf{K_r}/L_r = g(\mathbf{W_r}/R_r)$	$K_r/L_r = g(W_r/R_r)$
(B5)	$L_r = \mathbf{Q_r} \cdot \mathbf{PR_r} \cdot \text{ER}_r$	$L_r = Q_r \cdot \mathbf{PR_r} \cdot \mathbf{ER_r}$
(B6)	$\text{ROR}_r = R_r/P_r$	$\mathbf{ROR_r} = R_r/P_r$
(B7)	$I_r = u(\text{ROR}_r/\mathbf{\Lambda_r})$	$I_r = u(\mathbf{ROR_r}/\Lambda_r)$
(B8)	$I_r/\mathbf{K_r} = \Psi_r$	$I_r/K_r = \mathbf{\Psi_r}$
(B9)	$\text{NIM}_r = b\left(\{\mathbf{W_r}/P_r\} \cdot \text{ER}_r/\mathbf{F_r^{(SR)}}\right)$	$\text{NIM}_r = b\left(\{W_r/P_r\} \cdot \mathbf{ER_r}/F_r^{(SR)}\right)$
(B10)	$\text{NIM}_r/\mathbf{Q_r} = \Upsilon_r$	$\text{NIM}_r/Q_r = \mathbf{\Upsilon_r}$
(B11)	$\{\mathbf{W_r}/P_r\}/\{\mathbf{W}/\mathbf{P}\} = F_r^{(LR)}$	$\{W_r/P_r\}/\{\mathbf{W}/\mathbf{P}\} = \mathbf{F_r^{(LR)}}$
(B12)	$P_r = \mathbf{A_r}\, u(\mathbf{W_r},\ R_r)$	$P_r = \mathbf{A_r}\, u(W_r,\ R_r)$
(B13)	$C_r = \mathbf{APC_r} \cdot Y_r$	$C_r = \mathbf{APC_r} \cdot Y_r$
(B14)	$G_r^{(S)}/C_r = \mathbf{\Gamma_r^{(S)}}$	$G_r^{(S)}/C_r = \mathbf{\Gamma_r^{(S)}}$
(B15)	$G_r^{(F)}/\mathbf{Q_r} = \mathbf{\Gamma_r^{(F)}}$	$G_r^{(F)}/Q_r = \mathbf{\Gamma_r^{(F)}}$
(B16)	$X_r^{(*)} = b(P_r/\mathbf{V_r})$	$X_r^{(*)} = b(P_r/\mathbf{V_r})$
(B17)	$M_r^{(*)} = h(P_r/\mathbf{P},\ Y_r)$	$M_r^{(*)} = h(P_r/\mathbf{P},\ Y_r)$
(B18)	$M_r = d(P_r/\mathbf{P},\ Y_r)$	$M_r = d(P_r/\mathbf{P},\ Y_r)$
(B19)	$X_r = s(P_r/\mathbf{P})$	$X_r = s(P_r/\mathbf{P})$
Equations holding between any two adjacent years of the year-on-year baseline and policy simulations		
(B20)	$\Delta K_r = I_r$	$\Delta K_r = I_r$
(B21)	$\Delta Q_r = \text{NIM}_r$	$\Delta Q_r = \text{NIM}_r$
Lagged wage adjustment in the policy simulations		
(B22)	$\left(W_{(t),r}^{(\text{Policy})}/\mathbf{W_{(t),r}^{(Baseline)}} - 1\right) = \left(\mathbf{W_{(t-1),r}^{(Policy)}}/\mathbf{W_{(t-1),r}^{(Baseline)}} - 1\right) + \alpha\left(\text{ER}_{(t),r}^{(\text{Policy})}/\mathbf{ER_{(t),r}^{(Baseline)}} - 1\right)$	

Variables of the BOTE model

Variables in equations holding within any given year of the baseline and policy simulations (Eqs. B1–B19)

		Short-run	Long-run
GRE_r	Real gross regional expenditure	N	N
C_r	Real regional private consumption spending	N	N
I_r	Real regional gross fixed capital formation	N	N
$G_r^{(S)}$	Real state government consumption spending	N	N
$G_r^{(F)}$	Real federal government consumption spending	N	N
Y_r	Real gross regional product	N	N

(continued)

Table 1 (continued)

Variables of the BOTE model			
		Short-run	Long-run
$X_r^{(*)}$	Foreign export volumes	N	N
$M_r^{(*)}$	Foreign import volumes	N	N
$X_r^{(R)}$	Interregional exports	N	N
$M_r^{(R)}$	Interregional imports	N	N
A_r	Primary factor augmenting technical change	X	X
L_r	Employment	N	N
K_r	Capital stock	X	N
W_r	Average regional wage	X	N
R_r	Average rental rate on capital	N	N
P_r	Regional GDP at factor cost deflator	N	N
Q_r	Regional population	X	N
PR_r	Regional participation rate	X	X
ER_r	Regional employment rate	N	X
ROR_r	Average rate of return on capital	N	X
Λ_r	Shift in investment/rate of return schedule	X	N
Ψ_r	Investment/capital ratio	N	X
NIM_r	Net interregional migration to r	N	N
$F_r^{(\mathrm{SR})}$	Shift in migration/wage schedule	X	N
Υ_r	Net interregional immigration rate	N	X
$F_r^{(\mathrm{LR})}$	Regional wage/national wage ratio	N	X
W	National wage	X	X
P	National price level	X	X
APC_r	Average propensity to consume	X	X
$\Gamma_r^{(S)}$	State government/private consumption ratio	X	X
$\Gamma_r^{(F)}$	Per capita real federal government consumption	X	X
V_r	Shift in export demand schedule	X	X
Variables in equations holding between any 2 years of the year-on-year baseline and policy simulations (Eqs. B20–B21)			
		Short-run	Long-run
ΔK_r	Change in $\mathrm{K_r}$ between years t and $t+1$	N	N
ΔQ_r	Change in $\mathrm{Q_r}$ between years t and $t+1$	N	N
Variables of the lagged wage adjustment equation (Eq. B22)			
$W_{(t)\ r}^{(\mathrm{Policy})}$	Wage at time t in the policy simulation	N	N
$W_{(t-1)\ r}^{(\mathrm{Policy})}$	Lagged value of the wage in the policy simulation	X	X
$W_{(t)\ r}^{(\mathrm{Baseline})}$	Wage at time t in the baseline simulation	X	X
$W_{(t-1)\ r}^{(\mathrm{Baseline})}$	Lagged value of the wage in the baseline simulation	X	X
$\mathrm{ER}_{(t)\ r}^{(\mathrm{Policy})}$	Employment rate at time t in the policy simulation	N	N
$\mathrm{ER}_{(t)\ r}^{(\mathrm{Baseline})}$	Employment rate at time t in the baseline simulation	X	X

Equation (B2) is the regional gross domestic product identity in constant price terms:

$$Y_r = \mathrm{GRE}_r + \left(X_r^{(*)} - M_r^{(*)}\right) + \left(X_r^{(R)} - M_r^{(R)}\right) \tag{B2}$$

where $X_r^{(*)}$ and $M_r^{(*)}$ represent region r's foreign export and import volumes, respectively, and $X_r^{(R)}$ and $M_r^{(R)}$ represent region r's interregional export and import volumes, respectively.

Equation (B3) relates regional output to inputs of primary factors and technology via a constant-returns-to-scale production function:

$$Y_r = [1/A_r]f(L_r, K_r) \tag{B3}$$

where L_r is regional employment, K_r is the regional capital stock and A_r describes the effectiveness with which regional inputs of primary factors are transformed into output.

Since (B3) is constant returns to scale, under our assumption of cost-minimising behaviour on the part of regional producers, we can relate the regional capital/labour ratio to the regional wage/rental ratio only, via Eq. (B4):

$$K_r/L_r = g(W_r/R_r) \tag{B4}$$

Equation (B5) defines regional employment as the product of the regional population (Q_r), the regional participation rate (PR_r)[17] and the regional employment rate (ER_r):

$$L_r = Q_r \cdot \mathrm{PR}_r \cdot \mathrm{ER}_r \tag{B5}$$

Equation (B6) provides a stylised representation of rates of return by regional industry, and (B7) relates regional industry investment to rates of return:

$$\mathrm{ROR}_r = R_r/P_r \tag{B6}$$

$$I_r = u(\mathrm{ROR}_r/\Lambda_r) \tag{B7}$$

where ROR_r is the average rate of return on capital in region r and Λ_r is a shift variable allowing for short-run autonomous movements in regional investment.

Equation (B8) defines the regional gross capital growth rate (Ψ_r) as the ratio of regional real investment (I_r) to the regional capital stock (K_r):

$$I_r/K_r = \Psi_r \tag{B8}$$

[17] More generally, if we define L_r as employment in hours, then PR_r is the product of the regional participation rate, hours worked per worker and the share of the regional population that is of working age.

Section 2.2.2 introduced Eqs. (E1)–(E3), which set out the relationship between expected regional real wages and interregional migration. Equation (B9) is a stylised representation of these equations, describing a positive relationship between net interregional migration to region r (NIM_r) and the expected real wage in region r[18]:

$$\mathrm{NIM}_r = b\left(\{W_r/P_r\} \cdot \mathrm{ER}_r/F_r^{(\mathrm{SR})}\right) \tag{B9}$$

where $F_r^{(\mathrm{SR})}$ is a shift variable allowing autonomous movements in net interregional immigration to region r. (B10) calculates Υ_r, that part of region r's population growth rate that is attributable to net interregional migration:

$$\mathrm{NIM}_r/Q_r = \Upsilon_r \tag{B10}$$

Equation (B11) defines the ratio of the regional real wage to the national real wage:

$$F_r^{(\mathrm{LR})} = \{W_r/P_r\}\,/\,\{W/P\} \tag{B11}$$

Equation (B12) determines the regional price level (P_r) as a function of the efficiency of regional primary factor usage (A_r) and the prices of regional primary factors. More formally, it is the cost-minimising unit cost function that arises from (B3):

$$P_r = A_r\, u\,(W_r,\ R_r) \tag{B12}$$

Equation (B13) describes the regional consumption function. Regional real private consumption (C_r) moves with regional income under a given average propensity to consume (APC_r). In Eq. (B13), real regional income is simplified as real GDP at factor cost[19]:

$$C_r = \mathrm{APC}_r \cdot Y_r \tag{B13}$$

[18]To keep the BOTE model simple, we do not define the CPI. To define the real regional wage in (B9), we deflate by the regional GDP deflator. But note that in (E1)–(E3), for which (B9) serves as a proxy, the real wage appears as the real consumer wage.

[19]Readers familiar with the BOTE approach might be surprised at the absence of a terms of trade term in (B13). For example, (B13) might alternatively be written as $C_r = \mathrm{APC}_r\ \{\mathrm{PGDP}_r/\mathrm{PC}_r\}\mathrm{Y}$, where PGDP_r and PC_r are the regional GDP deflator and consumption price deflator, respectively. The ratio of these terms is a positive function of the terms of trade. By suppressing this ratio in (B13) and other relevant equations of BOTE, we do not wish to imply that terms of trade effects are absent at the regional level. However, regional terms of trade effects are not an important part of the explanations of results we present in Section 4. Hence, to keep BOTE simple, we do not include the terms of trade.

Equations (B14) and (B15) describe the determination of regional and federal government public consumption spending at the regional level. Equation (B14) defines $\Gamma_r^{(S)}$, the ratio of state government consumption to private consumption in region r. Equation (B15) defines $\Gamma_r^{(F)}$, per capita real federal government consumption in region r.

$$G_r^{(S)}/C_r = \Gamma_r^{(S)} \tag{B14}$$

$$G_r^{(F)}/Q_r = \Gamma_r^{(F)} \tag{B15}$$

Equation (B16) relates region r's foreign export volumes ($X_r^{(*)}$) to the price of regional output (P_r) and a vertical (willingness to pay) scalar on the position of region-specific export demand schedules (V_r).

$$X_r^{(*)} = b\,(P_r/V_r) \tag{B16}$$

In VURM, the Armington (CES) assumption is used to model imperfect substitution possibilities across alternative sources of commodity supply to each region. In general functional form, this gives rise to Eqs. (B17)–(B19). (B17) and (B18) relate region r's foreign and domestic import volumes, respectively, to regional activity (represented here by Y_r) and the relative price of goods produced in region r. Similarly, (B19) relates region r's interregional exports to the rest of the country to the relative price of region r's output.

$$M_r^{(*)} = h\,(P_r/P,\ Y_r) \tag{B17}$$

$$M_r = d\,(P_r/P,\ Y_r) \tag{B18}$$

$$X_r = s\,(P_r/P) \tag{B19}$$

(B20) and (B21) relate movements in key regional stock variables to relevant flow variables. (B20) relates changes in the regional capital stock to regional investment. (B21) relates change in regional population to net interregional migration.

$$\Delta K_r = I_r \tag{B20}$$

$$\Delta Q_r = \mathrm{NIM}_r \tag{B21}$$

Equation B22 governs the path of real regional wages in the policy simulation. With (B22) activated in the policy simulation, the deviation in the real regional wage grows (declines) as long as the regional employment rate remains above (below) its baseline forecast level.

$$\left(W_{(t),r}^{(\text{Policy})}/W_{(t),r}^{(\text{Baseline})}-1\right)=\left(W_{(t-1),r}^{(\text{Policy})}/W_{(t-1),r}^{(\text{Baseline})}-1\right)+\alpha\left(\text{ER}_{(t),r}^{(\text{Policy})}/\text{ER}_{(t),r}^{(\text{Baseline})}-1\right)\quad\text{(B22)}$$

3.1.2 Short-Run Closure and Operation of the BOTE Model

We now discuss appropriate closures for Eqs. (B1)–(B22). In doing so, we distinguish between equations that describe economic relationships within any given year (B1–B19), equations that describe movements in stock variables between years (B20–B21) and the equation describing sticky wage adjustment (B22). Within any given year of a year-on-year dynamic simulation, K_r and Q_r can be considered exogenous. The movement in these variables *between* years depends on investment and immigration *within* years. These accumulation relationships are described by (B20)–(B21). (B22) governs the transition of the policy-case labour market closure from a short-run to a long-run environment. When operational in the policy simulation, (B22) gradually moves the regional labour market from a short-run situation of exogenous real wage/endogenous employment rate to a long-run situation of exogenous employment rate/endogenous real wage. Recognising that (B20) and (B21) govern dynamics across years, our task of understanding model closure narrows to choosing appropriate short-run and long-run closures for Eqs. (B1)–(B19).

In Table 1, model closure is described by rendering exogenous variables in bold. Two closures are presented: a short-run closure and an 'effective' long-run closure. By 'effective' long-run closure, we mean that while ROR_r, Ψ_r, ER_r, Υ_r and $F_r^{(\text{LR})}$ are presented as long-run exogenous, no such exogeneity is actually imposed on these variables in the VURM simulations reported in Sect. 4. Rather, in year-on-year dynamic simulations, (B7) and (B20), (B9) and (B21) and (B22) lead the economy to a long-run position that can be satisfactorily described by exogenous status of ROR_r, Ψ_r, Υ_r, $F_r^{(\text{LR})}$ and ER_r.

(B1)–(B19) comprise 19 equations in 32 variables, requiring 13 variables be determined exogenously. A conventional short-run closure of (B1)–(B19) would have L_r, Y_r, GRE_r, C_r, I_r, $G_r^{(S)}$, $G_r^{(F)}$, $X_r^{(*)}$, $M_r^{(*)}$, $X_r^{(R)}$, $M_r^{(R)}$, R_r, P_r, ER_r, ROR_r, Ψ_r, NIM_r, Υ_r, and $F_r^{(\text{LR})}$ determined endogenously, given exogenous values for A_r, K_r, W_r, Q_r, PR_r, Λ_r, $F_r^{(\text{SR})}$, W, P, APC_r, $\Gamma_r^{(S)}$, $\Gamma_r^{(F)}$ and V_r. Under this closure, each equation can be associated with the determination of a specific endogenous variable, allowing us to trace lines of short-run regional macroeconomic causation that will prove helpful in understanding the multiregional CGE results we discuss in Sect. 4.

We begin by considering the regional price level, P_r, and the regional trade Eqs. (B16)–(B19). With elastic foreign demand schedules, exogenous import prices and flexible sourcing substitution possibilities via our settings for interregional and international Armington elasticities, we begin by noting that via Eqs. (B16)–(B19), scope for significant short-run movements in P_r is constrained. We conjecture that a natural way to enter the system of simultaneous equations described by (B1)–(B19) is to begin with the idea that P_r is largely given.

We assume that short-run regional wages are sticky. In BOTE, this is described by the exogenous status of W_r. With short-run movements in P_r constrained by the high price elasticity of demand of the regional traded goods sector, and with both primary factor productivity (A_r) and labour productivity (A_r^L) exogenous, we can identify (B12) with the short-run determination of capital rental rates (R_r).

With R_r determined by (B12), and with K_r, A_r and W_r exogenous, (B4) can be identified with the short-run determination of L_r. With K_r and A_r exogenous, and L_r known from (B4), Y_r is thus determined via (B3).

With Y_r determined, Eq. (B13) determines C_r. With $\Gamma_r^{(S)}$ exogenous, this allows $G_r^{(S)}$ to be determined via (B14). Note that with the short-run regional population (Q_r) exogenous, the exogenous status of $\Gamma_r^{(F)}$ determines $G_r^{(F)}$ via (B15).

Together, (B13)–(B15) determine the regional consumption component of gross regional expenditure (GRE_r). Via (B1), we see that the remaining element of GRE_r is regional investment (I_r). I_r is determined by (B7) as a positive function of rates of return (ROR_r). In turn, ROR_r is determined by (B6), given that R_r is largely determined by (B12). With short-run movements in I_r determined by (B7), (B8) calculates short-run movements in the gross capital growth rate (Ψ_r).

With both regional investment and regional private and public consumption determined, Eq. (B1) determines GRE_r. With Y_r determined by (B3), Eq. (B2) must determine the regional balance of trade: $\left(X_r^{(*)} - M_r^{(*)}\right) + \left(X_r^{(R)} - M_r^{(R)}\right)$. The variable that adjusts to accommodate the required balance of trade movement is the regional price level, P_r. Note that the individual components of the regional balance of trade, $X_r^{(*)}$, $M_r^{(*)}$, $X_r^{(R)}$ and $M_r^{(R)}$, are determined by (B16)–(B19). In each of the Eqs. (B16)–(B19), an important element is the relative regional price level, P_r/P. As argued earlier, $X_r^{(*)}$, $M_r^{(*)}$, $X_r^{(R)}$ and $M_r^{(R)}$ are elastic to movements in P_r/P. We view (B2) as determining the small movements in P_r necessary to generate outcomes for $X_r^{(*)}$, $M_r^{(*)}$, $X_r^{(R)}$ and $M_r^{(R)}$ via (B17)–(B19) that is compatible with the regional balance of trade deficit implicit in the difference between regional output determined by (B3) and regional expenditure determined by (B1).

With L_r determined by (B4), the regional population (Q_r) sticky in the short run and regional participation rates (PR_r) exogenous, Eq. (B5) determines short-run movements in the regional employment rate (ER_r). Via Eq. (B9), this determines short-run movements in the net interregional migration rate (NIM_r), for given values of W_r and $F_r^{(\text{SR})}$. With NIM_r determined by (B9), (B10) determines short-run movements in region r's net interregional migration rate (Υ_r).

3.1.3 Long-Run Closure and Operation of the BOTE Model

Column (2) of Table 1 presents the long-run closure of BOTE. Our description of the model's long-run closure differs in three respects from the short-run closure described above.

First, (B22) ensures that the policy-case level of the regional employment rate (ER_r) is eventually returned to its baseline level via regional wage adjustment. In BOTE, this is represented by long-run exogeneity of ER_r and endogeneity of W_r.

Second, the short-run operations of (B7) and (B20) gradually drive rates of return towards baseline via capital adjustment. In (B7), Λ_r can be interpreted as a normal rate of return. Hence, via (B7), regional investment will be above (below) baseline so long as current rates of return (ROR_r) are above (below) normal rates of return. The annual capital accumulation process is described by (B20). Capital accumulation (depreciation) gradually drives convergence of actual and normal rates of return. In column (2) of Table 1, we describe the long-run outcome of this process as effective exogeneity of ROR_r and endogeneity of K_r.

Third, long-run changes in equilibrium regional capital stocks require long-run adjustments to the level of real regional investment in order to maintain the new level of capital. We describe this via the long-run exogenous status of Ψ_r in (B8). With (B8) determining long-run real investment, we describe (B7) as inactive in the long run via the endogenous status of Λ_r.

Fourth, the short-run operations of (B9) and (B21) generate movements in population that return expected interregional real wage relativities to some independently given level. In BOTE, we represent this by the long-run endogenous status of Q_r and exogenous status of $F_r^{(LR)}$. Once long-run regional populations have adjusted to maintain independently determined interregional expected real wage relativities, interregional migration rates return to independently established values. In BOTE, this is represented by the exogenous status of Υ_r. With the long-run annual value of NIM_r determined by (B10), we describe (B9) as inactive in the long run via the endogenous status of $F_r^{(SR)}$.

We now describe the path of long-run macroeconomic causation implicit in the closure described by column (2) of Table 1. This will prove helpful in interpreting the economic mechanisms responsible for the long-run simulation results discussed in Sect. 4. We begin by noting that our long-run assumption of flexible regional capital and labour supply at given rates of return and interregional wage relativities effectively determines the long-run regional price level. This is clear from column 2 of Table 1 if we start by noting that with $F_r^{(LR)}$ exogenous, the long-run regional wage (W_r) is determined by (B11). With long-run rates of return (ROR_r) exogenous, the regional capital rental rate (R_r) is determined by (B6) for given movements in the regional price level (P_r). However, via (B12), for given levels of regional primary factor productivity (A_r), we see that movements in the long-run regional price level follow movements in regional wages (W_r) and capital rental prices (R_r). But, as already noted, long-run values for W_r and R_r are determined via the exogenous status of ROR_r and $F_r^{(LR)}$. Together, (B6), (B11) and (B12) remind us that in the long run, movements in a given region's factor prices, and with them, movements in a given region's price level, are all largely insulated from changes in regional economic conditions, barring movements in regional productivity.

With long-run movements in P_r determined by regional productivity and by long-run settings for regional factor markets, we now turn to explaining the long-run determination of the price-sensitive elements of regional GDP.

Equations (B16)–(B19) describe region-specific foreign and interregional export and import volumes. All depend on, inter alia, the relative price of the region's output. If the regional price level were to fall, for example, then demand for the output of the region's traded good sector would rise. Via (B16)–(B19), this will be expressed as a fall in foreign and interregional import volumes ($M_r^{(*)}$ and $M_r^{(R)}$, respectively) and a rise in foreign and interregional export volumes ($X_r^{(*)}$ and $X_r^{(R)}$, respectively). Via (B2), this will cause regional activity (Y_r) to rise. Via (B3), the rise in Y_r requires inputs of K_r and L_r to rise. The relative proportionality of increase in K_r and L_r is governed by (B4). As discussed earlier, ceteris paribus, there is little long-run scope for endogenous movement in the regional wage/rental ratio. Hence, via (B4), we might expect that K_r and L_r will rise in proportion with the increase in Y_r.

With L_r determined by (B3) and (B4), and with the regional participation rate (PR_r) and employment rate (ER_r) exogenous in the long run, the long-run regional population (Q_r) is determined by (B5). With the annual rate of net migration to region r (Υ_r) exogenous in the long run, and with Q_r known, so too is the long-run annual net migration to region r (NIM_r) via (B10).

With K_r determined by (B3) and (B4), regional investment (I_r) is determined by (B8). With Y_r determined by (B2), real private consumption spending (C_r) is determined by (B13). With C_r determined, the long-run movement in regional public consumption spending ($G_r^{(S)}$) is determined via (B14). With Q_r determined by (B5), regional federal public consumption spending ($G_r^{(F)}$) is determined by (B15). With I_r, C_r, $G_r^{(S)}$ and $G_r^{(F)}$ thus determined, gross regional expenditure (GRE_r) is determined by (B1). Note that via the above streams of macroeconomic causation, we might generally expect that the individual components of GRE_r, and with them, GRE_r itself, to move broadly in line with movements in Y_r.

4 Modelling a Fall in Regional Amenity

In terms of Eq. (E2), we model changes in regional amenity via movements in $F_r^{(M)}$. For example, a fall in region d's regional amenity, through, say, heightened perceptions of urban congestion and pollution, requires a compensating increase in region d's migration income relativity. Via (E2), this is implemented through an increase in the value of $F_d^{(M)}$. In the simulation below, we investigate the effects of a 1 % increase in the value of $F_{\mathrm{East}}^{(M)}$ in the year 2016.[20]

To understand the impact of a movement in $F_d^{(M)}$, we begin with BOTE. As discussed in Sect. 3.1.2, we assume that short-run regional real wages are sticky. In our short-run description of BOTE, this is represented by the exogenous status of W_r

[20]Like McGregor et al. (1996), we treat the change in amenity as being entirely exogenous. That is, we do not model the effects of the source of the amenity deterioration, such as reductions in government spending on infrastructure investment or urban renewal.

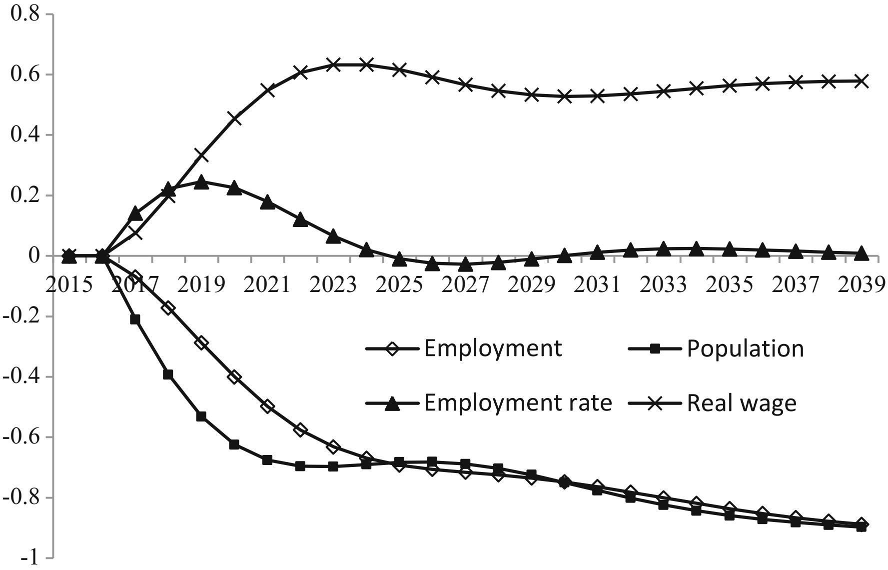

Chart 1 Population, employment, real wage and employment rate for the East region (percentage deviation from base case)

(column 1, Table 1). As discussed in Sect. 3.1.2, describing W_r as exogenous in the short run is a shorthand way of describing the operation of Eq. (B22). (B22) relates the deviation in the regional wage rate to the lagged deviation in the regional wage and the deviation in the regional employment rate. Since none of the right-hand-side variables in (B22) respond immediately to East's regional amenity deterioration, the regional wage does not deviate from its baseline value in the first year of the simulation (Chart 1). Hence, via (B4), year 2016 regional employment is not affected by the movement in $F_{\text{East}}^{(M)}$ (Chart 1). Via (B5), there is thus no immediate (year 2016) impact on the regional employment rate (Chart 1).

The immediate (short-run) effect of an increase in $F_{\text{East}}^{(M)}$ is to decrease $Y_{o,\text{East}}^{(\text{Diseq})}$ via Eq. (E2). Via (E3), this simultaneously raises the gross emigration rate from East to South and North and lowers the gross emigration rate from South and North to East. This causes East's net immigration to fall and North and South net immigration to rise (Chart 2). In BOTE, the joint operation of (E1)–(E3) is represented in a stylised way by (B9). (B9) describes a positive relationship between region r's net immigration numbers (NIM_r) and region r's migration income measure ($\{W_r/P_r\} \cdot \text{ER}_r$) divided by the short-run BOTE representation of the amenity shift variable $F_r^{(\text{SR})}$. In (B9), a rise in $F_r^{(\text{SR})}$ lowers the value of NIM_r for any given value of $\{W_r/P_r\} \cdot \text{ER}_r$. This is consistent with the short-run effect of a rise in $F_{\text{East}}^{(M)}$ in VURM Eqs. E1–E3.

Via the population accumulation Eq. (B21), the deviations in net regional immigration reported in Chart 2 translate through time into deviations in regional

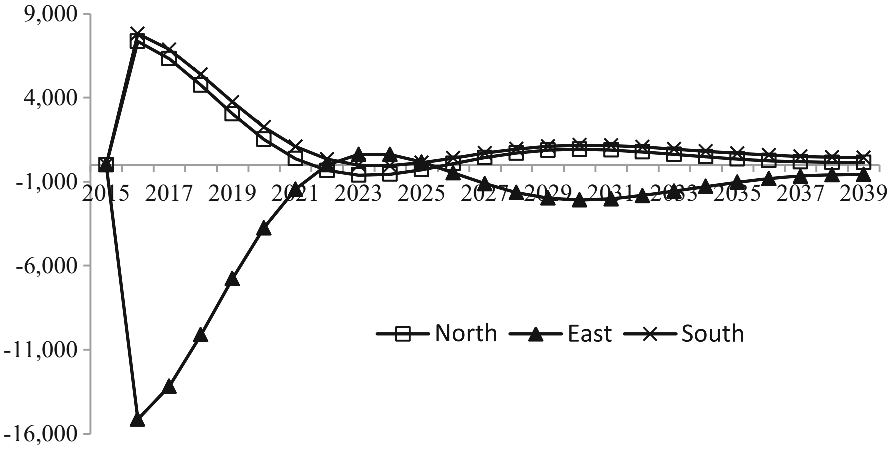

Chart 2 Net (planned) regional immigration by region (change from baseline)

population (Chart 1). In East, the population falls 0.21 % below baseline in 2017. However, short-run movement in East's wage is constrained by (B22). Via (B4), this limits scope for movement in East's employment. Hence, the East employment deviation in 2017, at −0.07 %, is less than the East population deviation (Chart 1). Via (B5), this requires East's employment rate to rise (Chart 1). The 2017 positive deviation in East's employment rate immediately begins placing upward pressure on the real consumer wage via (B22) (Chart 1). However, consistent with our assumption of regional wage stickiness, (B22) ensures that this pressure is not sufficient to immediately return East's employment rate to its baseline value (Chart 1).

East's capital stock adjusts gradually to the shock. In the short-run representation of BOTE, gradual short-run capital adjustment is described by exogenous determination of K_r. With short-run capital stocks adjusting slowly, as East's population declines, and with it, East's employment (Chart 1), East's short-run labour/capital ratio must fall (Chart 3). Via (B4), this causes a negative deviation in East's capital rental rate (Chart 3), which, via (B6), causes a negative deviation in East's rate of return on capital. In Chart 3, we report deviations in both East's average capital rental price and East's investment price deflator. The short-run negative deviation in East's rate of return is manifested in Chart 3 as a large negative gap between East's average capital rental price and East's investment price deflator. Via (B7), the negative deviation in East's rate of return causes a negative deviation in East's investment (Chart 3). Via (B20), this generates a growing negative deviation in East's capital stock (Chart 3).

The situation just described for East is reversed for the nation's other regions. For example, via Chart 2, we see that the short-run net immigration deviation for North is positive. Via BOTE Eq. (B21), this generates a growing positive deviation in North's population (Chart 4). Via BOTE Eq. (B22), North's wages adjust with

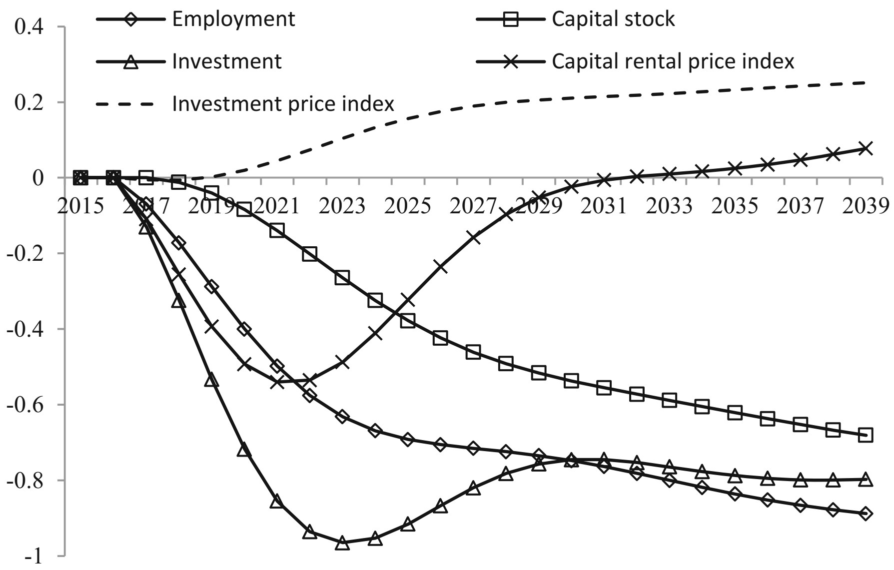

Chart 3 Rates of return, investment and the capital stock for the East region (percentage deviation from base case)

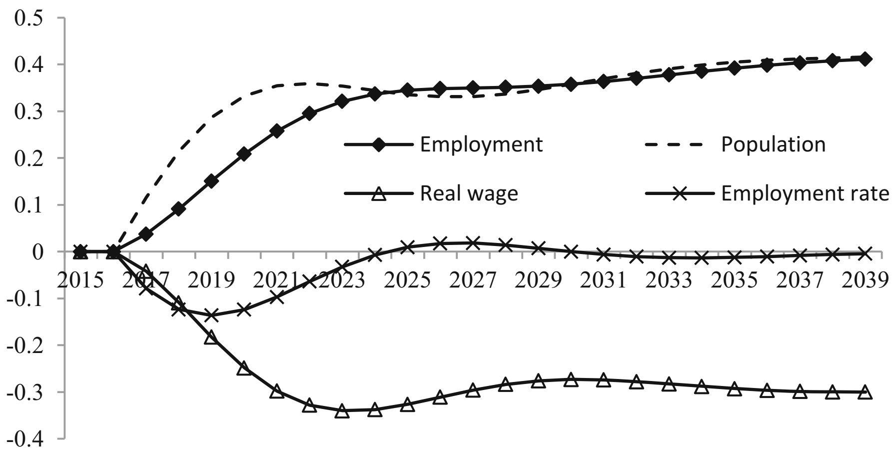

Chart 4 Population, employment and the real wage in North (percentage deviation from base case)

a lag to the regional labour market pressures generated by the positive population deviation. This constrains the short-run movement in North's employment via (B4). Via (B5), this ensures that as North's population deviation gradually increases over the short run, the short-run deviation in North's regional employment rate is initially negative (Chart 4). This accounts for the short-run gap between the regional population and employment deviations in Chart 4. Over the medium run, North's regional wage deviation decreases, allowing the regional economy to absorb the rising labour force through higher employment and gradually driving convergence of the regional employment rate to its baseline level (Chart 4).

To understand the long-run implications of the amenity shock, we begin by considering Eqs. B9–B11 in the long-run representation of BOTE (column 2, Table 1). In the long run, VURM Eqs. E1–E3 operate to ensure that regional populations (and with them, regional labour forces) eventually adjust to ensure that regional real wage relativities are little changed from independently determined levels and that net immigration rates eventually return to levels that are little different from their long-run trend values. In BOTE, we begin the description of this long-run equilibrium by deactivating (B9), the short- to medium-run equation that gradually achieves long-run equilibrium in interregional migration. In BOTE, deactivation of (B9) is described by the endogenous determination of $F_r^{(SR)}$. In the long run, we assume that the short- to medium-run immigration process described by (B9) in column 1 has returned real wage relativities to exogenously determined values. In the long-run representation of BOTE, this is described by exogenous determination of $F_r^{(LR)}$ in (B11). Our long-run representation of the amenity shock in BOTE is a one percent increase in the value of $F_r^{(LR)}$. In our VURM results, we see this as a long-run increase in the ratio of East's wage to wages in other regions (Chart 5).

The short- to medium-run operations of Eqs. B7 and B20 gradually drive regional rates of return back towards their baseline values via regional capital adjustment. As discussed in Sect. 3.1.3, the end point of this process can be represented by long-run exogeneity of regional rates of return and endogeneity of regional capital stocks. In the long-run representation of Eqs. B6 and B11, regional factor prices are effectively determined exogenously.[21] Hence, via (B12), so too are relative regional output prices. Via Eqs. B16–B19, relative regional output prices are the chief determinant of region-specific net exports. This ties down the long-run size of the regional macroeconomy via (B2). That outcomes for long-run regional macro outcomes following supply-side shocks hinge largely on movements in relative regional cost conditions has been noted previously (Giesecke et al. 2008; Giesecke and Madden 2010). The long-run representation of BOTE makes clear the connection between user-specified assumptions about regional factor prices and the long-run size of the regional economy.

Chart 6 reports deviations in real GDP and GDP deflators for the three regional economies. The relationship between deviations in GDP deflators and deviations in real GDP predicted by BOTE are borne out in the VURM results. Consistent with

[21] This is a useful approximation of the long-run condition holding in many regional CGE models. Of course, it is only an approximation. For example, in (B6), the denominator in the rate of return equation is the regional GDP deflator at factor cost. However, in a true regional CGE model, rates of return are calculated with reference to the regional cost of capital. Movements in regional capital costs can diverge from movements in average regional prices due to taxes or sectoral differences in productivity change.

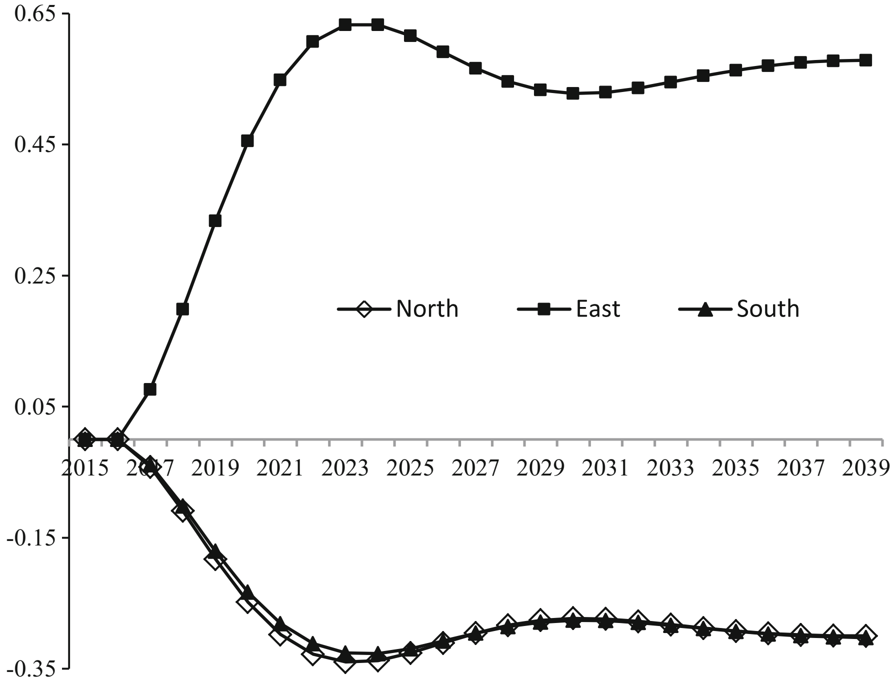

Chart 5 Wage rates by region (percentage deviation from baseline)

our positive shock to the relative East wage rate, in Chart 6 we find the East GDP deflator rising relative to our other two regions. By increasing the relative cost of goods sourced from East, this causes a negative deviation in East's real GDP. A corollary of the rise in the relative East wage rate is a fall in the relative South and North wage rates (Chart 5). This accounts for the relative declines in the South and North GDP deflators (Chart 6). By reducing the relative cost of goods sourced from South and North, this causes positive deviations in the real GDP of these regions. Note that the ranking of the real GDP deviations corresponds with the ranking of the deflator deviations. The negative deviation in South's GDP deflator lies below that for North (Chart 6).[22] The slight relative cost advantage this affords the South economy causes its real GDP deviation to lie slightly above that of North (Chart 6).

Via (B12), we can see that to explain the long-run movements in GDP deflators reported in Chart 6, we must explain long-run regional movements in wage rates and rental rates. Movements in long-run regional wage rates (Chart 5) were explained

[22]The movement of labour out of East reduces wages in North and South by the same amount (Chart 5). However, South is more labour intensive than North. Hence, the negative deviation in wages generates a larger negative deviation in South's GDP deflator relative to North's GDP deflator.

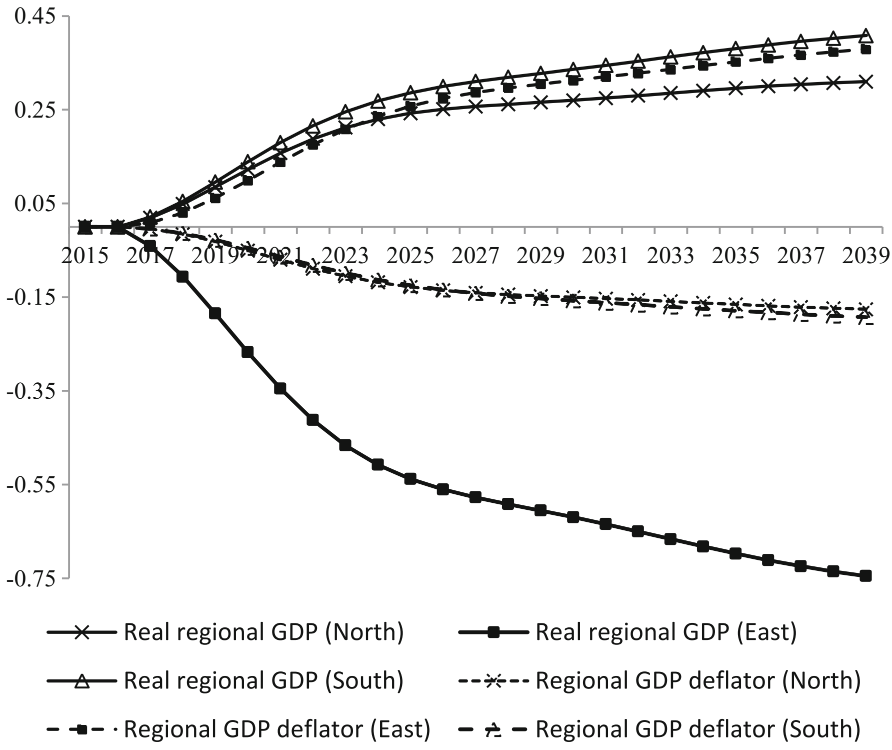

Chart 6 Real GDP and GDP deflators, by region (percentage deviation from baseline)

above by direct reference to our shock. To explain long-run movements in rental rates, we refer to our short-run investment and capital accumulation Eqs. B7 and B20 and our long-run rate of return Eq. (B6). Chart 7 reports VURM results for regional rental prices and investment price deflators. In the short run, Chart 7 reveals divergent deviations in region-specific capital rental prices and investment prices. In East, the deviation in the average capital rental prices initially lies below the East investment price deviation, implying a short-run negative deviation in East's rates of return. In North and South, short-run average capital rental prices initially rise relative to investment prices, implying a short-run increase in rates of return (Chart 7). In East, the short-run negative rate of return deviation generates a short-run negative investment deviation (Chart 3). This accounts for the growing negative deviation in East's capital stock (Chart 3). Over time, this allows the deviation in East's capital rental price to gradually recover, so that by the end of the simulation period, we find it steadily converging on the East investment price deviation (Chart 7). In North and South, we find the reverse situation, with capital accumulation gradually driving down the short-run positive deviation in the capital rental rate, so that by the end of the period, we find it steadily converging on the long-run deviation in the investment price index. In BOTE, we represent

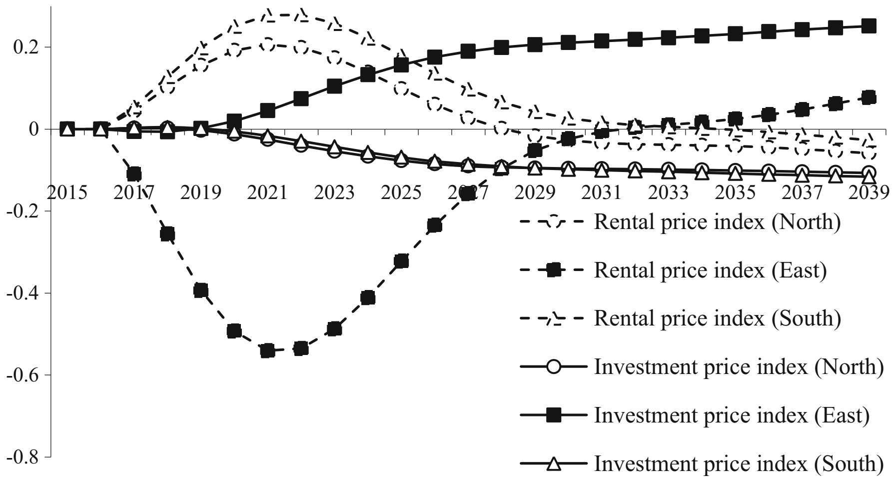

Chart 7 Capital rental prices and investment price deflators, by region (percentage deviation from baseline)

the propensity of the long-run VURM to exhibit convergent deviations in capital rental prices and capital construction costs through the exogenous status of ROR in Eq. (B6). This long-run representation of (B6) models the fact that changes in the long-run cost of constructing regional capital must eventually flow into the long-run regional cost stream via changes in capital rental prices.

5 Concluding Remarks

In this chapter, we analyse the effects of a loss in a region's amenities on the time path of net interregional in-migration and aggregate regional economic variables. Our analysis is carried out with the aid of a three-region dynamic CGE model, VURM, into which we incorporate a new method for regulating the stock/flow dynamic of interregional migration.[23]

Our simulations are carried out over a 25-year period from 2015 to 2039. We first undertake a baseline forecast for the period under the assumption that relative regional amenities are constant. We then undertake a forecast in which a relative loss of amenities occurs in the East region in 2016. Our simulation results for the deviation of variables in the second forecast from their baseline forecast results confirm the importance of amenities to regional economic outcomes. The loss of amenities in the East region relative to the two other regions (North and South) causes East's economy to contract as labour is attracted to the two other regions whose economies expand.

[23]Note, we first outlined this method in Giesecke and Madden (2013).

A major element of this chapter is a careful explanation, with the assistance of a BOTE model (a miniature model of VURM), as to how the time path of results for key regional economic variables emanates from the structure of the VURM. This forms an important component in validating the model's results for the regional amenity shift.

References

Adams PD, Parmenter BR (2013) Computable general equilibrium modeling of environmental issues in Australia: economic impacts of an emissions trading scheme. In: Dixon PB, Jorgenson DW (eds) Handbook of computable general equilibrium modeling. Elsevier, Amsterdam, pp 553–657

Adams PD, Horridge JM, Wittwer G (2003) MMRF-GREEN: a dynamic multi-regional applied general equilibrium model of the Australian economy, General Working Paper G-140. Centre of Policy Studies and Impact Project, Melbourne

Debelle G, Vickery J (1999) Labour market adjustment: evidence on interstate labour mobility. Aust Econ Rev 32:249–263

Dixon PB, Rimmer MT (2002) Dynamic general equilibrium modelling for forecasting and policy. Contributions to economic analysis 256. Elsevier, Amsterdam

Evans AW (1990) The assumption of equilibrium in the analysis of migration and interregional differences: a review of some recent research. J Reg Sci 30:515–531

Giesecke JA, Madden JR (2010) Uncovering the factors behind comparative regional economic performance: a multiregional CGE approach. Reg Stud 44:1329–1349

Giesecke JA, Madden JR (2013) Regional computable general equilibrium modeling. In: Dixon PB, Jorgenson DW (eds) Handbook of computable general equilibrium modeling. Elsevier, Amsterdam, pp 379–475

Giesecke JA, Schilling C (2010) The economic impact of the New Zealand fiscal stimulus package. N Z Econ Pap 44:231–257

Giesecke JA, Dixon PB, Rimmer MT (2008) Regional macroeconomic outcomes under alternative arrangements for the financing of public infrastructure. Pap Reg Sci 87:3–31

Giesecke JA, Burns W, Barret A, Bayrak E, Rose A, Slovic P, Suher M (2012) Assessment of the regional economic impacts of catastrophic events: CGE analysis of resource loss and behavioral effects of an RDD attack scenario. Risk Anal 32:583–600

Gillespie G, McGregor PG, Swales JK, Yin YP (2001) The displacement and multiplier effects of regional selective assistance: a computable general equilibrium analysis. Reg Stud 35:125–139

Graves PE (1980) Migration and climate. J Reg Sci 20:227–237

Greenwood MJ, Hunt G, Rickman DS, Treyz GI (1991) Migration, regional equilibrium, and the estimation of compensating differentials. Am Econ Rev 81:1382–1390

Groenewold N, Madden JR, Hagger AJ (2003) The effects of interregional transfers: a political-economy CGE approach. Pap Reg Sci 82:535–554

Harrison WJ, Pearson KR (1996) Computing solutions for large general equilibrium models using GEMPACK. Comput Econ 9:83–127

Herzog HW, Schlottmann AM (1993) Valuing amenities and disamenities of urban scale: can bigger be better? J Reg Sci 33:145–165

Hirte G (1998) Welfare effects of regional income taxes: results of an interregional CGE analysis for Germany. Ann Reg Sci 32:201–219

Jones R, Whalley J (1989) A Canadian regional general equilibrium model and some applications. J Urban Econ 25:368–405

Kahsai MS, Gebremedhin TG, Schaeffer PV (2011) A spatial analysis of amenity and regional economic growth in Northeast region. Rev Urban Reg Dev Stud 23:77–93

Klaiber HA (2014) Migration and household adaptation to climate: a review of empirical research. Energy Econ 46:539–547

Layard R, Nickell S, Jackman R (2005) Unemployment: macroeconomic performance and the labour market, 2nd edn. Oxford University Press, Oxford

Lecca P, McGregor PG, Swales JK, Yin YP (2014) Balanced budget multipliers for small open regions within a federal system: evidence from the Scottish variable rate of income tax. J Reg Sci 54:402–421

Li B, Higano Y (2007) An environmental socioeconomic framework model for adapting to climate change in China. In: Cooper R, Donaghy K, Hewings G (eds) Globalization and regional economic modeling. Springer, Berlin, pp 327–349

Li PC, Rose A (1995) Global warming policy and the Pennsylvania economy: a computable general equilibrium analysis. Econ Syst Res 7:151–171

Madden JR, Gwee E (2010) A spatial CGE model for assessing the vulnerability of regional economies to transport system failures. Paper presented to 57th Annual North American Meetings of the Regional Science Association International, Denver CO, November 10–13

McGregor PG, Swales JK, Yin YP (1995) Migration equilibria/disequilibria and the natural rate of unemployment in a regional context. Ind J Manpow 16:66–72

McGregor PG, Swales JK, Yin YP (1996) Migration equilibria in regional economies: a multi-period CGE analysis of an improvement in local amenities. In: van den Bergh J, Nijkamp P, Rietveld P (eds) Recent advances in spatial equilibrium modeling: methodology and applications. Springer, Berlin, pp 346–358

McKibbin W, Morris A, Wilcoxen P (2010) Comparing climate commitments: a model-based analysis of the Copenhagen accord, Discussion paper 2010–35. Harvard Project on International Climate Change Agreements, Cambridge, MA, June

Morgan W, Mutti J, Partridge M (1989) A regional general equilibrium model of the United States: tax effects on factor movements and regional production. Rev Econ Stat 71:626–635

Naqvi F, Peter MW (1996) A multi-regional multi-sectoral model of the Australian economy with an illustrative application. Aust Econ Pap 35(66):94–113

Oladosu G, Rose A (2007) Income distribution impacts of climate change mitigation policy in the Susquehanna river basin economy. Energy Econ 29:520–544

Rickman D (1992) Estimating the impact of regional business assistance programs: alternative closures in a computable general equilibrium model. Pap Reg Sci 71:421–435

Rogelj J, Nabel J, Chen C, Hare W, Markmann K, Meinshausen M, Schaeffer M, Macey K, Höhne N (2010) Copenhagen accord pledges are paltry. Nature 464:1126–1128

Rutherford TF, Törmä H (2010) Efficiency of fiscal measures in preventing out-migration from North Finland. Reg Stud 44:465–475

Shibusawa H, Miyata Y (2011) Evaluating the dynamic and spatial economic impacts of an earthquake: a CGE application to Japan. Reg Sci Inq J III(2):13–25

Shibusawa H, Yamaguchi M, Miyata Y (2009) Evaluating the impacts of a disaster in the Tokai region of Japan: a dynamic CGE model approach. Stud Reg Sci 39:539–553

Whalley J, Trela I (1986) Regional aspects of confederation. University of Toronto Press, Toronto

Valuing the Benefits of Cleaner Air in Jakarta Metropolitan Area

Mia Amalia, Budy P. Resosudarmo, Jeff Bennett, and Arianto Patunru

Abstract Air pollution negatively impacts the society in the form of health problems, unpleasant odour and low visibility. We estimate the benefit of having cleaner ambient air for the Jakarta Metropolitan Area's (JMA) citizens. The value people place on an improvement in air quality resulting from the implementation of three new transportation policies is estimated using choice modelling with four attributes: restricted activity days (RADs), visibility, odour and implementation costs. A public survey was conducted in the JMA across approximately 650 respondents. The implicit prices for individual attributes are estimated using conditional logit (CL) and random parameter logit (RPL) models. The results show that the respondents have significantly positive values for a lower number of RADs and less unpleasant odour. On average, respondents in the JMA are willing to pay from USD54 to USD57 per household per annum over a 3-year period for the implementation of a new transportation policy. This translates into a total benefit to the community in the range of USD219 million to USD230 million per year.

Keywords Air pollution • Cost-benefit analysis • Choice modelling • Transportation policy • Jakarta Metropolitan Area

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1 Introduction

Compared with big cities in other developing and developed countries, total suspended particulate (TSP) concentration in the Jakarta Metropolitan Area (hereafter JMA) is among the highest; it is second only to New Delhi (Health Effect Institute 2004). The PM-10 concentration in Jakarta was the 11th highest in the world in 2002, while in the case of SO_2 and NOx, it was ranked 97th and 67th, respectively, in 2001 (The World Bank 2006).[1]

Emissions from vehicle operation are one of the main sources of air pollution in JMA (Ostro 1994; Syahril et al. 2002; IMAP 2002). In 1992, vehicular emission loads for Jakarta were 35 % for NOx and 73 % for TSP (Ostro 1994).[2] In 1995, the loads were 49 % for NOx, 28 % for SO_2 (Hamonangan et al. 2002) and 70 % for PM-10 (Haryanto 2012). Syahril et al. (2002) predict that the emission load from vehicles in 2015 will be between 2.73 and 3.68 times higher than the 1998 emission loads.

Pollution control policies were implemented to tackle the problems. These policies vary from general standards to specific programmes. In JMA, the latter include the minimum of three passengers in one car requirement (three-in-one programme) for central Jakarta during busy hours, the inspection and maintenance (IM) of private vehicles programme, and public transportation enhancement. Despite these programmes, there has been no significant improvement of air quality in JMA over the last decade. Effective policies should bring higher net benefits to the society. To measure these *net* benefits, we need to estimate the benefits of having cleaner air against implementation costs. The objective of the research presented in this paper is to estimate the former, i.e. the benefits enjoyed by JMA citizens from having cleaner ambient air as a result of the implementation of three new transportation policies. This provides an important information for policymakers in considering the costs to implement each policy option. Attributes of air pollution used in this research are the number of restricted activity days caused by upper and lower respiratory illnesses, visibility level and odour level. The three proposed policies are (1) improvement of public transport facilities, (2) restriction of the number of vehicles in busy areas and (3) reduction in the number of old vehicles.

2 Air Pollution Policies in Jakarta Metropolitan Area

The existing policies in JMA to address the air pollution problem from the transportation sector are mainly of command-and-control approaches (Sadat et al. 2005). The national regulatory instrument is based on the Indonesian National

[1] PM-10, SO_2 and NOx refer to particulate matter smaller than 10 μm, sulphur dioxide and nitrogen oxide, respectively.

[2] Vehicular emission load: share of emission from vehicle to ambient air.

Air Pollution Control Policy (NAPC).[3] The NAPC sets the standards for ambient air quality, emissions, noise and air pollution. To meet all these standards, local governments are assigned a central role in keeping the air quality above the identified thresholds (GOI 1999, Article 18). The Ministry of Environment released a decree (the Ministry of Environment Decree No. 141/2003) regarding New Type and Current Production Motor Vehicle Exhaust Emission Standards (CPMV standard). This decree has tried to address the discrepancy between indirect ambient air pollution control and direct pollution control by controlling the source: vehicles. The CPMV standard also considers available air pollution control technology to reduce vehicular emission (KLH 2003).

In addition to national regulation, Jakarta Province has set its own Jakarta Air Pollution Control Regulation (Jakarta APC, Jakarta's Provincial Regulation No. 2/2005). With regard to air pollution caused by mobile sources, this policy makes periodic vehicular emission assessment compulsory for all types of vehicles. It also specifies that all public transport and local government fleets should use liquefied petroleum gas (LPG) as the energy source instead of petrol or diesel since the LPG emission load is lower than that of petrol and diesel and because LPG stations are available in the Jakarta Province area (Bappenas 2006).

Academics and policymakers are discussing newly proposed policies to control air pollution from the transportation sector in JMA. The first policy involves the *improvement of public transport facilities in Jakarta Province*: building bus rapid transport (BRT) facilities including special bus corridors and bus stops, building monorail facilities, improving light rail facilities and providing walking paths and bike lanes. The scenario for this first policy was such that, if the above plan and campaign were successful, JMA citizens would reduce private vehicle usage, especially in the Jakarta Province. The critical stage in scenario development for this policy was determining changes in vehicle fleet composition resulting from the implementation of the new policy. All information used to develop the first scenario was obtained from studies conducted by the Institute for Transportation and Development Policy (ITDP 2003, 2005, 2007). The ITDP conducted surveys asking current BRT users about their mode of transport prior to the availability of BRT. These survey data were used to estimate further mode shifting in the future.

The second policy proposed is designed to *reduce the number of private vehicles on the streets*. The policy would be implemented by raising parking fees in public areas such as shopping centres, by applying fees in public areas such as offices and by collecting entry fees to 'busy areas'. Under this policy, busy areas are defined as the five cities in Jakarta Province with the highest PM-10 concentrations. In this study, scenarios developed for the second policy are purely hypothetical since there

[3]Government Regulation No. 41/1999: National Air Pollution Control, mandated by Law No. 23/1997, Environmental Management.

was no previous study available to aid the analysis. The scenarios assume that the number of private vehicles, private cars and motorcycles only, operating in five cities in the Jakarta Province, is reduced to 50 %, 30 % and 10 % below the 2004 levels, respectively. We assume that a reduction in vehicle numbers would reduce PM-10 concentration.

This third policy involves *raising registration fees for old cars and motorcycles*. Old vehicles are defined as vehicles that do not comply with the new standard stated in the Ministry of Environment Decree No. 141/2003 (KLH 2003). Nugroho et al. (2005, p. 26–27) estimate the ratio of new to old vehicles operating in the JMA streets from 2003 to 2015. They used current 2002 vehicle numbers and available vehicle growth data from the National Police Department. For instance, according to their model, in 2015 about 57 % of operating passenger cars will be cars that comply with new emission standards as stated in MED No. 141/2003 (KLH 2003).

3 Choice Modelling

Choice modelling (CM) is a survey-based approach to estimate changes in welfare (Hanley et al. 2001). This approach has been used in various countries for different sectors, such as water resource sector in the Australian Capital Territory (Blamey et al. 1999), mangrove management in Malaysia (Othman et al. 2004) and cropland conversion in North West China (Wang et al. 2006). In a CM application, changes in welfare are estimated using the choices that the respondents pick from alternative future use options that are described using attributes of the goods in questions. In the various options presented to survey respondents, the attributes take on different levels. One necessary attribute is monetary value. By observing the choices respondents make, the analyst can estimate the willingness to pay for improvements in single attributes or combinations of attributes – using the monetary attribute as the proxy to price the other attributes. In this research, the good in question is the JMA's ambient air condition. The good was defined using four attributes: *number of restricted activity days caused by upper and lower respiratory illnesses* (*number of RADs*), *visibility level*, *odour level* and *cost* of policy implementation. In the CM questionnaire, all attributes, policies and choice sets were presented using cartoon illustrations which are commonly used in Indonesia for communicating ideas, public campaigns and advertisements. This strategy was found to suit Indonesia's condition and was appropriate for respondents with diverse educational attainments and who have a high reliance on spoken rather than written presentation.

Fig. 1 Problem description (Source: Authors' own design)

A typical CM questionnaire has the following components: problem definition,[4] payment of vehicle tax,[5] choice sets,[6] socioeconomic questions[7] and attitudinal questions[8] (Morrison and Bennett 2004). These components need to be defined clearly and should be tested before survey implementation so that all components can be well understood by respondents to ensure reliable responses (Blamey et al. 1999). In many CM studies, focus group discussions are used to assist with the problem of statement refinement, attributes and the payment of vehicle tax selection and also in questionnaire communication (Blamey et al. 2000). In our research, the questionnaire was refined using inputs from (1) experts on survey and air pollution control policy, (2) participants of focus group discussions and (3) field tests.

The questionnaire involved the use of seven show cards explaining (1) description of the problem (Fig. 1), (2) description of the current condition and proposed policies (Fig. 2), (3) explanation of the choice sets and (4) four choice set cards for

[4]Problem definition: description of the environmental issue and potential solutions.

[5]Payment of vehicle tax: means of paying for the potential solutions used in the questionnaire. Payment of a vehicle tax should be well accepted among respondents, being a secure and reliable indication that the contribution will be used for the right purpose.

[6]Choice set: presentation of the choice options available to respondents, described using attributes that take on differing levels across choice options.

[7]Socioeconomic question: questions designed to gather information such as monthly expenditure and education attainment.

[8]Attitudinal question: questions designed to obtain respondents' attitude and opinion towards the good in question.

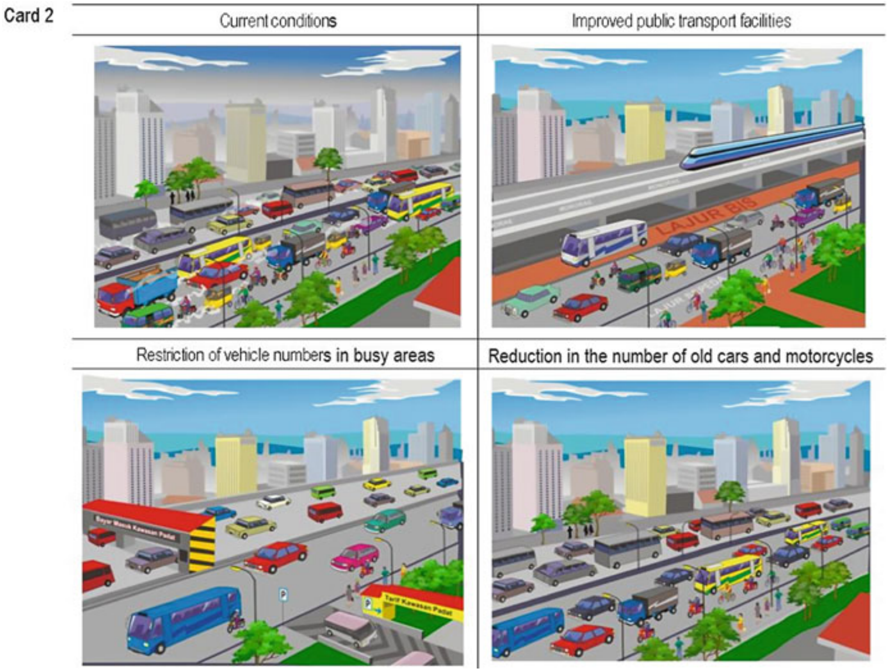

Fig. 2 Description of current conditions and new policies (Source: Authors' own design)

every respondent (Fig. 3). A combination of four vehicle tax payments was used: higher land and property tax, higher vehicle tax, higher parking fee in central Jakarta and payment to enter Central Jakarta. Thus, the choice of an option that involved a payment implied that the respondent would be faced with a mixture of increased fees and charges. The mixed payment vehicle tax was used to overcome issues such as high number of protests caused by a specific vehicle tax payment and was designed to link all proposed policies. A respondent has to choose one of the four choice set cards presented.

To construct the choice sets, combinations of attribute levels were used, following an efficient experimental design (Table 1). Prior values of the implicit prices of the attributes were estimated based on pilot surveys using the orthogonal design. The efficient design was chosen according to the lowest D-error (Rose et al. 2008). The final 24 choice sets were distributed into 6 blocks (hence the four choice set cards for each respondent). The orthogonal design for the choice sets used in the pilot surveys was constructed using the L^{MA} approach (Louviere et al. 2000 cited in Street et al. 2005).

The survey was implemented using the following steps: (1) sampling designs, (2) interviewer training, (3) pilot surveys and (4) surveys. A cluster sampling method was applied (Figs. 4 and 5), as it is the most suitable sampling method for JMA's condition where most citizens live in geographically unstructured neighbourhoods.

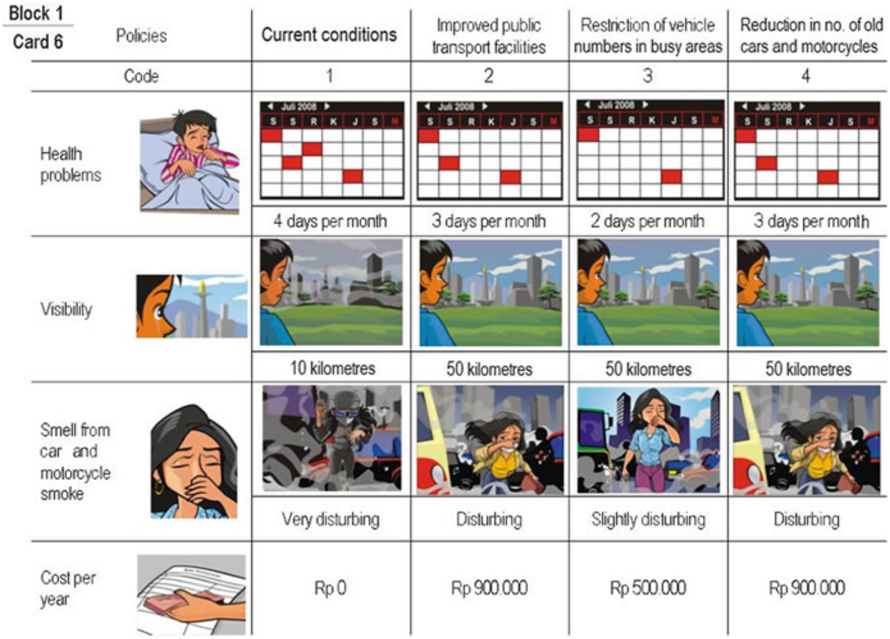

Fig. 3 Choice sets (Source: Authors' own design)

Table 1 Attributes and levels

Attributes	Unit	Status quo levels	Experimental design levels
RAD	Days	4	3, 2, 1
Visibility	Metres	10	30, 50, 70
Odour	–	Very disturbing	Disturbing, slightly disturbing, not disturbing
Cost	Rupiah	0	100,000; 500,000; 900,000

Thirteen subdistricts were selected from the 166 subdistricts in the JMA. The subdistricts were proportionally selected according to PM-10 levels and average income. Five villages were selected within every subdistrict and two sub-villages were selected from every village. Sub-villages were used to create primary sampling units (PSUs). The PSU was the smallest sampling unit consisting of 50 households within one sub-village. Five households per PSU were interviewed. Interviewer training began with an explanation of the survey objective and questionnaire content. The researcher explained the objective of every question and discussed appropriate probes to each. The interviewer then practised reading and pointing to the assigned show card. A discussion session of possible difficulties in the field and role playing completed the training. The pilot survey was conducted in 3 subdistricts and the main survey was conducted in 13 subdistricts.

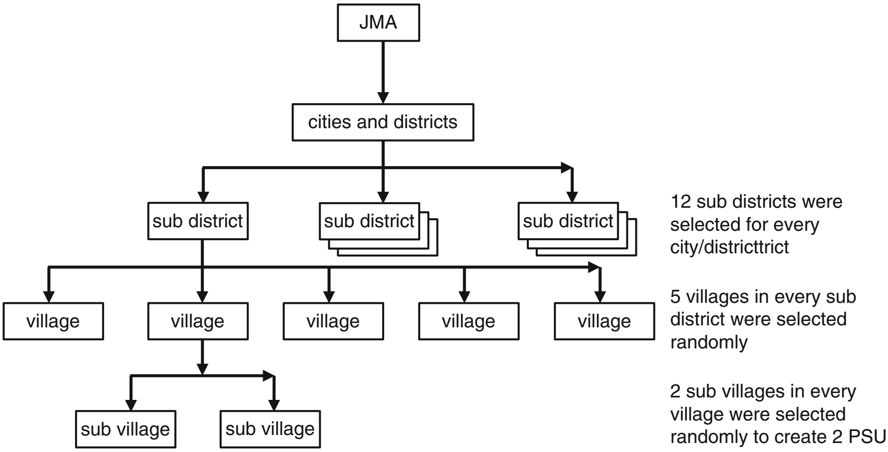

Fig. 4 Illustration of the cluster sampling method

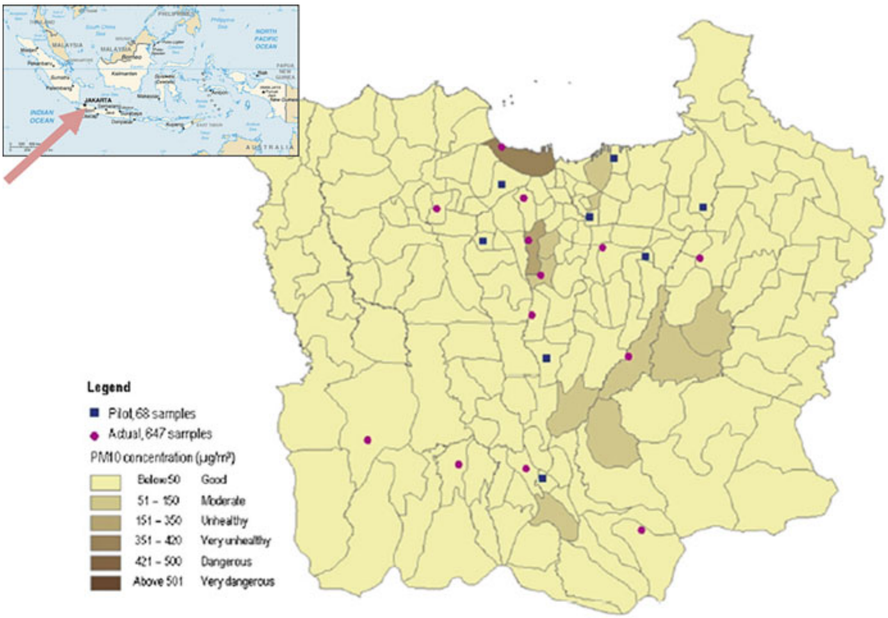

Fig. 5 Sampling areas

4 Model Specification

4.1 Conditional Logit Model

A CM application is based on the behavioural assumption modelled under the random utility theory that consists of two parts: observable (V_{ij}) and unobservable (ε_{ij}) components (Verbeek 2004):

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

In a conditional logit (CL) model, the utility functions (V_{ij}) consist of observed individual, choice invariant characteristics (z_i) and attributes of the choices (x_{ij}) (Greene 2007), and then V_{ij} can be written as

$$V_{ij} = \beta^i x_{ij} + y_j^i z_i \tag{2}$$

This model has a weakness relating to the assumption that all ε_{ij} are independent. This property is called independence of irrelevant alternatives (IIA). To analyse whether or not the IIA is violated, a Hausman and McFadden test is used. It compares two models with all variables to a model using a subset of variables. If the property of IIA is violated, other models which relax the IIA property are available. These models are multinomial probit model, nested logit model and random parameter logit model (Wang et al. 2006).

The indirect utility function, V_{ij}, can take different models, the simplest one being a linear model (Eq. 3 below) where ASC is the alternative specific constant, β is a vector of the estimated parameters and X is a vector of k attributes of the good in question from a choice set (Wang et al. 2006). ASCs are included to represent the influence of freestanding emotions and presentation effects (Blamey et al. 2000). Such inclusions can also improve the model fit (Adamowicz et al. 1997):

$$V_{ij} = \mathrm{ASC} + \sum \beta_k X_k, \text{ where } i = 1, \ldots, k \tag{3}$$

$$\mathrm{IP} = -\frac{\beta_k}{\beta_c} \tag{4}$$

$$\mathrm{CS} = -\frac{1}{\beta_c}(V_0 - V_1) \tag{5}$$

Models are compared based on the log likelihood values, rho-squared (ρ^2) and chi-squared statistics (χ^2) (Rolfe et al. 2000). Coefficients from the best available model are used to calculate implicit prices (Eq. 4) – the trade-off respondents are willing to take on average between attributes (Bennett and Adamowicz 2001), where β_k is the coefficient of the attribute in question and β_c is the coefficient of cost attribute calculated from the model (Rolfe et al. 2000). Compensating surplus is estimated using Eq. (5) where V_0 is the utility of the current or status quo condition and V_1 is the utility of the new proposed conditions (Wang et al. 2006).

4.2 Random Parameter Logit Model

The random parameter logit (RPL) model assumes 'heterogeneity' among respondents (Liljenstolpe 2008; Lusk et al. 2007). Dispersion around the coefficients' means is an indicator that heterogeneity exists within the model. CL models cannot capture dispersion and hence may lead to an imprecise estimation of population preference (Hynes et al. 2008; Wang et al. 2006; Lusk et al. 2007). Recognition of taste heterogeneity is therefore important to avoid bias that otherwise may result in poor policy selection (Hynes et al. 2008; Birol et al. 2006).

In the CL model, the parameters, β_k in Eq. (1), are fixed and take the same value for all respondents. The RPL, on the other hand, introduces a random component in the parameters (Eq. 6), where θ is a constant, Δz_k produces individual heterogeneity and $\Gamma \Omega_k v_k$ is a triangular matrix with selected distributional function in its diagonal. Then, Eq. (3) can be rewritten as Eq. (7) where β_k is a vector of fixed coefficient and θ_k is a coefficient vector that is randomly distributed across individual random parameters (Greene 2007):

$$\theta_k = \theta + \Delta z_k + \Gamma \Omega_k v_k \quad (6)$$

$$V_{ij} = \text{ASC} + \sum \beta_k X_k + \sum \theta_k X_k \quad (7)$$

To explain the sources of heterogeneity, interaction between socio-demographic variables with ASCs is included in the model, so that RPL can pick up preference variation to improve the model fit (Birol et al. 2006).[9]

5 Results and Discussion

5.1 Sample Representation

To check the sample representativeness, chi-squared tests were used. Respondents' socioeconomic status (SES) was not significantly different from the population with the chi-squared result equal to 2.10, which is lower than the critical value (12.59 with 6 degrees of freedom at the 0.05 level). Across the sample, the gender

[9]Some studies report that there is no improvement in model fit by implementing RPL (Provencher and Moore 2006), but others find that significant improvements are achieved (Birol et al. 2006).

compositions were the same as the JMA population, namely, 51 % male and 49 % female. The age structure was also not significantly different from the 2008 projection by the Statistics Indonesia with the chi-squared statistics equal to 3.64, which is lower than the critical value (12.59 with 6 degrees of freedom at the 0.05 level).

5.2 *Estimation of Utility Function Using Conditional Logit and Random Parameter Logit Models*

Four utility functions (Eqs. 8, 9, 10, and 11) were estimated simultaneously. Alternative specific constant (*ASC*) is included in each of the policy utility equations: A_{TS} for public transportation improvement, A_{RD} for reducing vehicle density in busy areas and A_{RO} for reducing the number of old vehicle ownerships in the JMA. Respondents' preferences for new policies (as opposed to the status quo) were captured by the three *ASCs*. *Illness*, *Visibility* and *Cost* are continuous variables, while *Odour* is a categorical variable. Therefore, the *Odour* variable was separated into *Odour 1* (from *disturbing* to *slightly disturbing* condition) and *Odour 2* (from *slightly disturbing* to *not disturbing* condition):

$$V_{SQ} = I\beta_I + V\beta_V + O1\beta_{O1} + O2\beta_{O2} + C\beta_C \quad (8)$$

$$V_{TS} = A_{TS} + I\beta_I + V\beta_V + O1\beta_{O1} + O2\beta_{O2} + C\beta_C \quad (9)$$

$$V_{RD} = A_{RD} + I\beta_I + V\beta_V + O1\beta_{O1} + O2\beta_{O2} + C\beta C \quad (10)$$

$$V_{RO} = A_{RO} + I\beta_I + V\beta_V + O1\beta_{O1} + O1\beta_{O2} + C\beta_C \quad (11)$$

Two CL models were estimated to obtain coefficients for the above four equations (Table 2). The first model is an 'attributes-only' model and the second model includes other explanatory variables. The probability of a 'change' option being chosen was hypothesised to increase with (1) lower RADs, (2) higher visibility, (3) lower degree of odour disturbance and (4) lower cost. All choice attributes were found to be significant and have the expected signs except for Visibility which was insignificant in both models. All ASCs were significant and negative. The results of the first model (Model 1) demonstrate that the respondents support reductions in air pollution. However, all the *ASCs* were negative suggesting that respondents oppose the implementation of new policies. Negative *ASCs* show a 'status quo bias choice' (Mazzanti 2001) or reluctance to move from the current condition (Kerr and Sharp 2008; Concu 2006; Brey et al. 2007). In the survey, 173 respondents consistently chose the status quo condition. The debriefing question showed that respondents' beliefs that their contribution will not be used to create better ambient air conditions

Table 2 Estimation results for CL and RPL models

Variables	Model 1 (CL)		Model 2 (CL)		Model 3 (RPL)			
					Coefficient		Standard deviation	
RAD	−0.240	***	−0.248	***	−0.247	***	0.324	***
Visibility	0.002		0.002		0.002			
Odour 1	−0.377	***	−0.407	***	−0.436	***	0.651	***
Odour 2	−0.097	**	−0.091	**	−0.037			
Cost	−0.002	***	−0.003	***	−0.003	***		
ATS	−0.220	*	−1.003	**	−0.868	*		
ATS*Age			−0.015	**	−0.018	***		
ATS*Gender			−0.351	***				
ATS*Education			0.415	***	0.472	***		
ATS*Income			−0.231	***	0.268	***		
ATS*Cough			−0.323	**	−0.393	**		
ATS*Distance			−0.035	***	−0.042	***		
ATS*PM-10			−20.824	**	−25.880	***		
ARD	−0.382	***	−1.002	**	−0.894	*		
ARD *Age			−0.017	***	−0.020	***		
ARD *Gender			−0.521	***	−0.612	***		
ARD *Education			0.443	***	0.513	***		
ARD *Income			0.231	***	0.271	***		
ARD *Cough			−0.441	***	−0.517	***		
ARD *Distance			−0.036	***	−0.043	***		
ARD *PM-10			−38.490	***	−44.344	***		
ARO	−0.444	***	−1.078	**	−0.940	*		
ARO *Age			−0.005		−0.007			
ARO *Gender			−0.390	***	−0.430	***		
ARO *Education			0.397	***	0.447	***		
ARO *Income			0.188	***	0.229	***		
ARO *Cough			−0.290	*	−0.327	*		
ARO *Distance			−0.042	***	−0.050	***		
ARO *PM-10			−27.128	***	−32.428	***		
LL function	−3090.273		−2799.018		−2791.552			
Restricted LL					−3587.730			
AIC	2.394		2.186		2.181			
BIC	2.412		2.251		2.251			
Chi-squared	839.764		1422.274		1592.356			
Probability chi-squared	0.000		0.000		0.000			
Rho-squared	0.120		0.203		0.222			

Notes: *, **, *** refer to significance at 10 %, 5 %, and 1 %, respectively might be the main cause of the negative *ASCs*. Another possible cause was that the lowest cost level (Rp100,000) was set too high, shifting too many respondents to the status quo condition.

In the second model, a combination of explanatory variables was added to observe other possible explanations for variations in choices. These are socio-demographic variables (age, gender, number of kids, education and income), air pollution-related illnesses (fever, cold, cough, asthma), habits (smoking, average number of hours spent outdoors) and location-specific condition (pollutant concentration: PM-10 total, dispersion and emission as well as respondents' home distance from JMA centre). All those variables were interacted with all *ASCs* so that respondents' preferences can be linked to proposed policies.

The socio-demographic variables, *Age*, *Gender*, *Education* and *Income*, are consistently significant. Young women with relatively high education and income were more likely to choose improvement over the current condition.

None of the PM-10 related illnesses consistently appeared as significant determinants of choice. *Asthma* was significant only for RD policy, while *Cough* was significant for TS and RO policies. Respondents who suffered *Asthma* in the past month of the survey appeared to choose improvement over the current condition. Unexpectedly, respondents who suffered *Cough* did not appear to choose improvement.

The third group of explanatory variables were respondents' habits. *Smoke* was not significant for the RD policy but was significant for both the TS and RO policies (at 1 % and 5 %, respectively) indicating that people who smoke tend to choose improvement. *Outdoor*, the average number of hours spent outdoors, was not significant for RO policy but significant for TS and RD policies. The negative signs were unexpected since they indicated that the more average hours spent outdoors the less respondents wanted the improvement.

The fourth group of explanatory variables was location-specific conditions: PM-10 concentration in the respondents' living area and distance from JMA city centre. *PM-10* was a significant variable across different policies. The *Distance* variable turned out to be significant, indicating that respondents who lived relatively close to the centre of JMA were more likely to choose improvement over the current condition.

Different combinations of CL models were estimated to find the best fit according to the rho-squared statistic and the significance of variables. Model 2 was the best model formulated with 0.203 rho-squared and significant explanatory variables. In this final model, the explanatory variables were *Age*, *Gender*, *Education*, *Income*, *Cough*, *Distance* and *PM-10*.

To check for IIA compliance in the CL model, the Hausman test was conducted by restricting one utility function at a time. The results are presented in Table 3. Model 1 was an 'attributes-only' model, while Model 2 was found to fit the data best with significant explanatory variables. The Hausman test for Model 1 showed that the IIA assumption could be rejected for all 'new policies' options, while for Model 2 the test showed that the IIA assumption cannot be rejected for *RD policy*

Table 3 Hausman test results for Model 1 and Model 2

CL Model		Excluded choices		
		TS	RD	RO
Model 1	p-value	0.009	0.004	0.010
Model 3	p-value	0.000	0.984	0.071

Table 4 Comparison of implicit prices (in thousand Rupiah)

Variables	CL (Model 2)		RPL (Model 3)		Proportion of difference
	IP	CI (95 %)	IP	CI (95 %)	
RAD	−97.716	±0.946	−88.857	±1.069	0.491
Visibility	0.929	±0.051	0.602	±0.050	0.000
Odour 1	−162.431	±1.125	−155.886	±1.142	0.471
Odour 2	−35.741	±1.029	−13.014	±1.120	0.982
Rho-squared	0.203		0.222		

(Table 3). Since the overall results failed to reject the IIA assumption, the random parameter logit (RPL) model which relaxes the IIA assumption was estimated.

An RPL model was constructed by including the explanatory variables found to be significant in Model 2. After testing for different combinations of random parameters, as suggested by Hensher et al. (2005), only the parameters that consistently appeared to have significant standard deviation were set as random. Initially, all attributes, except *Cost*, were set as random parameters. Then, *Visibility* and *Odour 2* were set as fixed parameters since both consistently showed insignificant standard deviations. All *ASCs* (*ATS*, *ARD* and *ARO*) were also set as fixed parameters since in the ten replication tests none of them had a significant standard deviation. Correlation among random parameters was tested and found to be low. The final models were estimated without allowing for correlation among parameters.

For the RPL model (Model 3), all *ASCs* were again negative and significant. Significant attributes were *Illness*, *Odour 1* and *Cost*. *Visibility* and *Odour 2* were insignificantly different from zero. All standard deviations for attributes set as random parameters were significant, indicating that unconditional unobserved heterogeneity existed for these attributes. Individual characteristics, interacted with *ASCs*, were added into the model to improve the model fit.

5.3 Model Comparison

The implicit prices were calculated using Eq. (4). Coefficients used in the calculation were generated using Model 3. The implicit prices revealed that respondents in the JMA were willing to pay for changes in health and environmental conditions (Table 4). Implicit prices estimated using CL and RPL were not significantly different except for *Odour 2* since it was significant in the CL model but not in the RPL model (Table 4, last column).

5.4 Compensating Surplus

To calculate the compensating surplus, each ‘change’ scenario and the status quo need to be specified. The ‘change’ scenarios were based on the attribute levels defined in Table 1: low impact, medium impact and high impact, using first, second and third levels for all attributes, respectively. The three ‘change’ scenarios for each of the three new transportation policies, improvement of the transportation facilities (TS), reduction of vehicle numbers in the city centre (RD) and reduction of old vehicles (RO), were investigated:

1. Low impact: an average of three RADs caused by respiratory-related illnesses, 30 km of visibility range and a disturbing odour from the transportation sector
2. Medium impact: an average of two RADs caused by respiratory-related illnesses, 50 km of visibility range and a slightly disturbing odour from the transportation sector
3. High impact: an average of one RAD caused by respiratory-related illnesses, 70 km of visibility range and a not disturbing odour from the transportation sector

The average compensating surplus for households was calculated using Eq. (5) where β_c is the marginal utility of income represented by the coefficient of the cost attribute, V_0 is the utility of the current condition and V_1 is the utility of the new proposed condition, with the *ASC* for each policy included in the calculation. Compensating surplus represents respondents’ willingness to pay for the proposed transportation policies. Using the above four scenarios, three compensating surpluses were estimated for each new transportation policy (Table 5).

Using estimation results from the RPL model, on average (using medium-impact scenario), respondents in the JMA were willing to pay Rp447,940 (USD54.40), Rp489,258 (USD55.46) and Rp503,555 (USD57.32)[10] per household per annum over a 3-year period for the implementation of TS, RD or RO policies, respectively (Table 5, RPL medium in bold). Even though respondents tended to choose the status quo, their average willingness to pay for the new transportation policies was revealed as positive.

Table 5 Comparison of compensating surplus for each scenario across three new transportation policies (in thousand Rupiah per household per annum over a 3-year period), RPL model (Model 3) estimation results

Policies	High	CI	Medium	CI	Low	CI
TS	634.19	±16.40	**447.94**	±18.76	321.70	±19.08
RD	643.50	±17.22	**487.26**	±19.58	331.02	±38.98
RO	659.80	±17.47	**503.56**	±19.83	347.31	±59.13
Rho-squared	0.222					

[10]Indonesia’s GDP per capita in 2010 was USD2946 (The World Bank 2012).

Table 6 Present value of total benefit for three new transportation policies for 3-year period

	NPV in million USD			NPV in trillion Rp		
Discount rate (%)	6.75	9.51	12.75	6.75	9.51	12.75
Policies						
TS	498	474	448	4373	4161	3934
RD	507	483	456	4459	4242	4010
RO	524	499	472	4608	4384	4144

The welfare estimates reported in Table 6 for the RPL model (medium-impact scenario) were aggregated over the whole sampling frame to determine the total benefit for the three new policies using Eq. (12), where CSA is the aggregate welfare estimates, RR is the response rate, P is population, r is the discount rate and n is the number of years:

$$\mathrm{CSA} = \mathrm{CS} \times \mathrm{RR} \times P \times n \times \frac{1}{(1+r)^n} \tag{12}$$

In the survey, the number of households contacted was 1170, and the number of households that agreed to be interviewed was 647; therefore, the fraction of the sample who agreed to take part in the survey was 55 %. The number of households for the whole of JMA in 2008 was approximately 6,310,790. Using these figures to extrapolate the total benefit for each policy per annum results in USD230m, USD219m and USD228m for TS, RD and RO, respectively. The present value of total benefit for each policy over a 3-year period is presented in Table 6 (using three discount rates[11]). These benefit estimates can then be compared with the present values of the respective policy costs.

6 Conclusion

The results presented here provide an understanding of JMA citizens' values for less RAD, better visibility and reducing odour by decreasing air pollution represented by PM-10. Since air is a non-market good, respondents' preferences were elicited via a household survey using the choice modelling method. This method was used since it can separate respondents' values regarding air quality improvement into air quality attributes derived from different policy instruments.

Most choice modelling studies have been conducted in developed countries with limited examples available from developing countries. The main challenges found in their application of CM in Indonesia were the low education level of respondents

[11]Discount rates used were 6.75, 9.5 and 12.75 % as minimum, average and maximum discount rates for Indonesia from July 2005 to July 2009 (www.bi.go.id, 30 July 2009).

and their high dependency on oral presentation. Consequently, respondents' reliance on the interviewers was very high. Three strategies were used to overcome the problem: (1) using show cards to describe the issue and the proposed solution to the issue and to present choice sets, (2) creating a 'story-like' questionnaire so that the respondents could be guided through the whole questionnaire by the interviewers (this was done by using conversational language in the written questionnaire that was read by the interviewers) and (3) training of interviewers so that they were capable of delivering the questionnaire using show cards and at the same time telling the 'story' so that the respondents could understand the linkage between problems, alternative solutions and choice exercises.

Survey results were analysed using two models: the conditional logit model and the random parameter logit model. Initially, the CL model was used, but since the IIA assumption was violated, the RPL model which relaxes the assumption was implemented.

Using results from the modelling stage, it can be concluded that the respondents in JMA have significant non-market values for air quality attributes, especially for *Illnesses* and *Odour* caused by air pollution from the transportation sector, and they were willing to pay for the changes. However, respondents were reluctant to choose one of the three proposed transportation policies. The main reasons might be because they did not believe that their contribution would be used to reduce air pollution from the transportation sector since most of policies implemented in the JMA have failed to remedy the problem. Another possible cause was that the lowest cost level (Rp.100,000/year) was set too high, shifting respondents' preference to the status quo condition. Nonetheless, on average, respondents in the JMA were willing to pay Rp447,940 (USD54.40), Rp489,258 (USD55.46) and Rp503,555 (USD57.32) per household per annum over a 3-year period for the implementation of TS, RD or RO policies, respectively.

Estimated net present values for total benefits can be used in cost-benefit analyses to estimate the total net benefits of implementing new transportation policies. The results can assist the local government in JMA in selecting the best transportation policy in JMA, the one that maximises the net benefit to the society.

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References

Adamowicz W, Swait J, Boxall P, Louviere J (1997) Perceptions versus objective measures of environmental quality in combined revealed and stated preference models of environmental valuation. J Environ Econ Manag 32:65–84

Badan Perencanaan Pembangunan Nasional (Bappenas) (National Development Planning Agency) (2006) Strategi dan rencana aksi nasional perbaikan kualitas udara perkotaan (in Indonesian). Bappenas, Jakarta

Bennett J, Adamowics V (2001) Some fundamentals of environmental choice modeling. In: Bennett J, Blamey R (eds) The choice modelling approach to environmental valuation. Edward Elgar, Cheltenham

Birol E, Karousakis K, Koundouri P (2006) Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. Ecol Econ 60:145–158

Blamey R, Gordon J, Chapman R (1999) Choice modelling: assessing the environmental values of water supply options. Aust J Agric Resour Econ 43:337–357

Blamey RK, Bennett JW, Louviere JJ, Morrison MD, Rolfe J (2000) A test of policy labels in environmental choice modelling studies. Ecol Econ 32:269–286

Brey R, Riera P, Mogas J (2007) Estimation of forest values using choice modelling: an application to Spanish forests. Ecol Econ 64:305–312

Concu GB (2006) Investigating distance effects on environmental values: a choice modelling approach, risk and sustainable management group. University of Queensland, Brisbane

Greene WH (2007) NLOGIT version 4.0: reference guide. Econometric Software, Plainview

Hamonangan E, Kondo A, Kaga A, Inoue Y, Soda S, Yamaguchi K (2002) Simulation and monitoring of sulphur dioxide and nitrogen oxides in the Jakarta Metropolitan Area. Asian J Energy Environ 3:159–183

Hanley N, Mourato S, Wright RE (2001) Choice modelling approaches: a superior alternative for environmental valuation? J Econ Surv 15:435–462

Haryanto B (2012) Human health risk to ultrafine particles in Jakarta. Jurnal Kesehatan Masyarakat Nasional

Health Effect Institute (2004) Health effects of outdoor air pollution in developing countries of Asia: a literature review, Special Report 15. Health Effect Institute, Boston

Hensher DA, Rose JM, Greene WH (2005) Applied choice analysis: a primer. University Press, Cambridge

Hynes S, Hanley N, Scarpa R (2008) Effects on welfare measures of alternative means of accounting for preference heterogeneity in recreational demand models. Am J Agric Econ 90:1011–1027

Indonesian Multi-sectoral Action Plan (IMAP) Group on Vehicle Emissions Reduction (IMAP) (2002) Action plan: integrated vehicle emission reduction strategy for Greater Jakarta, Indonesia. Asian Development Bank, Jakarta

Institute for Transportation and Development Policy (ITDP) (2003) Trans-Jakarta bus rapid transit system technical review. ITDP, Jakarta

Institute for Transportation and Development Policy (ITDP) (2005) Making Trans-Jakarta a world class BRT system. ITDP, Jakarta

Institute for Transportation and Development Policy (ITDP) (2007) Presentation to the Governor of Jakarta: making trans-Jakarta a world class BRT system. ITDP, Jakarta

Kementrian Lingkungan Hidup (KLH) (2003) The Ministry of Environment Decree (MED) No.141/2003, new type and current production motor vehicle exhaust emission standards (CPMV standard). KLH, Jakarta

Kerr GN, Sharp BMH (2008) Evaluating off-site environmental mitigation using choice modelling. Aust J Agric Resour Econ 52:381–399

Liljenstolpe C (2008) Evaluating animal welfare with choice experiments: an application to Swedish pig production. Agribusiness 24:167–184

Louviere JJ, Hensher DA, Swait JD (2000) Stated choice methods: analysis and application. Cambridge University Press, Cambridge

Lusk JL, Nilsson T, Foster K (2007) Public preferences and private choices: effect of altruism and free riding on demand for environmentally certified pork. Environ Resour Econ 36:499–521

Mazzanti M (2001) Discrete choice models and valuation experiments an application for cultural heritage. University of Rome III, Rome

Morrison M, Bennett J (2004) Valuing New South Wales rivers for use in benefit transfer. Aust J Agric Resour Econ 48:591–611

Nugroho SB, Fujiwara A, Zhang J (2005) Evaluating the effects of a new vehicle emission standard on urban air quality in Jakarta City. J Int Dev Cooperation 11:11–30
Ostro B (1994) Estimating the health effects of air pollutants: a method with an application to Jakarta, Policy Research Working Paper, no. 1301. World Bank, Washington, DC
Othman J, Bennett J, Blamey R (2004) Environmental values and resource management options: a choice modelling experience in Malaysia. Environ Dev Econ 9:803–824
Provencher B, Moore R (2006) A discussion of "Using angler characteristics and attitudinal data to identify environmental preference classes: a latent class model". Environ Resour Econ 34:117–124
Rolfe J, Bennett J, Louviere J (2000) Choice modelling and its potential application to tropical rainforest preservation. Ecol Econ 35:289–302
Rose JM, Bliemer MCJ, Hensher DA, Collins AT (2008) Designing efficient stated choice experiments in the presence of reference alternatives. Transp Res Part B 42:395–406
Sadat DN, Hanif F, Murhajanti P, Napitupulu L, Syahril S, Husin S, Soejachmoen MH (2005) Udara bersih hak kita bersama (In Indonesian), Pelangi and Indonesia Center for Environmental Law, Jakarta
Street DJ, Burgess L, Louviere JJ (2005) Quick and easy choice sets: constructing optimal and nearly optimal stated choice experiments. Int J Res Mark 22:459–470
Syahril S, Resosudarmo BP, Tomo HS (2002) Study on air quality Jakarta, Indonesia future trends, health impacts, economic value and policy options. The Asian Development Bank, Jakarta
The World Bank (2006) World development indicators. The World Bank, Washington
The World Bank (2012) World development indicators. The World Bank, Washington
Verbeek M (2004) A guide to modern econometrics, 2nd edn. Wiley, Hoboken
Wang X, Bennett J, Xie C, Zhang S, Liang D (2006) Estimating non market environmental benefits of the conversion of cropland to forest and grassland program: a choice modelling approach. Ecol Econ 63:114–125

Study of Fair Trade Products for Regional Development

Case of Bali, Indonesia

Yoko Mayuzumi and Takeshi Mizunoya

Abstract For this study, we conducted surveys of two kinds that are expected to be useful to improve management of fair trade products in agroforestry projects designed to mitigate forest degradation and poverty in Indonesia. Examination of the survey results can elucidate the subjects and solutions, thereby supporting management of sustainable activities. Effective circulation of the natural environment and local economy will be implemented. From results of survey No. 1, an appropriate price for these products was found. We were able to ascertain that it is better to increase the price of ready-made articles by approximately +200 yen when we give prices for fair trade products for university students in Japan. Because fair trade products are affected by demand, which depends on consumers' fashion preferences, it is better to prepare products in advance of tastes related to their fashion preferences, such as prevailing or ethnic styles. Based on results of survey No. 2, products with high probability of being purchased by university students were letter paper, envelopes, greeting cards, etc. As a common point for men and women, handmade paper is effective for them to present descriptive labels by creating a brand image of products with writing properties of materials and traditional culture.

Keywords Fair trade • Agroforestry • Handmade paper • Local economy • University students

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1 Introduction

For this study, we conducted surveys of two kinds to ascertain subjects to be managed for fair trade products from agroforestry projects to mitigate forest degradation and poverty in Indonesia. Results of our surveys might be useful along with sustainable activities such as this. Thereby, effective circulation of the natural environment and local economy will be implemented. Fair trade began as a result of NGO activity in the USA as an alternative form of trade. The fair trade international organization, Fairtrade Labelling Organizations International (FLO), describes fair trade as an alternative approach to conventional trade. It is based on a partnership between producers and consumers. Farmers who can sell on fair trade terms can make better trade and can benefit from improved terms of trade, which allows them the opportunity to improve their lives and plan for their future. Fair trade offers consumers a powerful means of reducing poverty through everyday consumption. The estimated market size of Japanese fair trade certification products is 9.4 billion yen (2014). Annual purchases of certified products per nation are 74 yen in Japan (2014). Results of a survey of "fair trade and ethical consumption (2015, $n = 1076$)" in Fair Trade Town Japan reveal that people who have actually purchased a fair trade product among people understanding fair trade are 33.7 % ($n = 315$). Therefore, few people have truly purchased fair trade products, even if they know about fair trade. Furthermore, from this survey, results show that the yearly income of people who understand fair trade has a peak from 5 million yen to less than 10 million yen. The rise in the cognitive rate shows correlation with yearly income. This relation was clarified by results of an earlier survey. The data suggest that the base of fair trade product purchases is small in Japan. Furthermore, results of this survey underscore many subjects related to fair trade products. Results show that subjects thought that fair trade products should be made more attractively (45.7 %, $n = 315$). Furthermore, regarding other survey results, respondents answered that there are no products that they want (38.1 %, $n = 172/2350$, when asked why people had not purchased fair trade products). When the Japanese market is considered, market expansion is an important subject. However, it is extremely important to devote some attention to "Japanese needs" for product development.

In economically developing countries, small fair trade industries are created through support from NGOs and collaborative associations. If management of such businesses creates good conditions only for the local people, it will be a sustainable business model for the future. This model is attempted in many places throughout the world. It has no meaning for a small sustainable industry such as this, if only producers such as NGO staff continue efforts. They require some market studies to assess consumer needs. Furthermore, they need a study of world trading methods and establishment of sales channels.

As described in this paper, we conducted a questionnaire in an agroforestry area of Bali Island in Indonesia to assess consumer needs related to a fair trade market in Japan because we have some projects there by promotion of NGO Bali Biodiversitas.

2 Research Method

As a trial for promotion of fair trade products in Japan, this study specifically examined university students as main consumers of fair trade goods. Japan has many potential supporters of fair trade. Survey results show that they are sometimes rich and of the intellectual class. However, fair trade campaigns by students are also active in Japan. Large networks such as the Fair Trade Student Network (FTSN) connect communities of university students. For that reason, we target university students.

In this study of fair trade products, we surveyed personal preferences and reasonable prices for supporters. In a fair trade project-producing area in Bali Island, Indonesia, the village people manage agroforestry (agriculture and forestry) by promoting NGO Bali Biodiversitas. They are trying to develop small industries using materials such as wood, plant fibers, and fruit. In support of this small industry, they are producing small wood products such as relief carvings and bracelets, paper products such as postcards and greeting cards, and fruit products such as jam. We collaborate with village people and propose new ideas for these products for Japanese sales by promoting NGO Bali Biodiversitas in Japan and Bali Biodiversitas Foundation in Indonesia. Furthermore, we are trying to connect markets for sales in Japan and in Indonesia.

3 Method and Results of Survey No. 1

3.1 Method of Survey No. 1: Choice of Fair Trade Wood Products

The flow of this survey is shown in Fig. 1. First, from results of this questionnaire, we selected some souvenirs in Bali that Japanese university students desire (Table 1). We asked village people whether they were able to produce them or not. We chose seven product items (A, key holder; B-1, B-2, B-3, bracelets of three kinds; C, wood carving; D, relief; E, art frame) that villagers can produce. We conducted another questionnaire survey in July 2013. Contents of this questionnaire are presented in Table 1. The subjects were first year to fourth year Bunkyo University students ($n = 54$) and university students ($n = 55$), except in Japan.

3.2 Results of Survey No. 1

Total respondents were 109 people. Details are 55 (men = 4, women = 50, no answer = 1) in Bunkyo University and 54 (men = 17, women = 36, no answer = 1) in university other than Bunkyo University. The sex ratio in Bunkyo University reflects the number of enrolled male students: 30 %. (Total men are 54. Total women are 86.)

Fig. 1 Flow of survey No. 1

Table 1 Contents of questionnaire in survey No. 1

1	Sex
2	Knowledge about fair trade
3	Purchase experience of fair trade goods
	For each of seven kinds of good
1	Degree of desire for the good
2	Reasonable price to buy goods in the case of ready-made
3	Reasonable price to buy goods in the case of fair trade

The method of response was a five-point Likert scale, with responses from *want* to *not want*. The difference of the mean between groups of university students was found only for the B-2 bracelet. Therefore, regarding B-2, the mean was found through the efforts of each university group. Furthermore, regarding other products, the means are found for these two groups as the total group. The result is presented in Table 2.

Among seven products, those with mean of more than three for the degree of preferences were A, B-1, B-2, B-3, and D.

The result of path analysis (covariance structure analysis) related to interest in fair trade is shown in Fig. 2 ($n = 109$). This figure shows that recognition of fair trade is connected slightly with interest in fair trade, but it is unrelated to the image of products for fair trade. Interest in fair trade slightly affects the image of fair trade

Table 2 Result of questionnaire in survey No. 1

	A	B-1	B-2	B-3	C	D	E
Bunkyo University	55	55	55	54	55	55	54
University (not Bunkyo)	52	49	52	51	51	51	50
Difference of the mean in the answer about degree of preference *Mann–Whitney *U* test	$p<0.811$	$p<0.681$	$p<0.000$	$p<0.087$	$p<0.294$	$p<0.566$	$p<0.873$
The mean in the answer about degree of preference (scale=5)	3.27	3.91	Bunkyo University, 4.20 University other than Bunkyo, 3.50	3.88	3.02	3.30	2.64
Expected price for purchase of ready-made goods (yen)	290	442	481	386	430	689	995
Expected price for purchase of fair trade goods (yen)	472	651	685	555	625	873	1,464
Degree of understanding about fair trade (yen)	182	209	204	169	195	184	469

A, key holder; B-1, B-2, B-3, bracelets of three kinds; C, wood carving; D, relief; E, art frame

products. Interest in fair trade is divisible into two modes of interest for fashion and for ethnic grocers. Interest for fashion was correlative with A, B-1, B-2, B-3, and D. Especially, this connects to B-1 and B-2. Interest for ethnic grocers was correlated with A, B-3, C, D, and E. Especially, this connects to A and E.

We were able to assess these considerations from results of path analysis. When university students specifically emphasize prevailing fashion, it is better to recommend bracelets of many kinds to them. Furthermore, when they emphasize ethnic fashion, it is better to recommend a key holder with a small wood carving and art frame.

Furthermore, the proper price for these products was found. Both reasonable prices for fair trade goods and for ready-made goods are shown in Table 2. As a result, the mean price that added some value for fair trade was 230 yen for fair trade products compared to the sale price of the ready-made article. Regarding E, the price

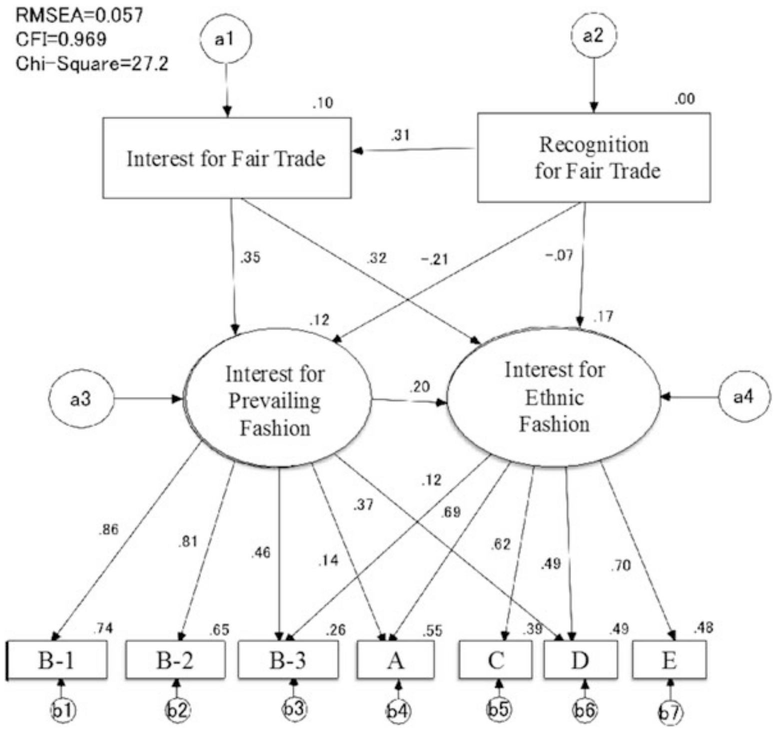

Fig. 2 Result of path analysis (covariance structure analysis) for interest in fair trade (*A*, key holder; *B-1*, *B-2*, *B-3*, bracelets of three kinds; *C*, wood carving; *D*, relief; *E*, art frame)

of added value is somewhat high, but when it is examined from this mean, we can ascertain that it increases around +200 yen to the price of ready-made articles when we assign prices for fair trade products.

4 Methods and Results of Survey No. 2

4.1 Methods of Survey No. 2: Feeling About Fair Trade Products of Handmade Paper

Regarding survey No. 2, we specifically examined handmade paper products. The questionnaires were divided into two steps. The contents of the questionnaire used for Step 1 were related to purchase experience and the target's preference for handmade paper. The contents of the questionnaire used for Step 2 were related to strong desire when targets purchase handmade paper. Subjects were university

Table 3 Respondents to questionnaire in survey No. 2

Bunkyo University		University other than Bunkyo	
Step 1	Step 2	Step 1	Step 2
$n = 110$	$n = 110$	$n = 106$	$n = 102$
Man = 41	Man = 38	Man = 38	Man = 35
Woman = 69	Woman = 67	Woman = 68	Woman = 67

Table 4 Contents of questionnaire in Step 1 of survey No. 2

	Step 1	Style of answer
Q1	Sex	Choice
Q2	Age	Choice
Q3	Occupation	Choice
Q4	Products they have purchased	Choice
Q5	Purpose to purchase	Choice
Q6	Degree of preference	Likert scale
Q7	Price at which they want to buy	Numeric value
Q8	Taste about handmade paper	Likert scale
Q9	Reasons they do not like handmade paper	Free answer

Table 5 Contents of questionnaire in Step 2 of survey No. 1

	Step 2	Style of answer
Q1	Sex	Choice
Q2	Age	Choice
Q3	Occupation	Choice
Q4	Strong will about “design sense”	Likert scale
Q5	Strong will about “manufacturing method and the land of origin”	Likert scale
Q6	Interest in “characteristics of the land of origin”	Likert scale
Q7	Shopping places where they want to buy	Likert scale
Q8	Characteristics of designs they like	Likert scale

students, Bunkyo University (Step 1, $n = 110$; Step 2, $n = 110$) and university other than Bunkyo University (Step 1, $n = 106$; Step 2, $n = 102$) in July 2014 (Tables 3, 4, and 5).

4.2 Results of Survey No. 2

According to results of Mann–Whitney U tests, a difference of the mean between men and women was found irrespective of the university group. Regarding Q4 in Step 1, similar tendencies of the answer between men and women were found. They have often purchased postcards and letter paper and mainly envelopes. Regarding Q4, the purpose for the use of the products was for domestic use and for gifts. The result of Q7 is shown in Table 2. The price at which they want to buy was the discount price of 20 % from the handmade paper products in Japanese markets

Table 6 Prices for handmade paper products for fair trade

Product	Price (yen)
Postcard (five-piece sets)	410
Letter (five-piece sets)	443
Envelope (five-piece sets)	479
Greeting card	340
Wrapping paper	511
Lampshade	1354
Luncheon mat	819

(Table 6). Regarding Q6 with multiple answers allowed, the products chosen by more than 60 % of them being responded with "want it a little," "want it," and "want it much" on a seven-point Likert scale were the letter paper and postcard. Furthermore, the products for which more than 50 % of them answered were envelopes, greeting cards, and lampshades. Regarding tastes related to handmade paper of Q8, 53 % (42/79) more than half of men answered "could say neither," and 42 % (33/79) of men answered as completely of "like it a little," "like it," and "like it much." In contrast, 36 % (49/137) of women answered "can say neither," and 70 % (96/137) more than half of the women answered as completely of "like it a little," "like it," and "like it much." This result demonstrated that women tended to like handmade paper more than men.

Furthermore, we obtained the results of covariance structure analysis as shown in Step 2 of survey No. 2. Responses of men and women differed, but we show results for women in Fig. 3 because there were many more women than men and because the result in the path figure was given correctly.

Examination of the results for women in Fig. 3 reveals their preferences for handmade products effect from their taste for the field of handmade products. These preferences are suitable for all products except lampshades. Especially they like letter paper and greeting cards, as well as postcards. The degree of preferences about handmade paper products is unaffected by design style and image. However, the image of the design itself is related to the terms elegant and gorgeous. The style of design itself links to the illustration irrespective of a print or a freehand drawing. The branding image of products is affected by properties of materials and traditional culture and by the land of origin. The place for purchases is the bookshop.

Regarding results of men, some different tendencies were found. Images of the design itself connect the cool and modern. Furthermore, the place for purchases is in art galleries, stationery shops, and bookshops. Another tendency of the results is that they were almost equivalent to those obtained for women.

Survey No. 2 results show that products with high probability for purchase by university students were letter paper, envelopes, and greeting cards. When the producer creates, it is better to use an image of a design with selection of elegant and gorgeous images for women and cool and modern images for men. As a common point for men and women, when handmade product paper is on sale, it is effective for the target to show descriptive labels. The brand image is often the main link associating products with properties of materials, traditional culture, etc.

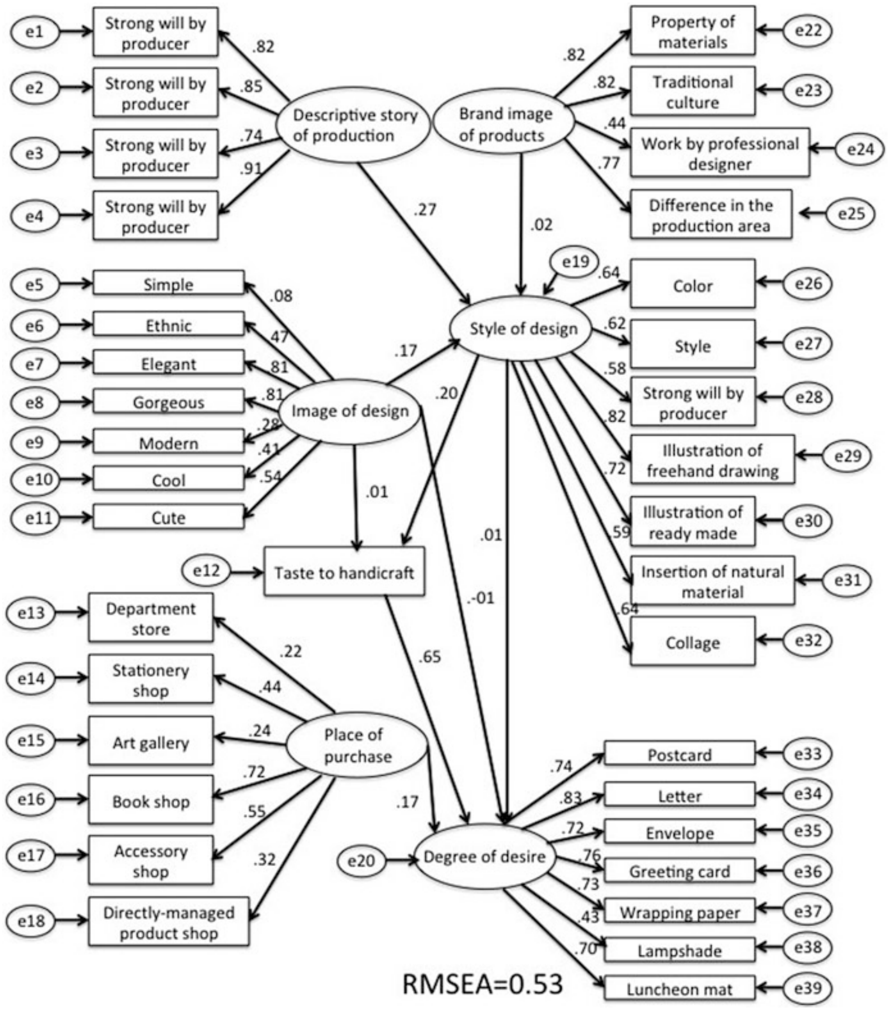

Fig. 3 Result of covariance structure analysis for feelings for handmade paper in Step 2 of survey No. 2

5 Consideration

By informing producers of the results of these surveys of the land of origin of handmade paper in Bali, Indonesia, handmade paper products that fit target tastes can be produced. Products with proper prices already have been sold at university festivals and other events. Additionally, we are going to increase markets to sell, for example, to local hotels in Bali Island and sales on the Internet, and shop channels of Japanese specialists of manual papermaking, such as Hosokawa paper ("Hiroko Tanino," a traditional artisan of Hosokawa paper).

The paper quality will continue to rise more if producers produce it many times. Furthermore, it is necessary for them to maintain a level of quality. As subjects of future surveys, we will use results of market research to sell popular handmade paper products more effectively and conduct surveys related to refined package design. We must clarify methods by which fair trade products can be sold consistently in Japanese markets.

References

Fair Trade Forum Japan (2015) The report of consciousness survey about "Fair trade and the ethical consumption"

Fairtrade Labelling Organizations International (FLO): Fairtrade International "Monitoring the Scope and Benefits of Fairtrade – Sixth edition – 2014"

Fairtrade Labelling Organizations International (FLO): Fairtrade International Official website. http://www.fairtrade.net/. Accessed 9 Dec 2015

FTSN (Fair Trade Student Network) Official website http://www.ftsnjapan.com/. Accessed 9 Dec 2015

goo research (2013.1) (No.212) Findings about the fair trade product

Mayuzumi Y, Mizunoya T, Higano Y (2014) Study of fair trade for Japanese market based on consumer needs. – research of the needs for handmade paper made in Indonesian local community. In: Proceedings of the 17th annual meeting of Japan Association for Human and Environmental Symbiosis, pp 141–145

Mayuzumi Y, Mizunoya T, and Higano Y (2014) Consciousness survey and practice for fair trade based on consumer needs. In: Proceedings of the 16th annual meeting of Japan Association for Human and Environmental Symbiosis, pp 270–274

NGO Bali Biodiversitas, and The government authorization in Indonesia, Bali Biodiversitas Foundation. http://www.langit-bali.com/bali_biodiversitas/index_jp.html

Statistics Japan, The population of Japan (November 1 2015): Used in the calculation of fair trade purchase amount per capita

Tesuki Washi Tanino: Official website of Hiroko Tanino of an expert in Hosokawa paper. http://monme.net

Social Public Spending in the Countries That Comprise the Andean Community of Nations (CAN)

Elizabeth Aponte, Emma B. Castro, and Lilian A. Carrillo

Abstract The Andean Community of Nations (CAN) is a South American economic and trade block that includes four countries: Colombia, Ecuador, Peru, and Bolivia. At the beginning of the 1990s, these countries made a bet for a higher economic growth through international trade. At the end of the decade, goals were prioritized and were oriented to improve the quality of life. It is in this last scenario that social policy takes a protagonist role in an environment of integration. According to that context, the aim of this work is to develop the following research question: Is social spending reflected in the improvement of quality of life conditions?

Results show a social spending growing tendency that has helped to reduce poverty levels, but an inadequate quality of life persists allowing to argue for a promising future. For example, analphabetism has been eradicated, but the education cycle is incomplete; mortality has decreased, but there are morbidities since two centuries ago (tuberculosis).

Keywords Public spending • Social spending • Social investment

1 Introduction

This research, developed by the authors within the research group (*Grupo de Investigación Economía y Desarrollo*, GIED), intends to draw a radiography, under an analytical and descriptive perspective, about the public spending and the social situation, especially in health and education, of the population from the CAN and its countries (see Fig. 1), from 1990 to 2010. It also compares decades which allows it to envision the changes in international paradigms that allowed guiding the improvements in the population quality of life. From that moment on, poverty is understood as a gap that requires a good economic dynamic in order to be

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Fig. 1 Andean Community of Nations (Reproduced from www.wikipedia.org)

eradicated; however, it is necessary to establish social policy goals so that the social spending takes a protagonist role in the policy actions to achieve welfare.

Results show the average behavior from the CAN in terms of social investment, not making exhaustive comparisons among countries due to the lack of disaggregated information, seeing the relative goodness from one another.

This document comprises five sections, including introduction and bibliography. The second section covers the theoretical context of social policy; the third section analyzes the macroeconomic priority indicator of social spending in the CAN countries with some social outcomes; the last section consists of concluding remarks.

2 Social Policy

During the mid-twentieth century at the London School of Economics and Political Science, Richard Titmuss stands out as the first professor who took an academic position about social policy, where social democratic ideas supported his theory that states that the government should take responsibility for the social welfare (Reisman 1997). However, there are multiple definitions of social policy (Donati 1985), among these are the following.

Montoro (1997) conceptualizes that social policy must be understood in a context of design and structured and planned implementation of all initiatives taken to address a series of needs considered basic for the population. In the same context, Quispe (1997) suggests that such policies should be directed toward overcoming poverty.

It could be said that, in a more precise way, Ortiz (2007) observes social policy as an instrument used by governments to regulate and supplement the market institutions and the social structures. In this respect, Midgley and Livermore (2009) state that policies adopted by governments meant to improve citizens' welfare are those so-called social, essentially those associated to health, education, housing, and income.

In this way, social policy is founded on the figure of the rule of law that contains a political, legal, and fiscal disposition to carry out programs intended to generate conditions for welfare. Nevertheless, it is not enough with these intentions; in addition, it requires some minimum conditions of society, like social cohesion (Midgley and Livermore 2009); the key part of this process is to motivate people for their performance in the society and the economy (International Monetary Fund, IMF 1998).

Social policies are a fundamental part of the set of public policies to organize a regulation that complements market institutions and social structures, ensuring redistribution of wealth, protection, cohesion, and social justice (United Nations Research Institute for Social Development, UNRISD 2011).

Social policy is divided in equity policies and social efficiency and compensation social programs. The first ones are addressed with integrity to motivate individuals (it comprises direct action plans in health and education for the entire population); the second ones develop explicit actions on the most needy and cover closing gaps on health and education, as well as housing, safety, and environment (Aponte 2008).

Likewise, these policies can be directed to specific groups or to the total population. Social policies should not be seen as a set of measures that apply in all cases, in all countries, and at all times; there are different circumstances that make each region to obtain different outcomes to the same social policies.

In this regard, in order to implement the social policy, Ortiz (2007) specifies that the environment variables are relevant to understand communities and achieve acceptance of such actions; in that sense, building a social diagnostic allows policy makers to understand and know what needs, obstacles, and risks are present.

In this sense, the importance of the size of national development is highlighted in order to make the most among the feasible with the available resources and avoid creating unachievable expectations that lead to macroeconomic imbalances (Ocampo 2010). These are the features of the concept of basic universalism (Molina 2006) or goods of social value (merit good).

In addition, Ocampo (2008) emphasizes that focalization should be seen not as a substitute but as a complement to universalization; in that sense, in a broad way, the best focalization is the universal social policy.

Therefore, social spending philosophy as a social policy instrument should be understood like the one who intends to close social gaps and scope welfare, which result from exclusion and rivalry market in the distribution and access of goods and services that meet the basic needs of the population. Hence, the budget allocated to social spending is considered as *social investment*, to the extent that in the medium and long run, they have an impact on improvements in the society quality of life in the quest for equity, poverty reduction, and welfare (Cardona 2011).

3 Social Spending in the CAN Countries

This section shows the results in social spending of the countries that comprise the CAN during 1990–2010. In this regard, it is pointed out that despite the effort made by the *Comisión Económica para América Latina y el Caribe* (CEPAL) in order to consolidate this information in a more uniform way, some discrepancies persist in terms of aggregation by type of spending and government basis which refers to central national government, nonfinancial public sector, and consolidated government; likewise, not all countries have data for the period studied; in this sight, it is not relevant to venture into deep comparative analysis within countries.

Social investment in the CAN sums just over 40 billion dollars (2005) in 2010. The formation of this expense through the years shows the following general characteristics: According to CEPAL data, Colombia is the country with the highest relative weight within the CAN countries (around 66 %); education is a very important social spending (around 33 %) that is losing relevance during the 2000s as social security spending defines a notable and increasing trend in its participation (around 40 %). In terms of countries, the general logic tends to be followed with some particularities: in the case of Peru, through the years, spending on housing acquires a very positive dynamic, while spending on social security, although it is important, is losing dynamic; in the case of countries like Ecuador and Bolivia, spending on education is always the predominant.

The total social spending trend as a proportion of gross domestic product (GDP) is growing strongly in the CAN until the end of the 1990s; from there, even though a higher peak is reached, it softens, increasing 2.70 percentage points compared to the previous decade (Table 1). Social spending per capita behaves similarly, following spending track as a proportion of GDP, but slightly higher than the last phase of the latter. This indicator increased on average 117 dollars during the analyzed decades, ranking in 318 dollars (2005) in this century, equivalent to a 60 % increase, approximately.

In terms of countries, in the early 2000s, Bolivia stands out by making a major social effort that allows it to achieve higher percentages (around 18 %) than the others: Colombia (around 12 %), Peru (around 9 %), and Ecuador (around 6 %).

Since the category of social security (the most important group in the whole CAN) is complex and given that education and health potentiate personal and productive development of the population, the main achievements are summarized involving the adequacy of housing as a variable that affects population's health.

Table 1 Social spending in the CAN

Indicator decade	Total social spending – millions of dollars 2005	Total population – millions of people	Total GDP – millions of dollars 2005	Social spending per capita – dollars 2005	% social spending – GDP
1990–1999 (average)	16,055	79	198,177	201	7.87
2000–2010 (average)	29,851	93	279,698	318	10.57
Difference	13,796	15	81,521	117	2.7

Source: GIED elaboration based on Cepalstat data, CEPAL in http://www.cepal.org/estadísticas

Table 2 Life expectancy at birth

Country/year	1990–1995	1995–2000	2000–2005	2005–2010
Bolivia	60.1	62.1	63.9	65.4
Colombia	68.7	70.3	71.7	72.9
Ecuador	70.1	72.3	74.2	74.9
Perú	66.8	69.3	71.6	73.1

Source: GIED elaboration based on Cepalstat data, CEPAL in http://www.cepal.org/estadísticas

About health, life expectancy in the countries of the CAN has increased over the period, being higher for women, led by Ecuador, while Bolivia is the country with the lowest rate; however, Peru is the country that has gained more years of life (6.3 years between 1990 and 2010) (Table 2).

Consequently, the mortality rate has decreased between 1990 and 2010 for all countries in different age groups of children and adults of both sexes, with Bolivia showing rates well above other countries. The main causes of death among children under 5 in recent years are prematurity and other diseases, while deaths from congenital anomalies are increasing. Meanwhile, conditions that lead to adult deaths are mainly cardiovascular (especially in Bolivia) and cancer (mainly in Peru) (Organización Mundial de la Salud, OMS 2012).

Other morbidities that require specialized care are human immunodeficiency virus (HIV) and tuberculosis; likewise, tropical diseases persist: malaria and mumps. In this panorama, Colombia stands out in all cases except tuberculosis, morbidity that has affected the most Peru and Bolivia (OMS 2012).

Now, housing characteristics are related to the issue of health. The percentage of the population living in slums (however, about 90 % of the urban population of the CAN has access to improved water sources), even though it is decreasing, is still high, especially for Bolivia and Peru, although the latter has been making a major effort in its reduction.

Regarding the satisfaction of education, some facts are detailed in subsequent paragraphs.

Through the period of analysis, illiteracy has declined considerably in the CAN. Particularly, Colombia has the lowest rate (6.6 % equivalent to approximately three million people), and Ecuador is the country that at the end of the period has the highest level for this indicator (17 % of the population, corresponding to 2.5 million people). Still, it is important to notice that even though in percentage Colombia has almost a third of Ecuador's illiteracy, Colombia exceeds by 500,000 in the number of illiterate people of Ecuador when expressing illiteracy in absolute values.

The characteristics of this indicator show that, in general, in rural areas illiteracy is more emphatic. Considering sex, Colombia is the only country where women have a lower percentage of illiteracy than men, whereas the difference in points by sex in Peru and Bolivia is large. In general, according to CEPAL data, illiteracy rate (it refers to the population over 15 years) in 2009–2010, arranged from the biggest to the lowest, is around 17 % (Ecuador), 10 % (Peru), 9 % (Bolivia), and 7 % (Colombia).

On the other hand, the situation is not as positive when the population in the four countries of the CAN does not cover secondary education, even though the coverage has improved vividly (over 80 %), which generates a dysfunction to potentiate access to higher education and technical preparation for the job market. In this sense, the average years of schooling for the population over 15 years old show that Ecuador has obtained better results in this indicator (9.2), followed by Peru (9.1); at a disaggregated level by areas, in the urban area, the order is inverted, leaving Peru in first place with 10.9 and Ecuador with 10.7, while in the rural area, Ecuador is again in the first position (6.3), followed by Peru (5.8). It is emphasized that Colombia is the country with the greatest deficiencies in this topic (8.6), while Bolivia outstands by its good progress (8.7 in 2009).

Lastly, although poverty has been reduced, it has not been the same so with inequality gaps: The Lorenz curve shows signs that overall inequality is high, stressing that Colombia has as much inequality as Bolivia, whereas Peru and Ecuador are less unequal (Fig. 2).

In that sense, the priority evolution in social spending for the CAN countries follows the implementation of policies intended to similar objectives, somehow influenced by the international environment that has been sheltering policies and strategies in order to eradicate extreme poverty, accompanied by specific social development policies promoted by the governing members of the CAN (see CEPAL-ILPES 2011 and General Secretariat Andean Community 2011).

Nevertheless, the implementation of the social policy in general follows the dynamic of the economy, fiscal priority of spending, and public finance conditions of the countries. During the 1990s, social spending had a pro-cyclical trend, while in 2000, in the upcoming Millennium Development Goal (MDG) policy, in general, this spending became countercyclical, supporting the fight against poverty and strengthening social protection, existing particularities according to the economic and social policy that frames each government in each economy (see CEPAL 2010, 2012).

Therefore, most of the national development plans (during the period of study) assign importance to goals about quality of life and accomplishments of equity and welfare, where the generation of productive employment, the provision of more and better social infrastructure, the access to education and health, and the substantial

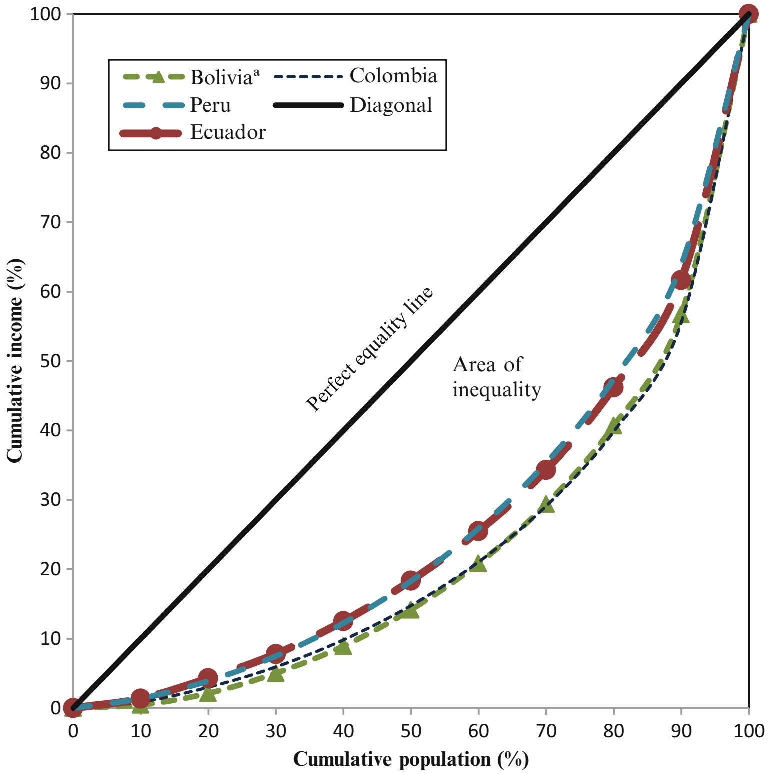

Fig. 2 Lorenz curve of the CAN countries 2010 (Source: according to http://www.cepal.org/estadísticas)

shrinking of poverty, among others, constitute pillars of public managements of governments.

Similarly, common plans and programs (not necessarily identical) are intended as a strategy for social development of the Andean population, contained mainly in the following topics, which acquire specific priorities at different times: democracy and human rights; social integration and poverty eradication; woman, child, and family; health and nutrition; environment and basic housing needs; education, science, and culture; productive employment and the economics of solidarity; and social security (General Secretariat of the CAN 2011). Though it should be noticed that this has been a long process of discussions and agreements, which the specification of a single canon was not possible in the period 2000–2010, it has let to start the design of themes for social integration.

On this matter, the second version of the Andean Social Agreement (1999) defined the following themes: youth, childhood, and adolescence; seniors; and indigenous people and Andean blacks and African people. As shown, the clarification of the themes is taking the way to vulnerable focus groups, later synchronized with the MDGs and the emphasis on climate change, biodiversity, and food security, committing each of the country members' government and their communities, especially through the Andean Social Agreement.

In these terms, social policy of the governments of the CAN is guided on the criterion of relatively boosting policies that maximize social impact referring to help existing gaps, but not necessarily to prevent the formation of these gaps, leaving this to the market, as space to generate opportunities for inclusion. In this way, for example, the analysis by CEPAL-ILPES (2011) on development plans in Latin America in this century states that although a common denominator is the exposure of inequalities reduction, decreasing poverty, and better standards of quality of life, it is also true that in their diagnostics, it is present the persistency of structural poverty, which parts of the endowment of public services and quality employment for all people, facts that are true paths, since as you go about its solution, the spending becomes.

4 Concluding Remarks

A relevant finding in this study is the fact that the fiscal effort in the CAN countries has been important, tracing an increasing tendency of total social spending as a share of GDP, as well as per capita social spending, especially to the late 1990s.

The per capita GDP of the CAN shows an increase among the decades, going from US$1,996 in 1990 to US$3,036 in 2010. By country, Colombia has the highest (US$3,955 in 2010), while Bolivia is the opposite case (US$1,191). By 2013, the per capita GDP of the CAN stays below 4,000 dollars.

In addition to the increase in the per capita GDP, social spending has allowed to improve living conditions, but still not enough to close social gaps, resulting in keeping poverty, though the indicator tends to decrease; for example, currently (2011–2013), the country that shows the greatest improvement in the Gini index is Bolivia with 0.472, and the level of education required, in order to potentiate the population as human capital, is still very weak (in any country, the achieved number of years of schooling has increased more than 0.4 point, getting a maximum of 3 or 4 years of secondary education).

As a result, long-term social conditions are not so clear, and, therefore, the possibility of reaching ideal states of inequality and welfare is limited; this will be the trend if policies continue being essentially directed to specific groups. It must generate a complementarity between the types of policy, which seems to have been abandoned during recent years in the CAN.

However, it is important to mention that within the context of integration, it has begun to establish pillars for social integration and this has allowed to talk the same international language of social character that results in consistent development plans among the governments of the four countries and respecting their specificities.

A policy recommendation for the best life, without the need of innovation in thought, just requests to put the symbiosis economy-society into practice. To break inequalities at the level of populations with all its characteristics, as well as between the territories, is an imperative act since there are disparities, and the most developed economies end up absorbing the problems of other countries, the fact that in the long run is counterproductive inside this big region and for its neighbors. In other words, positive convergences are important.

References

Aponte E (2008) Módulo de clase. Notas de teoría y política fiscal. Universidad Autónoma de Occidente. Publicación en medio magnético, Cali

Cardona LA (2011) Gasto público social- Colombia 2000–2010. Informe Final. Seminarios Técnicos DNP

CEPAL (2010) Panorama social de América Latina. Santiago de Chile

CEPAL (2012) Panorama social de América Latina, Santiago de Chile

CEPAL-ILPES (2011) Panorama de la gestión pública en América Latina. En la hora de la igualdad. Santiago de Chile, Naciones Unidas

Cepalstat (2009) Data bases and statistical publications. Economic commission for Latin America and Caribbean. Retrieved from www.eclac.org

Donati P (1985) Le frontiere della política social. Franco Angeli, Milan, p 7

IMF (1998) Should equity be a goal of economic policy?, IMF Fiscal Affairs Department Economic Issues, N. 16, Washington, DC

Midgley J, Livermore M (2009) Handbook of social policy. Sage Publications, Thousand Oaks

Molina CG (2006) Universalismo básico: una nueva política social para América Latina. BID, Washington, DC

Montoro R (1997) "Los fundamentos teóricos de la Política Social", en ALEMÁN C y GARCÉS, J (coord.): Política Social, MacGraw-Hill, Madrid; pp 33–50

Ocampo JA (2008) Las concepciones de la política social: universalismo versus focalización. Nueva Soc 215:36–61

Ocampo JA (2010) Políticas sociales para promover ciudadanía y cohesión social: serie reflexiones sobre políticas sociales y ambientales, CAF eds., Bogotá, pp 22

OMS (2012) Estadísticas sanitarias mundiales 2012, Switzerland. 64, 66, 72 y 86 pp., en http://apps.who.int/iris/bitstream

Ortiz I (2007) Política social. Estrategias nacionales de desarrollo: guías de orientación de políticas públicas. Organización de Naciones Unidas, New York, pp 7–12

Quispe E (1997) Política Social: retos y desafíos de la política social, Revista de la Facultad de Ciencias Económicas. No. 5. Lima: Universidad Nacional Mayor de San Marcos, 1997. pp 52

Reisman DA, Richard T (1997) Welfare and society. Heinemann Education Books, London

Secretaria General De La Comunidad Andina (2011) Revista de la Integración N.8. Políticas de desarrollo social en la Comunidad Andina

UNRISD (2011) Combating poverty and inequality: structural change, social policy and politics. UNRISD/UN publications, France, pp 4–10

Global Backward and Forward Multiplier Analysis: The Case Study of Japanese Automotive Industry

Sutee Anantsuksomsri, Nattapong Puttanapong, and Nij Tontisirin

Abstract Thailand is one of the major investment destinations of Japanese automotive industry. In addition to the major automobile companies, Japanese investors have also invested in small and medium enterprises in automobile parts and components in Thailand. Since the 1980s, the automotive industry has been a driving force of the Thai economy. Currently, Thailand is one of the world largest automobile producers. In this study, we analyze the global input-output table. Backward and forward multiplier analysis is used to conduct interindustry linkage analysis of Japanese automotive industry. Unlike a conventional trade statistical analysis, this global input-output table allows for the analysis of interconnection between economic sectors around the world. From our multiplier analysis, Japanese automotive industry has high backward linkages domestically. Internationally, its forward multiplier is among the top five after metal, chemicals and rubber, electrical and optical equipment, and wholesale and retail. In addition, structural path analysis is performed to illustrate the paths of global value chain of Japanese automotive industry. The analysis reveals the interconnection of automotive and other industries in Japan, Thailand, and the rest of the world.

Keywords Automotive industry • Input-output • Structural path analysis

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1 Introduction

The automotive industry consists of a wide range of activities including design, research and development, manufacturing, and marketing. These economic activities have taken place worldwide. In particular, Japanese automotive industry has taken the advantages of global value chain. As we can observe in a car assembling process, a manufacturer uses intermediate inputs from around the world. After the 1985 Plaza Accord, Japanese automotive industry has moved their production bases to many developing countries. These Japanese direct investments in other countries not only benefit the economies of the countries where factories are located but also the economy of Japan. However, increasing global interdependence of automotive producers may cause disruption in production if a producer of intermediate inputs in one country halts its production due to some difficulties from an economic crisis or disaster. In 2011, for example, the global supply chain of automotive industry faced difficulty from the impacts of Tsunami in Japan and flood in Thailand, emphasizing the vulnerability of the global value chain.

Thailand is one of the major investment destinations of Japanese automotive industry. It is the largest automobile producer in Southeast Asia and one of the largest producers in the world. Japan is the largest investor in Thailand in terms of amount of investment and number of projects. In addition to the major automobile companies such as Toyota, Honda, Nissan, Mazda, and Isuzu, Japanese investors have also invested in small and medium enterprises in automobile parts and components in Thailand. The automotive industry is a driving force of the Thai economy. It ranks the fifth largest export industry and accounts for ten percent of the GDP of the country, employs more than 500,000 direct skilled labor jobs, and creates spillover effects to other industries in the economy.

In this study, we analyze the global input-output table, which is publicly available on the World Input-Output Database (WIOD). In addition, we introduce the methodology of extending the WIOD table to cover additional data of Thailand based on sectoral distribution data from Global Trade Analysis Project (GTAP). Backward and forward multiplier analysis is used to conduct interindustry linkage analysis of Japanese automotive industry. Unlike a conventional trade statistical analysis, this global input-output table allows for the analysis of interconnection between economic sectors around the world. From our multiplier analysis, Japanese automotive industry has higher backward linkages domestically. Internationally, its forward multiplier is among the top five after metal, chemicals and rubber, electrical and optical equipment, and wholesale and retail. In addition, structural path analysis is performed to illustrate the influence of global value chain of Japanese automotive industry. The analysis reveals the strong interconnection of automotive industry and other industries in Japan, Thailand, and the rest of the world.

2 Japanese Automotive Industry

The legacy of Japanese automotive industry began in the 1910s. Nissan and Toyota started their business in 1933 after the World War I. But not until the 1950s, the Japanese automotive industry focused on producing their products mainly for commercial. The automotive industry has been one of the leading sectors in Japanese economy since the 1960s (Nakamura 1995). The industry grew rapidly during the 1970s–1990s because of domestic market and export. Japanese cars have become popular around the world since the 1970s due to their reasonable price and reliability. In 1980, Japan became the largest carmaker (OICA 2015). The following year, the USA imposed the voluntary export restriction on Japanese cars to limit the number of Japanese cars to the USA. In response, the Japanese automakers established assembly plants in the USA to locally produce cars in the USA (Feenstra 1984). In addition, as a result of the 1985 Plaza Accord, many Japanese automotive companies increased their investment abroad. The Japanese investment on automotive industry oversea has played an important role in the world economy.

2.1 Japanese Automotive Industry in Thailand

Thailand is currently one of the major car and automotive parts manufacturers in the global production network. Most of major automobile manufacturers, such as Hino, Honda, Mazda, Mitsubishi, Nissan, Suzuki, Toyota, Hyundai, Chevrolet, Ford, Chevrolet, BMW, Mercedes-Benz, MG, and Volvo, are located in Thailand. Among automotive manufacturers, there are approximately 690 Tier 1 automotive suppliers, employing more than 250,000 workers, and 1,700 Tier 2 and 3 companies, employing approximately 175,000 workers. More than half of the world leading automotive manufacturers have factories in Thailand (Thailand Board of Investment 2012). There are approximately 2,400 automotive suppliers in Thailand; more than 700 suppliers are original equipment manufacturers (OEMs) (Kohpaiboon and Athukorala 2010). This makes Thailand one of the strongest automotive suppliers producing all necessary automotive parts, from interior parts to exterior parts and from simple nuts and bolts to sophisticated engines.

The automotive industry began in Thailand in the 1960s (Rasiah 1999). Before that time, all cars in Thailand were imported from aboard. In 1961, Thailand government implemented "1960 Industrial Investment Promotion Act" to provide incentives for the automakers. Anglo-Thai Motor Company started to operate as the first automotive assembly plant in Thailand. The production of cars was 525 units in 1961 and became 10,667 units in 1970 (Thailand Development Research Institute 1993). In 1988, approximately 87,000 vehicles or 0.3 % of world automobile production was from Thailand (Thailand Development Research Institute 1997). In 2000, Thailand has become a major car producer with 411,721 units accounted for 0.7 % of world production capacity (OICA 2015). The domestic automobile production surpassed one million units in 2005 (Techakanont 2011). In 2010, Thailand produced 1,644,513 units of automobiles or 2.0 % of world production (OICA 2015).

In 2011, there was great flood in the central region of Thailand. One of the hardest hit industries by the flood is an automobile industry, which was already damaged by the East Japan Quake in March 2011. Many factories of automobile makers located in the flooded areas were forced to temporarily shut down. Some factories were under water for weeks and were forced to close for several months after this flood. However, only a year later, in 2012 the automobile industry quickly recovered from these disasters. The exceptionally high growth in both production and sales sectors in Thailand in 2012 pushed the car production to the new record, 2,429,142 units accounted for 7.2 % of world production (OICA 2015). In 2014, Thailand ranked as the largest carmaker in ASEAN and the 12th largest producer in the world (down from ninth in 2013) (OICA 2015).

The automotive industry has become highly export oriented since the mid-1990s, with exports increasing from 14,000 units of automobile in 1996 to 152,835 units in 2000 and 895,855 units in 2010. Vehicle exports have been accounted for more than 50 % of production since 2007. Over the period 2000–2011, exports accounted for 46.5 % of production (Thailand Automotive Institute 2012).

Japanese firms have played an important role in the automotive industry in Thailand since the beginning in the 1960s. In 1962, Nissan and Siam Motor established the first Japanese automobile plant in Thailand. In the following year, Toyota built a plant and began its operation. Isuzu and Hino have operated their businesses since 1963 and 1964, respectively. In 1974, the joint venture of Mazda Motor and local firm was founded. Honda started assembling cars in Thailand in 1984. Suzuki started producing 100,000 cars in Thailand in 2013. The Japanese automakers have assembled more than 85 % of car production in the past two decades (see Table 1). Many Japanese automotive firms have invested in Thailand to create their global and regional hubs of their productions.

2.2 Global Value Chain and World Input-Output Databases

Over the past few decades, the nature of international trade has changed dramatically due to increasing interconnectedness of production processes across many countries, with each country specializes in a particular stage of the production of goods (Hummels et al. 2001). These economic activities create international supply chain, which are the network of producers who produce raw and intermediate products in different regions and countries, and increase the flow of exports and imports among these countries. Hummels et al. (2001) call these dramatic changes in international

Table 1 Production capacity of automobile in Thailand (units)

	1989	1994	1999	2003	2005	2006	2013
Toyota	24,000	100,000	200,000	240,000	350,800	450,000	790,000
Mitsubishi	40,000	126,600	160,000	190,200	170,200	208,000	510,000
Isuzu	27,400	83,200	140,600	189,600	200,000	200,000	400,000
GM	–	–	40,000	40,000	100,000	160,000	250,000
Mazda	7200	8400	135,000	135,000	135,000	155,000	300,000
Ford							150,000
Nissan	23,520	96,500	113,100	124,000	102,000	134,400	370,000
Honda	8,220	39,000	70,000	80,000	120,000	120,000	270,000
Suzuki							100,000
Hino	9600	9600	9600	28,800	28,800	28,800	n.a.
Daimler	2340	4600	14,900	18,100	16,300	16,300	n.a.
YMC	12,000	12,000	12,000	12,000	12,000	12,000	n.a.
Volvo	6000	6000	6000	6000	10,000	10,000	100,000
BMW	–	–	–	–	10,000	10,000	3000
Total	160,280	485,900	901,200	1,063,700	1,255,100	1,576,500	3,243,000
Japanese ratio	87.31 %	95.35 %	91.91 %	92.85 %	88.18 %	86.15 %	84.49 %

Source: Kohpaiboon and Athukorala (2010)

trade "vertical specialization"—the use of imported inputs to produce exported outputs—and find that about 25 % of global trade could be categorized as a part of this vertical trade. A decade later, Escaith et al. (2010) find that the expansion of international supply chains contributed to an increase in trade elasticity, and over 50 % of the value of global trade was in the shipment of raw materials and intermediate inputs for production. Hayakawa (2007) also finds that increasing expenditure on intermediate goods is a contributing factor to rapid growth of trade in machinery parts in East Asia.

This increasing interdependence of different economic sectors across the globe has developed a need for more comprehensive databases that can be used to analyze such phenomenon. Global Trade Analysis Project (GTAP) was founded in the early 1990s as a network for researchers interested in global analysis issues. GTAP serves as a framework for multilateral trade analysis and provides data, models, and resources. Nonetheless, GTAP database is still needed to be adjusted to reflect more accurate trade balance. To analyze value added from international supply chain, Ahmad et al. (2011), Daudin et al. (2009), Johnson and Noguera (2012), and Koopman et al. (2008, 2011) used the GTAP database and found the values of trade balance have to be adjusted to reflect the volume of international shipment of intermediate goods. In Koopman et al. (2011), when adjusted, the US trade deficit to China may decrease about 30–40 %.

The notion of accounting for international supply chain has established a collaboration to create a global input-output database. Based on the data structure concept and applications of Leontief and Strout (1963) and Sanyal and Jones (1982), the World Input-Output Database (WIOD) was constructed by Dietzenbacher et al. (2013). The WIOD is a result of the compilation of 1995–2011 annual statistics of international trade and production structure of 35 sectors and 40 economies. The development of WIOD tables leads to the widespread application, especially for a deeper and broader insight of global production network. These WIOD tables are also main data sources for Timmer et al. (2013) and Ottaviano et al. (2014) to study impacts of the global production network on European economy. However, there is a limitation on a specific country's application due to the limited number of economies covered in the original data set. Therefore, this study introduces the methodology of extending the WIOD table to cover additional data of a specific economy. The method is described in the following section.

3 Methodology

3.1 World Input-Output Database Tables

World Input-Output Database (WIOD) serves as an important data system for analyzing the global value chain of Japanese automotive industry in this study. The WIOD contains sectoral transactions of 35 sectors in 40 economies from 1995 to 2011. Table 2 shows the sectors in WIOD, and Table 3 shows a list of countries included in WIOD. WIOD consists of four major components: world table, national table, socioeconomic accounts, and environmental accounts.

Since Thailand is not a country on the list of WIOD table, it is necessary to modify WIOD table so that it explicitly shows the trade and production statistics of Thailand. There are two major steps involved in this modification procedure. First, the dimension of WIOD table must be adjusted so that it is compatible with those of GTAP's global trade data because GTAP data is the main source of Thailand trade and production data. The second step involves consolidating two sources of data from WIOD and GTAP to formulate a modified WIOD table. In this study, 2007 data are used because it is the latest matching year for both WIOD table and GTAP data (Puttanapong 2015).

In the first step, WIOD table has been aggregated into the set of eight economies and 26 commodities. The aggregation is done in the General Algebraic Modeling System (GAMS) platform, and the GAMS code is developed based on computational techniques suggested by Corong (2007a, b), Jensen (2005), and Rutherford (2003). Countries are grouped based on the degree of trading partner with Thailand. The countries in the modified WIOD are (1) European Union (EU) countries, (2) the United States of America (USA), (3) China (CHN), (4) Japan (JPN), (5) South Korea (KOR), (6) Taiwan (TWN), (7) Thailand (TH), and (8) the rest of the world (ROW). The objective of data aggregation is to maintain the maximum number of sectors in WIOD and maintain the computability with GTAP's data. Table 4 shows

Table 2 Sectors in World Input-Output Database (WIOD)

Sector	Description
1	Agriculture, hunting, forestry, and fishing
2	Mining and quarrying
3	Food, beverages, and tobacco
4	Textiles and textile
5	Leather and footwear
6	Wood and products of wood and cork
7	Pulp, paper, printing, and publishing
8	Coke, refined petroleum, and nuclear fuel
9	Chemicals and chemical
10	Rubber and plastics
11	Other nonmetallic minerals
12	Basic metals and fabricated metals
13	Machinery, NEC
14	Electrical and optical equipment
15	Transport equipment
16	Manufacturing NEC; recycling
17	Electricity, gas, and water supply
18	Construction
19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
20	Wholesale trade and commission trade, except of motor vehicles and motorcycles
21	Retail trade, except of motor vehicles and motorcycles; repair of household goods
22	Hotels and restaurants
23	Other inland transport
24	Other water transport
25	Other air transport
26	Other supporting and auxiliary transport activities, activities of travel agencies
27	Post and telecommunications
28	Financial intermediation
29	Real estate activities
30	Renting of m&eq and other business activities
31	Public admin. and defense, compulsory social security
32	Education
33	Health and social work
34	Other community, social, and personal services
35	Private households with employed persons

the list of 26 sectors in the modified WIOD table in comparison with ISIC Rev. 3.1 code, classification in the original WIOD table, and GTAP sectors.

The GTAP's global trade data is extracted by using GTAPAgg, which is the GTAP software for data aggregation. Like the aggregated WIOD table, GTAP data contains 26 commodities of eight economies. Three major data sets for Thailand from the GTAP's data are the social accounting matrix (SAM), imports, and exports.

Table 3 Countries included in World Input-Output Database (WIOD)

European Union			North America	Latin America	Asia and Pacific
Austria	Germany	Netherlands	Canada	Brazil	China
Belgium	Greece	Poland	USA	Mexico	India
Bulgaria	Hungary	Portugal			Japan
Cyprus	Ireland	Romania			South Korea
Czech Republic	Italy	Slovak Republic			Australia
Denmark	Latvia	Slovenia			Taiwan
Estonia	Lithuania	Spain			Turkey
Finland	Luxembourg	Sweden			Indonesia
France	Malta	UK			Russia

In the second step, using the data from GTAP, the value of Thailand domestic economy and its international trades are disaggregated from the rest of the world in the WIOD table. With this procedure, 27 new rows and columns representing Thailand's production sectors are added to the WIOD table. To fill in the details of Thailand's production, the value of uses of imported intermediates in the WIOD table is extracted proportionally to the value of Thailand SAM from GTAP. All values in the rest of the world are then adjusted by subtracting with the value of Thailand to maintain the identical values of the total sums of each row and each column to the original WIOD table. The consolidation of the WIOD table and GTAP's data yields the global input-output table explicitly with Thai economy. The structure of the new input-output table is shown in Fig. 1.

3.2 Structural Path Analysis

Structural path analysis (SPA) can be employed as an extension of the input-output analysis to identify and measure flows in economy (Defourny and Thorbecke 1984). SPA decomposes the input-output multipliers and identifies a network of paths that are transmitted in the economic system. For more information of SPA, see Defourny and Thorbecke (1984), Azis and Mansury (2003), Lenzen (2007), and Anantsuksomsri and Tontisirin (2014). We calculated the multiplier effects of world input-output tables using the MATLAB code, originally developed by Cornell University Center for Advanced Computing (CAC). The CAC's MATLAB code improves the efficiency of multiplier calculation by implementing code on a modern matrix-oriented platform and can execute approximately 100 times faster than the original Visual Basic-based multiplier effect calculator software, MATS, developed by Berkeley Economic Advising and Research (Cornell University Center for Advanced Computing 2008).

Table 4 A Comparison of Sector Classification in the Modified WIOD Table, ISIC Rev. 3.1 Code, Original WIOD Table, and GTAP

New sector classification for consolidated WIOD table		ISIC Rev. 3.1 code	Original WIOD's sector classification	GTAP sector
1	Agriculture, hunting, forestry, and fishing	01–05	C1	prd, wht, gro, v_f, osd, c_b,
				pfb, ocr, prc, ctl, oap, rmk, wol, fsh, frs
2	Mining and quarrying	10–14	C2	coa, oil, gas, omn
3	Food, beverages, and tobacco	15–16	C3	cmt, omt, mil, sgr, ofd, vol,
				b_t
4	Textiles and textile products	17–19	C4–C5	tex, wap, lea
5	Wood and products of wood and cork	20	C6	lum
6	Pulp, paper, paper, printing, and publishing	21–22	C7	ppp
7	Coke, refined petroleum, and nuclear fuel	23	C8	p_c
8	Chemicals and rubber	24–25	C9–C10	crp
9	Other nonmetallic mineral	26	C11	nmm
10	Basic metals and fabricated metals	27–28	C12	i_s, nfm, fmp
11	Machinery	29	C13	otn
12	Electrical and optical equipment	30–33	C14	ele, ome
13	Transport equipment	34–35	C15	mvh
14	Manufacturing	36–37	C16	omf
15	Electricity, gas, and water supply	40–41	C17	ely, gdt, wtr
16	Construction	45	C18	cns
17	Wholesale and retail and hotels and restaurants	50–55	C19–C22	trd
18	Inland transport	60, 63	C23, C26	otp
19	Water transport	61	C24	wtp
20	Air transport and others	62	C25	atp
21	Post and telecommunications	64	C27	cmn
22	Financial intermediation	65–66	C28	ofi, isr
23	Real estate activities and renting	70–74	C29–C30	obs
24	Public admin and defense and health and education	75, 80, 85	C31–C33	osg
25	Other community, social, and personal services	90–95	C34–C35	ros
26	Private households with employed persons	–	–	dwe

Source: Puttanapong (2015)

	EU Industry	USA Industry	CHN Industry	JPN Industry	KOR Industry	TWN Industry	TH Industry	ROW Industry	
EU Industry	EU's intermediate use of domestic output	Intermediate use by USA (imported from EU)	Intermediate use by CHN (imported from EU)	Intermediate use by JPN (imported from EU)	Intermediate use by KOR (imported from EU)	Intermediate use by TWN (imported from EU)	Intermediate use by TH (imported from EU)	Intermediate use by ROW (imported from EU)	Final Demand of EU
USA Industry	Intermediate use by EU (imported from USA)	USA's intermediate use of domestic output	Intermediate use by CHN (imported from USA)	Intermediate use by JPN (imported from USA)	Intermediate use by KOR (imported from USA)	Intermediate use by TWN (imported from USA)	Intermediate use by TH (imported from USA)	Intermediate use by ROW (imported from USA)	Final Demand of USA
CHN Industry	Intermediate use by EU (imported from CHN)	Intermediate use by USA (imported from CHN)	CHN's intermediate use of domestic output	Intermediate use by JPN (imported from CHN)	Intermediate use by KOR (imported from CHN)	Intermediate use by TWN (imported from CHN)	Intermediate use by TH (imported from EU)	Intermediate use by ROW (imported from EU)	Final Demand of CHN
JPN Industry	Intermediate use by EU (imported from JPN)	Intermediate use by USA (imported from JPN)	Intermediate use by CHN (imported from JPN)	JPN's intermediate use of domestic output	Intermediate use by KOR (imported from JPN)	Intermediate use by TWN (imported from JPN)	Intermediate use by TH (imported from JPN)	Intermediate use by ROW (imported from JPN)	Final Demand of JPN
KOR Industry	Intermediate use by EU (imported from KOR)	Intermediate use by USA (imported from KOR)	Intermediate use by CHN (imported from KOR)	Intermediate use by JPN (imported from KOR)	KOR's intermediate use of domestic output	Intermediate use by TWN (imported from KOR)	Intermediate use by TH (imported from KOR)	Intermediate use by ROW (imported from KOR)	Final Demand of KOR
USA Industry	Intermediate use by EU (imported from TWN)	Intermediate use by USA (imported from TWN)	Intermediate use by CHN (imported from TWN)	Intermediate use by JPN (imported from TWN)	Intermediate use by KOR (imported from TWN)	TWN's intermediate use of domestic output	Intermediate use by TH (imported from TWN)	Intermediate use by ROW (imported from TWN)	Final Demand of TWN
TH Industry	Intermediate use by EU (imported from TH)	Intermediate use by USA (imported from TH)	Intermediate use by CHN (imported from TH)	Intermediate use by JPN (imported from TH)	Intermediate use by KOR (imported from TH)	Intermediate use by TWN (imported from TH)	TH's intermediate use of domestic output	Intermediate use by ROW (imported from TH)	Final Demand of TH
ROW Industry	Intermediate use by EU (imported from ROW)	Intermediate use by USA (imported from ROW)	Intermediate use by CHN (imported from ROW)	Intermediate use by JPN (imported from ROW)	Intermediate use by KOR (imported from ROW)	Intermediate use by TWN (imported from ROW)	Intermediate use by TH (imported from ROW)	ROW's Intermediate use of domestic output	Final Demand of ROW
	Value-Added of EU	Value-Added of USA	Value-Added of CHN	Value-Added of JPN	Value-Added of KOR	Value-Added of TWN	Value-Added of TH	Value-Added of ROW	

Fig. 1 The structure of modified WIOD table

4 Results

4.1 Japan Backward and Forward Multipliers

Backward and forward multipliers of Japanese sectors are calculated to show the linkages to both domestic and international industries. Figure 2 shows domestic backward and forward linkages of production sectors in Japan. Transport equipment sector is used as a proxy to the automotive industry. Among the 26 sectors, the automotive industry has the highest domestic backward multiplier, suggesting a strong interconnection of the automotive industry and its local suppliers. As expected, wholesale, retail, hotel, and restaurant sector has the highest forward multiplier. Although the forward multiplier of the automotive industry is not the highest domestically, it is among the top ten industries that have strong domestic linkages.

Internationally, Japanese automotive industry is among the highest forward multipliers industries. As shown in Fig. 3, the forward multiplier of Japanese automotive industry is the fifth highest, following metal, chemical and rubber,

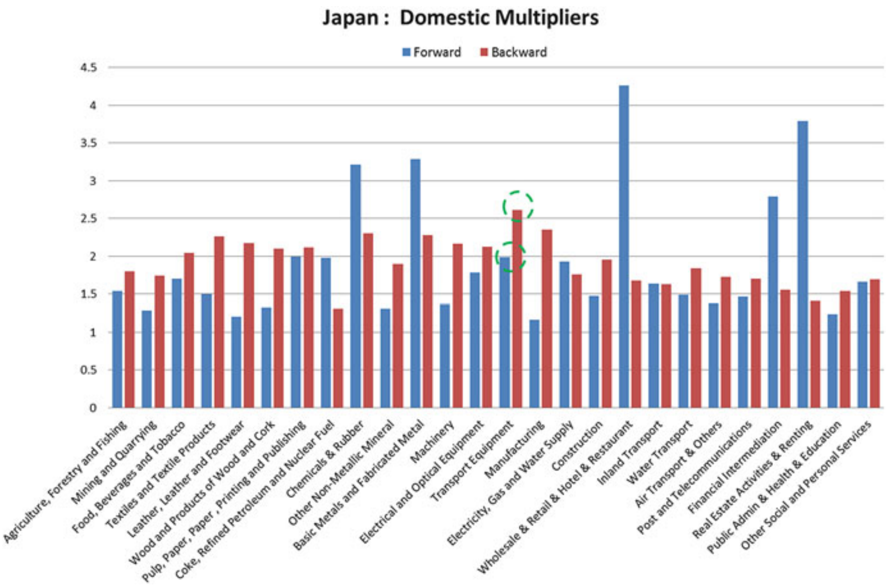

Fig. 2 Japan domestic backward and forward multipliers

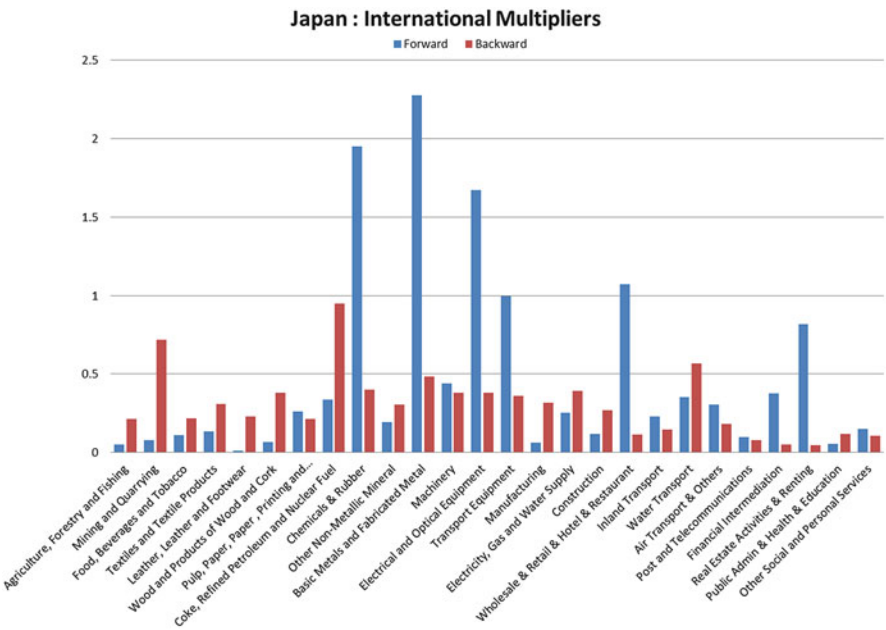

Fig. 3 Japan international backward and forward multipliers

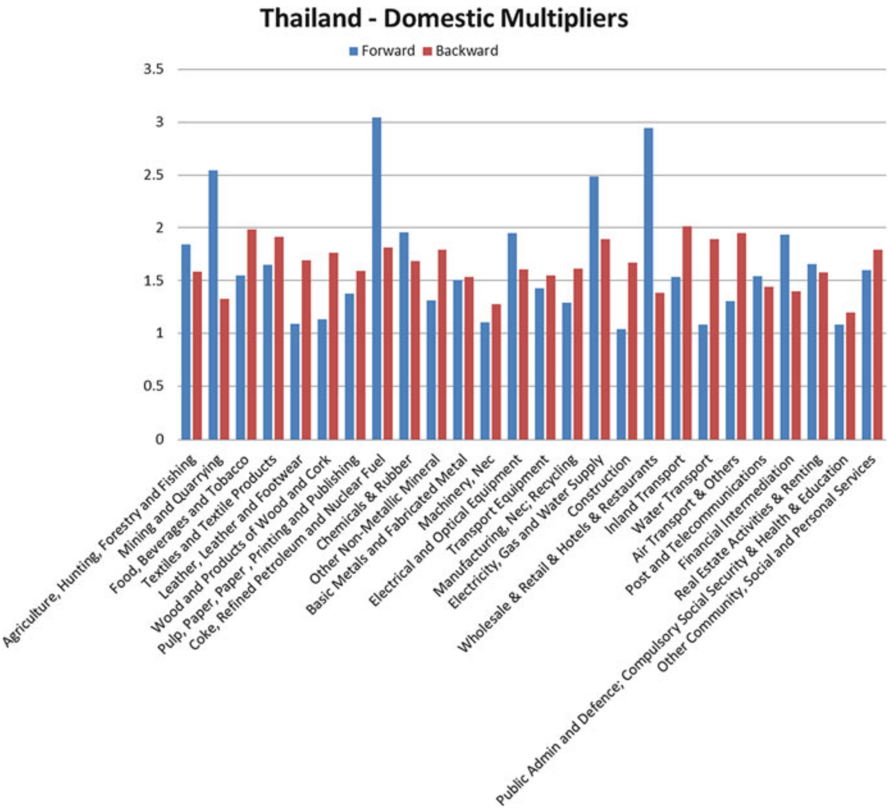

Fig. 4 Thailand domestic backward and forward multipliers

electrical and optical equipment, and wholesale, retail, hotel, and restaurant sectors, respectively. The high forward multiplier of automotive industry suggests the strong interconnection of Japanese automotive industry to its customers around the world.

4.2 Thailand Backward and Forward Multipliers

Thailand domestic backward and forward multipliers are shown in Fig. 4. The sectors in Thailand with the highest domestic backward multiplier are (1) inland transport; (2) food, beverage, and tobacco; (3) air transport; (4) textiles; and (5) water transport, respectively. Unlike Japan, the automotive industry in Thailand does not have a strong backward linkage locally. On the other hand, the sectors in

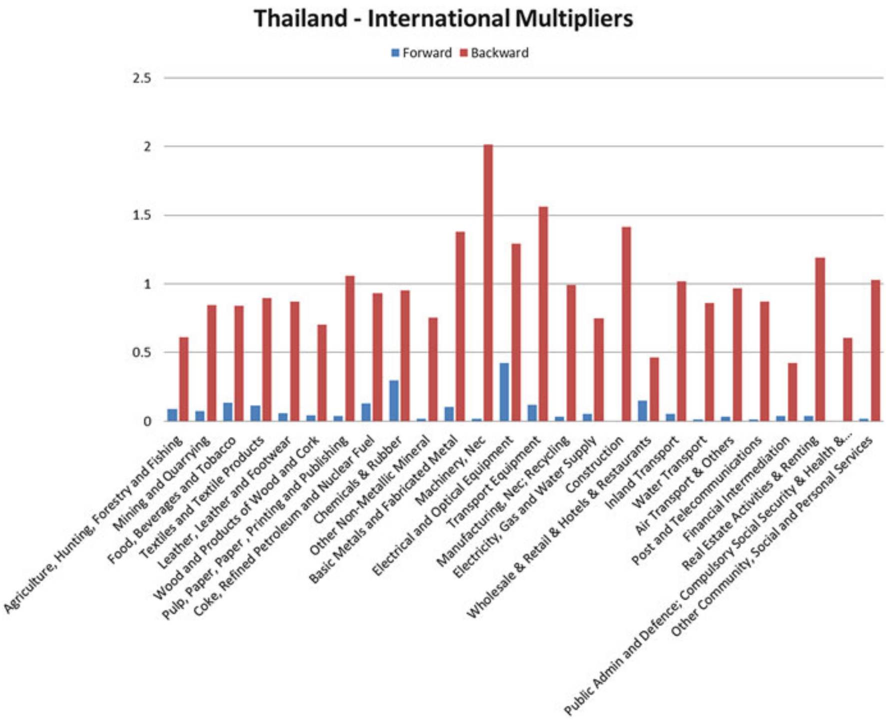

Fig. 5 Thailand international backward and forward multipliers

Thailand with the highest domestic forward multiplier illustrate the manufacturing-based nature of Thai economy. These sectors with the highest domestic forward multiplier are (1) coke, refined petroleum, and nuclear fuel; (2) wholesale, retail, hotel, and restaurant; (3) mining; (4) electricity, gas, and water supply; and (5) chemical and rubber, most of which are intermediate inputs for production. Overall, automotive industry in Thailand has a moderate forward and backward linkage locally.

Thailand international multipliers, however, are different from its domestic multipliers. Figure 5 shows international backward and forward multipliers of Thailand sectors. Internationally, backward multipliers of sectors in Thailand are significantly higher than forward multipliers. These high backward multipliers suggest that Thailand industries are strongly linked to the global supply chain through their international suppliers. The sectors with the highest backward multipliers are (1) machinery, (2) automotive industry (transport equipment), (3) construction, (4) metal, and (5) electrical and optical equipment, respectively. The multipliers also show that Thailand industries rely on their international suppliers much more than Japan industries.

4.3 Structural Path Analysis

The parameter settings for SPA are for the minimum threshold of path influence and the maximum number of arcs. In this analysis, the threshold of path influence and the number of arcs are set to 0.0001 and 4, respectively. As such, a path with the influence lower than 0.0001 or with the number of arc more than 4 will be excluded from the result. After all paths have been calculated, they are ranked according to their total influence values. Only top 100 and 200 are reported in the following section.

4.3.1 The Top 100 Highest Influence Values

To analyze the global influence of Japan industries, multipliers of all sectors from eight economies are decomposed and ranked. Table 5 shows the top 100 highest influences by sectors of origin. Out of the 100 highest influence paths, 77 paths originated in Japan, while the remainder is from other seven economies. The sum of total influence from Japan is 0.78, which accounted for 90 % of the sum of total influences of these highest 100 paths. The results suggest the dominance of Japan industries and its interconnectedness to the global economies.

4.3.2 The Top 200 Highest Influence Values

Table 6 shows the 200 highest influence paths. Out of the top 200, 145 paths have originated in Japan, while the other 55 originated elsewhere. Japanese sectors are among the top that is the source of most of the highest influences to the global economy. In comparison to 145 paths from Japan, 11 paths are from China, 9 from European economies, and 11 from the USA. Out of these 145 paths, basic metals and fabricated metals are the sector with the highest value of influences with 33 paths; followed by 24 paths from chemical and rubber sector; 18 paths from wholesale, retail, hotel, and restaurant; and 18 paths from electrical and optical equipment. Automotive industry is ranked the ninth in Japan and has originated six paths with the influence value of 0.021. As for Thailand, there are two sectors that have high influence from Thailand: transport equipment and electrical and optical equipment sectors.

5 Conclusions

The change of production process has made economies throughout the world increasingly interconnected. A country specializes in a particular stage of the production of goods and becomes a part of international supply chain. International

Table 5 The top 100 of highest influence values

Sector of Origin	Count of total influence	Sum of total influence
CHN	7	0.0260124
Transport equipment	2	0.0108522
Electrical and optical equipment	2	0.0084255
Basic metals and fabricated metals	1	0.0027729
Chemicals and rubber	1	0.0027661
Machinery	1	0.0011957
EU	2	0.0097641
Transport equipment	1	0.0073893
Basic metals and fabricated metals	1	0.0023748
JPN	77	0.7800027
Basic metals and fabricated metals	21	0.2494465
Chemicals and rubber	12	0.1321461
Wholesale and retail and hotel and restaurant	6	0.1080716
Electrical and optical equipment	6	0.0782295
Real estate activities and renting	4	0.0532993
Machinery	6	0.0365426
Electricity, gas, and water supply	5	0.0249906
Financial intermediation	2	0.0224786
Inland transport	1	0.0161991
Other nonmetallic minerals	2	0.0141421
Coke, refined petroleum, and nuclear fuel	2	0.0070947
Other social and personal services	1	0.0060180
Pulp, paper, paper, printing, and publishing	1	0.0058972
Air transport and others	1	0.0049450
Water transport	1	0.0042140
Textiles and textile products	1	0.0038116
Post and telecommunications	1	0.0030144
Construction	1	0.0027825
Manufacturing, NEC; recycling	1	0.0026699
Public admin and health and education	1	0.0020973
Wood and products of wood and cork	1	0.0019121
KOR	3	0.0066681
Basic metals and fabricated metals	1	0.0026078
Transport equipment	1	0.0024287
Electrical and optical equipment	1	0.0016316
ROW	5	0.0205289
Basic metals and fabricated metals	2	0.0104851
Transport equipment	2	0.0097348
Chemicals and rubber	1	0.0014225
TH	2	0.0044635
Transport equipment	1	0.0026346
Electrical and optical equipment	1	0.0018290
TWN	1	0.0012002
Transport equipment	1	0.0012002
USA	3	0.0146985
Transport equipment	3	0.0146985
Grand total	100	0.8644520

Table 6 The top 200 of highest influence values

Sector of Origin	Count of total influence	Sum of total influence
CHN	11	0.0289671
Transport equipment	5	0.0130333
Electrical and optical equipment	3	0.0091991
Basic metals and fabricated metals	1	0.0027729
Chemicals and rubber	1	0.0027661
Machinery	1	0.0011957
EU	9	0.0145859
Transport equipment	5	0.0101359
Basic metals and fabricated metals	1	0.0023748
Chemicals and rubber	1	0.0007841
Electrical and optical equipment	1	0.0007450
Machinery	1	0.0005462
JPN	145	0.8307073
Basic metals and fabricated metals	33	0.2576390
Chemicals and rubber	24	0.1402734
Wholesale and retail and hotel and restaurant	18	0.1188294
Electrical and optical equipment	18	0.0869346
Real estate activities and renting	5	0.0543370
Machinery	6	0.0365426
Electricity, gas, and water supply	7	0.0267327
Financial intermediation	3	0.0230969
Inland transport	6	0.0207596
Other nonmetallic mineral	8	0.0178727
Coke, refined petroleum, and nuclear fuel	2	0.0070947
Pulp, paper, paper, printing, and publishing	3	0.0070906
Other social and personal services	1	0.0060180
Air transport and others	2	0.0055540
Water transport	1	0.0042140
Textiles and textile products	1	0.0038116
Construction	2	0.0032932
Post and telecommunications	1	0.0030144
Manufacturing, NEC; recycling	1	0.0026699
Public admin and health and education	1	0.0020973
Wood and products of wood and cork	1	0.0019121
Food, beverages, and tobacco	1	0.0009197
KOR	5	0.0080060
Basic metals and fabricated metals	1	0.0026078
Transport equipment	1	0.0024287
Electrical and optical equipment	1	0.0016316
Water transport	1	0.0007225
Chemicals and rubber	1	0.0006154
ROW	14	0.0254855

(continued)

Table 6 (continued)

Sector of Origin	Count of total influence	Sum of total influence
Basic metals and fabricated metals	3	0.0121755
Transport equipment	4	0.0115934
Chemicals and rubber	1	0.0020948
Machinery	1	0.001057
Mining and quarrying	1	0.0006217
Wholesale and retail and hotel and restaurant	1	0.0005797
TH	2	0.0044635
Transport equipment	1	0.0026346
Electrical and optical equipment	1	0.0018290
TWN	3	0.0025011
Transport equipment	1	0.0012002
Electrical and optical equipment	1	0.0006682
Basic metals and fabricated metals	1	0.0006326
USA	11	0.0202938
Transport equipment	6	0.0164888
Electrical and optical equipment	1	0.0010284
Basic metals and fabricated metals	1	0.0008413
Chemicals and rubber	1	0.0007502
Machinery	1	0.0006736
Real estate activities and renting	1	0.0005115
Grand total	200	0.9376470

trade is no longer for raw materials or final goods but for intermediate inputs for a production of goods. As a result, economies throughout the world become highly interlinked through this network of international supply chain.

Japanese automotive industry is among the industries that take advantage of this global value chain since the automotive industry involves many production processes, from design, manufacturing, to marketing. A car, for example, may be designed in Japan, while the car assembling process may take place in a plant in Thailand using the intermediate inputs from around the world.

This study examines the global backward and forward multiplier of industries in Japan and Thailand, focusing on the automotive industry, as well as global influences of production sectors from eight economies. It employs input-output multiplier analysis and structural path analysis as an analytical framework. The analysis utilizes the World Input-Output Database (WIOD) table as a data system with some modifications to incorporate Thailand data in the table. Inland transport sector is used as a proxy for automotive industry.

The results of input-output multiplier analysis show that domestically Japanese automotive industry has a very strong backward linkage to other local industries. Internationally, Japanese automotive industry is among the top sectors with high forward influence. Thailand automotive industry does not have as strong domestic linkage as Japan. However, Thailand automotive industry is the second highest backward linkage to international economies. The results of the structural path analysis reveal that Japan is the leader in generating economic impacts both locally and globally. Japan industries contribute to 77 out of 100 highest influence paths and 145 out of 200 highest influence paths in the world. Japanese automotive industry originates one dominant impact in the top 100 and six paths in the top 200.

The extensions of this analysis include disaggregating automotive industry from inland transport sector and building a global CGE model to examine the interconnection of the automotive industry to other economies in the world.

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References

Ahmad N, Escaith H, Miroudot S, Webb C, Yamamo N (2011) Trade in value-added: concepts, methodologies, and challenges. Joint OECD/WTO Note. Retrieved from http://www.oecd.org/sti/ind/49894138.pdf

Anantsuksomsri S, Tontisirin N (2014) Distributional impact of university-led revitalization on the neighborhood economy: a computable general equilibrium model of a small urban area. Int J Build Urban Inter Landsc Technol 4:5–22

Azis IJ, Mansury Y (2003) Measuring economy-wide impacts of a financial shock. J Southeast Asian Econ 20(2):112–127

Cornell University Center for Advanced Computing (2008) Modeling Cornell's economic impact on New York. Retrieved from https://www.cac.cornell.edu/about/studies/Azis.pdf

Corong E (2007a) Input_Output_2.gms: the accompanying GAMS code for the note— aggregating input-output table in GAMS: accounting for changes in sectoral aggregation. Poverty and Economic Policy (PEP) Research Network. Available at www.pep-net.org

Corong E (2007b) Aggregating input-output table in GAMS. Poverty and Economic Policy (PEP) Research Network. Available at www.pep-net.org

Daudin G, Rifflart C, Schweisguth D (2009) Who produces for whom in the world economy? Can J Econ 44(4):1403–1437

Defourny J, Thorbecke E (1984) Structural path analysis and multiplier decomposition within a social accounting matrix framework. Econ J 94(373):111–136

Dietzenbacher E, Los B, Stehrer R, Timmer M, de Vries G (2013) The construction of world input-output table in the WIOD project. Econ Syst Res 25(1):71–98

Escaith H, Lindenberg N, Miroudot S (2010) International supply chains and trade elasticity in times of global crisis. World Trade Organization Economic Research and Statistics Division. Staff Working Paper ERSD-2010-08. Retrieved from https://www.wto.org/english/res_e/reser_e/ersd201008_e.pdf

Feenstra RC (1984) Voluntary export restraint in U.S. Autos, 1980–81: quality, employment, and welfare effects. In: National Bureau of Economic Research Chapters (ed) The structure and evolution of recent U.S. Trade Policy, Inc., University of Chicago Press, Chicago, pp 35–66

Hayakawa K (2007) Growth of intermediate goods trade in East Asia. Pac Econ Rev 12(4):511–523

Hummels D, Ishii J, Yi K (2001) The nature and growth of vertical specialization in world trade. J Int Econ 54(1):75–96

International Organization of Motor Vehicle Manufacturers (OICA) (2015) World motor vehicle production by Country and Type. Retrieved from http://www.oica.net/category/production-statistics/

Jensen J (2005) Lecture on: aggregating input-output tables using GDX. Introduction to CGE modeling using GAMS and MPS/GE. Essen, Germany. Jesper Jensen's website: www.tecatraining.dk
Johnson RC, Noguera G (2012) Accounting for intermediates: production sharing and trade in value added. J Int Econ 86(2):224–236
Kohpaiboon A, Athukorala P (2010) Detroit of the East: Thailand in global automobile networks. Paper submitted to Study for the International Trade Centre, Geneva
Koopman R, Wang Z, Wei S J (2008) How much Chinese exports is really made in China – assessing foreign and domestic value-added in gross exports. NBER Working Paper No. 14109
Koopman R, Powers W, Wang Z, Wei S J (2011) Give credit to where credit is due: tracing value added in global production chains. NBER Working Papers No. 16426
Lenzen M (2007) Structural path analysis of ecosystem networks. Ecol Model 200(3–4):334–342
Leontief W, Strout A (1963) Multiregional input-output analysis. In: Barna T (ed) Structural interdependence and economic development. St-Martin's Press, New York, pp 119–150
Nakamura T (1995) The postwar Japanese economy: its development and structure, 1937–1994, 2nd edn. University of Tokyo Press, Tokyo
Ottaviano G, Pessoa JP, Sampson T, van Reenen J (2014) The costs and benefits of leaving the EU, No 472, CFS Working Paper Series, Center for Financial Studies (CFS). http://EconPapers.repec.org/RePEc:zbw:cfswop:472
Puttanapong N (2015) Tracing and quantifying Thailand's linkages to international supply chains: the modification of world input-output database and the application of multiplier and structural path analysis. Proceedings, Singapore Economic Review Conference 2015
Rasiah R (1999) Liberalization and the car industry in South East Asia. Occasional Paper No. 99, Department of Intercultural Communication and Management, Copenhagen Business School
Rutherford T (2003) A GAMS program which maps social accounting data into labeled submatrices. University of Colorado, Boulder. Available at www.mpsge.org
Sanyal K, Jones R (1982) The theory of trade in middle products. Am Econ Rev 72(1):16–31
Techakanont K (2011) Thailand automotive parts industry. In: Kagami M (ed) Intermediate goods trade in east Asia: economic deepening through FTAs/EPAs. BRC research report no. 5. Bangkok Research Center, IDE-JETRO, Bangkok, pp 192–229
Thailand Automotive Institute (2012) Master plan for automotive industry 2012–2016. Ministry of Industry, Bangkok
Thailand Board of Investment (2012) Opportunities in Thailand's automotive industry. Retrieved from http://www.boi.go.th/index.php?page=opp_automotive
Thailand Development Research Institute (1993) TNC involvement in the Thai auto industry. TDRI Quarterly Review (in Thai)
Thailand Development Research Institute (1997) Master plan for industrial development (in Thai)
Timmer M, Los B, Stehrer R, de Vries G (2013) Fragmentation, incomes, and jobs: an analysis of European competitiveness. Econ Policy 11(4):613–661

Transportation Infrastructure and Economic Growth in China: A Meta-analysis

Zhenhua Chen and Kingsley E. Haynes

Abstract Transportation infrastructure has experienced a rapid development in China over the past decade. Although the economic contribution of transportation infrastructure has been widely examined in the literature using various data and approaches, the understanding remains unsatisfactory as the economic output elasticities for transportation are found to vary substantially across different studies. Our study improves the understanding of the linkages between transportation infrastructure and economic growth with a focus on China using a meta-analysis. Through a statistical analysis of 133 estimates from 18 empirical studies, our results find that the average output elasticity of the Chinese transportation system is 0.13. Variations in earlier estimates were found to be due to the different dependent variables, transportation variables, control variables, data, and models being used. Although the results are generally consistent with previous studies based on different survey samples, some unique characteristics of the Chinese economy and its transportation system are found to play a significant role. These should be considered carefully and suggest interpretive cautious in future research endeavors.

Keywords Transportation infrastructure • Economic growth • China • Meta-analysis

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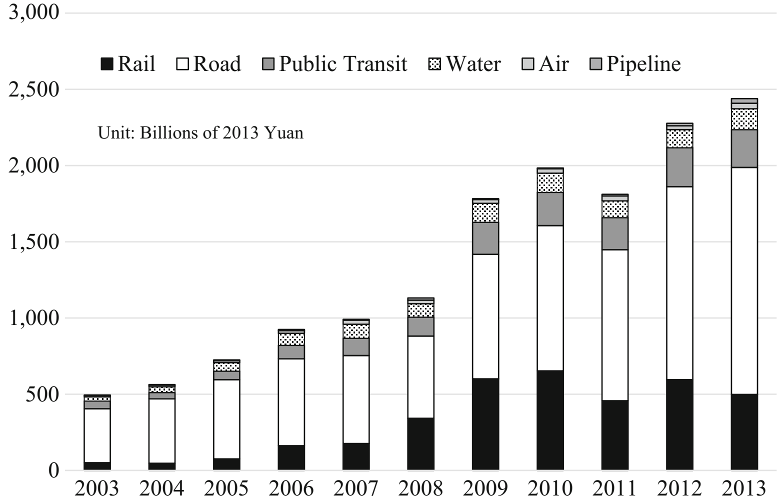

Fig. 1 New added infrastructure by mode in China (Source: the National Bureau of Statisics)

1 Introduction

Transportation infrastructures in China have experienced unprecedented evolution in the last decade due to strong government support of public infrastructure investment. As illustrated in Fig. 1, transportation infrastructures, such as road, rail, and public transit, experienced rapid development during the period 2003–2013. The average growth rate of infrastructure investment was 18 %. Each year, approximately $200 billion of government funds were allocated for the development of various transportation infrastructures, such as highways, high-speed rail, urban metro systems, and airports. Such an ambitious investment in transportation infrastructure has fundamentally changed the Chinese economy and society. On one hand, the improved accessibility of freight and passenger mobility facilitated regional trade flows and increased the allocative efficiency of factor endowments, which in turn improved the productivity of economic activities. On the other hand, transportation bottleneck constraints due to a shortage of infrastructure supply were alleviated as new infrastructures were built. Meanwhile, a reduction of transportation costs was expected to promote an expansion of travel demand, which in turn would further promote economic growth. Although the positive stimulus effect of transportation infrastructure on economic growth has been generally recognized among scholars and practitioners, it is unclear as to what extent the contribution to economic growth is attributable to transportation infrastructure investments. In other words, what is the magnitude of output elasticity that Chinese transportation infrastructure possesses? This question needs to be addressed.

Part of the reasons for the lack of a valid understanding of transportation's role in economic growth in China is due to the simultaneous interaction between transportation infrastructure and economic activities. To capture this complex interaction, general equilibrium analysis becomes not just relevant but central to any assessment particularly when the objective of assessment is to identify macroeconomic benefits in terms of contributions to GDP, gross output, and employment. The interaction between transportation infrastructure and economic activities becomes further complex when given the consideration of the various temporal effects which are taken into account. When the assessment focuses on the short run, the influence of transportation infrastructure on economic growth is likely to be driven by an expansion of factor inputs during the process of project construction. However, if the impact assessment focuses on the long run, the contribution from transportation may be due to the improvement of productivity of transportation sectors themselves. Modeling the impact of transportation infrastructure on economic growth using general equilibrium analysis is costly and time consuming since the assessment requires a set of complex simultaneous equations which often consists of thousands of equations and variables representing the entire economic system. Examples of economic impact assessment of transportation infrastructure in China using a general equilibrium assessment method can be found in Horridge and Wittwer (2008), Ando and Meng (2009), and Chen et al. (2015).

Alternatively, the economic contribution of transportation can be evaluated under a partial equilibrium framework. Here demand is considered invariant and economic output elasticity of transportation infrastructure is estimated statistically in a production function form. There is a growing set of empirical studies using such an approach to analyze economic contribution of transportation infrastructure in China. However, since the empirical modeling structure of each analysis has to be specified in terms of variables, data, and estimation procedures, this approach has limitations in that economic output elasticity of transportation infrastructure found in each individual assessment seems ad hoc and sometimes contradictory. This is partially due to the lack of theoretical motivation for modeling structure. For instance, although a large number of studies have confirmed positive and significant output elasticity estimates for transportation infrastructure, negative estimates explained as a negative spillover effect are also found (Zhang 2012). It is clear that conclusions and policy implications generated from these research findings can be problematic without an appropriate validation test.

This chapter is written with two research objectives in mind. First, the study is conducted to gain a comprehensive understanding of transportation infrastructure's role in economic growth in China based on a survey of the literature and using meta-analysis. One hundred and thirty-three output elasticity estimates of transportation infrastructure are obtained from 18 empirical studies. This analysis helps us to identify the average economic contribution of transportation infrastructure under the partial equilibrium framework. Second, our study identifies the cause for the variation of output estimates based on a statistical investigation. We differ from earlier studies analyzing similar issues using meta-analysis because they focused on different countries, e.g., Button (1998) and Melo et al. (2013). We limit ourselves to China and the Chinese transportation infrastructure only. We believe that the robustness of statistical analysis could be improved substantially when the focus is on a single country, because issues such as heterogeneity among estimates covering various countries can be avoided.

The rest of the chapter is organized as follows. Section 2 reviews the literature with a focus on identifying the unique traits of the transportation infrastructures in China. Data and the statistical method are introduced in Sect. 3. Section 4 interprets the research results, whereas Sect. 5 summarizes and concludes.

2 Literature Review

Discussions of the economic benefits of transportation infrastructure were stimulated by Aschauer (1989)'s pathbreaking study, which argued that public expenditure on infrastructure provision facilitates economic growth. Since then, a large number of studies emerged to evaluate economic benefits of infrastructure investment in the United States by following the neoclassical economic theory with a focus on a long-run impact (Duffy-Deno and Eberts 1991; Gramlich 1994; Harmatuck 1996; Nadiri and Mamuneas 1996; Fernald 1999; Bhatta and Drennan 2003; Boarnet 1997; Boarnet and Haughwout 2000; Mattoon 2002). Infrastructure was generally considered as the third factor input variable in addition to private capital and labor force and it was frequently modeled through a Cobb-Douglas production function. Estimated output elasticities of infrastructure were found generally inconsistent due to the differences in evaluation method, time period, measurement for economic outcomes, and control variables being used. Some studies found that the highway system in the United States had a positive stimulus effect on productivity (Harmatuck 1996; Fernald 1999; Keeler and Ying 2008), while others, such as Harmatuck (1996) and Boarnet (1997), cast doubt on the level of effects based on their analysis using different data and research methods.

The output elasticity of public infrastructure in the United States is found to range between 0.03 and 0.56. For instance, Aschauer (1989) found that the estimates are between 0.38 and 0.56, whereas the estimate was found to be only 0.15 in Munnell and Cook (1990), with highways alone contributing over a third of the benefit. By focusing on nonmilitary public capital from 1949 to 1985 in the United States, Lau and Sin (1997) found that the output elasticity was positive and significant with a value at approximately 0.1. Harmatuck (1996) found a much lower estimate than what Aschauer and Munnell had found at 0.03 using a trans-log production function. Conversely, other studies, such as Holtz-Eakin and Lovely (1996) and Garcia-Mila et al. (1996), found that there was no positive relationship between public capital and private output. Some scholars argue that this was due to the scale of analysis being adopted in the assessment. For instance, Munnell (1992) indicated that the output elasticity estimate of public infrastructure becomes smaller as the geographic scale of analysis narrows. This is because the spillover effects of infrastructure investment could not be captured at a small geographic area, which thus leads to an underestimated bias. This was also confirmed in a general equilibrium analysis conducted by Chen and Haynes (2015a).

In fact, the lack of appreciation of spatial interaction among different geographic units was criticized as one of the major shortfalls of those early studies as spatial homogeneity was assumed among their samples. As the scale of geographic unit changes, the estimates of output elasticity change as well. Based on a meta-analysis of 80 estimates from 35 studies discussing highway infrastructure and economy, Shatz et al. (2011) found that the effects of highway infrastructure on the economic outcomes vary when different levels of data are applied. They pointed out that quite a few studies tend to find a higher rate of return and a strong productivity effect of highway infrastructure at the national level than at the state and the substate levels.

Indeed, recent studies examining the relationship between infrastructure and economic outcomes find relative smaller output elasticity estimates. For instance, after controlling for spatial dependence using a spatial Durbin model, Chen and Haynes (2014) found that the output elasticity of public surface transportation infrastructure in the US northeast corridor is approximately 0.12, most of which is achieved through regional spillover effects (0.08). The estimate was then found to be slightly higher (at 0.14) when public airport infrastructure was taken into account (Chen and Haynes 2015b).

Early studies were the subject of criticism regarding endogeneity and variable selection. Gramlich (1994) pointed out that many neoclassical empirical studies suffered from the following problems:

- Unclear specification of the causal relationship between infrastructure provision and economic performance
- Vague definition of "infrastructure" making the quantitative analysis speculative
- Short-run policy variables inconsistent with longer-run infrastructure variables
- The lack of isolation of factors influencing macroeconomic performance: from transport technology to soft infrastructure elements such as law, education, business services, and defense
- Different methodologies applied on different types of datasets, resulting in implications that attribute quantitative precision where none exists

Nevertheless, the importance of those early contributions from Aschauer and others in this context, as pointed out by Button (1998), is in raising the issue of the potential role that infrastructure investment can play. The influence of output elasticity was further investigated using a meta-analysis with 28 estimates in Button (1998). After controlling for eight factors reflecting the special character of the countries in the analysis, data types, and model specification, the study found that only the dummy variable reflecting whether a study was of US origin or not was statistically significant. This suggested other things being equal to US studies tend to produce lower elasticities than studies conducted elsewhere. However, in another meta-analysis conducted by Melo et al. (2013), in which a larger sample retrieved from 33 studies was adopted, the estimates of output elasticity were found to be higher for studies with a focus on the US system. The inconsistent findings are likely to be caused by the uncontrolled heterogeneous issue among the country groups being studied, as acknowledged by Melo et al. (2013).

3 Meta-analysis in the Context of China

Meta-analysis has been widely adopted to investigate the sources of systemic variation on the output elasticities in empirical studies through statistical regression analysis. Previous research outcomes regarding the investigation of factors affecting the output elasticity estimate of transportation using a meta-analysis were found inconsistent due to the involvement of heterogeneous characteristics (Melo et al. 2013). Our analysis attempts to avoid the issue of uncontrolled heterogeneity by using only survey data focused on the transportation system in China. To understand what the average output elasticity estimate of the Chinese transportation infrastructure is and what factors affect the magnitude of estimates, we reviewed over 45 studies including journal papers and seminar discussion papers, published in both English and Chinese. Given the research objective concentrates on empirical studies with estimated output elasticity of transportation infrastructure, a total number of 133 estimates from 18 studies were selected, all of which were conducted during the period of 2001–2014.

The descriptive statistics of the 18 studies are summarized in Table 1. One should note that although the investigation period among these studies ranges between 1952 and 2010, most studies de facto focused on the recent three decades. This is not surprising, as there is a growing interest in understanding the effectiveness of government investment policies. Chinese economic development has experienced a rapid transformation since 1978 due to the implementation of the reform and opening-up policy. Hence, the evaluation of the transportation infrastructure's contribution to economic growth becomes important and relevant. The mean estimates of output elasticity of transportation infrastructure, as shown in Table 1, vary substantially across different studies. The lowest mean is 0.016 (Liu and Wang 2012), whereas the highest one is 0.513 (Demurger 2001). The wide range of estimates further suggests that the output elasticity estimates of transportation infrastructure in China are very inconsistent among different studies. Therefore, a comprehensive survey of characteristics related to each assessment and research design becomes necessary.

The distribution of output elasticity estimates of the sample in our analysis is illustrated in Fig. 2. Despite some extreme estimates, above 0.5 and below zero, the majority of the estimates fall into the range between zero and 0.3, with a mean value at 0.1305, which suggests that a one percent increase of transportation infrastructure capital stock is associated with a 0.13 % increase of economic outcome in China, ceteris paribus.

To understand which factors have influence on the magnitude of the estimates, the following five groups of explanatory variables are introduced in the meta-analysis: economic outcome variables, transportation infrastructure variables, control variables, data characteristic variables, and variables representing model specification. As illustrated in Table 2, these variables are designed to capture various attributes of research design, the unique characteristics of the Chinese economy, and the transportation development in China.

Table 1 Studies included in the meta-analysis

Authors	Publication	Obs.	Share (%)	Time period	Mean	Range
Demurger (2001)	Journal of Comparative Economics	7	5.26	1985–1998	0.513	[0.17, 0.75]
Lin and Song (2002)	Urban Studies	5	3.76	1991–1998	0.117	[0.10, 0.13]
Sahoo et al. (2010)	IDE Discussion Paper	6	4.51	1975–2007	0.332	[0.27, 0.41]
Fan and Chan-Kang (2008)	Transport Policy	4	3.01	1982–1999	0.101	[0.03, 0.17]
Fan and Zhang (2004)	China Economic Review	1	0.75	1996	0.032	
Liu and Hu (2010)	China Industrial Economics[a]	4	3.01	1987–2007	0.033	[0.03, 0.04]
Jin (2012)	Journal of South China Normal University[a]	4	3.01	1994–2008	0.174	[0.17, 0.18]
Liu et al. (2010)	China Industrial Economics[a]	13	9.77	1997–2007	0.055	[0.00, 0.52]
Hu and Liu (2009)	China Industrial Economics[a]	8	6.02	1985–2006	0.203	[0.13, 0.29]
Zhang and Sun (2008)	Economic Survey[a]	12	9.02	1978–2003	0.138	[0.11, 0.20]
Zhang (2007)	Journal of Finance and Economics[a]	8	6.02	1993–2004	0.126	[0.05, 0.23]
Liu and Wang (2012)	Journal of Xi'an Jiaotong University[a]	9	6.77	2001–2010	0.016	[0.00, 0.05]
Jin et al. (2005)	Journal of the China Railway Society[a]	6	4.51	1952–2002	0.042	[0.03, 0.05]
Zhang (2012)	Social Sciences in China[a]	10	7.52	1993–2009	0.058	[0.02, 0.29]
Li and Hua (2011)	Chinese Scientific Paper Online[a]	1	0.75	2000–2009	0.026	
Liu and Wang (2014)	Review of Economy and Management[a]	2	1.50	1995–2010	0.245	[0.06, 0.43]
Liu (2010)	China Industrial Economics[a]	27	20.30	1978–2008	0.114	[−0.27, 0.68]
Liu et al. (2009)	Economics Research[a]	6	4.51	1987–2007	0.058	[0.04, 0.09]

[a]Indicates a Chinese publication

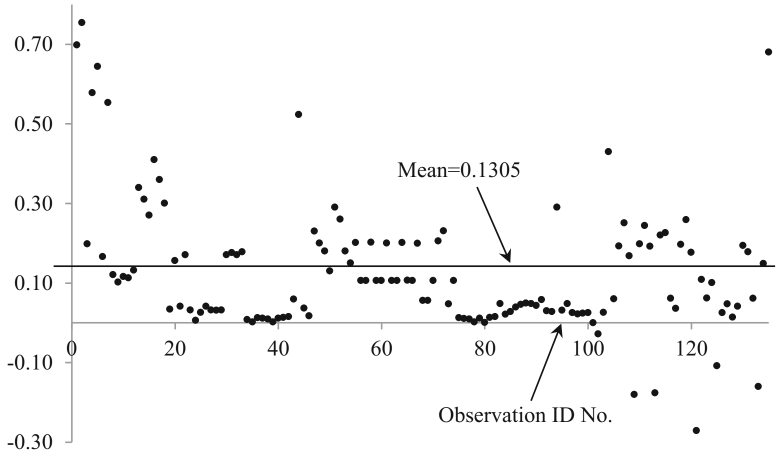

Fig. 2 Distribution of the output elasticity of transportation infrastructure

The first group of variables captures various measurements for economic outcome. These variables are introduced to examine to what extent the different measurements for economic performance in an empirical study has an influence on the output elasticity estimate of transportation infrastructure. Five dummy variables are created to represent different types of dependent variables being adopted among the 18 surveyed studies. For instance, "npcgdp" measures whether the dependent variable is in a per capita term or not; "agrgdp" measures whether GDP includes the agriculture sector or not; "growthr" represents whether the dependent variable is measured as GDP growth or not; "ngdp" denotes whether GDP is measured in the nominal term or not; etc. One should note that the adoption of various measurements for economic performance as the dependent variable is expected to lead to drastically different findings, due to the introduction of uncontrolled bias related to regional demographic patterns and economic characteristics.

The second group of variables represents the characteristics of transportation infrastructure, such as which transportation mode, whether the transportation infrastructure stock is measured in network density or not and whether it is measured in monetary terms or not. In addition, a dummy variable called "pca" is created to reflect whether the infrastructure variable is an index generated from principal component analysis (PCA) or not. Due to data availability, output elasticity of transportation was estimated based on network density instead of monetary terms in some studies. As pointed out by Chen and Haynes (2015b), these physical unit substitutes for financial data, although relevant in engineering terms, are less satisfactory in economic terms.

The third variable group represents control variables being adopted in an empirical study. Unlike many studies that examined transportation systems with focuses on North America and Europe, foreign direct investment (FDI) is generally considered as a key driver to economic growth especially in developing countries

Table 2 Explanatory variables used in the meta-analysis

Category	Variable	Mean	Definition
Economic outcome	npcgdp	0.74	1 if GDP is not measured in per capita term, 0 otherwise
	agrgdp	0.01	1 if GDP of agriculture sector is used, 0 otherwise
	growthr	0.04	1 if GDP is measured in growth rate, 0 otherwise
	ngdp	0.37	1 if GDP is measured in nominal term, 0 otherwise
	tfp	0.17	1 if TFP is used as the dependent variable, 0 otherwise
Transportation infrastructure variable	Rail	0.07	1 if the infrastructure is rail, 0 otherwise
	Road	0.29	1 if the infrastructure is road, 0 otherwise
	pca	0.05	1 if the infrastructure is an index generated from PCA, 0 otherwise
	Density	0.32	1 if the infrastructure is measured in network density
	financialme	0.49	1 if the infrastructure is measured in economic term
Control variable	fdi	0.20	1 if FDI is included as a control variable, 0 otherwise
	Education	0.41	1 if education is included as a control variable, 0 otherwise
	yeardummy	0.28	1 if year dummies are included as control variables, 0 otherwise
	Urban	0.14	1 if urban area is included as a control variable, 0 otherwise
	Coast	0.09	1 if a costal dummy is included as a control variable, 0 otherwise
	lagy1	0.06	1 if the infrastructure is measured in 1-year lag, 0 otherwise
	lagy2	0.01	1 if the infrastructure is measured in 2-year lag, 0 otherwise
	lagy3	0.01	1 if the infrastructure is measured in 3-year lag, 0 otherwise
	lagy4	0.01	1 if the infrastructure is measured in 4-year lag, 0 otherwise
	lagy5	0.06	1 if the infrastructure is measured in 5-year lag, 0 otherwise
Data characteristics	East	0.09	1 if the observations are in the east region, 0 otherwise
	West	0.12	1 if the observations are in the west region, 0 otherwise
	Nation	0.75	1 if the observations covers the whole nation, 0 otherwise
	City	0.13	1 if the data is measured at a city level, 0 otherwise

(continued)

Table 2 (continued)

Category	Variable	Mean	Definition
	sr	0.16	1 if the data captures a short-run period (less than 5 years), 0 otherwise
	lperiod	0.41	1 if the data captures a long-run period (more than a decade), 0 otherwise
	after2000	0.23	1 if the data only captures the period after 2000, 0 otherwise
	Panel	0.86	1 if the data is a panel, 0 otherwise
	cs	0.05	1 if the data is cross-sectional, 0 otherwise
Model specification	spatialm	0.53	1 if a spatial model is adopted, 0 otherwise
	sdm	0.04	1 if a SDM model is adopted, 0 otherwise
	sar	0.24	1 if a SAR model is adopted, 0 otherwise
	slx	0.21	1 if a SLX model is adopted, 0 otherwise
	sem	0.04	1 if a SEM model is adopted, 0 otherwise
	gmm2sls	0.14	1 if GMM or 2SLS is adopted, 0 otherwise
	granger	0.32	1 if Granger test is conducted, 0 otherwise
	barro	0.13	1 if Barro growth model is adopted, 0 otherwise
	fx	0.29	1 if fixed effect is adopted, 0 otherwise
	rd	0.16	1 if random effect is adopted, 0 otherwise

in addition to factor inputs, such as labor, capital, and transportation infrastructure (Demurger 2001). The level of education, which is often measured as a percentage of population with different education levels, is also considered as an important control variable in a few studies, such as Fan and Chan-Kang (2008). Hence, a dummy variable is created to control its influence on the economic output elasticity estimate for transportation infrastructure. Other key factors that have been adopted frequently include variables representing the lag effect of transportation investment, dummy variables used to control for time trend effects and different regional characteristics. In particular, a coastal dummy is created to control for the regional economic disparity between coastal and non-coastal regions. An urban dummy variable is introduced to capture whether the output estimates differ between urban regions and nonurban regions.

The variable group representing data characteristics includes variables for data structure type, geographic location, spatial scale of analysis, and period of analysis. Specifically, two dummy variables “east” and “west” are created to examine whether output elasticity of transportation infrastructure in the East and the West differ significantly from the reference region in the Middle of China. The dummy variables representing national and city are introduced to test whether the geographic scale of analysis has any influence on the output elasticity estimates. In addition, a dummy called “after2000” measures whether the data period in the selected empirical studies covers only the period after the year of 2000 or not. Such a data characteristic is expected to have an influence on the magnitude of output elasticity primarily for two reasons: First, the geographic emphasis of transportation infrastructure investment has a major shift toward the West and underdeveloped regions due to the implementation of the Chinese Western Development Policy. Second, investment in transportation infrastructure expanded substantially after 2000 due to strong government support.

The fifth variable group represents model specifications, such as whether a generalized method of moments (GMM) or a two-stage least square (2SLS) estimation was adopted to capture the potential endogeneity. The variable "granger" is introduced to measure whether a Granger test was conducted to help identify causation. "fx" and "rd" represent whether a fixed effect model or random effect model was applied. In addition, we add variables to capture whether estimates differ due to the various spatial models being adopted and whether the estimates differ between an endogenous growth model and a neoclassical model.

As far as method is concerned, meta-analysis is a statistical extrapolative technique which extracts its information from past studies (Button 2002). Although the approach is rooted in medical research and has been used for many years in physical sciences, it has also received extensive applications in social sciences in recent years. Meta-analysis enables researchers to identify the influences of various data characteristics and analytical features on the five research themes identified earlier. The basic modeling structure is denoted as

$$E_j = a + \left[\sum b_i X_{ij}\right] + \varepsilon_j \qquad (i = 1, 2, \ldots k) \ (j = 1, 2, \ldots R) \tag{1}$$

where, in our case, E represents the output elasticity of transportation infrastructure in the jth study from a total of R studies, a is the summary value of E; X_i are the variables which reflect the relevant characteristics of an empirical study that could explain variations among studies, b_i are the coefficients of the k study characteristics that are controlled for, and ε_j is the error term. Our meta-analysis was conducted in six different regression models for robustness and consistency checks. The separations of variables with high correlation in different regression models also help the analysis to avoid multicollinearity.

4 Results

The results of the meta-analysis are summarized in Table 3. Models 1–4 examine the statistical influences on the level of output elasticity of transportation from factors representing the characteristics of dependent variables, explanatory variables, data, and model specifications, respectively, whereas Models 5 and 6 investigate the influences of various combined factors.

Specifically, Model 1 examines the influences of dependent variables on the magnitude of output elasticity estimates. Four dummy variables are found to be statistically significant. If the economic performance is measured in agricultural GDP, growth rate form, nominal GDP, or TFP, respectively, the output elasticity

Table 3 Results of the meta-analysis

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Coff.	T-Sta.	Coff.	T-Sta.	Coff.	T-Sta.	Coff.	T-Sta.	Coff.	T-Sta.	Coff.	T-Sta.
Constant	0.204***	(4.92)	−0.066	(−0.88)	0.134*	(1.69)	0.144***	(5.79)	0.337***	(4.10)	0.079	(0.85)
npcgdp	−0.010	(−0.27)							−0.414***	(−5.89)		
agrgdp	−0.162***	(−9.28)									−0.171	(−1.13)
growthr	−0.077***	(−4.28)										
ngdp	−0.099***	(−3.28)							−0.129***	(−3.04)	−0.027	(−0.46)
tfp	−0.155***	(−5.32)										
Rail			−0.074*	(−1.91)							0.062	(0.88)
Road			0.020	(0.47)							0.104*	(1.73)
pca			0.449***	(6.35)					0.225**	(2.30)	0.218*	(1.94)
Density			0.178***	(3.04)					0.179***	(2.92)	0.046	(0.75)
financialme			0.183**	(2.46)					0.285***	(5.23)		
fdi			−0.003	(−0.08)					−0.355***	(−5.21)	−0.133**	(−2.03)
Education			−0.051	(−1.58)							−0.182***	(−2.75)
yeardummy			0.016	(0.58)					−0.103**	(−2.43)	−0.030	(−0.55)
Urban			0.165***	(3.29)							0.097*	(1.68)
coastdummy			0.259***	(5.12)					0.560***	(7.92)	0.390***	(4.01)
east					−0.024	(−0.29)					−0.028	(−0.39)
west					−0.025	(−0.31)					−0.003	(−0.05)
nation					−0.011	(−0.16)					0.020	(0.33)
panel					−0.010	(−0.22)					0.052	(0.82)
city					0.023	(0.45)					−0.152**	(−2.06)
lperiod					0.090***	(2.93)					0.0169	(0.31)
after2000					−0.095**	(−2.46)			−0.087***	(−2.78)	−0.104**	(−2.29)

barro							0.054	(0.63)	−0.349***	(−3.42)		
sdm							−0.089**	(−2.35)				
sar							−0.064**	(−2.01)				
sl							0.0164	(0.40)				
sem							0.041	(1.14)				
gmm2sls							0.046	(0.60)	0.184**	(2.20)	0.180**	(2.18)
granger							−0.072*	(−1.95)			−0.038	(−0.90)
fx							0.060	(1.63)	0.077***	(3.01)	0.061*	(1.84)
rd							−0.061	(−1.44)				
spatialm											0.019	(0.58)
Obs.	133		133		133		131		131		131	
adj. R-sq	0.110		0.373		0.146		0.119		0.534		0.489	

Estimates of some explanatory variables such as the different lags of transportation stock are displayed in the table as they are not statistically significant in all the models

$p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$

estimate of transportation infrastructure is likely to be 0.162, 0.077, 0.099, and 0.155 lower ceteris paribus. Model 2 examines the influences of explanatory variable characteristics on the level of output elasticity of transportation infrastructure. The model controls for ten different characteristics of explanatory variables that were utilized frequently and six were found to be statistically significant. Studies with a particular focus on rail infrastructure tend to find a lower output estimate as compared to those investigating transportation in general without a differentiation by mode, ceteris paribus. Conversely, the estimates are found to be larger by 0.178 and 0.183 if transportation infrastructure is measured in network density and financial terms, respectively. The coefficient of the variable representing transportation infrastructure was estimated as an index based on PCA that is found to have the largest influence on the level of output elasticity of transportation with a value at 0.449. This suggests that transportation infrastructure measured as an index is likely to lead to a relatively high output elasticity. This makes sense given that uncontrolled factors are likely to be included if the original indicators used to measure transportation stock are selected inappropriately. An example could be found in Sahoo et al. (2010), in which the adopted infrastructure index factored in not only transportation but also energy and telecommunication.

In addition, the two dummy variables representing whether the studied area is located in urban area and whether it is located in coastal regions were also found to be statistically significant with estimates at 0.165 and 0.259, respectively. The findings suggest that output elasticity estimates of transportation infrastructure are likely to be higher in developed urban regions, such as in the east and south coastal areas in China.

Model 3 examines the influences of data characteristics on the level of output elasticity of transportation infrastructure. The explanatory variables include seven dummies representing the data characteristics in terms of geographic concentration, geographic scale of analysis, temporal concentration, and data structure. The result shows that only the two variables representing temporal concentration of data are statistically significant, though the signs of estimates are opposite. The estimate of "lperiod" is 0.09, suggesting that using data with a coverage of long-run period (more than a decade) is likely to find output elasticity of transportation higher by 9.42 %.[1] Conversely, the estimate of "after2000" is –0.095, indicating that utilizing a dataset covering the period after 2000 is expected to produce an output elasticity estimate of transportation lower by 9.06 % than those estimates based on a dataset covering period both before and after the year of 2000. The lower output elasticity for the period after 2000 may suggest that the overall economic contribution of transportation infrastructure in China declines, even though the total investment continues to rise significantly after the year 2000.

Model 4 examines the influences from model specifications on output elasticity of transportation infrastructure. The model includes nine dummy variables, repre-

[1]The interpretation of the coefficient of a dummy variable was converted using exp(0.09)−1. Same applies to the interpretations of the rest of dummy variable coefficients.

senting whether statistical issues such as heterogeneity, endogeneity, and spatial dependence were considered using via various modeling techniques. The result suggests that spatial dependence does matter in the analysis. Without controlling for spatial dependence, output elasticity estimate of transportation infrastructure is likely to be estimated incorrectly. In addition, the result also reveals that the estimate is likely to be found 6.95 % lower if the causality between economic performance and transportation infrastructure was well identified statistically using techniques, such as the Granger causality test.

Models 5 and 6 provide comprehensive examinations of the influences from various combinations of factors on the level of output elasticity of transportation infrastructure. Model 6 differs from Model 5 in that additional variables were introduced to reflect various characteristics in terms of explanatory variables, data, and methodology. Variance inflation factor (VIF) tests were conducted to assure that multicollinearity was not present in the estimations. The adjusted R-square of Model 5 is 0.534, suggesting that 53.4 % of the estimated variance can be explained by the introduced explanatory variables. The signs of estimates are consistent with those estimates in Models 1–4. Some variables, such as "npcgdp," "fdi," "yeardummy," and "barro," were found to have negative and significant influences on the level of output elasticity estimates of transportation infrastructure, suggesting the fact that without adopting GDP at a per capita and without controlling for key factors, such as FDI and temporal influence, the output elasticity of transportation is likely to be overestimated. Model 5 also confirms that the output elasticity estimate is likely to be 29.46 % lower if an endogenous growth model ("barro") is adopted instead of a neoclassical model, ceteris paribus. Conversely, the positive estimates of "gmm2sls" and "fx" are found in both Models 5 and 6, suggesting that the controls for endogeneity and unobserved heterogeneity are likely to increase the level of output elasticity estimate of transportation infrastructure, ceteris paribus.

5 Conclusion

Transportation infrastructure has experienced a rapid development in China over the past decade. Although a plethora of empirical studies has examined the economic contribution of transportation infrastructure using various data and approaches, the understanding remains unsatisfactory. Estimates of economic output elasticity of transportation infrastructure are found to vary substantially across different studies. Our study improves the understanding of the linkages between transportation infrastructure and economic growth using a meta-analysis, based on 133 estimates from 18 empirical studies with a focus on China.

The influences of various factors related to variables being selected, data and modeling specifications on output elasticity estimation for transportation infrastructure, can be summarized in a more perceptible format as illustrated in Table 4. First, in terms of the measurement for economic performance, our analysis confirms that the output elasticity of transportation infrastructure is likely to be underestimated if

Table 4 Estimated sign of variables

Dependent variable	Sign	Transport variable	Sign	Control variable	Sign	Data	Sign	Model	Sign
npcgdp	−	Rail	−	fdi	−	East	n/a	spatialm	n/a
agrgdp	−	Road	+	education	−	Middle	n/a	sdm	−
growthr	−	pca	+	yeardummy	−	West	n/a	sar	−
ngdp	−	Density	+	urban	+	Nation	n/a	slx	n/a
tfp	−	financialme	+	coastdummy	+	City	−	sem	n/a
				lagy1	n/a	lperiod	+	gmm2sls	+
				lagy2	n/a	after2000	−	granger	−
				lagy3	n/a	Panel	n/a	barro	−
				lagy4	n/a	cs	n/a	fx	+
				lagy5	n/a	sr	n/a		

Note: "+" denotes positive estimate, while "−" denotes negative estimate; *n/a* indicates the sign is not found statistically significant

the variable is not measured in per capita terms, or it measures only the agricultural sector, or it is measured in terms of growth rate, in nominal term and by TFP. In terms of the variables measuring transportation infrastructure stock, we found that the infrastructure index generated from PCA, road transportation, infrastructure measured in network density, and monetary terms is likely to drive up the estimates of output elasticity, ceteris paribus. Conversely, rail infrastructure tends to have relatively smaller output elasticity than other modes, such as roads, ceteris paribus.

Our analysis also found that control variables such as FDI, education, and year dummy variables play pivotal roles in affecting the estimates of economic output elasticity of transportation infrastructure in China. Without a control for these key variables, the impact is likely to be overestimated. Regional characteristics, such as urbanization and whether the studied area is located in a coastal region, are also found to be important as ignoring these variables is likely to underestimate the output elasticity estimates.

Some data characteristics are also found to be important. For instance, a dataset covering a longtime period is likely to lead to a higher estimate of the output elasticity, suggesting that the economic contribution from transportation infrastructure tends to be larger during a relatively longer time period. On the contrary, an empirical study is more likely to find a smaller effect of transportation infrastructure to economic growth if the assessment is based on a data covering the period after 2000, ceteris paribus. This is also true if a city-level data instead of provincial- or national-level data is being used. Such patterns reflect the fact that the spillover effects of transportation infrastructure on economic growth are less likely to be captured at a smaller geographic scale of analysis.

Meta-analysis confirms that spatial spillover effects in the form of spatial dependence are important given the fact that studies tend to produce upward biased elasticity estimates if spatial dependence is not considered by adopting spatial econometric techniques, such as spatial Durbin model or spatial autoregressive models. Examples can be found in Melo et al. (2013). In addition, modeling techniques addressing endogeneity, unobserved heterogeneity, are confirmed to be important as ignoring these issues is likely to cause underestimated elasticity estimates. Our analysis also found that an endogenous growth model tends to provide a relative smaller output elasticity estimate of transportation infrastructure than a neoclassical model, ceteris paribus.

Two implications could be drawn from the research findings. First, although the central government invested heavily in transportation infrastructure in China after the year 2000, the overall contribution of transportation infrastructure to economic growth de facto declines as compared to the period before 2000. Although such a decline in output elasticity estimate could be due to the fact that the economic contribution of a large number of new infrastructure facilities has still not materialized as many are still under massive construction, the decline of output estimates may also reflect the decline of marginal economic contribution from transportation infrastructure investments. In part this may due to the repetitive infrastructure construction. Future investment policy on transportation infrastructure should be implemented more appropriately to maximizing their contributions to economic growth.

Second, future studies using a partial equilibrium approach to estimate output elasticity of transportation infrastructure should be conducted cautiously in terms of selections of variables, data, and modeling specifications. Given that factors such as FDI, education quality, and geographic characteristics of regional economy have been confirmed to play important roles in affecting economic growth in developing countries such as China, these factors should be taken into account accordingly in future assessment so as to avoid estimation bias.

References

Ando A, Meng B (2009) The transport sector and regional price differentials: a spatial CGE model for Chinese provinces. Econ Syst Res 21(2):89–113

Aschauer DA (1989) Is public expenditure productive? J Monet Econ 23(2):177–200

Bhatta SD, Drennan MP (2003) The economic benefits of public investment in transportation. J Plan Educ Res 22(3):288–296

Boarnet MG (1997) Infrastructure services and the productivity of public capital: the case of streets and highways. Natl Tax J 50(1):39–57

Boarnet MG, Haughwout AF (2000) Do highways matter? Evidence and policy implications of highways' influence on metropolitan development. A discussion paper prepared for The Brookings Institution Center on Urban and Metropolitan Policy, Washington, DC

Button KJ (1998) Infrastructure investment, endogenous growth and economic convergence. Ann Reg Sci 32(1):145–162

Button KJ (2002) An evaluation of the potential of meta-analysis in value and function transfer. In: Florax RJ, Nijkamp P, Willis KG (eds) Comparative environmental economic assessment. Edward Elgar, Cheltenham, pp 74–89

Chen Z, Haynes KE (2014) Public surface transportation and regional output: a spatial panel approach. Pap Reg Sci 94(4):727–751

Chen Z, Haynes KE (2015a) Multilevel assessment of public transportation infrastructure: a spatial econometric computable general equilibrium approach. Ann Reg Sci 36:1–23
Chen Z, Haynes KE (2015b) Regional impact of public transportation infrastructure a spatial panel assessment of the US northeast megaregion. Econ Dev Q 29(3):275–291
Chen Z, Xue J, Rose AZ, Haynes KE (2015) The impact of high-speed rail investment on economic and environmental change in China: a dynamic CGE analysis. Available at SSRN: http://ssrn.com/abstract=2636385
Demurger S (2001) Infrastructure development and economic growth: an explanation for regional disparities in China? J Comp Econ 29(1):95–117
Duffy-Deno KT, Eberts R (1991) Public infrastructure and regional economic development: a simultaneous equations approach. J Urban Econ 30(3):329–343
Fan S, Chan-Kang C (2008) Regional road development, rural and urban poverty: evidence from China. Transp Policy 15(5):305–314
Fan S, Zhang X (2004) Infrastructure and regional economic development in rural China. China Econ Rev 15(2):203–214
Fernald JG (1999) Roads to prosperity? Assessing the link between public capital and productivity. Am Econ Rev 89(3):619–638
Garcia-Mila T, McGuire TJ, Porter RH (1996) The effect of public capital in state-level production functions reconsidered. Rev Econ Stat 78(1):177–180
Gramlich EM (1994) Infrastructure investment: a review essay. J Econ Lit 32(3):1176–1196
Harmatuck DJ (1996) The influence of transportation infrastructure on economic development. Logist Transp Rev 32(1):63–76
Holtz-Eakin D, Lovely ME (1996) Scale economies, returns to variety, and the productivity of public infrastructure. Reg Sci Urban Econ 26(2):105–123
Horridge M, Wittwer G (2008) SinoTERM, a multi-regional CGE model of China. China Econ Rev 19(4):628–634
Hu A, Liu S (2009) Economic growth and spillover effects: spatial econometric analysis based on Chinese provincial data. China Ind Econ 5:5–14 (in Chinese)
Jin J (2012) Transport infrastructure and economic growth in the pearl river delta region: a spatial analysis. J S China Norm Univ (Soc Sci Ed) 1:125–129 (in Chinese)
Jin F, Dai T, Wang J (2005) Modeling economic effect of transport investment in China. J China Railw Soc 27(3):9–14 (in Chinese)
Keeler TE, Ying JS (2008) Measuring the benefits of a large public investment: the case of the U.S. federal-aid highway system. J Public Econ 36(1):69–85
Lau S-HP, Sin C-Y (1997) Public infrastructure and economic growth: time-series properties and evidence. Econ Rec Econ Rec 73(221):125–135
Li M, Hua J (2011) Regional economic impact analysis of transportation infrastructure construction in Jiangsu. China science paper online (in Chinese)
Lin S, Song S (2002) Urban economic growth in china: theory and evidence. Urban Stud 39(12):2251–2266
Liu Y (2010) Transport infrastructure investment, regional economic growth and the spatial spillover effects: a panel data analysis based on highway and water transport. China Ind Econ 12:37–46 (in Chinese)
Liu S, Hu A (2010) Transport infrastructure and economic growth: perspective from China's regional disparities. China Ind Econ 4:14–23 (in Chinese)
Liu Y, Wang X (2012) Transport infrastructure and TFP growth in new silk road economic corridor. J Xi'an Jiaotong Univ (Soc Sci) 32(2):54–59 (in Chinese)
Liu Q, Wang G (2014) Analysis of road transportation network's spillover effect on local economic growth in Jinan. Rev Econ Manag 2:517–548 (in Chinese)
Liu S, Wang Y, Hu A (2009) The effect of western development program and regional economic convergence in China. Econ Res J 9:94–105 (in Chinese)
Liu B, Wu P, Liu Y (2010) Transportation infrastructure and the increase in TFP in China: spatial econometric analysis on provincial panel data. China Ind Econ 3:54–64 (in Chinese)

Mattoon R (2002) Midwest infrastructure: assessing the contribution of basic infrastructure to economic growth. Chicago Fed Lett 184b (Special Issue Dec)

Melo PC, Graham DJ, Brage-Ardao R (2013) The productivity of transport infrastructure investment: a meta-analysis of empirical evidence. Reg Sci Urban Econ 43(5):695–706

Munnell AH (1992) Policy watch: infrastructure investment and economic growth. J Econ Perspect 6(4):189–198

Munnell AH, Cook LM (1990) How does public infrastructure affect regional economic performance? N Engl Econ Rev (Sep), 11–33 http://www.bostonfed.org/economic/neer/neer1990/neer590b.pdf

Nadiri MI, Mamuneas TP (1996) Contribution of highway capital to industry and national productivity growth (No. BAT-94-008). Report prepared for Apogee Research, Inc., for the Federal Highway Administration Office of Policy Development

Sahoo P, Dash RK, Nataraj G (2010) Infrastructure development and economic growth in China. Institute of Developing Economies Discussion Paper No. 261

Shatz HJ, Kitchens KE, Rosenbloom S (2011) Highway infrastructure and the economy. Rand Corporation, Santa Monica

Zhang X (2007) Regional comparative analysis of Chinese transportation infrastructure and economic growth

Zhang X (2012) Has transportation infrastructure promoted regional economic growth? An analysis of the spatial spillover effects. Soc Sci China 3:60–77 (in Chinese)

Zhang X, Sun H (2008) Transportation infrastructure, spatial aggregation and economic growth. Econ Surv 4:20–23 (in Chinese)

Statistical Analysis of Sustainable Livelihood in China

Guoping Mao

Abstract This study establishes a statistical indicator system of China's livelihood from the perspective of sustainability. Moreover, it describes the current situation of China's livelihood and employs multivariate statistics to analyze both its characteristics and problems. The findings indicate that the depravation of livelihood environment counts the development of China's sustainable livelihood as a whole; however, such negative effects on the environment can be offset to a certain extent by relying on the enhancement of livelihood ability and implementation of livelihood policies, and the improvement of livelihood has been fairly evident recently. This study indicates five urgent problems to be solved regarding the Chinese livelihood, which should be given much more attention to promote the Chinese livelihood in the view of sustainable development.

Keywords Sustainable livelihood • Livelihood environment • Livelihood ability • Livelihood process • Livelihood achievements

1 Introduction

Through the economic development and progress of human society, people increasingly focus on eliminating poverty to improve the living standards. In 1988, the United Nations passed a report on "our common future," in which the concept of "sustainable development" was officially proposed for the first time. The report reflects new ideas on transforming the traditional development model and ways of life for the human society. The United Nations Development Programme (UNDP)

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issues a “human development report” every year since 1990 and compiles the “human development index” (HDI), which significantly influences studies on sustainable livelihood. In 1991, Chambers and Conway (1991) elaborated the original and classical definition of sustainable livelihood as follows: a livelihood comprises the capabilities, assets (including both material and social resources), and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shock as well as maintain or enhance its capabilities and assets both at present and in the future, while not undermining its natural resource base. Lasse (2001) emphasized the following regarding sustainability: sustainability has several requirements, the ability to recover from the blow and pressure of the economy, ecological harmony, and social harmony. Based on the above definition, living condition, living ability, and living environment can be determined as the basic premise to discuss livelihood. Lasse (2001) argued that living condition includes natural conditions, such as geography, climate, population, etc. as well as political and economic conditions, such as politics, history, and macroeconomy. Chambers and Conway (1991) argued that living ability is engaged in the activity, including the ability to survive, and changes according to the environment. In discussing living environment, Lasse (2001) suggested that natural environment, such as water and pollution, significantly impacts livelihood and that we should therefore focus on the protection and regeneration of environment. In addition social and political environments also impact the improvement of livelihood. Balgis et al. (2005) argued that environmental awareness, environmental measurement, and global environmental changes are required to determine the environment of livelihood.

With the rapid development of the modern economy, China considered improving people’s livelihood to be the main national development goal. From the beginning of the twenty-first century, China has conducted a wide range of studies on livelihood issues. Jia (2010) indicated that livelihood mainly refers to the bottom line of basic public living conditions, the people’s basic development opportunity and development ability, and the social welfare state of people above the basic living line. Li (2008) suggested that livelihood should be people oriented and consider human comprehensive development as its target to effectively solve the problems of interest that are most important, direct, and realistic to the people, such as education, health, employment, income distribution, social security, etc. Liu et al. (2009) indicated that economic development should consider human development as its basic development goal and promote the sustainable development of human beings. Xu (2008) suggested that the political essence of livelihood is to establish an economic and political system in line with the social fares and justice to let most people live happy and stable lives. Li (2009) revealed that the content of the people’s livelihood is wide ranging and involves six different aspects, namely, social security, education, employment, housing, medical treatment, and stability. Sha and Yang (2008) interpreted 36 statistical indicators from five aspects, namely, education, employment and income, healthcare and social security, housing, and stability, as an indicator system of the livelihood.

The study of livelihood in China features much discussion on a theoretic and conceptual level, but little discussion on the sustainability of livelihood and empirical analysis of the actuality of sustainable livelihood. Based on this consideration, this study examines the aspect of sustainable livelihood. This study first establishes a statistical indicator system of China's livelihood from the perspective of sustainability. Based on the collected data, it then performs a statistical analysis of China's sustainable livelihood of the past 10 years. After determining the current situation and problems of China's sustainable livelihood, the study finally proposes policy suggestions for promoting China's sustainable livelihood.

2 The Statistical Indicator System of Sustainable Livelihood

Livelihood refers to the people's basic living conditions, the basic development opportunity rights and interests that they possess, etc. Sustainable livelihood means that every person can have fairness and justice in the process of intergenerational life continuation and that by living a dignified life, humanity can be updated, evolved, and developed.

2.1 Livelihood Environment

Human survival and development constitute the livelihood environment which means the natural and artificially modified complex that human beings rely on, including natural environment, artificial environment, and social environment.

Natural environment living space including climate conditions, geographical conditions, and ecosystems associated with the survival of plants and animal is the sum of natural factors, such as sunlight, temperature, climate, magnetism, air, water, rocks, soil, plants and animals, microorganisms, and the stability of the earth's crust. Human beings are the product of their environment, while the natural environment forms the material base for human survival and reproduction. All human activities must be established on the basis of healthy living, and health requires clean water, air, soil, and other natural factors. Environmental quality constitutes the necessary guarantee for realizing the health life of human being. Protecting and improving the natural environment is the premise of human survival and development. Artificial environment constitutes the living environment that is gradually formed through long-term human plans and work on a natural basis, including residential and public service facilities, green areas, etc. Social environment refers to social public order, social morality, and interpersonal relationship related to social system, including ethics, social security, social public order, etc. An indicator system of livelihood environment may be formed on the basis of three aspects: natural environment, artificial environment, and social environment.

2.2 Livelihood Ability

Livelihood ability is a sustainable survival ability that enables people to live in the present without compromising the future generations and enables human intergenerational continuing. The purpose of human existence is to improve human living environment and quality of life, so that everyone can be happy and healthy and enjoy life for its limited time. People must continue to depend on their livelihood ability to realize the purpose of human existence. Livelihood ability mainly includes education, scientific research, social infrastructure, the ability to respond to emergencies, etc.

Education nurtures persons with practical consciousness and ability. In addition, it offers the main way and means to transmit life experience and skills and is also the way to realize harmonious human development as well as provide the means to constantly improve human quality. Furthermore, education can demonstrate and develop people's survival ability and achieve a higher level of freedom for human survival. Scientific research not only greatly promotes the changes in the field of human society, economy, politics, culture, etc. but also affects the way people live and think, to lift the modernization and its social lives of human beings to a higher level. Scientific research promotes the development of social productivity in innovative ways, namely, through the ceaseless progress of productive technology, the constant improvement of labor quality and skills, and the constant improvement of labor means, to improve social labor productivity. As a result of the progress of science and technology, changes have occurred in all aspects of human daily life. Scientific research is important because studying human beings and constantly exploring the growing laws of humanity extend human life expectancy. Social infrastructure refers to public infrastructure meant to overcome natural barriers, to strengthen survival ability, and to improve the efficiency of social sharing of human resources, including transportation, network, communication, water supply, gas supply, waste disposal, and other infrastructures. With the progress of human civilization, the human ability to create a living environment has gradually strengthened and increasingly contains more components. The infrastructure is certainly an important material condition for survival ability. The ability to respond to natural disasters constitutes the ability to rescue people from and withstand natural disasters when they occur, as well as to protect people's safety and reduce property loss to maximum. Natural disasters are unavoidable. When facing natural disasters, humanity can only improve itself by responding according to their survival ability. The ability to respond to natural disasters mainly includes the ability to prevent natural disaster and conduct emergency rescue. An indicator system of livelihood ability may comprise the following four aspects: education, scientific research, social infrastructure, and the ability to respond to natural disasters.

2.3 Livelihood Process

The process of sustainable livelihood constitutes the process of survival and the living conditions for human intergenerational continuity. Through the advancement of the process of life, human life spans have continued to extend and will ultimately reach a more comprehensive, freer, and better living space for humanity itself. The process of sustainable livelihood mainly includes employment, income distribution, consumption level, medical and healthcare, welfare structure, and social security.

Labor is the most basic activity as well as the condition for human survival and development. Only labor meets the most basic necessities of life, such as food, clothing, shelter, and other human requirements; labor creates social material wealth and spiritual wealth as well as transforms the human living space. It is an important symbol of social progress to achieve full employment and to protect people's labor rights and interests. Unemployment will decrease the life quality of the unemployed and their family due to a decline in revenue, which affects their survival. Income distribution is conducted on the basis of production factors, and income depends on the social distribution system. Improper distribution of income can lead to insufficient effective demand for the national economy and thus affect livelihood. Achieving a fair income distribution is beneficial for safeguarding the basic of people's lives and enhancing their confidence, thus enabling people to live with dignity. Unfair income distribution will affect the fairness and justice of society and intensify social contradictions. Equal income distribution is an effective tool for improving livelihood. Consumption level refers to the consumption of goods and services per capita within a certain period and indicates the level that needs to be met to enable survival. To constantly improve people's consumption level, people's growing material and cultural needs must be met constantly to guarantee a dignified life. Consumption level is the manifestation of livelihood condition. Medical and healthcare is a system meant to guarantee people's health by preventing and treating diseases. Human life activity is always marked by the process of fighting disease, maintaining good health that is a basic requirement to realize full human development and an important goal of social development. Medical and healthcare constitutes an important component of livelihood and is an important means to guarantee people's health, improve the quality of life, and achieve social harmony. Social security is a social system that gives a certain substance to help people with special difficulties and guarantee their basic living rights. Social welfare means that the state provides various welfare subsidies, public goods, and welfare services for improving people's quality of life and for promoting comprehensive human development. Social welfare and security, including pension, medical care, social assistance, and public utilities, is the manifestation of social civilization. An indicator system of livelihood process may comprise the following five aspects: labor employment, income distribution, consumption level, medical and healthcare, and welfare structure and social security.

2.4 Livelihood Achievements

The goal of sustainable livelihood is to update people's evolution through the process of continuous intergenerational life activities and finally realize comprehensive, free, and harmonious human development. From a short-term perspective, the achievement of the livelihood process can be observed in the reduction of social poverty, improvement of population quality, increase of leisure time, increase of life expectancy, etc.

The UNDP (1997) indicated that poverty makes people unsatisfied with their basic life conditions, namely, health, housing, knowledge, participation, personal safety, and environmental aspect, and this limits people's choices. This definition indicates the essence of poverty. Reducing and eliminating poverty are an important symbol of modern society's progress. Population quality refers to the level of people's ideological, moral, and scientific culture, labor skills, and physical quality, which includes factors such as physical, intellectual, and cultural levels, labor skills, etc. With the development of society, the overall level of population quality increases. Leisure time is the personal discretionary time spent outside of work. People are free to do leisure activities during this time and can express their spiritual liberation and free will. Leisure time includes entertainment, sports, amateur study, tours, social interaction, etc. The more the society develops, the richer the leisure time, and active content will become to realize the purpose and goodness of life. As the society develops, human life expectancy will constantly improve. Life expectancy refers to the ultimate performance of sustainable livelihood. An indicator system of livelihood achievements may comprise the following four aspects: reduction of social poverty, improvement of population quality, increase of leisure time, and improvement of life expectancy.

Livelihood environment and livelihood ability determine the quality of the livelihood process. The livelihood process can reveal livelihood performance after a certain period of time. Livelihood achievements, in turn, will impact livelihood environment and ability and promote the continuous improvement of livelihood environment and ability. Humanity develops through this circulatory livelihood process. Analyzing sustainable livelihood enables us to understand our own status of livelihood and living standards and constantly incites us to improve our own level of life. Figure 1 illustrates the analysis framework for sustainable livelihood.

Based on the above-discussed concept of sustainable livelihood and the analysis framework, this study screened out numerous statistical indicators related to livelihood as basic indicators from the statistical yearbook of the National Bureau of Statistics and subsequently calculated those basic indicators to compose an indicator system for China's sustainable livelihood. Considering the requirements for data availability, some alternative indicators were adopted as theoretic indicators. Table 1 indicates the statistical indicator system for China's sustainable livelihood.

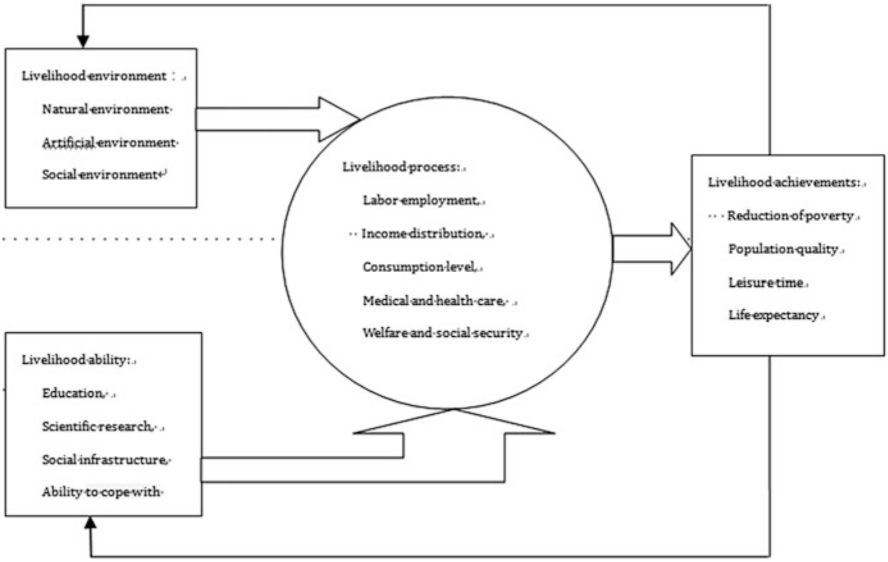

Fig. 1 The analysis framework for sustainable livelihood

Table 1 The statistical indicator system of China's sustainable livelihood

Subsystem	Statistical indicator	
Livelihood environment	Natural environment	X_1, daily wastewater emissions (10,000 tons/day); X_2, daily chemical oxygen demand (cod) emissions (10,000 tons/day); X_3, daily so^2 emissions (tons/day); X_4, forest coverage rate (%); X_5, water resources per capita (m^3/person)
	Artificial environment	X_6, total length of operating lines per 10,000 people (m); X_7, urban green space area per 10,000 people (m^2/10,000 person); X_8, treatment rate of life garbage (%); X_9, urban resident housing area per capita (m^2/per person)
	Social environment	X_{10}, criminal cases per 10,000 people (number/10,000 person)
Livelihood ability	Education	X_{11}, number of university students per 100,000 people (person); X_{12}, student's expenditure on education per capita (Yuan/person); X_{13}, share of education expenditure to GDP (%)
	Scientific research	X_{14}, number of researchers per 10,000 people (person/10,000 person); X_{15}, number of published scientific papers per 100 persons (number)
		X_{16}, number of patent applications per 10,000 people (item/10,000 person); X_{17}, share of technology market turnover to GDP (%)
	Social infrastructure	X_{18}, urban environmental investment per capita (10,000 Yuan/person)
		X_{19}, penetration rate of urban gas (%)
	Ability to cope with	X_{20}, investment in geological disaster prevention per 10,000 people (Yuan)

(continued)

Table 1 (continued)

Subsystem	Statistical indicator	
Livelihood process	Labor employment	X_{21}, employment rate (%)
	Income distribution	X_{22}, disposable income of urban households per capita (Yuan)
		X_{23}, net income of rural households per capita (Yuan)
	Consumption level	X_{24}, urban household's consumption expenditure in cash per capita (Yuan)
		X_{25}, rural household's consumption expenditure in cash per capita (Yuan)
	Medical and healthcare	X_{26}, number of health professionals per 10,000 person (person)
		X_{27}, health expenditure per capita (Yuan)
	Welfare structure and social security	X_{28}, number of beds in social service agencies per 10,000 person (number/10,000 person); X_{29}, number of persons receiving minimum living security (10,000 person); X_{30}, share of person having pension insurance to population (%)
Livelihood achievements	Reduction of poverty	X_{31}, share of urban residents having minimum living security to urban population (%); X_{32}, share of rural residents having minimum living security to rural population (%)
	Population quality	X_{33}, ratio of persons having university education to population (%)
		X_{34}, rate of change in criminal cases (%)
	Leisure time	X_{35}, number of tourist per 10,000 person (person/10,000 person)
	Life expectancy	X_{36}, life expectancy (years old); X_{37}, ratio of the age over 80 years to population (%)

Note: X_i in the table represents the serial number of the indicator variables

3 Statistical Analysis of China's Sustainable Livelihood

Based on the indicator system of sustainable livelihood shown in Table 1, this study collects data for 37 indicators of this system in 2002–2013 from China statistical yearbook (National Bureau of Statistics 2003–2014). This study only analyzes China's sustainable livelihood for a 12-year period because of lack of date on some indicators before 2002. It performs a factor analysis in the four major fields of sustainable livelihood (livelihood environment, livelihood ability, livelihood process, and livelihood achievements). First, the principal component is calculated for each field to observe the dynamic trend of these four fields of China's sustainable livelihood in the past 12 years. Thereafter the score of common factor is calculated to observe the change in the main variables in each field and to understand the main problems regarding the process of China's sustainable livelihood.

Table 2 Communalities

Variable	Initial	Extraction
X_1	1.000	0.984
X_2	1.000	0.598
X_3	1.000	0.720
X_4	1.000	0.888
X_5	1.000	0.611
X_6	1.000	0.947
X_7	1.000	0.977
X_8	1.000	0.982
X_9	1.000	0.953
X_{10}	1.000	0.968

Table 3 Total variance explained

	Initial eigenvalues			Extraction sums of squared loading			Rotation sums of squared loading		
Component	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	7.201	72.012	72.012	7.201	72.012	72.012	7.171	71.706	71.706
2	1.426	14.260	86.271	1.426	14.260	86.271	1.457	14.565	86.271
3	0.794	7.939	94.211						
4	0.421	4.211	98.422						
5	0.080	0.803	99.225						
6	0.042	0.418	99.642						
7	0.023	0.226	99.868						
8	0.011	0.107	99.974						
9	0.002	0.020	99.995						
10	0.001	0.005	100.000						

3.1 Factor Analysis of the Livelihood Environment

The variables of livelihood environment in this study are $X_1, X_2, \ldots, X_{10}$ (see Table 1). This study extracts two common factors and constitutes two principal components by the calculation for the factor analysis. The corresponding results are shown in Tables 2, 3, and 4.

The first principal component (Z_1) and the second principal component (Z_2) are calculated and extracted using the principal component analysis as follows:

$$Z_1 = 0.37X_1 + 0.29X_2 - 0.11X_3 + 0.34X_4 - 0.03X_5 + 0.36X_6 + 0.37X_7 + 0.37X_8 + 0.35X_9 + 0.36X_{10}$$

$$Z_2 = 0.08X_1 - 0.05X_2 + 0.67X_3 + 0.20X_4 - 0.65X_5 - 0.15X_6 + 0.04X_7 - 0.07X_8 + 0.21X_9 - 0.10X_{10}$$

Table 4 Component matrix

Variable	The first principal component	The second principal component
X_1	0.988	0.092
X_2	0.771	−0.062
X_3	−0.288	0.798
X_4	0.912	0.239
X_5	−0.071	−0.778
X_6	0.957	−0.175
X_7	0.987	0.050
X_8	0.987	−0.087
X_9	0.945	0.246
X_{10}	0.977	−0.116

Table 5 Rotated component matrix

Variable	The first principal component	The second principal component
X_1	0.992	−0.019
X_2	0.764	0.118
X_3	−0.229	−0.817
X_4	0.926	−0.172
X_5	−0.128	0.771
X_6	0.942	0.244
X_7	0.988	0.022
X_8	0.978	0.159
X_9	0.960	−0.176
X_{10}	0.966	0.186

The first principal component Z_1 contains the information on natural environment (X_1, X_4), on artificial environment (X_6, X_7, X_8, X_9), and on social environment (X_{10}), which is an "ordinary factor" reflecting the environment. While the second principal component Z_2 is mainly formed by the information on natural environment (X_3, X_5), water resource (X_5) is extremely important, sulfur dioxide (X_3) is highly toxic, and a combination of X_5 and X_3 could be interpreted as "environment mark factor." Z_1 and Z_2 contain 86 % of the information on the ten variables. The serial numerical value of Z_1 from 2002 to 2013 is (−3.43, −2.98, −2.22, −1.96, −1.96, −0.94, −0.29, 0.87, 1.88, 3.18, 3.78, 4.08), which presents a monotonous rising trend according to the time sequence. The serial numerical value of Z_2 from 2002 to 2013 is (−2.30, −1.04, 0.47, 0.54, 1.47, 1.25, 0.40, 1.01, −1.11, 1.07, −0.98, −0.77), which does not present an evident monotonous trend. The calculated factor scores of "environment ordinary factor" and "environment mark factor" are shown in Tables 5 and 6.

The factor score equation reveals that the first common factor mainly dominates X_1, X_4, X_7, X_8, X_9, and X_{10}. For the first common factor, X_1, X_4, and X_{10} are "negative energy" variables with high score, ranked at the top. This monotonous increase of the numerical value of "environment ordinary factor" indicates that

Table 6 Component score coefficient matrix

Variable	The first principal component	The second principal component
X_1	0.141	−0.054
X_2	0.104	0.051
X_3	0.001	−0.561
X_4	0.138	−0.158
X_5	−0.050	0.544
X_6	0.124	0.132
X_7	0.139	−0.025
X_8	0.132	0.071
X_9	0.143	−0.162
X_{10}	0.129	0.091

the environment presented a deterioration trend. This trend can also be verified by the raw data of the variables. The second common factor mainly dominates X_3 and X_5, and the "environment mark factor" reflects no evident monotonous trend, which indicates that the environmental improvement is not evident. Based on the above calculation and analysis, the following can be concluded regarding livelihood environment in China: at the beginning of the twenty-first century, China's livelihood environment has presented a deterioration trend, including the deterioration of both natural and social environments and a slow improvement of artificial environments. Overall the current environmental situation is harmful to China's sustainable livelihood.

3.2 Factor Analysis of the Livelihood Ability

The variables of livelihood ability in this study are $X_{11}, X_{12}, \ldots, X_{20}$ (see Table 1). This study extracts one common factor and constitutes one principal component by the calculation for the factor analysis. The corresponding results are shown in Tables 7, 8, and 9.

The first principal component (Z_3) of livelihood ability is extracted using the principal component analysis as follows:

$$Z_3 = 0.31X_{11} + 0.33X_{12} + 0.32X_{13} + 0.33X_{14} - 0.32X_{15} + 0.32X_{16}$$
$$+0.30X_{17} + 0.32X_{18} + 0.29X_{19} + 0.32X_{20}$$

Z_3 sums up 92 % of the information on the ten variables that represent education, scientific research, social infrastructure, and the ability to cope with natural disasters. Therefore, Z_3 can be interpreted as a factor of livelihood ability. The serial numerical value of Z_3 from 2002 to 2013 is (−3.87, −3.18, −2.85, −2.32, −1.99, −1.10, −0.11, 0.91, 2.46, 2.88, 4.27, 4.91), which presents a monotonous rising

Table 7 Communalities

Variable	Initial	Extraction
X_{11}	1.000	0.883
X_{12}	1.000	0.975
X_{13}	1.000	0.951
X_{14}	1.000	0.993
X_{15}	1.000	0.965
X_{16}	1.000	0.966
X_{17}	1.000	0.840
X_{18}	1.000	0.926
X_{19}	1.000	0.781
X_{20}	1.000	0.925

Table 8 Total variance explained

	Initial eigenvalues			Extraction sums of squared loading		
Component	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	9.203	92.035	92.035	9.203	92.035	92.035
2	0.424	4.237	96.271			
3	0.202	2.204	98.296			
4	0.104	1.037	99.333			
5	0.042	0.419	99.752			
6	0.013	0.132	99.884			
7	0.007	0.075	99.958			
8	0.003	0.030	99.988			
9	0.001	0.012	100.000			
10	0.000	0.000	100.000			

Table 9 Component matrix

Variable	The first principal component
X_{11}	0.940
X_{12}	0.987
X_{13}	0.975
X_{14}	0.996
X_{15}	−0.982
X_{16}	0.983
X_{17}	0.917
X_{18}	0.962
X_{19}	0.884
X_{20}	0.962

trend according to the time sequence. The factor of livelihood ability indicates that investments in education, scientific research, and social infrastructure in China have increased in recent years, and consequently the ability of sustainable livelihood has been decidedly enhanced; particularly the trend of Z_3 is clearly increased from 2009.

The subsequent calculation of the factor loading matrix, factor score, and formula of the principal components indicates that the factor of livelihood ability principally dominates X_{12} and X_{14}, then dominates X_{13}, X_{16}, X_{18}, and X_{20}, and slightly dominates X_{11}, X_{17}, and X_{19}. The intensive order of the variables that dominated by the livelihood ability factor indicates the following: (1) X_{12} and X_{14} constitute an important position in the livelihood ability factor since these two variables reflect the quantity of livelihood ability. Namely, if the Chinese livelihood ability has only increased in terms of quantity, they cannot explain improvement in terms of the quality. (2) The variables X_{11}, X_{16}, X_{17}, and X_{15} which reflect the livelihood ability in terms of quality constitute an unimportant position in the livelihood ability factor, especially in which X_{15} appears with a minus sign in the formula of the principal components, which indicates a lack of high-tech research activities and innovation in China at present. The quality of livelihood ability factor is not positive and has much space for improvement in terms of quality. (3) The variables X_{18} and X_{19} which reflect the social infrastructure, and the variable X_{20} which reflects the ability to cope with natural disasters, are not currently at an important position in the livelihood ability factor, indicating that China's urban environment is not very desirable, that is, social infrastructure likewise has much space for development and that the ability to cope with natural disasters need to be improved. Based on the above analysis, the following can be concluded about the Chinese livelihood ability: at the beginning of the twenty-first century, the Chinese livelihood ability had evidently enhanced, but that improvement constituted only a quantitative aspect, while it still has much space for enhancement in terms of quality. The slow development of social infrastructure and the lack of ability to cope with natural disasters hinder the development process of the Chinese livelihood ability.

3.3 *Factor Analysis of the Livelihood Process*

The variables of the livelihood process in this study are $X_{21}, X_{22}, \ldots, X_{30}$ (see Table 1). This study extracts one common factor and constitutes one principal component by the calculation for the factor analysis. The corresponding results are shown in Tables 10, 11, and 12.

The first principal component (Z_4) of the livelihood process is extracted using the principal component analysis as follows:

$$Z_4 = 0.07X_{21} + 0.34X_{22} + 0.34X_{23} + 0.34X_{24} + 0.34X_{25} + 0.33X_{26}$$
$$+0.34X_{27} + 0.34X_{28} + 0.31X_{29} + 0.342X_{30}$$

Z_4 sums up 88.1 % of the information on the ten variables that represent labor and employment, income distribution, consumption level, medical and healthcare, and social security. Therefore, Z_4 can be interpreted as a factor of livelihood process. The serial numerical value of Z_4 from 2002 to 2013 is (−3.43, −3.38, −2.98, −2.51,

Table 10 Communalities

Variable	Initial	Extraction
X_{21}	1.000	0.039
X_{22}	1.000	0.999
X_{23}	1.000	0.993
X_{24}	1.000	0.992
X_{25}	1.000	0.998
X_{26}	1.000	0.978
X_{27}	1.000	0.991
X_{28}	1.000	0.993
X_{29}	1.000	0.835
X_{30}	1.000	0.997

Table 11 Total variance explained

	Initial eigenvalues			Extraction sums of squared loading		
Component	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	9.814	88.141	88.141	8.814	88.141	88.141
2	0.967	9.672	97.812			
3	0.196	1.959	99.771			
4	0.011	0.114	99.885			
5	0.010	0.102	99.987			
6	0.001	0.006	99.993			
7	0.000	0.004	99.997			
8	0.000	0.002	99.999			
9	0.000	0.001	100.000			
10	0.000	0.000	100.000			

Table 12 Component matrix

Variable	The first principal component
X_{21}	0.198
X_{22}	0.999
X_{23}	0.996
X_{24}	0.996
X_{25}	0.999
X_{26}	0.989
X_{27}	0.995
X_{28}	0.996
X_{29}	0.914
X_{30}	0.998

−1.83, −0.71, 0.06, 0.76, 1.74, 2.98, 4.07, 5.25), which presents a monotonous rising trend according to the time sequence. The upward trend reflects the basic situation of China's livelihood process in recent years and indicates that the people's income and consumption levels increase year by year, while the government's investments in medical and healthcare and social security also increase. The upward trend of the livelihood process has increased significantly since 2009.

The subsequent calculation of the factor loading matrix, factor score, and formula of the principal components indicates that the factor of the livelihood process principally dominates X_{22}, X_{23}, X_{24}, X_{25}, X_{26}, X_{27}, X_{28}, and X_{30}, then dominates X_{29}, and finally slightly dominates X_{21}. The intensive order of the variables that dominated by the livelihood process factor indicates the following: (1) In recent years, the status of the Chinese livelihood has significantly improved. Namely, people's income has increased faster, consumption ability has been strengthened, living standards has improved, medical conditions have improved, and social security has been strengthened. Significant improvement of the livelihood has been mainly due to the vigorous implementation of the government's livelihood policies. (2) X_{29} represents the number of people who receive the minimum living allowance, which reflects the status of social welfare and social security, and constitutes a minor position in the livelihood process factor. X_{29} has both forward and reverse effect: the forward effect of the rising value for X_{29} indicates that more people with low income or without income can enjoy social welfare and security, whereas the reverse effect indicates that the income gap between the rich and the poor has been sharply widened in China. (3) X_{21} has not significantly increased in recent years, its performance is inconsistent with the rising trend of the livelihood process factor, which means that increasing employment rates is a long-term task for China to maintain a stable economic development and improve livelihood. Based on the above analysis, the following can be concluded regarding the Chinese livelihood process: In recent years, the status of Chinese livelihood has indicated an obvious improvement due to the government's livelihood and distribution policies, residents' income has increased quickly, and living standards have visibly improved; however, simultaneously, the trend of the income gap between the rich and the poor has widened sharply, and improving the employment rate will be an arduous task in the livelihood process.

3.4 Factor Analysis of the Livelihood Achievements

The variables of livelihood achievements in this study are $X_{31}, X_{32}, \ldots, X_{37}$ (see Table 1). This study extracts one common factor and constitutes one principal component by the calculation for the factor analysis. The corresponding results are shown in Tables 13, 14, and 15.

The first principal component (Z_5) of the livelihood achievements is extracted using the principal component analysis as follows:

$$Z_5 = -0.40X_{31} + 0.40X_{32} + 0.40X_{33} + 0.15X_{34} + 0.41X_{35} + 0.41X_{36} + 0.40X_{37}$$

Table 13 Communalities

Variable	Initial	Extraction
X_{31}	1.000	0.955
X_{32}	1.000	0.924
X_{33}	1.000	0.938
X_{34}	1.000	0.136
X_{35}	1.000	0.971
X_{36}	1.000	0.993
X_{37}	1.000	0.950

Table 14 Total variance explained

	Initial eigenvalues			Extraction sums of squared loading		
Component	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	5.868	83.821	83.821	5.868	83.821	83.821
2	0.909	12.983	96.805			
3	0.142	2.026	98.831			
4	0.054	0.770	99.601			
5	0.024	0.347	99.948			
6	0.003	0.041	99.989			
7	0.001	0.011	100.000			

Table 15 Component matrix

Variable	The first principal component
X_{31}	−0.977
X_{32}	0.961
X_{33}	0.969
X_{34}	0.369
X_{35}	0.985
X_{36}	0.997
X_{37}	0.975

Z_5 sums up 83.8 % of the information on the seven variables that represent the degree of social poverty, population quality, leisure time, and life expectancy. Therefore, Z_5 can be interpreted as a factor of livelihood achievements. The serial numerical value of Z_5 from 2002 to 2013 is (−3.34, −3.00, −2.16, −1.93, −1.23, −0.42, 0.07, 1.01, 1.59, 2.28, 3.27, 3.85), which presents a monotonous rising trend according to the time sequence. The upward trend indicates that the development of the Chinese economy improves livelihood, reduces social poverty, improves population quality, and increases residents' leisure time and life expectancy. Particularly from 2009, the livelihood achievements are evidently shown.

The subsequent calculation of the factor loading matrix, factor score, and formula of the principal components indicates that the factor of livelihood achievements principally dominates X_{32}, X_{33}, X_{35}, X_{36}, and X_{37} and subsequently dominates X_{34}. The intensive order of the variables that is dominated by the livelihood achievement factor indicates the following: (1) The Chinese livelihood has evidently improved in the past 10 years and expresses a good trend on the whole, which is characterized by the gradual reduction of social poverty, the improvement of the population's cultural quality, the increase of residents' leisure time, and the expansion of life expectancy. (2) X_{34} constitutes a minor position in the factor of livelihood achievements, and its improvement is not evident, which indicates that further improvement of population quality is needed. Criminal cases indicate a slight rising trend, which is significantly related to population quality, as too many criminal cases will cause social unrest. (3) The coefficient of X_{31} in the formula of the principal components for livelihood achievements has a minus sign. X_{31} is a contrary indicator that presents the decline as a good phenomenon. However, the decline trend is not evident, which indicates that social poverty has gradually been reduced, but the degree of reduction is slow. There is still much space for improvement regarding the reduction of social poverty in China. Based on the above analysis, the following can be concluded regarding the Chinese livelihood achievements: Chinese livelihood has been significantly improved as there is an overall positive trend in recent years.

3.5 *Overall Analysis of the Sustainable Livelihood*

This study takes Z_1, Z_2, Z_3, Z_4, and Z_5 which are the values of five extracted principal components (the livelihood environment has two principal components) from the four fields of sustainable livelihood as intermediate variables and subsequently conducts a factor analysis to determine a simplified general factor of the Chinese sustainable livelihood. The calculation results are shown in Tables 16, 17, 18, and 19.

Table 16 Communalities

Variable	Initial	Extraction
Z_1	1.000	0.993
Z_2	1.000	1.000
Z_3	1.000	0.998
Z_4	1.000	0.995
Z_5	1.000	0.997

Table 17 Total variance explained

	Initial eigenvalues			Extraction sums of squared loading		
Component	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	3.978	79.560	79.560	3.978	79.560	79.560
2	1.006	20.112	99.673	1.006	20.112	99.673
3	0.011	0.213	99.886			
4	0.005	0.092	99.978			
5	0.001	0.022	100.000			

Table 18 Eigenvector

Variable	Eigenvector 1	Eigenvector 2
Z_1	0.4999	0.0000
Z_2	0.0010	0.9970
Z_3	0.5004	−0.0369
Z_4	0.4999	−0.249
Z_5	0.4999	0.0598

Table 19 Component matrix

Variable	The first principal component	The second principal component
Z_1	0.997	0.000
Z_2	0.002	1.000
Z_3	0.998	−0.037
Z_4	0.997	−0.025
Z_5	0.997	0.060

The two principal components are calculated using principal component analysis. The first principal component Y_1 is the integration of Z_1, Z_3, Z_4, and Z_5, as shown below:

$$Y_1 = 0.4999Z_1 + 0.0010Z_2 + 0.5004Z_3 + 0.4999Z_4 + 0.4999Z_5$$

Y_1 sums up 80 % of the total information of Z_1, Z_2, Z_3, Z_4, and Z_5 which reflect the livelihood environment, livelihood ability, livelihood process, and livelihood achievements. This constitutes the overall factor of sustainable livelihood. The serial numerical value of Y_1 from 2002 to 2013 is (−2.54, −2.26, −1.83, −1.56, −1.25, −0.56, −0.05, 0.65, 1.37, 2.03, 2.76, 3.24), which presents a monotonous increasing trend. Figure 2 illustrates the orbit of the Chinese sustainable livelihood. As can be derived from the trend, the overall status of the Chinese livelihood is promoted year by year and has significantly improved since 2009.

The values of the rotating component matrix indicate that three major fields (livelihood ability, livelihood process, and livelihood achievements) present an almost similar trend, namely, changes in these three livelihood fields are roughly synchronized and that the degree of improvement of these three fields is similar and stable. Y_1 mainly dominates Z_1, Z_3, Z_4, and Z_5, and the scores of livelihood ability, livelihood process, and livelihood achievements have increased, which confirm that China's sustainable livelihood has apparently improved in the last 10 years.

The second principal component Y_2 is primarily an integration of environment factor Z_2 as shown below:

$$Y_2 = 0.0000Z_1 + 0.9970Z_2 - 0.0369Z_3 - 0.0250Z_4 + 0.0598Z_5$$

Y_2 sums up 20 % of the total information on livelihood environment, livelihood ability, livelihood process, and livelihood achievements. The serial numerical value

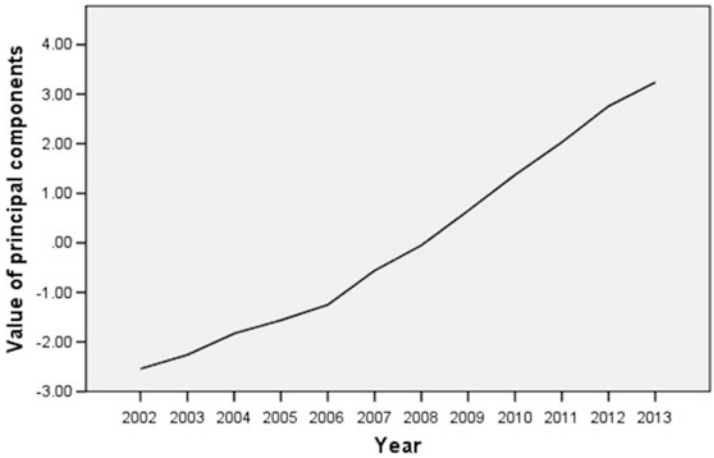

Fig. 2 The orbit of China's sustainable livelihood

of Y_2 from 2002 to 2013 is (−1.93, −0.88, 0.40, 0.45, 1.23, 1.05, 0.34, 0.85, −0.93, 0.89, −0.82, −0.65). The value of the second principal component has not formed a trend, and the direction is not stable. The fact that Y_2 mainly reflects the livelihood environment can explain why China's livelihood environment has not improved. Y_2 mainly dominates Z_2 from the point of the factor score. High pollution and emission of toxic chemicals have been somewhat controlled in recent years, but the value of Y_2 has not evidently declined, which means that the improvement of the livelihood environment has not been ideal.

At the beginning of the twenty-first century, the Chinese livelihood environment showed a trend of deterioration. Overall, the environmental situation is not good for the sustainable livelihood in China. Nonetheless, livelihood ability has been evidently promoted. While this improvement only affects quantity and has not improved quality, the government's efforts have still worked and achieved results. Moreover, the government's livelihood and distribution policies have tended to significantly improve livelihood in recent years, thereby rapidly increasing residents' income, improving living standards, reducing social poverty, improving population quality, and increasing residents' leisure time and life expectancy. Overall, the Chinese livelihood improved visibly in recent years. Therefore, the future status of the Chinese livelihood can be expected to improve even more.

4 Conclusion

This study establishes a statistical indicator system of China's livelihood from the perspective of sustainability. It describes the current situation of China's livelihood and employs multivariate statistics to analyze both its characteristics and problems.

The findings indicate that the depravation of livelihood environment counters the development of China's sustainable livelihood as a whole; however, such negative effect on the environment can be offset to a certain extent by relying on the enhancement of livelihood ability and implementation of livelihood policies, and the improvement of China's livelihood has been fairly evident recently. This study indicates five urgent problems to be solved regarding the Chinese livelihood, which should be given much more attention to promote the Chinese livelihood in the view of sustainable development. These problems include the following: China's livelihood environment has presented a deterioration trend, including the deterioration of both natural and social environment, and a slow improvement of artificial environment; the quality of livelihood ability is not positive, and there is still much space for enhancement in terms of quality; the development of social infrastructure and the ability to cope with natural disasters are slow; the income gap between the rich and the poor has been widened sharply, and there is still much scope for improvement in reducing poverty; and improving the employment rate will be an arduous task in the livelihood process.

To maintain the sustainability of the Chinese livelihood, China must solve these five arduous problems over a long period of time in the future. Key points for this may include the following: (1) Regarding livelihood environmental problems, China should incite environmental protection consciousness among all people, strengthen its environmental protection responsibility system, conduct regulations of environmental protection, develop environmental protection industry, promote recycling economy and emissions reduction, and actively introduce foreign advanced environmental protection technology and management expertise. (2) Regarding the improvement of livelihood quality, China should foster many talented individuals with an ability for innovation, continue to develop education and scientific research, develop high-technology industries, and improve the innovation system. (3) Regarding the problems of social infrastructure and the ability to cope with natural disasters, China should vigorously develop the construction of social infrastructure and improve its ability to cope with natural disasters. (4) Regarding the problem of the income gap between the rich and the poor, China should establish a reasonable mechanism for income distribution and actively build a social environment and market through which people can become enriched by production factors, such as labor, capital, technology, and knowledge. China should adequately use its fiscal policy tools, optimize its tax system, and create opportunities for more people to own property income. China should accelerate economic development in underdeveloped regions, strive to narrow regional gaps, and optimize its social security system to solve the problem of social security in underdeveloped areas. (5) Regarding the problem of the employment rate, China should effectively conduct labor skills training, expand employment, develop new service industries, and actively provide more convenience for the development of small- and medium-sized enterprises and for university graduate's self-employment. Solving these five aforementioned problems is essential at this stage. If these efforts are fully implemented, China's sustainable livelihood will enter a new stage in which the welfare of the Chinese people will increase, and they will live happier lives.

References

Balgis OE, Nameldin GE, Hanafi A, Sumaya Z (2005) Sustainable livelihood approach for assessing community resilience to climate change: case studies from Sudan. AIACC Working Paper No. 17, August

Chambers R, Conway G (1991) Sustainable rural livelihoods: practical concepts for the 21st century. IDS Discussion Paper 296, Brighton

Jian J (2010) Analyses of the relationship between livelihood improvement and social harmony. J Shanxi Inst Youth Manag Cadre 3:87–89 (in Chinese)

Jie S, Zhigang Y (2008) Discuss on statistical indicator system of the livelihood. China Stat 7:56–57 (in Chinese)

Lasse K (2001) The sustainable livelihood approach to poverty reduction, an introduction. SIDA Working Paper, February

Minquan L, Jiantuo Y, Wang S (2009) View of human development and sustainable development. J Nanjing Univ (Philos Humanit Soc Sci Ed) 1:20–30 (in Chinese)

National Bureau of Statistics (2003–2014) China statistical yearbook. China Statistical Publishing House

UNDP (1997) Human development report 1997. Oxford University Press, New York/Oxford

Xiangmin L (2009) Analysis on the thought of the communist party of China about livelihood since the reform and opening. J Fujian Norm Univ (Philos Soc Sci Ed) 4:1–8 (in Chinese)

Xiudong X (2008) Confirmation on political category of the concept for livelihood. J Shandong Univ Sci Technol 4:19–22 (in Chinese)

Yejie L (2008) Confirming on connotation and denotation of the concept about livelihood. J Shandong Univ Sci Technol 4:22–25 (in Chinese)

Green Environment Social Economic System for Urban-Rural Integration

Bin Li, Wen-Hong Cheng, and Cheng-Long He

Abstract This chapter highlights a small-scale green water environment social economic system in the context of the New Normal for China's urban-rural integration. A literature review of water environment social economic system was carried out and included a discussion of a small- and medium-sized urban coordinated development theory on land and infrastructure aspects relative to Jiaxing's location, scale, and administrative division. Jiaxing is a prefecture city with a population of four million, located in Yangtze River Delta of Eastern China within Zhejiang province, between the cities of Shanghai and Hangzhou, and belongs to a typical area of river network. Furthermore, water governance and rural non-point source pollution due to intensive livestock breeding in the south of Yangtze River region, especially due to a recent incident involving diseased pigs, were comprehensively analyzed. Finally, recommendations on green environment social economic system for urban-rural integration in China were proposed.

Keywords Jiaxing • Green water environment social economic system • Urban-rural integration

1 Introduction

A global water sustainability perspective focused on regional environment social economic system is different from either a management perspective or an institutional perspective.

In the New Normal of China, measures against sewage, flood water, drainage water, water supply, and water saving, namely, governance of water's five aspects, have been taken in Zhejiang for regional provincial water sustainability, instead of expression of ecosystem services, water resource management, water service management, and flood defense principle. Both Yiwu city of Jinhua prefecture-level city and Yuhuan county of Taizhou prefecture-level city of Zhejiang province

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in China have implemented some pilot projects and have already achieved some performance in water-saving society construction (Li et al. 2009; Li and Yang 2011). However, since reform and opening up, complexity of regional environment social economic system has been growing in small- and medium-sized cities of Yangtze River Delta, where water shortage due to the deterioration of water quality is quite serious (Li 2005; Li et al. 2006, 2008). A drinking water crisis, caused by blue algal bloom in Taihu Lake due to eutrophication in Wuxi city, Jiangsu province, in May 2007, has brought about great losses, with increased risk of cancer. The mode for an economic and social system with characteristic of resource sharing, realizing industrialization firstly and marketization secondly, has even to be reviewed due to this above drinking water crisis. Furthermore, dead pigs pulled from rivers in Shanghai had become a hot issue of great both domestic and foreign emotional concerns on a river water environment in 2013. Therefore, water governance in Yangtze River Delta in China has become an urgent problem to be solved arising with rapid urbanization of the area (Xu et al. 2008, 2009; Li et al. 2012; Li 2013, 2014a).

In this chapter, a literature review of the water environment social economic system was carried out. Then, Yangtze River Delta's location and Jiaxing's urban system were summarized. Further, water system and water issues in Jiaxing city were analyzed. Finally, recommendations on green environment social economic system for urban-rural integration in China were proposed.

2 Literature Review for Water Environment Social Economic System

Regional environment social economic systems are connected with a local hydrological structure, definitions of environmental flow, of total water withdrawal, and of adaptive capacity from the Southern Hemisphere to the Northern Hemisphere. Environmental flow refers to how much water is needed by a river and when, in order to support the river's basic ecological functions due to the case of Santa Fe River in the United States (Groenfeldt and Schmidt 2013). Total water withdrawal represents sustainability capacity of environment social economic system to mobilize water resources available without distinction of uses (Dondeynaz et al. 2012). And adaptive capacity is an underlying ingredient for dealing with some of the fundamental challenges to aligning complex adaptive environment social economic system, and institutional dynamics in practice of Perth and Adelaide in Australia were given (Bettini et al. 2015).

In the Southern Hemisphere, case studies in Africa for water resource and public participation were summarized. Three of South Africa's major rivers (Orange-Senqu, Limpopo, and Inkomati) are shared with neighboring countries; however, the properties of institutional arrangements governing water resources often do not fit ecosystem properties (Herrfahrdt-Pähle 2014). Ghana's capital city, Accra, is a fast-growing, coastal urban center facing considerable environmental social system planning challenges, especially public participation in three kinds of community, namely, indigenous community, in-migrant community recently established, and poor community with population growth (Morinville and Harris 2014).

And in the Northern Hemisphere, case studies in Japan, Bangladesh, India, Turkey, the United States, the Netherlands, and England for flood damage, a dynamic socioeconomic model, rural village sanitation, water provision, water transfer, land development, prevention of mudslides, water strategy, and adaptive management were summarized. Regarding water resource management as the regional and purpose-wise distribution of public goods, damage to agriculture and residents due to flood in Chitose River basin, Hokkaido, was analyzed; and based on the principle of material balance, an ecosystem model and a dynamic socioeconomic model were specified to analyze an optimal policy to improve the water quality of Lake Kasumigaura, Ibaraki, Japan (Yamamura and Miyata 1980; Higano and Yoneta 1998). Sanitation issues in Bansbaria and Jessore, Bangladesh, and willingness to improve their living environment after installing pond sand filter facility were introduced (Sakai et al. 2011). Unsustainable water provision of Hyderabad in India to the global level and its interactions with national- and city-level decision-making bodies were described (Nastar 2014). Interbasin water transfer projects in Melen and Kizilirmak, Turkey, concerning urban-rural life, unsustainable water use, and agricultural water resource practices were assessed (Islar and Boda 2014). Challenges in EU benchmarks, schematic layout, and the development timeline of Dublin's water supply system were described, in relation to the largest water works project for long-distance water transfer ever proposed in Ireland from the midlands to Dublin (Kelly-Quinn et al. 2014). Adaptive management may foster ecological resilience in the Columbia River basin covering 672,102 km^2 in Canada and the United States (Cosens and Williams 2012); however, a much longer-term water quality monitoring effort is needed to identify the effectiveness of alternative land development and water governance policies, due to a conceptual model for coupled natural and human systems framework for understanding the coupled environmental governance and water quality in the Columbia River of Portland-Vancouver metropolitan area (Chang et al. 2014). Canada lacks a current well-coordinated water strategy, while Chile lacks regional discretion, leaving rural communities especially vulnerable in times of disasters such as mudslides and with water programs (crop insurance and drinking water or sanitation) that have not been particularly effective (Hurlbert and Diaz 2013). There are such factors as financial compensation, broad environment social economic system changes, and flood disasters in the Dutch island of IJsselmonde in the Netherlands near Rotterdam (Mostert 2012).

3 Yangtze River Delta's Location and Jiaxing's Urban System

The region in Yangtze River Delta in China is developing most rapidly along with the line of Nanjing-Shanghai-Hangzhou-Ningbo, called the "Z" route (see Fig. 1). Experiences with private sector participation in water services lead to doubts about

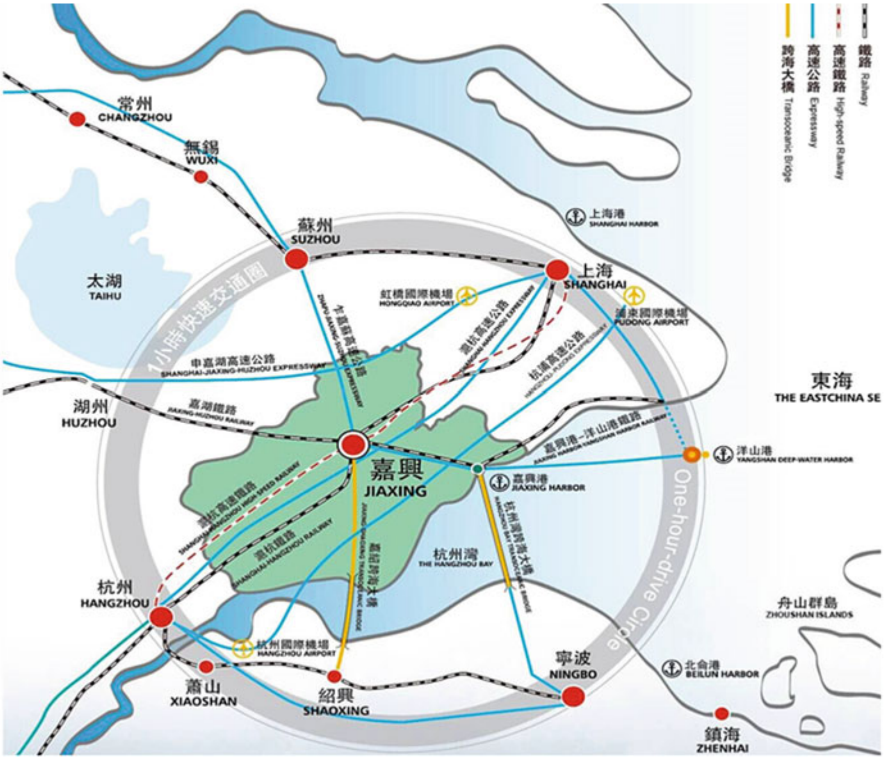

Fig. 1 Yangtze River Delta's "Z" route (Source: http://www.jxedz.com/cn/about/show.php?id=4)

whether water privatization poses a long-term risk to regional environment social economic system. Of course, agriculture, urban infrastructure, land use, overuse behavior, and environmental pollution also affect water use (Gupta and Pahl-Wostl 2013).

The concept of Yangtze River Delta includes Shanghai, which is one municipality under the direct control of the central government, and two provinces Jiangsu and Zhejiang and generally includes 16 cities: Shanghai, Suzhou, Hangzhou (provincial capital city, sub-provincial city), Wuxi, Ningbo (sub-provincial city, city specifically designated in the state plan), Nanjing (provincial capital city, sub-provincial city, national regional central city), Nantong, Shaoxing, Changzhou, Taizhou (Zhejiang), Jiaxing, Yangzhou, Zhenjiang, Taizhou (Jiangsu), Huzhou, and Zhoushan.

Jiaxing city, Zhejiang province, China, is located in the center of the "Z" route in Yangtze River Delta, which belongs to the "Hang-Jia-Hu" (namely, Hangzhou-Jiaxing-Huzhou) plain in the northeast section of Zhejiang province, and is a typical area of river network. The provincially administered municipality of Jiaxing consists of seven parts, comprising two districts of Nanhu (which means South Lake) and Xiuzhou; two counties, namely, Jiashan and Haiyan; and three county-level cities, namely, Tongxiang, Pinghu, and Haining.

Jiaxing city is also one of the cities in the southern wing of Yangtze River Delta and Taihu Lake basin areas; the southwest region of the city is close to Qiantang River and Hangzhou Bay, the north to Shanghai and Suzhou city, the west to Huzhou and Hangzhou city, and the south to Ningbo city. Jiaxing city is connected with Ningbo city by the Hangzhou Bay Sea-Crossing Bridge; its geographic district scope is in the E 120°18′–121°18′, N 30°15′–31°.

Jiaxing has become a transportation hub of the metropolitan interlocking region. As an important transportation hub in Yangtze River Delta, Shanghai-Hangzhou railway, Shanghai-Hangzhou high speed railway, Shanghai-Hangzhou highway, Zhapu-Jiaxing-Suzhou highway, and Shanghai-Jiaxing-Huzhou highway connect Jiaxing and its nearby cities. It takes 4 h to travel from Jiaxing University to Shanghai Pudong International Airport, 2 h to Shanghai Hongqiao International Airport, 3 h to Hangzhou Xiaoshan International Airport, and 4 h to Ningbo city by public transportation means. Foreign trade is easily accessible to the area through the port of Shanghai and port of Zhapu, Jiaxing. Jiaxing is known throughout the nation as the birthplace of the Chinese Communist Party. Generally, people live with a relaxed and comfortable lifestyle, and needs for clothing, eating, housing, and traveling are easily satisfied.

The distance from east to west in Jiaxing is 94 km and from north to south is 79 km. The distance of the Grand Canal in Jiaxing was 81 km (Lv 2004a). The “Hang-Jia-Hu” (namely, Hangzhou-Jiaxing-Huzhou) plain covered a total area of 6,391 km^2, while Jiaxing covered a total area of 5,827 km^2; Jiaxing was inhabited by 3.36 million people in 2006 and its population density was 850 people/km^2 (Quan and Shen 2002; Jiaxing Local Chronicles Editing Committee 2003; Luo and Wan 2006). There were 1.19 million auto vehicles in 2012 (Yangtze River Delta Joint Research Center 2012). Water area accounted for 8 % of the total area while paddy field accounted for 80 % of arable area in Jiaxing (Dai et al. 2002; Zhang and Wang 2000). Total arable area in Jiaxing was 212,000 ha and that of the two districts (namely, Nanhu and Xiuzhou) was 52,000 ha in 2006 (Bureau of Statistics of Zhejiang Province 2007). The district of Nanhu, with five townships, covered a total area of 426 km^2 and was inhabited by 0.46 million people in 2005. The district of Xiuzhou covered a total area of 542 km^2 (Du et al. 2006). The total arable area was 22.77 thousand hectares, and the total amount of live pigs in the district of Nanhu was 2.01 million heads (Bureau of Statistics and Development and Reform of Nanhu District 2007). Jiaxing is known as the “home of silk” and hence has been a producer of textiles as well, including woolens. It is one of the world’s largest exporters of leather goods. The city also has precision machinery, chemical raw material, and auto parts industries.

4 Water System and Water Issues in Jiaxing City

Jiaxing is mainly affected by three major water systems, namely, the Taizhou Lake, with a drainage area of 2,338 km^2; Grand Canal, with a length of 1,794 km; and Qian-tang-jiang, with a basin area of 55,600 km^2. Jiaxing has an energetic Wuyue culture with a clear geographical advantage (Yang and Wang 2005; Mao et al. 2010). However, water use amount was more than water resource available (Zhu 2004). Annual amount of runoff in Jiaxing reached 1.58 billion m^3, and amount of environmental flow in Jiaxing was estimated to be about 5.4 billion m^3, while amount of environmental flow in Fuyang city located in the upper stream of Qiantang-jiang was estimated to be about 33.6 billion m^3 (Xu and Lv 2004a; He and Chen 2005; Wang and Zhong 2006). Channel distribution density was 3.5 km/km^2. Design drainage discharge reached 255 m^3 per second, while design flood discharge reached 204 m^3 per second (Ye et al. 2001; Xu and Lv 2004b). Sewage discharged in ocean reached 0.55 million m^3 per day (Lu 2004). An average of 10,000 yuan GDP water consumption in Jiaxing was 47.5 m^3 (Lv 2004b).

In recent decades, economic growth has reached a new stage in Jiaxing, but the ecosystem has been damaged as a result. The South Lake in Jiaxing, together with the West Lake in Hangzhou and the East Lake in Shaoxing, constitutes the three major lakes in Zhejiang. The South Lake, where the Communist Party of China was officially founded, is a scenic lake and a frequent destination of tourists and sightseers. The first national congress of the Communist Party of China was transferred from Shanghai to Jiaxing in July 1921, and the final agenda was carried out in a pleasure boat on the South Lake, thus marking the birth of the Party and making it one of the most important and sacred places of the Revolution. Lying half a kilometer southeast of Jiaxing, the South Lake is composed of two parts (the eastern lake part and the southwestern lake part) which look like a pair of mandarin ducks tumbling merrily about giving the South Lake the nickname “the Mandarin Duck Lake.” The lake is long from south to north and narrow from east to west and covers an area of 54 ha with the depth of 3–5 m. The annual rainfall is 1,155 millimeters (mm), and the annual amount of evaporation is 910 mm. The water level of the lake is self-maintained and is generally above 2.8 m. The South Lake connects to Pinghutang, Huairenhe, Changfenggang, and Jinjieqiaogang. It is quite important for Jiaxing’s sustainable development since it is used for many aims ranging from socioeconomic activities such as fishing and tourism, as well as a transportation route, and a place to dump solid/liquid waste. The changes of water quality affect the water ecosystem directly. The pollutants such as industrial wastewater, sewage, fertilizer, and pesticides have caused the eutrophication in South Lake. The water quality in South Lake has turned to a level V (five) degree according to Chinese national standard, namely, “Environmental Quality Standard for Surface Water GB 3838-2002.” The deterioration has damaged the agricultural irrigation, fishery cultivation, and the municipal drinking water.

Pollutants from the “Hang-Jia-Hu” (namely, Hangzhou- Jiaxing- Huzhou) plain were decided by the Grand Canal. Water quality in the waterways network of Taihu Lake basin of Jiaxing section varied from a level IV degree to a level V degree, mainly inferior to a level V degree. According to annual monitoring results, the number of cross sections where water quality was a level V degree or inferior to a level V degree accounted for 61.1–94.4 % of the total cross section number in the waterway network of Jiaxing. The water quality in the Grand Canal of Jiaxing section was inferior to a level V degree (He and Hu 2000). Therefore, water in

Taihu Lake basin of Jiaxing section had also been seriously polluted. Water quality for 80 cross sections of 42 rivers and 6 lakes was monitored and assessed in 2002 (Zhou and Su 2005). The monitoring assessment showed that in the monitored waterways of 758.14 km, only 0.9 %, namely, 6.8 km of the waterway's quality, reached a level III degree; about 19.2 %, namely, 145.55 km, reached a level IV degree; about 8.5 %, namely, 64.23 km, reached a level V degree; and about 71.4 %, namely, 541.56 km of the waterway's quality, was inferior to a level V degree. The monitoring assessment also showed that in the monitored six lakes of 8.68 km^2 in the whole year, water bodies of a level III degree accounted for 13 %, a level IV degree accounted for 43.6 %, a level V degree accounted for 23 %, and inferior to a level V degree accounted for 20.4 %. The monitoring assessment in June 2003 showed water bodies of a level III degree accounted for 7.4 %, a level IV degree accounted for 16.0 %, a level V degree accounted for 6.2 %, and inferior to a level V degree accounted for 70.4 % (Tao and Jiang 2005). The monitoring assessment in January 2005 showed there were no water bodies of a level III degree, water bodies of a level IV degree accounted for 4.4 %, water bodies of a level V degree accounted for 7.4 %, and water bodies inferior to a level V degree accounted for 88.2 % (Zhou and Su 2005; Li 2014b). From April 2002 to April 2003, the distribution of microorganisms had been investigated in six sampling points of surface area in the South Lake. The annual mean value was 2,752 entries/mL for heterotrophic bacterium, 326 entries/mL for cellulose-decomposing bacterium, 393 entries/mL for ammonia-oxidizing bacterium, 305 entries/mL for ammonia-oxidizing bacterium, 1507 entries/mL for nitrate-reducing bacterium, 55 entries/mL for denitrifying bacterium, 36.5 entries/mL for organic phosphorus-decomposing bacterium, and more than 5,000 entries/ml for coliform (Liu et al. 2005). The distribution of organic phosphorus-decomposing bacteria had a linear relationship with the total amount of phosphorus in the lake. The total phosphorus, ammonia nitrogen, and volatile phenol were still on a high level. The South Lake was of eutrophication. The water quality had turned in a positive direction from a level V degree in some indexes, such as ammonia, nitrogen, and total phosphorus, to a level III degree. But chemical oxygen demand (COD), biochemical oxygen demand (BOD), volatile phenol, etc. reached a level IV degree. Organic matter resulted in massive reproduction of cellulose-decomposing bacterium, ammonia-oxidizing bacterium, and nitrate-reducing bacterium. Sprinkling of organic phosphorus pesticides resulted in many organic phosphorus-decomposing bacterium. In addition, especially large amount of coliform indicated the South Lake also had been seriously polluted.

Because Jiaxing expands continuously and quickly, lots of farming lands around the constructed urban area were expropriated by the government in order to meet the demand of city development; meanwhile, some villages surrounded by the constructed urban area turned into inner city villages (Zhang 2004). However, in the New Normal of China under low fertility and aging (Suzuki 2011), the one-child policy has been abolished, of course also affecting Jiaxing's sustainability.

Two issues exist with the Jiaxing water sustainability. First, the drinking water source pollution was serious. Water qualities in some drinking water source areas have not reached the national standard. There were nine water plants in Jiaxing

(Zhang et al. 2002). In 2002, taking the five water plants' upper stream of intakes as monitor location, including Jiaxing by Jiaxing Nanmen water plant, Shijiuyang plant, Shuangxiqiao water plant in Haining city, Guoyuanqiao water plant in Tongxiang city, and water plant in Jiashan county, various synthesized mean values were assessed, according to the "Environmental Quality Standard for Surface Water GB 3838-2002." In the whole year, among the five water plants, water quality of intakes in four plants was assessed as inferior to a level V degree, and only one plant reached a level V degree. The indicators exceeding the national standard include dissolved oxygen, ammonia nitrogen, total phosphorus, total nitrogen, iron, and manganese, a total of six indexes.

Second, some drinking water of shallow wells in rural areas was not safe. Deep underground water was generally polluted. The population using deep confined water as drinking water grew year by year. In 2002, of the 3.6 million people in the city, 0.9 million people drank from municipal ground tap water plants; 1.8 million people drank deep underground water, which accounts for 50 % of the total population; and 0.9 million people drank from shallow wells in rural areas. In 2003, among the whole city of 4.2 million people, 1 million people drank from municipal ground tap water plants; 2.7 million people drank deep underground water, which accounts for 64.3 % of the total population; and 0.5 million people drank from shallow wells in rural areas. The number of people who drank deep underground water in 2003 increased by 14.3 % from that in 2002. And industrial water consumption access point in Jiaxing city is more than Shaoxing city in the South of Hangzhou Bay. Obviously, deep underground water used as material of local enterprise had been seriously overexploited. Thus, surface subsidence appeared in a large area, while related cumulative settlement depth reached 589–814 mm in Jiaxing (Zhang and Zhang 2005; He 2003). However, artificial recharge technology had been adopted in Shanghai as surface subsidence countermeasure (Lei 2005).

In general, the seawater environmental quality of Jiaxing's sea areas was good. The sea area where the water quality accorded with the Sea Water Quality Standard Category I accounted for 94 % of the total sea area. However, there was about 48,000 km^2 of coastal waters where quality was worse than Category IV, and pollution in Hangzhou Bay occupied 6,673 km^2 aggravating the area, causing the red tide to grow year by year. From Qian-tang-jiang, the amount of oil flow into the sea was 3,640 tons, COD was 0.31 million tons, heavy metals was 690 tons, and arsenic was 44 tons in 2008 (State Oceanic Administration 2009).

As all items according to "Standards for Drinking Water Quality GB 5749-2006" were implemented in July 2012, some cities had difficulty to adopt the stricter standards in Yangtze River Delta in China. As an existing policy tool, pollutant emission trading markets were established in Jiaxing city in November 2007, Xiuzhou district in June 2002 (Du et al. 2006), and Nanhu district in January 2008, respectively. Pollutants mean COD and SO_X. Price of sewage per ton was 200–300 yuan. Preliminary onsite investigation for biomass technologies in Jiaxing, Zhejiang, China, was taken (see Fig. 2). We found the existing biomass technologies in the township of Zhuling, Nanhu district, Jiaxing, for feces and urine of pigs raised,

Fig. 2 Onsite investigation for biomass technologies in Jiaxing, Zhejiang, China (Photos taken by the authors)

could not reduce the emission of the greenhouse gases effectively and should be improved in many aspects for future generations. Non-point source pollution could not be easily corresponded to actors at individual level, involving with land use (Li et al. 2011). Based on behavior-pressure-effect-impact-response model, non-point source pollution involved feces and urine recycling level (Ma et al. 2005). As a primary result, non-point source pollution in Nanhu district was reduced through organic fertilizer sold in domestic area by biogas technology, and biogas liquid crust had become another issue to be solved. Meanwhile, non-point source pollution in Xiuzhou district was reduced through fertilizer sold in Japan.

5 Recommendations on Green Environment Social Economic System for Urban-Rural Integration in China

Global case studies for water resource governing, public participation, flood damage, a dynamic socioeconomic model, rural village sanitation, water provision, water transfer, land development, prevention of mudslides, water strategy, and adaptive management were summarized. Global warming may change some aspects of the water circles, such as twin typhoons or trityphoons, and/or in the most withered period, which affect sustainability development of small- and medium-sized cities. Water environment social economic system is a superb system for local region people and would not be changed temporarily. Furthermore, climate change adaptation strategies need to be tailor-made with respect to local environment social economic system. For example, usually Jiaxing could not be influenced by a typhoon; however, the typhoon named Cuckoo in 2015 thoroughly checked the infrastructure of Jiaxing.

In the New Normal of China, governance of water's five aspects has been taken in Zhejiang province for regional water sustainability. Jiaxing is mainly affected by three water systems, namely, Taihu Lake, Grand Canal, and Qian-tang-jiang. As an existing policy tool, pollutant emission trading markets were established firstly in the prefecture level in China. National standards related with water supply are the "Environmental Quality Standard for Surface Water GB 3838-2002" and "Standards for Drinking Water Quality GB 5749-2006." Water supply project from Taihu Lake to Jiaxing and/or that from Qian-tang-jiang to Jiaxing was under discussion due to serious pollution of urban water source. On the contrary, water supply project from Qian-dao-hu of Qian-tang-jiang to Jiaxing or to Ningbo was also investigated.

"Green water castle peak is the jin-shan silver," initially the slogan for circular economy in Zhejiang province, would also be an ideal for green environment social economic system. Existing biomass technologies for rural non-point source pollution would be improved in many aspects for future generations considering such factor as environmental tax reform. In the long term, water price for livelihood would increase while that for industry and agriculture would decrease. The practice of green environment social economic system for urban-rural integration in "Hang-Jia-Hu" (namely, Hangzhou-Jiaxing-Huzhou) plain demands a small and beautiful town to be constructed with rural sewage disposal facilities, considering inner city village, a combination recycling model of farming and animal husbandry, adaptive capacity, community public participation, and balanced supplying services.

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References

Bettini Y, Brown RR, de Haan FJ (2015) Exploring institutional adaptive capacity in practice: examining water governance adaptation in Australia. Ecol Soc 20(1):47–66

Bureau of Statistics and Development & Reform of Nanhu District (2007) Statistical yearbook of Nanhu District, Jiaxing 2006, Internal Book (in Chinese)

Bureau of Statistics of Zhejiang Province (2007) Zhejiang provincial statistical yearbook 2007. China Statistical Press, Beijing (in Chinese)

Chang H, Thiers P, Netusil NR, Yeakley JA, Rollwagen-Bollens G, Bollens SM, Singh S (2014) Relationships between environmental governance and water quality in a growing metropolitan area of the Pacific Northwest, USA. Hydrol Earth Syst Sci 18(4):1383–1395

Cosens BA, Williams MK (2012) Resilience and water governance: adaptive governance in the Columbia river basin. Ecol Soc 17(4):3–16

Dai Q-Y, Zheng F-J, Zhang C (2002) Genesis of water and soil loss in Jiaxing and countermeasure. Zhejiang Hydrotech 6:41–43 (in Chinese)

Dondeynaz C, Carmona MC, Cespedes LJJ (2012) Analysing inter-relationships among water, governance, human development variables in developing countries. Hydrol Earth Syst Sci 16(10):3791–3816

Du D-R, Xu W-X, Sun D-M (2006) Xiuzhou model of emission trading system. Zhejiang Today 3:44–46 (in Chinese)

Groenfeldt D, Schmidt JJ (2013) Ethics and water governance. Ecol Soc 18(1):14–23

Gupta J, Pahl-Wostl C (2013) Global water governance in the context of global and multilevel governance: its need, form, and challenges. Ecol Soc 18(4):53–62

He X-Z (2003) The condition and management of water resources in Jiaxing. Water Resour Dev Res 3(3):25–26 (in Chinese)

He X-Z, Chen H (2005) Preliminary discussion on ecological environment water demand in Jiaxing. Water Resour Dev Res 5(3):15–16, 19 (in Chinese)

He X-Y, Hu Y (2000) Analysis of surface water environment quality in the Taihu drainage basin of plain of Hang-Jia-Hu. Environ Pollut Control 22(6):33–35 (in Chinese)

Herrfahrdt-Pähle E (2014) Applying the concept of fit to water governance reforms in south Africa. Ecol Soc 19(1):25–36

Higano Y, Yoneta A (1998) Economical policies to relieve contamination of Lake Kasumigaura. Stud Reg Sci 29(3):205–218 (in Japanese)

Hurlbert MA, Diaz H (2013) Water governance in Chile and Canada: a comparison of adaptive characteristics. Ecol Soc 18(4):61–75

Islar M, Boda C (2014) Political ecology of inter-basin water transfers in Turkish water governance. Ecol Soc 19(4):15–22

Jiaxing Local Chronicles Editing Committee (2003) Jiaxing year book 2003. Local Chronicles Press, Beijing, pp 1–520 (in Chinese)

Kelly-Quinn M, Blacklocke S, Bruen M, Earle R, O'Neill E, O'Sullivan J, Purcell P (2014) Dublin Ireland: a city addressing challenging water supply, management, and governance issues. Ecol Soc 19(4):10–22

Lei W (2005) Analysis of the mechanism and social benefit to the urban land subsidence in China. Ind Technol Econ 6(24):118–119, 126 (in Chinese)

Li B (2005) Environmental economic research on technological policy to improve water environment in Yangtze River Delta – the example of Jiaxing, China. Proceedings of the environmental and resource economics early-career researcher workshop, Sturt University, Bathurst, 27–28 October

Li B (2013) Green small-scale urban environment social economic system planning: theory and methods for Jiaxing City, Zhejiang Province, China. Collection of papers and abstracts for sub-forum: urbanization – sustainable planning and diversity, Beijing Forum 2013, 272–283. Beijing University, 1–3 November

Li B (2014a) Study on regional environment social economic system near Hangzhou Bay in China – the case of the Jiaxing City. Adv Mater Res 962–965:2489–2492
Li B (2014b) Study on regional water environment social economic system due to governance of water's five aspects. Appl Mech Mater 587–589:166–170
Li B, Yang H-G (2011) Sustainable development and utilization of water resources – case study of Zhejiang Province. Proceedings of International Conference on E-Business and E-Government of Institute of Electrical and Electronic Engineers (IEEE), 6408–6411, Howard Johnson Caida Plaza Shanghai, Shanghai, 6–8 May (in Chinese)
Li B, Du H-Z, Higano Y (2006) A preliminary research on comprehensive assessment to improve water environment in Yangtze River Delta: the example of Jiaxing, China. Proceedings of the 9th Summer Institute of Pacific Regional Science Conference Organization, Berjaya Times Square Hotel & Convention Center, Kuala Lumpur, 18–20 July
Li B, Du H-Z, Higano Y (2008) Water management in Yangtze River Delta – the case of the Jiaxing City. Proceedings of the Austria-China International Expert Conference of "Water for Future Generations", Northwest Agricultural and Forestry University, Yangling, 8–11 May (in Chinese)
Li B, Yang H-G, Lu J-Z, Li X-Q, Shen Y-P, Du H-Z, Li Z-X, Hu M, Yu X-J (2009) Study on basin water resource sustainable transaction in Zhejiang. Proceedings of the 13th World Lake Conference by the Chinese Society for Environmental Sciences, Chinese Environment Academy of Sciences, Wuhan City people's Government and co-sponsored by the International lake Environment Committee, Wuhan international Convention and Exhibition Centre, 1–5 November (in Chinese)
Li H, Xu F, Mizunoya T, Luo J, Yabar H, Higano Y (2011) Comprehensive watershed management policies in the Dian Chi Lake China with a focus on non-point source pollution. Stud Reg Sci 41(2):467–476
Li B, Yang H-G, Cheng W-H, Song Y, Zhang G-Z, Wang Z, Shibusawa H, Zhang C-W, Liu X-H, Yu X-J, Du H-Z (2012) Water environment social economic issues in Yangtze River delta in China-the case of the Jiaxing City. Proceedings of the 49th Annual Meeting of the Japan Section of the Regional Science Association International, Rissho University, Tokyo, 6–8 October
Liu Y, Zhao H-M, Cai L-L (2005) The present situation and impact assessment for the microorganism in the water Bay of South Lake in Jiaxing. Environ Pollut Control 27(1):41–43, 59 (in Chinese)
Lu B (2004) Design of sewage engineering project toward sea in Jiaxing city. China Water Waste Water 20(1):58–61 (in Chinese)
Luo Y-L, Wan P (2006) How does Jiaxing realize the master plan in urban and rural area? Urban Rural Dev 1:36–38
Lv H-L (2004a) Canal in Jiaxing water environment condition analysis and evaluation. J Zhejiang Water Conserv Hydroelectric Coll 16(2):10–11 (in Chinese)
Lv H-L (2004b) Investigation of water quality for drinking water in rural areas of Jiaxing City. Zhejiang Hydrotech 4(4–5):46 (in Chinese)
Ma Q-F, Huang X-J, Peng B-Z, Zai W-X, Liu L-W (2005) A positive study of the evaluation on the development of regional agricultural recycling economy. J Nat Res 20(6):891–899 (in Chinese)
Mao G-P, Shibusawa H, Wang Y, Higano Y (2010) Why Jiaxing does not benefit from its geographical advantages – case study of the Shanghai metropolitan area in China's Yangtze river delta –. Stud Reg Sci 40(3):809–817
Morinville C, Harris LM (2014) Participation, politics, and panaceas: exploring the possibilities and limits of participatory urban water governance in Accra, Ghana. Ecol Soc 19(3):36–47
Mostert E (2012) Water management on the island of IJsselmonde 1000 to 1953: polycentric governance, adaptation, and petrification. Ecol Soc 17(3):12–23
Nastar M (2014) What drives the urban water regime? An analysis of water governance arrangements in Hyderabad, India. Ecol Soc 19(2):57–66
Quan W-M, Shen J-F (2002) Countermeasure against agricultural non-point pollution in the rural area of plain of Hang-Jia-Hu. Agro-Environ Dev 19(2):22–24 (in Chinese)

Sakai A, Takahashi K, Sakamoto M (2011) A study on planning scheme to improve the living environment through safe water supply and sanitation in a rural village in Bangladesh. Stud Reg Sci 41(3):811–825 (in Japanese)
State Oceanic Administration (2009) Bulletin of marine environmental quality of China in 2008. Read on 5 July 2015. http://www.soa.gov.cn/zwgk/hygb/zghyhjzlgb/hyhjzlgbml/2008ml/201212/t20121208_21660.html (in Chinese)
Suzuki M (2011) Sustainability of the regional economic development under low fertility and aging society in China. Stud Reg Sci 41(3):799–810
Tao Y-Y, Jiang F-H (2005) Water pollution in Jiaxing City and precautions. J Jiaxing Univ 17(2):37–40 (in Chinese)
Wang Y-H, Zhong S-Z (2006) Countermeasure to sustainable water use in Fuyang City. Zhejiang Hydrotech 1:48–51 (in Chinese)
Xu F, Du H-Z, Li B, Yan J, Higano Y (2008) The synthetic evaluation of water quality improvement policy in Jiaxing City, Zhejiang Prefecture, China. In: Proceedings of the 45th annual meeting of the Japan Section of the Regional Science Association International, Future University, Hakodate, Hokkaido, 25–27 October (in Japanese)
Xu F, Du H-Z, Li B, Yan J, Higano Y (2009) The synthetic evaluation of environmental policy to reduce water pollutant in Jiaxing City, China. In: Proceedings of the 3rd Japan Association for Planning Administration (JAPA) Academic Exchange Meeting for Young Researchers, Tokyo Institute of Technology, Ookayama Campus, Tokyo, 8 March (in Japanese)
Xu K-W, Lv H-L (2004a) Research on the selective river-head areas for the diversion works in Jiaxing. Water Resour Prot 20(3):29–32 (in Chinese)
Xu K-W, Lv H-L (2004b) Effectiveness evaluation of the water adjusting experiments in the flood control engineering of Jiaxing City. J Hydrodyn 19(3):294–299 (in Chinese)
Yamamura E, Miyata Y (1980) On the total evaluation of water resources management planning in river basin development – in case of Chitose River basin. Stud Reg Sci 11:99–118 (in Japanese)
Yang W-J, Wang X-Y (2005) Research on the planning of tourist resource development of the South Lake of Jiaxing. J Jiaxing Univ 17(2):26–29 (in Chinese)
Yangtze River Delta Joint Research Center (2012) Yearbook of Changjiang delta development 2012. Hohai University Press, Nanjing (in Chinese)
Ye Z-X, Lu J-M, Zhu H (2001) Influence and countermeasure for watercourse's water quality in the city of Jiaxing due to urban flood control engineering. Zhejiang Hydrotech 3:24–26 (in Chinese)
Zhang F-J (2004) A research on urban renovation of city village settlements in Jiaxing inner city. A master's dissertation, Tsinghua University, China (in Chinese)
Zhang G-F, Zhang L-H (2005) Results and countermeasures of false water level due to land subsidence in the plain of Hang-Jia-Hu. Zhejiang Hydrotech 4:23–25 (in Chinese)
Zhang H, Wang X-R (2000) Study on the countermeasures of exploitation and protection of water resource in Jiaxing City. Resour Dev Mark 16(4):210–212 (in Chinese)
Zhang L-Y, Chen X-Y, Min Z-X (2002) Viewing water environment in Jiaxing City from water supplying situation. Zhejiang Hydrotech 6:37–39 (in Chinese)
Zhou L, Su S-L (2005) Analysis of exploitation of deep groundwater and land subsidence in Jiaxing City. Zhejiang Hydrotech 3(23–25):28 (in Chinese)
Zhu H-L (2004) Research of mechanism for sustainable water resources utilization: the case study of Jiaxing City. Price: Theory Pract 12:34–35 (in Chinese)

Climate Change and Livelihood Adaptation Strategies of Farmers in Northern Bangladesh

Md. Fakrul Islam and Wardatul Akmam

Abstract The increasing vulnerability to climate change and possibilities of livelihood adaptation in Bangladesh is a great concern for its inhabitants. The most vulnerable groups within Bangladesh are the poor and marginalized farmers living in climate change-prone areas. Northern Bangladesh is a plain and farmers face severe flood in rainy season and drought in summer. They depend on underground water for irrigation as all giant rivers become dried up due to unilateral withdrawal of dry season water through upstream barrages on the Ganges and Teesta rivers built by India. Marginal farmers along with all other people face tremendous water crisis for this man-made intervention on natural climate. Farmers have changed their traditional cropping pattern with artificial and underground water, which makes the fertile land unfertile. It is creating another severe and uncertain environmental disaster for the country. Moreover, they are also drastically changing their cropping pattern, e.g., transforming cultivable lands (used for paddy cultivation) into fruit orchards (mango, banana, lychee, guava, plum, etc.). In such situations, farmers with small amounts of land (who had converted total amount of land they possessed into fruit orchards) suffer the most. This is the key finding of this paper, based on a primary survey that focuses on the problems of socio-environmental vulnerability due to climate change and livelihood adaptation strategies of farmers in Northern Bangladesh.

Keywords Climate change • Livelihood pattern • Adaptation strategy • Shifting crops • Mango orchard

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1 Introduction

At present, climate change is one of the burning issues of the world. It is not only one of the threats against maintenance of ecological balance of the globe but also an impediment toward improvement of socioeconomic conditions of people especially in developing countries like Bangladesh. Bangladesh is one of the countries severely affected by climate change. The southern region of the country is vulnerable to sea level rise, floods, and cyclones, whereas the northern region, the *Barind* Tract in particular, suffers from shortage of rain and desertification, caused by many factors including the withdrawal of water by India at the upstream of the Ganges River (named Padma River in the Bangladesh territory).

To overcome the problem of shortage of surface water for irrigation, farmers are using deep tube wells to extract groundwater in the *Barind* region. But it results in lowering the underground water table. Moreover, they are changing their cropping pattern, e.g., transforming cultivable lands previously used for paddy or lentil cultivation into fruit orchards.

According to Bangladesh Bureau of Statistics (BBS 2011), "Bangladesh has an area of 14.43 million hectares of land of which 3.75 million hectares (26.0 %) covers housing, water bodies, roads etc. and forest covers 2.25 m ha (15.6 %). Agriculture remains the most important sector of Bangladeshi economy, contributing 19.6 % to the national GDP and providing employment for 66 % of the population. Agriculture sector contributed to about 22 % of total GDP, out of which crop sector shared 73 %. The net area available for crop production is 7.96 m ha (55.2 %). Out of the total net-cropped area 36 % is single cropped, 51 % double cropped and 13 % triple cropped. The total cropped area comes to 14 million hectares making a cropping intensity of 177 %." Northwestern districts like Chapai Nawabganj and Rajshahi are famous for fruit cultivation. There are many mango, banana, plum, guava, and lychee orchards in these two districts. But cultivating mango is the most popular. Usually, mango orchard owners are rich and marginal farmers seasonally take lease of their gardens. In spite of this, there is a huge socioeconomic gap among the inhabitants living in this region. This region is called *Barind* Tract (highland). Due to unpredictable nature of the climate and considering the profits that can be gained through fruit cultivation, the cropping patterns in this region are changing day by day.

According to Masum et al. (2009), "[A]bout 85 % of the population who are living in the rural areas of Bangladesh are mostly small, marginal and landless farmers and fully dependent on agriculture. Farms are usually very small due to heavily increasing population, unwieldy land ownership, and inheritance regulations. Half of the population now live below the absolute poverty line as measured by the minimum calorie intake of 2,122 kcal/day." In this regard, to increase the opportunity of mitigating basic needs and to establish the fundamental rights of the marginal farmers of the northern region, adaptation with the climate change vulnerable situation should be prioritized.

As we have mentioned here, different studies give us different statistical data about the affected people; we do not get the actual picture regarding the difficulties they have to face due to the cruel nature of climate change-related disasters. There are many study reports and popular writings on this problem, but the problem of livelihood adaptation of marginal farmers is still unchanged. In the context of livelihood adaptation strategy and socioeconomic survival pattern, there still exists some research gap. So, an exploratory and comprehensive study is essential to get concrete idea about the status of affected people due to climate change in the northern districts of Bangladesh.

Farmers of Northern Bangladesh are living in a vulnerable situation. They are being compelled to change their traditional cropping pattern with underground water, which has negative impact on fertility of land. It is creating another severe and uncertain environmental disaster for the country. In this paper, we reflect on such adaptations made by farmers in two areas of Rajshahi and Chapai Nawabganj districts which are also situated in the *Barind* Tract, namely, *Shibganj* and *Bagha* upazilas.

2 Objectives of the Paper

The objectives of the paper are:

1. To investigate the socioeconomic conditions and environmental awareness of the respondents, especially regarding climate change
2. To explore the before-after crop cultivation and livelihood patterns adopted by the farmers
3. To identify the causes of changes in cropping patterns followed by the respondents
4. To identify the efforts to combat the impact of change and to assess the livelihood of the respondents

3 Clarification of Key Concepts

Some key concepts have been used in this paper. These are explained below:

1. *Farmer and marginal farmer*: The farmers who were possessing a minimum of 100–1000 decimals of land under fruit gardening have been considered as "farmers," and "marginal farmer" means a farmer cultivating (as owner or tenant or share cropper) agricultural land up to 1 acre (100 decimals).
2. *Livelihood adaptation*: Adaptation means a form of structure modified to fit a changed environment. It is a slow, usually unconscious modification of individual and social activity to adjust with the cultural surroundings. Livelihood adaptation strategy means the adaptation techniques and patterns maintained by the farmers due to climate change in the target area.

3. *Food security*: Food security is the right of people to define their own food and agriculture, to protect and regulate domestic agricultural production and trade in order to achieve sustainable development objectives, to determine the extent to which they want to be self-reliant, and to restrict the dumping of products in their markets.
4. *Crop vulnerability*: In climate change terms, vulnerability is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (McCarthy et al. 2001). In this study, by crop vulnerability collapse, we also meant such kind of extreme situation.
5. *Cash crop*: The crops produced with a purpose of making money and not to be consumed by producers are generally known as cash crops. The main cash crops of our country are jute, betel nut, sugarcane, cotton, etc.
6. *Hybrid crop*: Hybrid crops mean such types of crops which are more productive and profitable than the ordinary types of crops. Though it is more productive and profitable, there is no difference in terms of nutrition.
7. *Socioeconomic collapse*: Money is a very essential part of living which can ensure standard of living. But due to bad effect of climate change, men lost their economic power and they become too poor to purchase their essential commodities. As a result, their status, social dignity, and power go down, thanks to the negative effects of climate change. In this study, by socioeconomic collapse, we mean such kind of unexpected situation.

4 Research Methodology

Social survey method has been used to collect data from the field. The nature of the study suggests that the social survey is the most applicable method to accomplish its objectives.

1. *Selection of the study area*: Shibganj Upazila from Chapai Nawabganj and Bagha Upazila from Rajshahi District have been selected as the research area purposively. Changing of cropping pattern is occurring severely in Northern Bangladesh compared to other regions of the country. In recent days, it has become a vital concern of the farmers. These two upazilas are most affected by the climate change as these are standing on the bank of the Padma River. Therefore, easy access from the university campus to these areas has allured us to conduct this research in these areas (Fig. 1).
2. *Study population and unit of analysis*: All the cultivators of *Shibganj* and *Bagha* upazilas who have converted their crop land into fruit gardens were the potential respondents of this study. According to estimation, a total of 2260 farmers have changed their crop field into fruit orchards, and they constituted the study population. The heads of household of these farmer families were the respondents and unit of analysis.

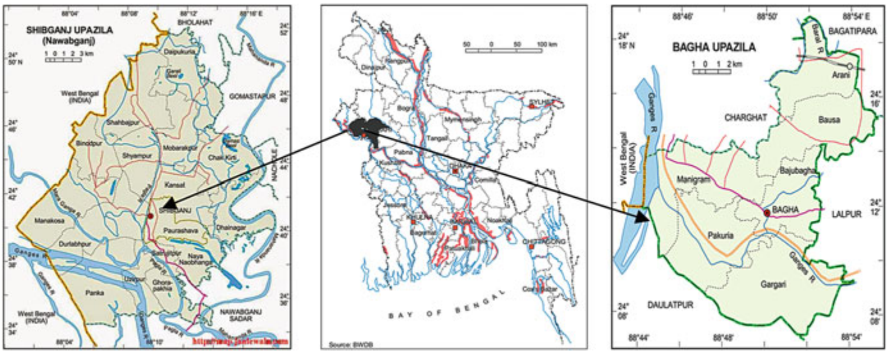

Fig. 1 Map of Bangladesh (*middle*) and the study areas of Shibganj Upazila of Chapai Nawabganj District (*left*) and Bagha Upazila of Rajshahi District (*right*)

3. *Sources of data*: Data have been used both from the primary and secondary sources. Face-to-face interview has been conducted by using a set of questions to collect data from the respondents from the primary source. Related research literature, journals, newspaper reports, some websites, and online documents have been used.
4. *Sampling procedure*: Multistage sampling has been used in conducting the study. The study area was selected purposively; the two upazilas were divided into 16 clusters, and through systematic selection of the clusters, respondents were chosen using simple random sampling from these clusters.
5. *Sample size*: A total of 206 respondents were selected as sample through simple random sampling.
6. *Methods of data collection and data analysis*: Face-to-face interview schedule has been followed to collect data from the respondents in this research. The schedule included both open- and close-ended questions. After collecting data from the primary source through a schedule, data have been classified and tabulated based on different characteristics. Then, data have been set into SPSS 16 program spreadsheet for statistical analysis.

5 Results and Discussions

This chapter has been designed to present the findings of the research. Based on the survey data, the socioeconomic, agricultural (both crops and fruits), irrigation, and environmental awareness have been analyzed.

The study reveals (see Table 1) that one third (32 %) of respondents of the study are illiterate. Fifty-seven percent of people are educated up to the primary level and 10 % are highly educated. Though, at present, the enrollment rate in primary schools

Table 1 Educational qualification of the respondents

Level of education	Frequency	Percentage
Illiterate	66	32.0
One to five	50	24.3
Six to ten	41	19.9
HSC	28	13.6
Higher education	21	10.2
Total	**206**	**100.0**

Table 2 Amount of cultivable land

Cultivatable land of the respondents (in acres)	Before 20 years	Percent	At present (2014)	Percentage
1–3	48	23.3	96	46.6
4–6	69	33.5	47	22.8
7–10	29	14.1	26	12.6
11–15	24	11.7	22	10.7
16–20	16	7.8	7	3.4
21–30	10	4.9	6	2.90
31–40	6	2.9	0	0
Above 40	**4**	**1.9**	**2**	**1**
Total	**206**	**100**	**206**	**100**

at the national level is high, the level of education among the respondents shows poor conditions because in their childhood, it was not compulsory to get enrolled into a primary school.

Table 2 shows that 20 years ago, about 3% of people had an average of 31–40 acres of cultivable land for crops, but in 2014, none belonged to that category. Twenty years ago, about 56 % of the respondents had 1–6 acres of land for crop cultivation, but in 2014, 70 % of the respondents had below 1–6 acres of land for crop cultivation. This study reveals that the amount of land for crop cultivation was decreasing day by day. The main reasons of this change are market failure of agricultural goods, increasing price of fertilizer and pesticides, unavailability of modern agricultural instruments, lack of storage facilities, shortage and high price of irrigation water, etc.

Table 3 reveals that 20 years ago, 78 % of the respondents had no fruit gardens. But in 2014, 58.3 % of the respondents had fruit gardens and 17 % of the farmers had above 3 acres of land as fruit orchards. It has showed that the involvement of farmers with fruit gardening is increasing day by day. The factors behind this are low price of crops (food grains) and high price of fruits and also bad impact of climate change in the region.

Table 4 shows distribution of duration of developing orchards and changing of cropping pattern. Cultivating almost all types of fruits is seen profitable in the study area. Banana takes short duration (1–3) years after that the garden can be changed into other fruits or crops. Guava, plum, and litchi take 3–4 years to

Table 3 Transformation of paddy fields into mango orchards (situation before-after 20 years)

Amount of land occupied by mango orchards	Before 20 years	Percentage	In 2014	Percentage
0	160	77.7	0	0
1–3	32	15.5	10	4.9
4–6	6	2.9	120	58.3
7–10	8	3.9	41	19.9
11–15	0	0	21	10.2
Above 16	0	0	14	6.8
Total	**206**	**100**	**206**	**100**

Table 4 [t!]Time taken to develop orchards and change in cropping pattern

Duration in years	Types of fruit gardens	Whether changed cropping pattern		Total
		Yes	No	
1–3	Banana, plum	16	5	21
		76.2 %	23.8 %	100.0 %
4–6	Guava, plum, litchi, mango (grafting, etc.)	59	9	68
		86.8 %	13.2 %	100.0 %
7–10	Mango, litchi, plum (grafting, etc.)	40	5	45
		88.9 %	11.1 %	100.0 %
11–15	Mango, litchi, plum, others (both normal and grafting, etc.)	31	7	38
		81.6 %	18.4 %	100.0 %
Above 15	Mango, litchi, plum, others	24	10	34
		70.6 %	29.4 %	100.0 %
Total		**170**	**36**	**206**
		82.5 %	**17.5 %**	**100.0 %**

grow and start bearing fruits and it can continue to grow fruits for 10–11 years. Sometimes, modern agricultural technology can initiate rapid growth of fruit cultivation. However, the main cash fruit mango takes 6–15 years to develop into a fully grown orchard.

Table 5 shows that 201 out of 206 of the respondents were habituated to use chemical fertilizers and pesticides. Due to shortage of manure, they used chemical fertilizers in all steps of growing and harvesting. Sometimes, the illiterate farmers used overdoses of pesticides from the time of budding to preserving fruits and caused harms to human health due to lack of proper knowledge.

Table 6 shows the level of consciousness among the respondents about climate change. It shows that 44.7 % of the respondents were conscious and 55.3 % were not conscious about the impact of climate change. As most respondents were illiterate, they were not conscious about the issue.

Table 5 Relationship between use of fertilizer and causes of its use

Whether uses chemical fertilizer and pesticides or not	Causes				Total
	Shortage of manure	Use of cow dung as fuel	To get high yield	All that have been mentioned earlier	
Yes	28	8	111	54	201
	13.9 %	4.0 %	55.2 %	26.9 %	100.0 %
No	1	0	3	1	5
	20.0 %	0.0 %	60.0 %	20.0 %	100.0 %
Total	**29**	**8**	**114**	**55**	**206**
	14.1 %	**3.9 %**	**55.3 %**	**26.7 %**	**100.0 %**

Table 6 Consciousness of the respondents about climate change

Whether conscious or not	Frequency	Percentage
Yes	92	44.7
No	114	55.3
Total	**206**	**100.0**

Table 7 Source of irrigation water (before-after situation)

Sources	Before 20 years	Percentage	At present (2014) frequency	Percentage
Rainwater	159	77.18	5	2.4
River and pond water	44	21.35	5	2.4
Underground water	3	1.67	196	95.1
Total	**206**	**100.0**	**206**	**100.0**

Interestingly, the study has revealed that the marginal farmers were lacking knowledge of climate change. They only knew that tree plantation was needed for facing climate change. They heard it on TV. They did not know the effects of excessive use of fertilizer and pesticides.

Table 7 shows that 20 years ago, 159 (77.18 %) of the respondents depended fully on rainwater for their aman (paddy) cultivation. However, in 2014, 196 (96.1 %) of these respondents did not depend on rainwater at all. In 2014, 95.1 % of the respondents depended on underground water for cultivation. Table 7 also shows that almost all of the respondents used underground water for irrigation. The main cause of this was that the rivers were dried up due to unilateral withdrawal of water through Farakka Barrage on the Padma River, low rainfall, and drastically decrease of underground water level in the target area.

Table 8 shows that according to 59 % of the respondents, fruit gardening was more profitable than crop production. There was uncertainty regarding whether rainfall, shortage, high price of irrigation water, etc. were the main causes. Seventeen percent of the respondents said that they had started gardening 15 years ago, 21 % respondents started 10 years ago, and 33 % started 6 years ago. It shows that instead of crop production, farmers were producing fruits. If this tendency continues, all the crop fields will be converted into fruit orchards.

Table 8 Causes of changing cropping patterns (crop fields into orchards)

Causes of changing crop fields into fruit orchards	Frequency	Percentage
(1) Profitable than other crops	117	56.8
(2) Shortage of irrigation water	8	3.9
(3) Uncertainty involved in crop production	6	2.9
(4) Gardening beside own land	7	3.4
2 and 3	16	7.8
1 and 4	28	13.6
All the above	24	11.7
Total	**206**	**100.0**

Table 9 Time of selling fruits

Time of selling	Frequency	Percentage
Before budding	65	31.6
Before ripening	122	59.2
After ripening	19	9.2
Total	**206**	**100.0**

Table 10 Efforts of combating the impact of climate change

Techniques to combat	Frequency	Percentage
Tree plantation	113	54.9
Reduce emission of carbon dioxide	7	3.4
Global participation and movement	5	2.4
No comments	81	39.3
Total	**206**	**100.0**

Table 9 shows 59.2 % of the fruits of the gardens were sold out before ripening and 32 % were sold out before budding. Multinational companies bought these gardens; they make fruit juice, pulp, etc. The consumers of these fruit products were the rich people of the society. The marginal farmers were almost always deprived from fruits produced in their gardens as they were not able to buy the juice produced from these fruits.

Table 10 shows that 55 % of the respondents suggested tree plantation as the principal remedy to combat climate change. More than 39 % of the respondents made no comments.

In the cross table above (Table 11), the relationship between the levels of education and the consciousness of the respondents has been shown. It reveals that among illiterate people, 89.4 % said "no" and only 10.6 % said "yes" when they were asked about their awareness of the impact of the climate change. Among the HSC graduates, 82 % said "yes" and 18 % said "no." Among the higher educated, 76.2 % said "yes" and 23.8 % said "no." It shows that the educated respondents were much more conscious about climate change. But it also shows that there was still a mixed attitude toward the concept of climate change among the respondents of the study area.

Table 11 Relationship between education and consciousness

	Consciousness		
Education	Yes	No	Total
Illiterate	7	59	66
	10.6 %	89.4 %	100.0 %
One to five	22	28	50
	44.0 %	56.0 %	100.0 %
Six to ten	24	17	41
	58.5 %	41.5 %	100.0 %
HSC	23	5	28
	82.1 %	17.9 %	100.0 %
Higher education	16	5	21
	76.2 %	23.8 %	100.0 %
Total	**92**	**114**	**206**
	44.7 %	**55.3 %**	**100.0 %**

Table 12 Distribution of the amount of mango orchard before 20 years and in 2014 (in acres)

Amount of land in mango orchard before 20 years in acres	Amount of land in mango orchard in 2014 (in acres)					
	1–3	4–6	7–10	11–15	Above 16	Total
0	9	107	30	10	4	160
	5.6 %	66.9 %	18.8 %	6.3 %	2.5 %	100.0 %
1–3	1	13	10	6	2	32
	3.1 %	40.6 %	31.3 %	18.8 %	6.3 %	100.0 %
4–6	0	0	1	1	4	6
	0.0 %	0.0 %	16.7 %	16.7 %	66.7 %	100.0 %
7–10	0	0	0	4	4	8
	0.0 %	0.0 %	0.0 %	50.0 %	50.0 %	100.0 %
Total (206)	10	120	41	21	14	206
	4.9 %	58.3 %	19.9 %	10.2 %	6.8 %	100.0 %
		χ^2 = Significant at 5 % at 7 d.f.				

Table 12 shows that before 20 years, there was no tendency of changing crop field into fruit garden. Of the total 206 respondents, 20 years ago, 160 (77.66 %) respondents had no fruit garden, 32 (15.53 %) respondents had 1–3 acres of orchard, 6 (2.91 %) had 4–6 acres of garden, and 8 (3.88 %) respondents owned 7–10 acres of fruit garden. Respondents in the last two categories owned that amount of land in continuation of their family heritage.

Gradually, fruit orchards have become popular as it is thought to be more profitable. The study has revealed that the present use of land (in acres in 2014) has increased from "0" category to "1–3 acres" among 5.6 % of the respondents, 4–6 acres among 66.9 % of the respondents, and to the level of above 16 acres among

2.5 % of the respondents. This means the number of fruit orchards is increasing. The nonparametric $(\chi)^2$ test also shows that increasing tendency of orchards is significant.

It has been observed that the income level of the respondents has been increased due to the shifting of crop land into fruit gardens. Marginal farmers did not have much benefit because their average amount of land used for fruit garden is very small (96 % of the farmers use 1–3 acres of land for fruit gardens). Big farmers were getting more profit than before but the food security became a concern in the region. Marginal farmers were losing everything because of intervention of the middlemen.

The result of the survey has shown that due to changes in the amount and time of rainfall, farmers faced severe crop failure, and to avoid such loss and maximize their profits, they changed their cultivation pattern. One of the most notable changes was conversion of grain-producing land into fruit (especially mango) orchards. Had grain been cultivated, there would have been chances of getting three harvests in a year. However, through converting these lands into fruit orchards, the farmers were getting one harvest in a year. So, if the fruit trees do not bear fruit in 1 year, the farmers are left with nothing. In such situations, farmers with lower amounts of land (who had converted the total amount of land they possessed into fruit orchards) suffer the most.

Thus, from the above findings, the following strategies can be taken into consideration to make an adaptation policy with this changing situation.

6 Recommendations

Climate changes will rapidly alter the lands and waters of the globe—a process which has already started. Proper government initiatives toward motivating people and giving them financial support in adapting to new jobs and business and moving to off-farm activities are necessary. The present study has revealed that the marginal farmers have taken some initiatives on their own for their survival. But those are not well organized and up to the mark to fulfill all their needs. They should be motivated and informed of the following:

(a) Climate change is both a natural and man-made reality.
(b) Farmers as well as the community people must move on instead of being panicked.
(c) Innovating indigenous ways and means through conducting field research should be given priority.
(d) Community planning is needed to survive this challenge.

According to the results of this survey, some specific issues should be taken into consideration for the betterment of the people of study area. These are as follows:

(A) There is a huge gap of land-holding position among the respondents (marginal farmers hold on an average of only 1 acre and big farmers hold 10–40 acres of land in the study area). Poverty of marginal farmer and hard-core poor is notable. So, pro-poor income-generating activities should be provided.
(B) Though Bangladesh is an agrarian society and the people of the study area is solely dependent on agriculture, unplanned and malpractice in crop-shifting pattern should be avoided to protect local food security. Research on transforming crop field into mango or fruit orchard should be carried out by the respective scientists soon.
(C) Massive use of underground water in the study area should be avoided.
(D) Government policy should be formulated on a priority basis to tackle climate variability and to develop and confirm action plan for livelihood adaptation for the marginal farmer of the study area.

7 Conclusion

Bangladesh is vulnerable to different types of disasters, which have been more prominent in recent years due to potential impacts of climate change. The marginal farmer and the hard-core poor are the main victim of such adverse situation as they are totally dependent on natural resources for survival. Minor changes in environmental condition make them more vulnerable and they become environmental refugee. We need to create expertise and ensure involvement of our young professionals in the field of climate change and adaptation for such marginal community people. We also need to share our experiences with others and develop an attitude toward learning from the world—especially from those who had experience in combating such situations. The economy of Bangladesh is to a great extent dependent on agriculture, so climate change is not only a sensitive issue for the people of this country, but people's survival is largely dependent on this phenomenon. As the national development of Bangladesh is dependent on the development of grassroots people's development, we should emphasize and prioritize it.

Appendix: Pictures

Source: (Photo) Figs. 2, 3, 4, and 5 by Md. Fakhrul Islam and Md. Badsha Alam and Figs. 6, 7, and 8 by ARCAB

Fig. 2 Shifting crop field with mango orchard

Fig. 3 Paddy field into mango orchard—nature of transformation in Ganguria Union (Northern Bangladesh)

Fig. 4 Mango orchard in low paddy land

Fig. 5 Mango orchard in low paddy land

Fig. 6 Livelihood adaptation of farmers through mulching vegetables to protect from high temperature

Fig. 7 Livelihood adaptation of farmers through mulching vegetables to protect from high temperature

Fig. 8 Changing crop pattern in the mango orchards

References

ARCAB –Action Research for Community Adaptation in Bangladesh; Webpage of ARCAB http://www.arcab.org/index.php. Accessed on 12 June 2012

Bangladesh Bureau of Statistics-BBS (2011) Peoples' Republic of Bangladesh, Dhaka, 2009

Masum SJ, Hasan M, Mahbub M (2009) Climate change impact on food sovereignty in Bangladesh (This article was submitted to *On the Frontlines of Climate Change* 02/09/2009)

McCarthy J, Canziani O, Leary N, Dokken D, White K (eds) (2001) Climate change 2001: impacts, adaptation & vulnerability. Cambridge University Press, Cambridge

Nongovernment Organizations' Contributions to Poverty Reduction and Empowerment of Women through Microcredit: Case of a Village in Gaibandha District, Bangladesh

Wardatul Akmam and Md. Fakrul Islam

Abstract This study attempts at discovering impact of nongovernment organization (NGO) activities (particularly disbursing microcredit) on women in a village named Kathalbari within Gobindaganj Thana of Gaibandha district. The NGOs working in the village include Thengamara Mohila Sabuj Sangha (TMSS), Bangladesh Rural Advancement Committee (BRAC), Association for Social Advancement (ASA), and Grameen Bank (GB). Although all these NGOs disbursed microcredit, they had their own goals and strategies. The present study endeavors to find out these strategies from the NGO officials and their impact on the people through a social survey—how the recipients evaluated these programs and what their experiences were regarding microcredit. The findings of the study show that microcredit in Kathalbari had been disbursed to women only, all of whom were married. Decision regarding spending the money received as credit was usually made by either the husbands or sons of the credit receivers. Significant improvements had been made among the respondents regarding the number of meals taken in a day, having a sanitary latrine within the household, amount of savings, etc. through microcredit. Although the main objective of microcredit was to engage women in income-generating jobs, only one fourth of the respondents (credit receivers) succeeded in becoming engaged in such work. Only six of them could buy some cultivable land for their households using the credit or the profit earned through using the credit. Comparing the conditions imposed on disbursing microcredit by the different NGOs, the most preferred NGO was ASA, while the strictest conditions were applied by TMSS, according to most of the respondents.

Keywords NGOs • Microcredit • Poverty reduction • Empowerment of women

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1 Introduction

Poverty reduction in Bangladesh has been a major issue among government policy planners and the NGOs working in the country. One of the major means currently used to achieve the goal of poverty reduction is disbursing microcredit, which is also considered a means of empowering women at the grassroots level. NGOs in Bangladesh generally emphasize the system of disbursing microcredit involving women in income-generating activities by organizing them into small groups, reducing illiteracy, and raising awareness through dissemination of information in order to empower them. It is a special feature of microcredit that no collateral is required to get the loan. Many studies have been carried out relating empowerment to microcredit (Mahmud 2003; Pitt et al. 2006; Banu et al. 2001; Lakwo 2006; Garikipati 2008; Fernando 1997; Amin et al. 1998; Akmam et al. 2007, etc.). Some show positive impact of disbursing microcredit to women in reducing poverty and/or increasing women borrowers' empowerment, while other studies present a different picture. Mahmud (2002) in her review paper has shown that microcredit makes room for women's access to certain resources like self-employment and physical mobility which enhance women's decision-making capacity within the household. With their increased mobility, they were now able to go to the health center to seek health care. A positive picture is portrayed by Pitt et al. (2006) who in their study found that disbursing microcredit to women worked positively in women's empowerment, but disbursing the same to males made women's position worse. Parveen and Chaudhury (2009) have found that the respondents who took microcredit from BRAC were better empowered than those who did not take any microcredit at all. Gaiha and Kulkarni (2013) in their study in India have seen that microcredit helped to reduce poverty, made people less vulnerable to health shocks, and helped them to reorganize their lives soon after a natural disaster takes place. Findings of a study carried out in Sierra Leone "... suggested that microcredit had a substantial impact on women's economic empowerment, only an initial impact on social empowerment and no impact on political empowerment" (Roxin et al. 2010: iv). Some other studies that have documented positive impact of microcredit on women's poverty reduction and empowerment include Razzaque and Bidisha (2012), Quddus (2012), Habib and Jubb (2012); Pitt and Khandker (1998) and Mamun (2013).

However, Garikipati (2008) showed that in order for women to be empowered, disbursing microcredit to women was not enough; rather, it was necessary to challenge the patriarchal pattern of owning assets. In a study conducted by Mahmud (2002: 14), it was observed that "[s]ocio-economic status differentials among women respondents were more strongly related to household poverty than to participation in a micro-credit program." Rahman (1999: 67) in his study found that "... many borrowers maintain their regular payment schedules through a process of loan recycling that considerably increases the debt-liability on the individual households, increases tension and frustration among household members, produces new forms of dominance over women and increases violence in society." Kabeer (2005b) acknowledges that microcredit can increase economic productivity and social well-being, but according to her it does not automatically bring about empowerment.

Among others who also portrayed a pessimistic view regarding the positive impact of microcredit include Fernando (1997), Al-Amin and Chowdhury (2008), Melik (2010), Hashmi (2012), and Islam (2015). Dessy and Ewoudou (2006) in their study concluded that microfinance alone could not bring about female empowerment.

The present study is an attempt at discovering impact of NGO activities (particularly disbursing microcredit) on women in a village named Kathalbari within Gobindaganj Thana of Gaibandha district. The NGOs that were working in the village at the time of data collection (January 2010) included Thengamara Mohila Sabuj Sangha (TMSS), Bangladesh Rural Advancement Committee (BRAC), Association for Social Advancement (ASA), and Grameen Bank (GB). TMSS had been working in the village for the longest period of time (10 years), followed by GB (3 years) and BRAC and ASA (2 years each).

2 Clarification of Concepts

The authors have defined the key concepts of this paper as follows:

1. *Microcredit*: Credit amounting up to Taka 20,000 given without any collateral to women belonging to poor households.
2. *Poverty*: The state of households having less than 0.5 acres of land or assets worth that amount of land. Indicators of poverty used in this study include income, ownership of house and cultivable land, having a sanitary toilet and a tube well within household, use of electricity, expenditure on children's education, number of meals per day, etc.
3. *Women's empowerment*: Empowerment according to Moser (1989: 1815) is "... the capacity of women to increase their own self-reliance and internal strength. This is identified as the right to determine choices in life and to influence the direction of change, through the ability to gain control over crucial material and non-material resources." The authors used this definition to measure empowerment of women in the study area. Indicators of empowerment that have been included were decision-making capacity on various issues, e.g., spending loan money, buying and selling of land, use of contraceptives, ability to earn a separate income, personal cultivable/non-cultivable land, physical mobility, whether mentally tortured or not, etc.

3 Objectives of the Study

Overall objective of this study is to find out the impact of disbursing microcredit to women on poverty reduction and empowerment of the loan receivers. More specifically the objectives of the study were the following:

1. To learn about the conditions set by different NGOs regarding disbursing microcredit to women
2. To measure the contribution of microcredit toward reducing poverty among the respondents
3. To find out whether the program made any contribution toward empowering the respondent women

4 Area of the Study

There are 64 districts in Bangladesh. Gaibandha is one of them. The study area of this paper is Kathalbari Village situated within Katabari Union[1] of Gobindaganj Upazila,[2] Gaibandha district, Bangladesh. This village has been selected for this study because to the extent of the knowledge of the authors no study has been conducted on microcredit use in this area.

5 Methodology

Social survey was the method used for conducting this study. Primary data have been collected through face-to-face interview using a questionnaire containing both open-ended and closed-ended questions. Female borrowers of microcredit from the four NGOs mentioned above were the respondents. All the women residing in Kathalbari who were found to have received microcredit from one or more NGOs (48 women) were brought under the present study. Household was the unit of analysis for assessing impact of microcredit on poverty reduction, but individual respondents were the unit of study for assessing impact on empowerment of women.

6 Rules of Disbursing Microcredit

In order to understand the impact of microcredit on women, it is necessary to know about the process and regulations under which such credit is disbursed. The relevant information on the NGOs mentioned here are as of 2010, when data from the borrowers were collected. Although all the NGOs considered in this study [Grameen Bank (GB), BRAC, TMSS, and ASA] disbursed microcredit and followed similar rules in lending microcredit, they had some differences. These differences are shown in Table 1.

[1]Union is a local administrative level immediately below the Upazila level.

[2]Upazila (subdistrict) is an administrative unit immediately below the district level.

Table 1 Eligibility for getting microcredit

GB	BRAC	ASA	TMSS
Permanent residence, possession of <50 decimals of land, ability to pay installments in time	Permanent residence, possession of assets worth the amount of 50 decimals of land or less, capacity to sell labor, etc.	Possession of assets worth the amount of <30 decimals of land, ability to pay installments in time, selling labor for less than 180 days	Permanent residence, possession of <50 decimals of land, ability to pay installments in time

Table 2 Differential conditions given by different NGOs

Criteria	GB	BRAC	ASA	TMSS
Time taken to disburse loans after applying	1 week	3 weeks	1 week for new members, 2 weeks for old members	1 week
Amount disbursed at the initial stage (in Tk.)	5000–20,000	4000–30,000	1000–10,000	5000–10,000
Interest rate	12.5 %	12.5 %	15 %	12.5 %
Percentage of total amount of loan kept as initial saving	None	5 %	None	10 %
Weekly minimum saving	Tk. 10	Tk. 20	General saving Tk. 10 and security saving Tk. 10	Tk. 10
Amount of weekly installment for insurance	Paid at the beginning at the rate of Tk 60/1000	Tk 3/1000	Tk. 10/1000	Tk. 5/1000

Having a permanent residence was a common condition of eligibility imposed by GB, BRAC, and TMSS. However, this condition was waived by ASA. Possession of land/assets worth no more than 50 decimals of land was a condition of getting microcredit from GB, BRAC, and TMSS; but for ASA the amount was less than 30 decimals of land. While GB, TMSS, and ASA emphasized ability to pay the installments in time, BRAC was more concerned about capacity of selling labor.

Particular rules and regulations regarding lending money were followed by the different NGOs (Table 2). All the NGOs disbursed loans to eligible applicants (new) within only 1 week after submitting application. ASA took 2 weeks to lend money to old clients. Different amounts of loans were disbursed to clients as microcredit by the different NGOs at the initial stage. The highest amount (Tk. 30,000) was disbursed by BRAC and the lowest amount was disbursed by ASA (Tk. 1000). Only ASA took 15 % interest from the clients. All the other three took 12.5 % interest. GB and TMSS compelled their clients to save at least Tk. 10 per week, while the

Table 3 Conditions for withdrawing credit

GB	BRAC	ASA	TMSS
Savings could be withdrawn after all the installments have been paid	Could withdraw some savings after paying 35 installments	General saving: could withdraw any amount keeping in the bank 5 % of the disbursed amount	General saving: could withdraw any amount keeping in the bank 5 % of the disbursed amount
		Security saving: could withdraw any amount keeping Tk. 1000	Special saving: could withdraw any amount keeping Tk. 100

amount is double for BRAC and ASA. The clients of all the NGOs were compelled to pay back their loan along with interest in 44–45 installments.

While disbursing the loan to the clients, BRAC and TMSS kept 5 % and 10 % of the total allotted money as initial savings under their custody. However, such rules were not imposed by GB and ASA. As insurance different amounts of weekly installments are received by the lending organizations from their clients. The highest amount was charged by GB (Tk. 60/1000), while the lowest amount was charged by BRAC (Tk. 3/1000).

As a condition of disbursing microcredit, all the NGOs imposed a condition of saving a particular amount of money every week in the respective NGO bank account. Table 3 depicts the conditions for withdrawing the weekly savings kept under the custody of the lending organizations. From GB the savings could be withdrawn only when all the installments of the loan had been paid. From BRAC some of the savings could be withdrawn after at least 35 installments had been paid. ASA divided the weekly savings into two sections—general savings and security savings. The clients could withdraw from their general savings any amount of money keeping at least 5 % of the total disbursed money under custody of the authorities. Clients could withdraw any amount of money from their security savings account keeping at least Tk. 1000 as balance. As per rules of TMSS borrowers could withdraw any amount keeping in the bank 5 % of the disbursed amount from their general savings. From their special savings, they were able to withdraw any amount keeping only Tk. 100.

7 Socioeconomic Condition of the Microcredit Borrowers

Before we go on to the discussion on the different aspects of the respondents' borrowing of microcredit, we need to know some basic facts on the respondents' socioeconomic situation. All of them were housewives. None of the respondents were heads of households themselves. One (2.22 %) had her son as the head of household and others had their husbands as their head of household.

Table 4 Schooling years of the money borrowers

No. of schooling years	No. of respondents	Percentage
0	07	14.58
1–5	27	56.25
6–10	14	29.17
Total	48	100.00

Table 5 Number of family members

No. of family members	No. of respondents	Percentage
2–3	23	47.92
4–5	24	50.00
>5	01	02.08
Total	48	100.00

Education is a basic socioeconomic factor that influences our lives. Table 4 presents schooling years completed by the respondents. While most of them (56.25 %) had not completed any more than 5 years in school, a little less than one third (29.17 %) of the respondents completed 6–10 years in school. Again, almost 15 % of the respondents did not complete even a single year in school. Thus, we observe that microcredit was disbursed to women belonging to different categories of educational qualification.

Table 5 portrays the number of members in the respondents' families. Almost all the families were limited to having five members or less. This is a common feature of rural households in Bangladesh. Half of the respondents had four to five members in their households.

8 Microcredit-Related Information on the Respondents

At first we must learn about the NGOs with which the respondents were affiliated (see Table 6). Although none of the NGOs officially allowed borrowing of microcredit from any NGO other than their own, we observe that 19 (39.58 %) of the respondents borrowed money from more than one NGO. Three of these 19 respondents regularly used the microcredit received from one NGO to pay their installments to other NGOs. In order to increase their number of clients and to ensure that the clients pay their dues regularly, NGO officials hardly monitored this condition of disbursing microcredit. Table 6 also reveals that TMSS had the highest number of clients from the study village (28), followed by ASA (25), GB (11), and BRAC (6).

Not all the respondents had the same duration of experience with borrowing microcredit. Almost one third of them (31.25 %) had borrowed money for the first time less than a year before. So, there was no scope that microcredit would have immense effect on their poverty and empowerment levels. Almost half of the respondents (47.92 %) had been borrowing microcredit for 1–3 years (see Table 7).

Table 6 NGOs with which the respondents were affiliated

Name of NGO	No. of respondents	Percentage
BRAC	02	04.17
BRAC + TMSS	02	04.17
ASA + TMSS	12	25.00
GB + TMSS	02	04.17
ASA + TMSS + GB	01	02.08
ASA	10	20.83
TMSS	09	18.75
GB	08	16.66
TMSS + ASA + BRAC	02	04.17
Total	48	100.00

Table 7 Length of period for which respondents continuously borrowed money from NGOs

Period	No. of respondents	Percentage
<1 year	15	31.25
1–3 years	23	47.92
3–6 years	04	8.33
>6 years	03	6.25
Cannot remember	03	6.25
Total	48	100.00

The respondents used the money they received as microcredit for various purposes—breeding chickens/ducks, buying and raising cows with the hope of earning money through selling milk, buying a *van* (a three-wheeler used as transport) as means of income, building a house, to open a small grocery store, to get back land that had been handed in as mortgage, fish culture, etc.

8.1 Impact of Microcredit on Poverty Reduction

In order to measure whether any change in poverty situation of the respondents had occurred, "before" and "after" (taking microcredit) information on several variables had been collected and presented in Tables 8, 9, 10, 11, 12, 13, 14, and 15. Income is the first variable to consider in measuring change in poverty reduction. Table 8 shows that positive changes in income had taken place for only 2 (4.17 %) households (increased from Tk. 2000–4000 category to Tk. 4000–6000 category). Table 9 portrays that only 27 (56.25 %) respondents had school-age children and no changes had taken place in the respondents' expenditure for their children's education. Table 10 indicates a positive change in having a sanitary latrine within the home compound. Eleven (22.92 %) households that did not have a sanitary latrine before were able to construct and use sanitary latrine in their home compounds after taking microcredit.

Table 8 Changes in monthly income

Before (Taka)					
After (Taka)	<2000	2000–4000	4000–6000	>6000	Total
<2000	03	00	00	00	03
2000–4000	00	23	00	00	23
4000–6000	00	02	19	00	21
>6000	00	00	00	1	01
Total	03	25	19	01	48

Table 9 Expenditure for children's education

Before				
After	0–300 Taka	300–600 Taka	>600 Taka	Total (Taka)
0–300 Taka	19	00	00	19
300–600 Taka	00	07	00	07
>600 Taka	00	00	01	01
Total	19	07	01	27

Table 10 Whether there is a sanitary latrine in the home compound

Before			
After	Yes	No	Total
Yes	24	11	35
No	0	13	13
Total	24	24	48

Table 11 Ownership of house (by the head of household)

Before			
After	Yes	No	Total
Yes	40	00	40
No	00	08	08
Total	40	08	48

Table 12 Whether there is a tube well in the house or not

Before			
After	Yes	No	Total
Yes	21	04	25
No	08	15	23
Total	29	19	48

Table 13 Source of energy for illuminating house at night

Before			
After	Kerosene	Electricity	Total
Kerosene	40	00	40
Electricity	04	04	08
Total	44	04	48

Table 14 Ownership of cultivable land

Before			
After	Yes	No	Total
Yes	15	04	19
No	00	29	29
Total	15	33	48

Table 15 Number of meals per day

Before				
After	≤1	2	≥3	Total
≤1	00	00	00	00
2	00	04	00	04
≥3	00	09	35	44
Total	00	13	35	48

Table 11 shows that there was no change in the ownership of house after the respondents began to borrow microcredit from the NGOs. Regarding having a tube well within their home compound (Table 12), it is observed that four (8.33 %) households that did not have a tube well before managed to get a tube well after taking microcredit. However, eight (16.67 %) of the households that did have a tube well before did not have functioning tube wells at the time of the interview (after taking microcredit).

Some change in energy use was observed before and after the respondents had borrowed microcredit (Table 13). Four (8.33 %) households that used kerosene before were using electricity after they had taken microcredit. Some changes in ownership of cultivable land (see Table 14) were also seen. Four (8.33 %) households that did not have any cultivable land before managed to own some cultivable land after taking microcredit from NGOs.

Number of meals taken by all members of household is a very important indicator of poverty reduction. Table 15 shows that members of four households had two meals before taking microcredit, and no improvement in this regard had been made after taking microcredit. However, there were nine (18.75 %) households, members of which able to take only two meals per day before borrowing money from NGOs managed to offer three or more meals per day after taking the loan. This is indicating a positive impact of microcredit.

Table 16 Respondents' ownership of land

Before			
After	Yes	No	Total
Yes	10	03	13
No	00	35	35
Total	10	38	48

Table 17 Respondents' engagement in income-earning activities

Before			
After	Yes	No	Total
Yes	02	12	14
No	02	32	34
Total	04	44	48

Table 18 Decision-making on buying/selling of land

Before					
After	Husband	Wife	Husband and wife	Son	Total
Husband	26	00	00	00	26
Wife	00	00	00	00	00
Husband and wife	08	00	13	00	21
Son	00	00	00	01	01
Total	34	00	11	01	48

Table 19 Decision regarding expenditure of loan money

Decision-maker	No. of respondents	Percentage
Husband	36	75
Wife	00	00
Husband and wife	11	23
Son	01	02
Total	48	100.00

8.2 *Impact of Microcredit on Women's Empowerment*

Empowerment of women is a widely studied concept all over the world, especially in developing countries (see, e.g., Mahmud 2003, Mahmud et al. 2012; Ethiopian Society for Population Studies 2005; Kabeer 2005a, b; Garikipati 2008; Banu et al. 2001, etc.). The concept has been viewed, explained and modeled in many different ways. "... definitions of empowerment usually include a sense of people making decisions on matters that are important in their lives and being able to carry them out" (Mosedale 2005). Tables 16, 17, 18, and 19 portray information on the effect of microfinance on empowerment of women.

Table 16 shows slight changes in personal ownership of land among the respondents before and after they started taking microcredit. It is to be mentioned here that land is the most cherished material asset in rural Bangladesh. Financial condition of a person (and the power derived from that) is often linked to ownership of land. According to Table 16, only three (6.25 %) of the respondents who did not have any personally owned land before taking microcredit were able to buy at least a piece of land after taking microcredit. Having a regular personal income is also a good source of self confidence and an indicator of empowerment. Table 17 shows that 12 (25 %) respondents who did not engage in any income-generating activities before taking loan got themselves involved in such activities after taking microcredit. However, 2 (4.17 %) women who were involved in income-generating activities before withdrew themselves from such activities after taking microcredit. The reason could be that they worked as maid servants for wealthier families, which is considered a job that lowers family prestige. Once people are able to procure sufficient food for all members in their households, women try to refrain from such kind of income-generating activity. Table 17 also reveals that 35 (72.91 %) women respondents were not engaged in any kind of income-generating activity before or after taking the loan, although the main objective of microfinance was to help women engage in some kind of income-generating activity. Women usually brought the money from the NGO and gave it to their male head of household (mostly their husbands), who actually used the money. Table 19 shows that among the respondents decision regarding use of the loan was mostly made by the respondents' husbands ($n = 36$, 75 %). For 11 (23 %) of the respondents, this decision was jointly made by themselves and their husbands. Regarding decision-making on buying/selling of land, slight change was observed among eight of the respondents. Before taking microcredit, it was only the husbands who made decisions on the issue. After borrowing microcredit, the respondents themselves also participated in the decision-making activities (Table 18).

Information on some other indicators of empowerment was collected from the respondents. The survey results revealed that the respondents faced no barriers in physical mobility (going to relatives' house, going to the doctor, etc.) or in using contraceptives either before or after taking microcredit. All of them mentioned that they were not physically or mentally tortured by their husbands either before or after they started borrowing money from the NGOs.

8.3 Respondents' Own Ideas on Microcredit and Its Impact

According to 37 (77.08 %) respondents, their savings had increased through borrowing microcredit. Thirty-eight (79.17 %) respondents said that they were able to pay the installments from their earnings through microcredit. However, 26 (54.16 %) said that they had difficulty in paying the installments (part of the loan + savings + insurance) in time.

Of the 19 respondents who received microcredit from more than one NGO, 15 (78.94 %) were significantly benefited, others were a little benefited, but no one was harmed by taking microcredit from more than one NGO. According to 11 (57.89 %) respondents, ASA offered the best conditions; another 11 (57.89 %) said TMSS had the hardest conditions. The personnel of TMSS were most strict regarding payment of installments.

According to the respondents, the following could ease the pressure and make microcredit more beneficial for them:

1. Increasing number of installments
2. Lower interest rates
3. Larger amount of loan
4. Opportunity to pay larger amounts after harvest and lower amounts during lean season
5. Setting up installment amounts according to capacity of the borrowers

9 Conclusions

Findings of this study reveal that microcredit may help toward reduction of poverty to some extent—increase amount of savings, increase the number of meals consumed per day, enable use of electricity, allow access to sanitary latrines and tube well water, etc. Regarding ownership of vital assets, participation in income-generating activities, and making decisions on financial affairs—variables that are used as indicators of empowerment—the impact of microfinance does not appear as decisive as desired. Thus, we may conclude that though some instances of positive outcomes of microcredit on poverty reduction and empowerment indicators are observed, it is not as per expectation. In order to make microcredit programs more effective, the following are suggested:

1. There is no set of laws (as stated by NGO officials) to deal with different issues regarding operation of microcredit transactions. Formulation and implementation of such laws will certainly go toward better operation of the microcredit programs.
2. Proper monitoring to ensure use of microcredit in income-generating activities would also help to make the programs more successful.
3. A more humanitarian approach to recollect the credit disbursed would be preferred to ensure human dignity.

References

Akmam, Wardatul, Islam MF, Barman RK (2007) Poverty reduction and empowerment through micro credit disbursed by BRAC in Bangladesh: a case study of five villages in Rajshahi District. Paper presented at the 44th Annual Conference of the Japan Section of the Regional Science Association, International (JSRSAI) held in Fukuoka, Japan during October 6–8, 2007

Al-Amin M, Chowdhury T (2008) Women, poverty and empowerment: an investigation into the dark side of microfinance. Asian Aff 30(2):16–29

Amin R, Becker S, Bays A (1998) NGO-promoted microcredit programs and women's empowerment in Rural Bangladesh: quantitative and qualitative evidence. J Dev Areas 32(2):221–236
Banu D, Farashuddin F, Hossain A, Akter S (2001) Empowering women in rural Bangladesh: impact of Bangladesh Rural Advancement Committee's (BRAC) Programme. J Int Womens Stud 2 (3). Downloaded on 8-12-2013 at http://vc.bridgew.edu/jiws/vol2/iss3/3/
Dessy S, Ewoudou J (2006) Microfinance and female empowerment. Working Paper No. 0603, The Centre interuniversitaire sur le risque, les politiques économiques et l'emploi (CIRPÉE) (Inter-University Centre on Risk, Economic Policies, and Employment)
Ethiopian Society of Population Studies (2005) Gender inequality and women's empowerment. UNFPA, Addis Ababa
Fernando JL (1997) Nongovernmental organizations, micro-credit, and empowerment of women. Ann Am Acad Pol Soc Sci 554(1):150–177. doi:10.1177/0002716297554001010
Gaiha R, Kulkarni VS (2013) Credit, microfinance and empowerment. http://www.un.org/esa/socdev/egms/docs/2013/EmpowermentPolicies/Expert-paper_Raghav-Gaiha.pdf. Accessed on 27-9-2015
Garikipati S (2008) The impact of lending to women on household vulnerability and women's empowerment: evidence from India. World Dev 36(12):2620–2642
Habib M, Jubb C (2012) Role of microfinance in political empowerment of women: Bangladesh experience. OIDA Int J Sustain Dev 5(5):99–110
Hashmi T (2012) Microfinance and its discontents: women in debt in Bangladesh by L. Karim – a review article. J Bangladesh Stud Special Issue: Microfinance:54–60
Islam MA (2015) Contribution of the Grameen Bank to the socio-economic changes of rural women: a critical analysis. Soc Sci J 19:63–78
Kabeer N (2005a) Gender equality and women's empowerment: a critical analysis of the third millennium development goal 1. Gend Dev 13(1):13–24
Kabeer N (2005b) Is microfinance a 'magic bullet' for women's empowerment? Analysis of findings from South Asia. Econ Polit Wkly. http://www.lse.ac.uk/genderInstitute/about/resourcesNailaKabeer/kabeerNoMagicBullets.pdf. Accessed on 27 Sept 2015
Lakwo A (2006) Microfinance, rural livelihoods, and women's empowerment in Uganda. African Studies Center, Research Report no. 85, viewed 20 October 2007 at http://www.openaccess.leinuniv.n/bitstream/1887/11945/1/rr85/akwo.pdf
Mahmud S (2002) Actually how empowering is micro credit? http://pksf-bd./images/stories/papersimeen%20mahmud.pdf. How empowering is micro credit? Accessed on 27 Sept 2015
Mahmud S (2003) Actually how empowering is microcredit? Dev Chang 34(4):577–605
Mahmud S, Nirali MS, Becker S (2012) Measurement of women's empowerment in rural Bangladesh. World Dev 40(3):610–619
Mamun MZH (2013) Impact of microcredit on rural livelihood: a case study in Bangladesh. Paper presented at the BDI/CSAS conference on "Bridging the Policy-Action Divide: challenges and prospects for Bangladesh" at the University of California at Berkeley (February 22–24)
Melik J (2010) Microcredit 'Death Trap' for Bangladesh's poor. http://www.bbc.co.uk/news/business-11664632. *BBC News Online*, BBC News of November 2, 2010
Mosedale S (2005) Policy arena—assessing women's empowerment: towards a conceptual framework. J Int Dev 17:243–257
Moser CON (1989) Gender planning in the Third World: meeting practical and strategic needs. World Dev 17(11):1799–1825
Parveen S, Chaudhury MSR (2009) Micro-credit intervention and its effects on empowerment of rural women: the BRAC experience. Bangladesh Res Publ J 2(3):641–647
Pitt M, Khandker S (1998) Household and intra-household impacts of the Grameen Bank and similar targeted credit programmes in Bangladesh. Paper presented at workshop on 'Credit programmes for the poor: household and intra-household impacts and programme sustainability'. World Bank and Bangladesh Institute of Development Studies, Dhaka
Pitt M, Khandker SR, Cartwright J (2006) Empowering women with micro finance: evidence from Bangladesh. Econ Dev Cult Chang 54(4):791–831

Quddus M (2012) A commentary on "Microfinance and its discontents: women in debt in Bangladesh by L. Karim – a review article". J Bangladesh Stud (Special Issue: Microfinance):61–67

Rahman A (1999) Micro-credit initiatives for equitable and sustainable development: who pays? World Dev 27(1):67–82

Razzaque MA, Bidisha SH (2012) Does microfinance promote women's empowerment? An empirical investigation, J Bangladesh Stud (Special Issue: Microfinance):11–29

Roxin H et al (2010) Economic empowerment of women through micro-credit: the case of microfinance investment and technical assistance facility. SLE, Freetown

Part III
Japan Perspectives

On Environmental Risk Management: The Interactions of Economic and Noneconomic Factors

Yasuhiro Sakai

Abstract This paper aims to discuss environmental risk management from a new point of view. Although there is a growing literature dealing with the relation between the economy and the environment in the absence of risk and uncertainty, it is quite unfortunate that the effects of a variety of risk factors on such a relation have not been intensively investigated by social scientists. Before 11 March 2011, most people believed in the myth of absolute safety. Since the Great East Japan Earthquake really took place, however, their concept of risk for nuclear power generation has been changed completely. What was once regarded as unthinkable may be a thinkable reality. This clearly indicates the necessity for studying environmental risk management in a new perspective. It is shown that mere applications of the conventional expected utility theory would possibly result in wrong conclusions. In order to newly establish a more realistic theory of decision making under conditions of uncertainty, this paper attempts to combine both economic and noneconomic factors in a more general framework than ever before. There remain many other possibilities for future research.

Keywords Environment • Risk management • Noneconomic factors • Nuclear power plant

1 Introduction

The purpose of this paper is to discuss environmental risk management from a new perspective. The paper is especially concerned with the relationship among the following three key concepts: risk, the economy, and the environment. It is true that there is a growing literature dealing with the last two in the absence of risk

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and uncertainty.[1] It is noted, however, that the introduction of risk factors would probably cause a drastic change for the conceptive framework and analytical tools.

First of all, we have to discuss what risk is all about. In historical perspective, there exist two different concepts of risk – old and new.[2] In old times, the following four used to be the most fearful items in Japanese people's mind:

Earthquake, lightning, fire and arrogant father.

Japan is a rather small yet beautiful country. It is a long archipelago spreading from the subarctic area to semitropical zone: it is surrounded by so many seas and contains so many volcanoes and hot springs. And as the old saying goes, the Japanese people have experienced so many earthquakes, so many lightning, and so many fires since the beginning of time. However, fearful fathers are now almost nonexistent, actually being replaced by friendly papas.

Time has changed so drastically since then. In modern times, we have to deal with new kinds of risk factors. Among these new factors, the following four items may be very conspicuous:

Radioactivity, global warming, garbage and AIDS.

As can be seen above, it appears that the old set of risk items are so different from the new set. Surely, there are some gaps between these two sets. It should be noted, however, that those gaps have been wiped out by the historic great earthquake that hit the Tohoku region 4 years ago.

On 11 March 2011, the Japanese nation marked the fourth anniversary of the 2011 Great East Japan Earthquake, which was characterized as the combination of the three great evils: great earthquake, great tsunami, and great nuclear plant accident. It was also the unique union of old and new concepts of risk abovementioned: earthquake and radioactivity. More than 18,000 people died or remain missing following the disaster, which has completely devastated much of the Tohoku region. Remarkably, the dreadful nightmare still continues at Tokyo Electric Power Company's Fukushima No. 1 nuclear plant, which already suffered three reactor core meltdowns and remains plagued daily by increasing amounts of radioactive water.

Before the great earthquake happened, most people believed in the *myth of absolute safety*: they regarded a nuclear power plant as a sort of accident-free, dreamlike facility. They were told that the nuclear facility could bring them an ideal set of cheap cost, stable power supply, more jobs, and above all absolute safety. However, the reality is sometimes more cruel than a fiction: the tragic disaster really happened in the Tohoku region 4 years ago. Since then, people's concept of risk for nuclear power generation has been changed completely. What they once regarded as the unthinkable event is no longer beyond imagination. There should be no "black

[1] For environmental economics, see Mäler (1974), Miyamoto (1989) and Ikeda et al. (2004).

[2] For a detailed discussion on risk and uncertainty, see Keynes (1921), Knight (1921), Hey (1979), Sakai (1982, 1991, 2006, 2010, 2015) and Bernstein (1996).

swans" in scientific mind. This clearly indicates the necessity for studying the main subject of this paper in a new perspective, namely, environmental management under conditions of risk and uncertainty.[3]

The outline of this paper is as follows. Section 2 will set up a general framework for decision making when environmental risks are present. Section 3 will introduce dreadful risks, discussing the effects of noneconomical (psychological and cultural) factors on individual decision making. In Sect. 4, following F. H. Knight (1921), measurable risk and nonmeasurable uncertainty will be distinguished, and the determination of the optimal project under true uncertainty will be explored. Concluding remarks will be made in Sect. 5.

2 Decision Making Under Environmental Risk: A General Framework

This section is concerned with individual decision making. In the absence of risk and uncertainty, the relationship between a person's act and its outcome is clear and straightforward. For instance, let us consider a bread factory in which a certain amount of flour combined with a certain amount of labor produces a certain amount of bread. If both the labor and the land are ignored, then the relation between flour and bread is simply described by the production function: F (flour) = bread.

In contrast to such a simple world, the introduction of risk and uncertainty would make the correspondence between human act and outcome considerably complex. It is rather common that a single act yields several outcomes. Presumably, which one among those outcomes will really come out depends on the state of the world. Let us take an example of farming. While a given amount of rice planting in June is supposed to produce a flexible amount of harvest in October, whether the harvest is good or bad cannot be foreseen by the farmer. Although the good weather produces the good harvest and the bad weather the bad harvest, the weather condition between planting and harvesting is generally unpredictable and perhaps beyond human power of knowledge. It would be safe to say that in the world of risk and uncertainty, the relationship between planting and harvesting is described by the following correspondence: F (planting, good weather) = good harvest, F (planting, bad weather) = bad harvest.

Let us discuss a general framework for the decision problem under conditions of risk. As is seen in Table 1, let us denote by a_i ($i = 1, \ldots, m$) the set of all possible choices by the individual and by s_j ($j = 1, \ldots, n$) the set of all possible states of the world. The basic characteristic of these states of the worlds is that the individual has

[3]The concept of black swan was first applied to social sciences by Taleb (2007).

Table 1 The decision problem under risk: a general framework

Alternative choices	States of the world				
	s_1	...	s_j	...	s_n
a_1	y_{11}	...	y_{1j}	...	y_{1n}
⋮	⋮		⋮		⋮
a_i	y_{i1}	...	y_{ij}	...	y_{in}
⋮	⋮		⋮		⋮
a_m	y_{m1}	...	y_{mj}	...	y_{mn}
Probability	p_1	...	p_j	...	p_n

Table 2 The allocation problem of a thermal power plant: the city or the country?

Alternative choices	States of the world	
	Non-accident	Accident
The city	2	−2
The country	1	−1
Probability	1-p	p

no control whatever over which s_j will occur: in other words, he/she is not informed at all in advance which s_j actually does occur.[4]

When the individual has chosen a specific a_i, and when a specific state s_j is revealed, such a combination (a_i, s_j) yields a specific outcome for him. More formally, the outcome depends on both a_i and s_j, and thereby denoted by y_{ij} ($i = 1, \ldots, m$; $j = 1, \ldots, n$). It is assumed that the probability that any particular state s_j actually occurs is denoted by p_j.

Summing up, a general framework of the decision problem is described by the payoff matrix (y_{ij}) with choice vector ($a_1, \ldots, a_m$) and state vector ($s_1, \ldots, s_n$). The probability vector ($p_1, \ldots, p_n$), where $p_1 + \ldots + p_n = 1$, is found in the last row in Table 1.

We are now in a position to focus on the more specific allocation problem of a thermal power plant. In modern times since the industrial revolution, people have benefited a great deal from the effective use of electricity. In order to meet additional demand for electricity, suppose that we are going to construct a new thermal power plant. As in Table 2, there are only two allocation choices available: the densely populated city or the depopulated country. The thermal power plant is not an absolutely safe facility and may break down because of an accident. We assume that there are two states of the world: the state of non-accident and the one of accident, with the rate of accident being p.

The construction of a thermal power plant in the city area is regarded as the one of "high return and high cost." On the one hand, if no accident occurs, then residents can enjoy the benefit of the short distance from the place of power supply

[4]Decision making under conditions of risk was systematically discussed by Borch (1968), Hey (1979), Sakai (1982), and Sinn (1983).

to the one of power demand: a shorter distance is expected to contribute to a less transmission cost. It is assumed that the payoff of the pair (the city, non-accident) is as great as 2 (see Table 2). On the other hand, the thermal power plant may cause air pollution and noise in the neighborhood. Besides, once any kind of plant accident in the urban area occurs, the resulting damage would be very serious, possibly causing even human casualties. Therefore the payoff of the pair (the city, accident) may be (−2), definitely a negative value.

In stark contrast to the above, the construction of a thermal power plant in the countryside can be regarded as the one of "low return and low cost." In the case of non-accident, the net benefit will surely be positive yet small since the power transmission to the consumption area will be fairly expensive: so the payoff is assumed to be 1. In the case of accident, the resulting damage would be relatively small: it would be safe to say that the payoff is (−1).

People live in the world of risk and uncertainty. The knowledge of the natural environment is limited, and the security of a thermal power plant per se is not perfect.

We have to make decision making under conditions of imperfect information. When we face the payoff matrix of the plant as shown in Table 2, we must do the best possible judgment subject to the technological and informational constraint. The question of much interest would be like this. Which is a better allocation for the power plant, in the city or in the countryside? No doubt, this constitutes a very important problem of environmental risk management.

In order to find the best possible choice among several candidates, it is convenient to introduce a particular form of *judgment criterion*. In the field of the modern economics of risk and uncertainty, perhaps the most fashionable criterion is provided by the *expected utility rule*, which was first introduced into moral science very long time ago by Daniel Bernoulli (1738), a very famous Swiss mathematician.[5]

It is noted that the level of expected utility brought by a choice a_i is given by

$$\begin{aligned} EU_i &= \Sigma_j\, p_j U\left(y_{ij}\right) \\ &= p_1 U\left(y_{i1}\right) + \cdots + p_j U\left(y_{ij}\right) + \cdots + U\left(y_{in}\right). \end{aligned} \tag{1}$$

Then the expected utility rule is stated as a lucid rule by which the best possible choice must be made in the sense that the act yielding the maximum value among those expected utilities $EU_1, \ldots, EU_i, \ldots, EU_m$ is selected. In other words, the following maximizing operation should be done:

$$\mathrm{Max}_i EU_i = \mathrm{Max}_i \left\{\Sigma_j\, p_j U\left(y_{ij}\right)\right\}. \tag{2}$$

[5]For the Bernoulli principle and its economic applications, see Arrow (1970) and Diamond and Rothschild (1978).

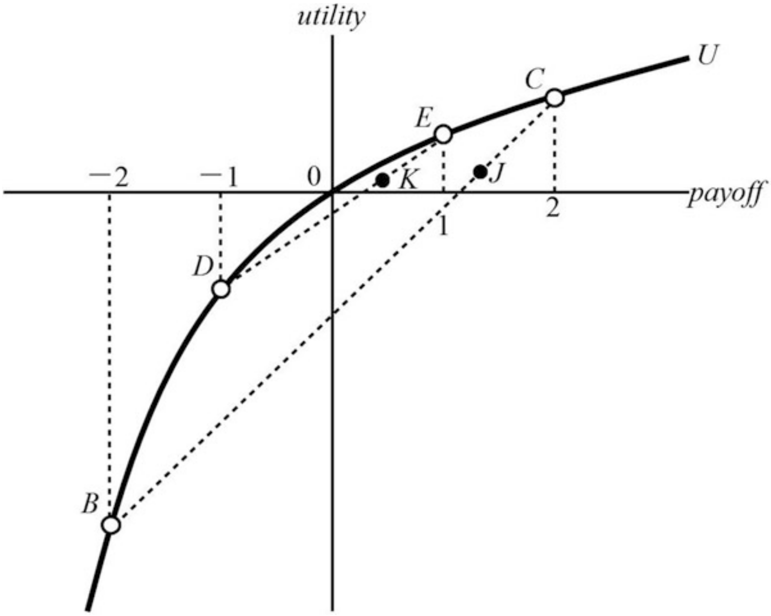

Fig. 1 Where to allocate a thermal power plant, the city or the country?

As the saying goes, the proof of the pudding is in the eating. Let us get back to the allocation problem of a thermal power plant mentioned above. Then, the levels of expected utility attainable from the construction of the plant in the city and in the country are, respectively, given by

$$EU\,(\text{city}) = (1-p)\,U(2) + pU\,(-2)\,, \tag{3}$$

$$EU\,(\text{country}) = (1-p)\,U(1) + pU\,(-1)\,. \tag{4}$$

The question of much interest is which one gives us a greater value, EU(city) or EU(country). The answer should be like this: it depends. It really depends upon the shape of the utility function U, the rate p of accident, and several other factors. As can clearly be seen in Fig. 1, the greater the degree of risk aversion or the value of the rate of accident, the more likely do they select the countryside as a site for the thermal power plant.

The allocation problem of a thermal power plant is depicted in Fig. 1. For the sake of presentation, let us put $p = 1/5$, a larger value than usual. Then, the point J on the line segment BC and the point K on the line segment DE, respectively, indicate the value of EU (city) and EU (country). Note that BJ: $JC = DK$: $KE = 4$: 1. Since K is located higher than J, the country should be more desirable as a plant site than the city. Needless to say, exactly the opposite conclusion would come if K is located lower than J. This is another possibility if circumstances are different.

3 The Presence of Dreadful Risk and the Effects of Noneconomic Factors

As we have discussed above, when we deal with a number of problems associated with environmental risk management, the application of the conventional expected utility theory would clearly very powerful in finding reasonable solutions. In general, we have no objections against such a rule. It is also obvious, however, that the rule is not almighty: there exist many other important exceptions in social science.

First of all, we should bear in mind that the utility function which is rather commonly used in any microeconomic textbook has no solid scientific and objective foundation at all. That function must have a very personal and subjective nature: it may differ from person to person. The man who displays a stronger aversion to risk is expected to have a more concave utility curve. Even if the same person is under investigation, the stability of his/her utility curve may not be guaranteed: the utility curve may shift upward or downward, depending upon his/her psychology. On the one hand, some persons would possibly feel high by engaging in gambling, thus shifting their utility curves upward. On the other hand, some other persons who face dreadful risks and feel frightened would shift their utility curves downward.

Secondly, regarding environmental risks, the amount of damage and the rate of accident may have no objective support, possibly differing from person to person. For instance, let us consider the case of environmental damage caused by the construction of a dam. Then probably, the dam constructer in question has a tendency to underestimate the amount of possible damages and the rate of accident per se. As a result, there would emerge a considerable perception gap between the constructor and the general public.

Taking account of these points aforementioned, we see that when dreadful risks and/or psychological and cultural factors are present in human minds, both the utility function and the accident rate are no longer stable and indeed may change upward or downward. The simple application of the conventional expected utility theory would possibly lead us to come to wrong conclusions. So it is high time to combine both economic and noneconomic factors toward a more synthetic theory of decision making under risk and uncertainty. There exist several attempts to further generalize the established expected theory in the academic profession. One of these attempts may be stated as the *generalized expected utility theory* to be explained below.[6]

In a more general framework work than the traditional one, the utility function is no longer the function of a single variable y , but rather the function of the two variables: an independent variable y and a shift parameter β. Therefore the new utility function $U = U(y; \beta)$ emerges. On the one hand, when people feel excited in

[6] For a detailed analysis, see Sawa and Ueda (2002, Chapter 8. It is in that chapter that the author developed a new version of the generalized expected utility theory, which is even more general than the prospect theory of Kahneman and Tversky (1979).

gambling, the value of β is expected to increase, which will in turn shift the utility curve upward. On the other hand, if they are mentally horrified in front of dreadful risks, the value of β will decline, whence the utility curve will shift downward.[7]

There is one more thing to say. When we are talking about the evaluation of risk frequency, we should not simply take account of probability p per se, but rather its weighted value $\omega(p)$, namely, the value obtainable by further filtering p through ω. Since people have a tendency to attach the greatest importance to 100 % safety, the distance between $\omega(1)$ and $\omega(0.9)$ will psychologically be greater than 0.1 in people's minds. Besides, when people are forced to do decision making under dreadful environmental risk, it is highly likely that they do not believe in the official rate p of accident which is announced by the government authority. In such a situation, the weighed value $\omega(p)$ will probably be greater than p per se.

Now let us return to Table 1. If the payoff matrix of payoff of an individual is given as in this table, it is possible to calculate the *weighted value* of his/her choice a_i in the following manner:

$$\begin{aligned} WV_i &= \Sigma_j\, \omega\left(p_j\right) U\left(y_{ij};\beta_i\right) \\ &= \omega\left(p_1\right) U\left(y_{i1};\beta_i\right) + \cdots + \omega\left(p_j\right) U\left(y_{ij};\beta_i\right) \\ &\quad + \cdots + \omega\left(p_n\right) U\left(y_{in};\beta_i\right) \end{aligned} \tag{5}$$

Then the *generalized expected utility rule* or *weighted value rule* requires that we make the best possible choice in the sense that the act yielding the maximum value among these weighed values $WV_1, \ldots, WV_i, \ldots, WV_m$ is chosen. That is to say, we are interested in doing the following maximizing operation:

$$\text{Max}_i\ \ WV_i = \text{Max}_i \left\{\Sigma_j\, \omega\left(p_j\right) U\left(y_{ij};\beta_i\right)\right\}. \tag{6}$$

Let us compare the two Eqs. (2) and (6). Then, we will be able to immediately understand that economic factors and noneconomic factors are now delicately intermingled. Decision under risk and uncertainty has to be made by an ordinary man with feelings and fears, not simply by economic man with cold-blooded calculation.

Now for an instance, let us consider the case in which the construction of a power plant at the designated place is planned. Concerning the type of the plant, there are two options: a thermal power plant and a nuclear power plant. As is shown in Table 3, the two states of the world are considered here as before: the state of non-accident and the one of accident.[8]

[7]The introduction of a shift parameter into the utility function is the author's own idea, which has been rather neglected in the mainstream of microeconomics today.

[8]It appears that the allocation problem of a thermal power plant was first discussed by Ikeda et al. (2004), even before the 2011 Great East Japan Earthquake took place. By writing Chapter 8 in Sawa and Ueda (2002), the author intended to break the myth of absolute safety associated with nuclear power generation.

Table 3 Alternative types of a power plant: thermal or nuclear

Alternative types of a power plant	States of the world		Psychological
	Non-accident	Accident	Factors
Thermal	2	−3	Not effective
	Prob. (1-*p*)	Prob. *p*	
Nuclear	4	$-(5+\alpha)$	Strong aversion to radioactivity
	Prob. (1-*p*)	Prob. *p*	

We would naturally expect that the rate of accident differs between the two types of power plants. Let us denote the rate of accident of a thermal power plant by p, and the one of a nuclear power plant by q. According to the official view of the government authority, q is estimated to be considerably lower than p. Local residents, however, may have some objections against such an estimate.

As is seen in Table 2, on the one hand, the thermal power plant is assumed to give us the payoff 2 if no accidents occur and (−2) if an accident occurs. On the other hand, the nuclear power plant is supposed to be economically efficient than the thermal one, presumably yielding a handsome amount of payoff 4. Remember that the effects of the nuclear facility are always double-edged. Schumacher (1973) once paid special attention to such knife-edge situation, thus inventing before us the remarkable phrase "nuclear energy – salvation or damnation?" Once the nuclear power plant suffers a serious accident, the resulting damage would possibly be devastating: it is estimated to be at least (−5) and the "plus α" factor that represents the additional nonmeasurable damages.[9]

Let us see what will happen if we dare to mechanically adopt the conventional expected utility theory. Then, we can easily calculate the value of the expected utility attainable from the thermal power plant and the one associated with the nuclear power plant:

$$EU\,(\text{thermal}) = (1-p)\,U(2) + pU\,(-3)\,, \tag{7}$$

$$EU\,(\text{nuclear}) = (1-q)\,U(4) + q\;\;U\,(-\,(5+\alpha))\,. \tag{8}$$

In Fig. 2, the utility curve U represents the reference point for our analysis. For the sake of convenience, let us assume that the rates of accident are considerably larger than usual: we simply put $p = 1/5$ and $q = 1/10$. Then while the ratio of line segment BJ to line segment JC is given by 4:1, the rate of DK to KE is 9:1.

[9]In his popular book (1973), Schumacher discussed the question whether nuclear energy was really salvation or damnation. Unfortunately, his pioneering work has been more or less ignored in the academic circle of theoretical economics. However, it is no doubt a subject worthy of more attention: it should be duly incorporated into environmental risk management.

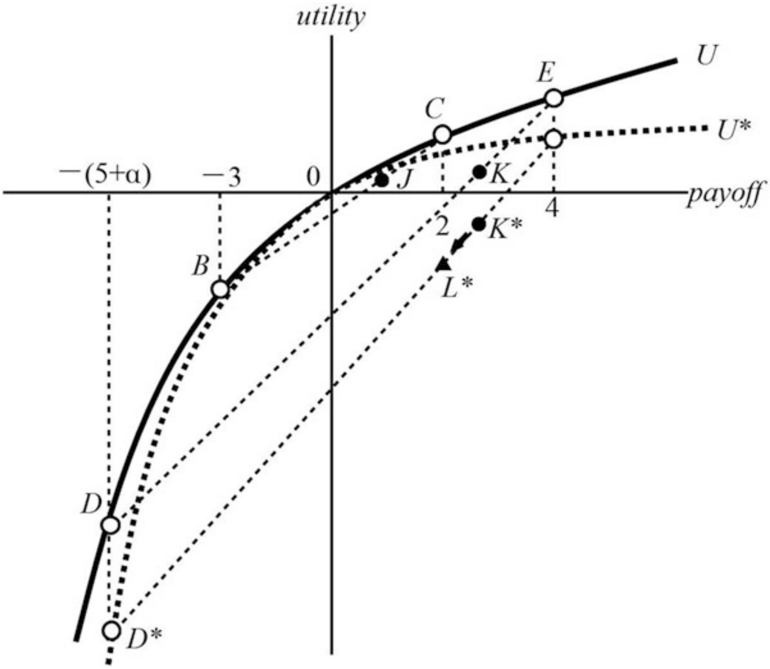

Fig. 2 The thermal power plant versus the nuclear power plant: people may display strong risk aversion to radioactivity

The positions of the two points *J* and *K*, respectively, indicate the value of *EU* (thermal) and *EU* (nuclear). Figure 2 shows the situation in which *K* happens to be located higher than *J*. Therefore if we simply apply the established expected utility theory to such a situation, then we would too quickly come to the conclusion that the nuclear power plant is a better facility. However, some people would have strong objections against this "simple-minded conclusion." We have so far repeatedly stated that so many people have nonmeasurable fears for dread risks associated with nuclear power generation. This is particularly true in Japan, where so many people have suffered so much by the explosion of atomic bombs in the Second World War. Understandably, peoples' risk aversion for nuclear power continues to be strong, and their trust level for the government policy might be far from satisfactory.

It is now high time that we go beyond the conventional expected theory by introducing noneconomic (psychological and historical) factors, so that we will be able to establish a more comprehensive decision theory, namely, a generalization of the traditional expected utility theory toward a new framework. When such a newly expanded type of decision theory under conditions of risk and uncertainty is adopted, we can find the weighted values of the two power plants in the following manner:

$$WV\,(\text{thermal}) = \omega\,(1-p)\,U\,(2;\beta) + \omega(p)U\,(-3;\beta)\,, \tag{9}$$

$$WV\,(\text{nuclear}) = \omega * (1-q)\,U\,(4;\beta *) + \omega * (q)U\,(-\,(5+\alpha)\,;\beta *)\,. \tag{10}$$

Honestly speaking, as far as the thermal power plant is concerned, the psychological factor is not so effectively working; hence, the conventional expected utility theory is still applicable as before. If this is the case, then the influence of β on U may be neglected, and the weighted value function ω(p) may be reduced to the most simple form of linear function; therefore, Eq. (9) is really equivalent to Eq. (7).

The same story should not be applied to the nuclear power plant, however. The difference between conventional and nuclear power generations cannot be overestimated. Everywhere in the world, and especially in Japan, people have strong feeling against use of nuclear power. Hence it would be quite natural for us to think that such strong fear causes a downward shift of the utility function from U and U*. Then, in Fig. 2, the "new" point of evaluation is K*, which is located lower than point J, the point of evaluation for the thermal power plant.

Interestingly enough, this is not the end of our story! Note that the new point K* is now located lower than the horizontal axis, meaning that the nuclear plant per se might be regarded as harmful rather than beneficial. Moreover, if people do not trust much the nuclear policy of the government and tend to think that the "true" rate of nuclear accident ω*(q) substantially exceeds the "officially announced" rate q, then the point of evaluation for nuclear power generation would be further downward, possibly reaching the point L* down below.

It would be pretty fair to say that the above illustration by Fig. 2 is of a very special type, perhaps being a bit far from satisfactory. We would honestly admit the limitation of our simple graphical analysis. However, we must understand that the introduction of noneconomic (psychological or cultural) factors into our analysis would drastically change the whole story of the existing literature on nuclear power generation. This is really a very important point. We believe that the results of our analysis taken here are fundamentally robust and can be applied to many other problems.

4 Selection of the Optimal Project: The World of True Uncertainty

When we are dealing with the problems of environmental risk management, we sometimes wonder if the risks under consideration are really numerically measurable. For one thing, the probability that a certain state occurs may be too ambiguous to be represented by any numerical value. For another, the two states of the world are not clearly distinguishable between them. Therefore, it is necessary

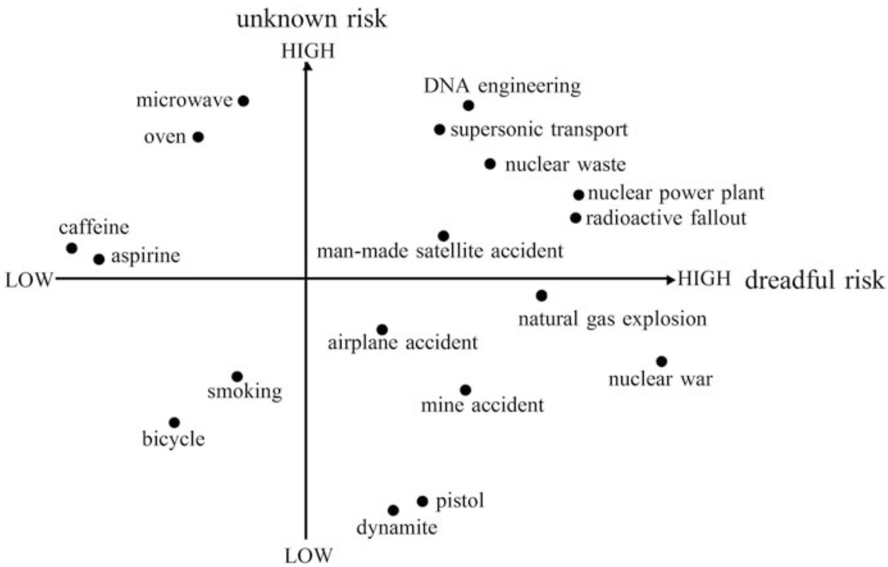

Fig. 3 Unknown risk versus dreadful risk: considering the quality of risks

but not sufficient to consider the *quantity* of risk only. Due considerations of the *quality* aspect of risk should be the next task of our risk analysis.[10]

In his famous paper on psychology, Paul Slovic (1987) reported the results of his empirical research on many risk perceptions of American people. The list of 17 items adopted by him is as follows:

> Nuclear power plant, radioactive fallout, nuclear waste, DNA engineering,
> supersonic transport, man-made satellite accident, nuclear war,
> natural gas explosion, mine accident, air plane accident, pistol, dynamite,
> microwave, oven, caffeine, aspirin, smoking, bicycle.

Slovic attempted to classify these risk items in terms of *unknown risk* and *dreadful risk*. His research results were edited and summarized in Fig. 3. As can easily be expected, while nuclear power plant is not an unknown risk, it is indeed very dreadful risk. In contrast, DNA engineering represents unknown risk rather than dreadful risk. Microwave has the characteristic that its risk is not dreadful but unknown. Bicycle is regarded as a quite safe means of transportation since its risk is well known and not dreadful at all.

[10]Investigation into selection of optimal project under true uncertainty remains an underdeveloped area in social sciences. The author intends to mend such unfortunate state by giving an attempted analysis below.

Table 4 Alternative scenarios under conditions of uncertainty: a general framework

Alternative projects	Scenarios				
	s_1	…	s_j	…	s_n
a_1	y_{11}	…	y_{1j}	…	y_{1n}
⋮	⋮		⋮		⋮
a_i	y_{i1}	…	y_{ij}	…	y_{in}
⋮	⋮		⋮		⋮
a_m	y_{m1}	…	y_{mj}	…	y_{mn}

According to the history of economic thought, there have existed a small number of economists who dared to investigate the problem of risk and uncertainty. Frank Knight (1921) was among those exceptional scholars. In his famous book, he once remarked:

> Uncertainty must be taken in a sense radically distinct from the familiar notion of risk, from which it has never been properly separated. … A measurable uncertainty … is so far different from an unmeasurable one that it is not in effect an uncertainty at all.

In line with Knight' argument, what is usually called risk should be measured: it is typically represented by a certain distribution function. In a sharp contrast to such risk, uncertainty is a radically distinct concept since it is not measurable at all. The concepts of psychological risks including unknown and dreadful risks aforementioned are of non-quantity type, so that they should be included in the general category of uncertainty.

So much as the general discussion on uncertainty versus risk, we are now ready to turn to the more interesting and more realistic situation in which we have to choose the optimal one out of the set of many projects when no probabilities can be attached to possible scenarios.

Suppose now that we are facing the environmental uncertainty indicated by Table 4. There are m different *projects* that can be adopted and n distinctive *scenarios* available. If we take account of all the combinations of the pair (projects, scenarios), then we are able to have the $m \times n$ *payoff matrix*.

Let us make comparisons between the two tables – Table 1 associated with measurable risk and Table 4 related to nonmeasurable uncertainty. Then we see that there are several points worthy of special attention. First of all, states and scenarios are entirely different concepts. Although each state s_j has its own probability p_j, no numerical probability is attached to any scenario. Second, while any two states are independent and exclusive, this may not be true for scenarios: one project and another project may be partly "overlapped" since their boundaries are ambiguous and not clearly defined. We can see a number of optimistic and pessimistic scenarios that have no solid objective foundations. Third, the selection of scenarios is more or less arbitrary, so that some "gaps" between a pair of them is conceivable.

Now let us get back to Table 4. There are m projects: $a_1, \ldots, a_m$. In order to select the optimal one out of these projects, it is necessary to introduce some forms of selection rules. Specifically, we will consider the following three rules.

The first rule of selection is the one to simply obey the *average rule*: in other words, *we* have to select such a project that it maximizes the average value of payoff. Let us write

$$\mathrm{Ave}_i = \Sigma_i y_{ij}/n = \left(y_{i1} + \cdots + y_{ij} + \cdots + y_{in}\right)/n. \tag{11}$$

Then the average rule requires that the project yielding the maximum value should be chosen:

$$\mathrm{Max}_i \ \ \mathrm{Ave}_i = \mathrm{Max}_i \ \left\{\Sigma_j \, y_{ij}/n\right\}. \tag{12}$$

This rule is apparently based on the common sense: following the middle of the road may often be the wise rule when nothing is known in advance.

The second rule of selection is what we call the *maximax rule*. It distances itself from the middle of the road and takes a very optimistic, and even aggressive, course: we dare to seek the "very-best-of-the-best targets." According to this rule, we have to first pick up the best scenario for every possible project and then proceed to choose the very best project out of these selected projects. Let us write

$$M_i = \mathrm{Max}_\mathrm{j} \quad \left\{y_{i1}, \ldots, y_{ij}, \ldots, y_{in}\right\}. \tag{13}$$

Then the maximax rule says that the project giving the maximum value must be selected:

$$\mathrm{Max}_\mathrm{i} \ \ M_i = \mathrm{Max}_\mathrm{i} \left\{\mathrm{Max}_\mathrm{j} \ \ y_{ij}\right\} \tag{14}$$

The third rule of selection is named the *maximin rule*, representing a more prudent, and even defensive, behavior. We must first think of the worst possible scenario for every project and proceed next to find the "best" one out of these worst scenarios. Let us define

$$N_i = \mathrm{Min}_j \left\{y_{i1}, \ldots, y_{ij}, \ldots, y_{in}\right\}. \tag{15}$$

Then the maximin rule requires that the project yielding the maximum value must be chosen:

$$\mathrm{Max}_\mathrm{i} \ \ N_i = \mathrm{Max}_i \left\{\mathrm{Min}_j \ \ y_{ij}\right\}. \tag{16}$$

These three rules of selection abovementioned are different from each other and may lead us to obtain entirely different conclusions. In order to understand this important point more clearly, let us look at the three alternative highway projects (Projects A, B, and C) with two opposite scenarios (Scenarios I and II). Let us take a look at Table 5.

Table 5 Alternative highway projects under conditions of uncertainty: how should we choose the best one?

Alternative projects	Scenarios *I*	Scenarios *II*	Ave.	Max.	Min.
A	6	−2	(2)	6	−2
B	8	−6	1	(8)	−6
C	2	0	1	2	(0)

Project *A* represents a large-scale development project in which a superhighway with affiliated lodging facilities is to be constructed on a partly deforested area.

We can have either an optimistic scenario (Scenario *I*) or a pessimistic one (Scenario *II*), depending on the business conditions and more personal philosophies. Under Scenario *I*, this project is expected to yield a handsome amount of money: the payoff is as big as 6. Under Scenario *II*, the cost of environmental destruction will be very heavy and may exceed the expected benefit: the payoff is minus 2.

Project *B* is more aggressive than Project *A*. It is indeed a super grand-designed project which includes an attractive golf course in addition to all the plans of Project *A*. If everything is going well (Scenario *I*), the project will yield a further increase in revenue (the payoff is 6). If something is going against us because of enormous deforestation together with very poor golf revenue (Scenario *II*), however, it will impose extra burden on us (the payoff is minus 6).

In comparison with these two projects aforementioned, Project *C* is a very modest and even defensive project. The philosophy behind the project is natural preservation: the small-scale facilities such as walking trails and camping places are all we want to have. While Scenario *I* will bring us a small benefit (the payoff is 2), Scenario *II* will yield a negligible amount of loss (the payoff is assumed to be zero).

The question of much interest would be which project is likely to be adopted. The answer should be like this: it depends. It really depends on the life philosophy and ethical judgment of local residents. As can easily be understood, Project *A* will be adopted by the eclectic average rule, Project *B* by the aggressive maximax rule, Project *C* by the prudent maximin rule.

We live in an uncertain world. The long human history has taught us the effectiveness of the safety-first principle. The nature is too overwhelming for a small creature like us to control. As Terahiko Terada (1934), a legendary scientist and essay writer, once remarked:

> A natural disaster will repeat itself on a forgetful mind.

It would be very interesting to see whether and to what extent the old warning of Terada is still alive today. We can learn new lessons from old teachings.

5 Concluding Remarks

More than 40 years ago, Kikuo Iwata (1981), then a rising star in Japanese economics profession, honestly remarked:

> I have so often been asked: 'What do modern economists think of nuclear power generation? What on earth are they doing now?' ... I myself have never been duly responded to such an important question.

Although Iwata's remark was clear and correct, it was destined to be forgotten soon. When the author published *The Economics of Uncertainty* in 1982, he never touched upon the subject of the relationship between nuclear power generation and modern economics. One of the reasons of such neglect was that many people believed in the myth that nuclear power plant was absolutely safe. It is needless to say, however, that such a myth has been completely broken since the 2014 Great East Japan Earthquake.

There is one more thing to add. Environmental management under conditions of risk and uncertainty, which includes as a part the economics of nuclear power generation, is still a young and underdeveloped area. We believe that there remain so many problems which will be left for future research.

Michio Morishima is probably the most famous economist Japan has ever produced since the Second World War.[11] In his popular book (1999), he remarked:

> This book [Morishima's book] represents what I once called *Symphonic Economics*, namely, a sort of interdisciplinary and comprehensive research in social sciences, where economics, sociology, education, history and related field are all present and unified into one. It is such an ambitious project that I have had a strong desire to consistently promote for a very long time.

The author has highly appreciated the *Morishima spirits*. In fact, a symphonic economic approach *a la* Morishima to environmental risk management under conditions of uncertainty has been attempted to be adopted here.

There should be another long way to go for the completion of the mission. Life is a challenge! We need to have strong courage as well as solid determination in order to carry out our ambitious task to a successful finish. As the saying goes, where there is a strong will, there is a way.

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[11] For a detailed essay on the life and work of the late Prof. Michio Morishima, see Sakai (2011).

References

Arrow KJ (1970) Essays in the theory of risk-bearing. North-Holland, Amsterdam
Bernoulli D (1738) Specimen theoriae novae de mensura sortes. Commentarii Acad Sci Imperialis Petropolitanae 5:175–192, English translation by Sommer L. Exposition of a new theory on the measurement of risk. Econometrica. 1954; 22:23–36
Bernstein PL (1996) Against the gods: the remarkable story of risk. Wiley, New York
Borch KH (1968) The economics of uncertainty. Princeton University Press, Princeton
Diamond P, Rothschild M (1978) Uncertainty in economics: readings and exercises. Academic, New York
Hey JD (1979) Uncertainty in microeconomics. New York University Press, New York
Ikeda S, Sakai Y, Tawada M (eds) (2004) Risk, the environment, and the economy. Keiso Publishing Co, Tokyo
Iwata K (1981) What are modern economists doing now?: nuclear power generation and modern economics. Sci Thought 10:46–54
Kahneman D, Tversky A (1979) Prospect theory: an analysis of decision under risk. Econometrica 47:263–291
Keynes JM (1921) A treatise on probability. Macmillan, London
Knight FH (1921) Risk, uncertainty and profit. Houghton Mifflin Co, Boston
Mäler KG (1974) Environmental economics: an theoretical inquiry. Johns Hopkins University Press, Baltimore
Miyamoto K (1989) Environmental economics. Iwanami Publishing Co, Tokyo
Morishima M (1999) Why will Japan fall? Iwanami Publishing Co, Tokyo
Sakai Y (1982) The economics of uncertainty. Yuhikaku Publishing Co, Tokyo
Sakai Y (1991) Risk and information: towards a new economics. Keiso Publishing Co, Tokyo
Sakai Y (2006) Risk society: a comprehensive approach. Iwanami Publishing Co, Tokyo
Sakai Y (2010) Economic thought of risk and uncertainty. Minerva Publishing Co, Kyoto
Sakai Y (2011) Towards 'symphonic economic science': my academic life and homage to the late Prof. Michio Morishima. The Morishima Memorial Lecture, Kyoto Citizens University
Sakai Y (2015) J.M. Keynes versus Frank Knight: comparing the two economic giants in the age of uncertainty. Minerva Publishing Co, Kyoto
Sawa T, Ueda K (eds) (2002) Economic theory of the environment. Iwanami Publishing Co, Tokyo
Schumacher EF (1973) Small is beautiful: economics as if people mattered. Blond & Briggs Ltd, London
Sinn HW (1983) Economic decisions under uncertainty. North-Holland, Amsterdam
Slovic P (1987) Perception of risk. Science 236:280–285
Taleb NN (2007) The black swan: the impact of the highly improbable. Random House Publishing Group, New York
Terada T (1934) Natural disasters and national defense. Tokyo: Keizai-Ohrai J 5:10–12

Product Design for Recycling and Recycling Industry

Makoto Tawada and Tomokazu Sahashi

Abstract This paper treats the analysis of a recycling industry in an economy where the quality of product design is incorporated. We assume three types of market failures caused by a monopoly power, environmental damage by wastes, and cost of the product design for recycling. In order to solve these market failures, we consider three policy instruments and characterize these policies in this present economy. Finally, a comparative statics analysis is carried out with respect to the consumption good supply, production design quality, and recycling ratio in response to changes in the recycled material price, landfilling cost of wastes, and degree of environmental damage by wastes.

Keywords Recycling firm • Product design • Monopoly • Environmental damage by wastes

1 Introduction

Due to the recent remarkable economic development of emerging countries, demand for natural resources is rapidly expanding. It is said, for example, that all mineral resources that are known to exist at present would have been exploited up by 2050 if the present trend of worldwide economic development would continue. So, in order to prevent natural resources from their extinction, we need a constant effort to promote recycling activities to reduce waste disposal in not only advanced countries but also developing countries.

In order to form a recycling-oriented society, governments should be committed to construct an environmentally sustainable society and strive to create an economic

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mechanism for this. Because of the fear of resource extinction and worsening of natural environment, companies and households have been gradually promoting the activities of reducing, reusing, and recycling of natural resources by the slogan “3Rs” representing those activities. We need to achieve building an efficient recycling system to reduce the burden of the environmental cost in production as well as consumption. In the production side, producers become conscious of the importance of renewable resource use and recycled material use in addition to the effort to make more efficient use of natural resources. For promoting recycling of end-of-life products and making efficient use of resources, one important method is to adopt the designs of produced commodities which make easier to recycle the commodities after their use, so that waste disposal could be decreased.

There are some studies of the product design and recycling. Fullerton and Wu (1998) employed a simple general equilibrium model and made an analysis of a subsidy for the recyclable design of consumption goods. They demonstrated that, if households should pay the social cost of disposal, they would send a signal to the producers to make them design their products for promoting recycling. Considering the case where the consumption goods can be disassembled, Choe and Fraser (1999) provided a study of waste management policies with possibilities of waste reduction efforts made by firms and households and waste disposal illegally made by households. Einchner and Pething (2001) showed that the policy instruments needed for green design are a tax on the consumption good supply and a subsidy on the demand for input of recycled materials under certain conditions. Calcott and Walls (2000) treated product recyclability and packaging and weight and analyze the effect of weight on recycling activities. Einchner (2005) expands the study of Einchner and Pething (2001) by the introduction of imperfect competition. That is, producers and households act under perfect competition, whereas the recycling firm is assumed to be a monopolist on the market of recycling services for the waste goods. He considered the case where a waste disposer is required a high share of costs to collect the wastes. This cost is supposed to be like a fixed cost and recycling is supposed to be carried out by long-term firm in the area across multiple municipalities. Then, the recycling firm in the recycling industry could use a monopoly power in the long run. Under these circumstances, Einchner (2005) examined the recycling ratio, the level of product design, and the effect of policies to restore efficiency.

We investigate a recycling model into which the concept of product design is incorporated on the basis of Einchner (2005). Our paper is different from his model in three aspects. First, in his paper it is the recycling firm rather than the producers that determines the level of the product design. Since the recycling firm determines the level of product design so that recycling cost is minimized, the social optimum level of product design can be achieved in the market economy. Hence, external diseconomies cannot be caused by product design. But our paper employs more realistic model in which the producers determine the level of product design. In this case, the producers decide the design level so as to minimize production cost. Therefore, we cannot achieve the level of product design which is socially efficient because recycling costs increase and thus external diseconomies appear.

Second, since policy variables have been introduced in an arbitrary manner in Einchner (2005), it is hard to understand which policy can take care of which market failure, that is, each policy objective is ambiguous. In our model there are three kinds of market failures, that is, monopoly, environmental externality, and product design externality. These three types of market failures are related to the production amount of a consumption good, the level of product design, and the recycling ratio, respectively. As policy instruments to resolve these failures, we can consider a production subsidy for the recycling firm as a monopolist, a waste tax imposed on the discarded waste to promote recycling, and a material subsidy to encourage the product design suitable to recycling. We will introduce these three policies and demonstrate how these market failures are resolved by these policies.

Third, we provide some comparative statics analysis so as to examine how the changes of the degree of an environmental damage caused by waste, the waste disposal cost of landfilled goods, and the price of the recycled materials affect the level of production, the product design, and the recycling ratio.

Our paper is organized as follows. In Sect. 2, we present our model and characterize the social optimum. Section 3 discusses market allocation and shows the policies which would restore economic efficiencies. We provide a comparative statics analysis in Section 4 and finally present our conclusions in Section 5.

2 Model and Social Optimum

We employ the model which is partial equilibrium in nature. The amount of a consumption good is denoted by y which is produced by the use of recycled materials, virgin materials, and labor. The producers determine the attribution of the consumption good in addition to production level. The attribution of the consumption good is expressed by an index of product design q. It is assumed that the waste good can be recycled by a lower cost according to a greater q. The cost function of the producer is given by

$$C(y, q) = yF(q), \tag{1}$$

where $F(q)$ is the unit production costs of the consumption good with recyclability degree q, and we suppose that $F_q > 0$ and $F_{qq} > 0$. For any consumption amount of the good, the same amount of the waste good is supposed to be generated. We assume that the producers collect the waste good and bring them into a recycling firm. The recycling firm produces recycled materials by the use of a part of the waste and discards the remaining by landfilling.

Then, for consumed amount of the consumption good y, we have

$$y = r + w, \tag{2}$$

where r and w are the recycled and discarded amounts of the waste good, respectively. Let α represent the recycling ratio of the wasted good. Then, the following holds:

$$r = \alpha y, \tag{3}$$

$$w = (1 - \alpha)\, y. \tag{4}$$

Next we define the cost structure of a recycling firm. We assume that the recycling cost function is represented by the following function:

$$N = yG\,(q, \alpha)\,, \tag{5}$$

where N is the cost to produce $r(= \alpha y)$ units of recycle materials from y units of the waste good. As for the function $G\,(q, \alpha)$, we assume that $G_\alpha \equiv \partial G/\partial \alpha > 0$, $G_{\alpha\alpha} \equiv \partial G_\alpha/\partial \alpha > 0$, $G_q \equiv \partial G/\partial q < 0$, and $G_{qq} \equiv \partial G_q/\partial q > 0$.

The consumption good market is supposed to be perfectly competitive, and the producers of the consumption good determine the quality of the product design and produce the good by the use of recycled and virgin materials. These producers have an obligation to collect the used consumption good from households and hand bring them into a recycling firm. In the recycling market, only one firm exists so that the firm can act as a monopolist. This recycling firm receives the used consumption good from the consumption good producers and produce recycled materials which will be reused in the consumption good production. The non-recycled parts of the used consumption good are landfilled as waste. Finally the resource and material market is supposed to be perfectly competitive. Here, we summarize the life cycle and flows of goods and materials in Fig. 1.

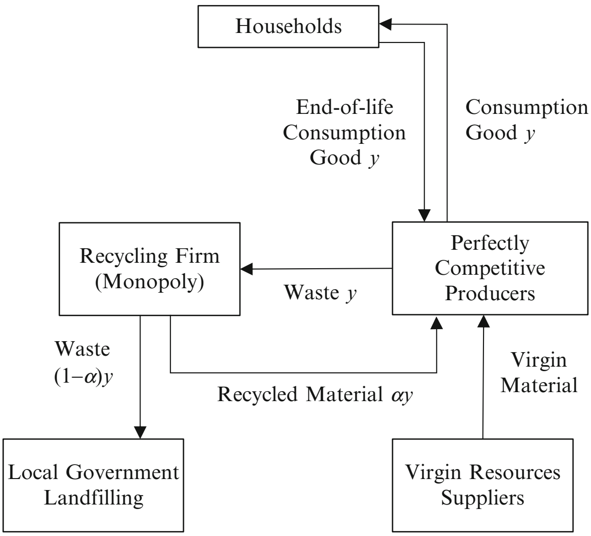

Fig. 1 The product life cycle, flows of goods, and materials

The linear inverse demand function of the consumption good is represented by $P(y) = \beta - \delta y$ where β and δ are strictly positive parameters. The landfilling of waste is supposed to cause an environmental damage. We assume that the marginal landfilling cost of end-of-life products is c^w and the marginal environmental damage by landfilling waste is c^d. Both c^w and c^d are positive and constant. Then, the social welfare is

$$W(y, q, \alpha) = \int_0^y (\beta - \delta s)\, ds - yF(q) - yG(q, \alpha) - \left(c^w + c^d\right)(1 - \alpha)\, y + \alpha y p^r, \tag{6}$$

where p^r is the price of resources and materials for production.

Our first task is to demonstrate the socially optimal allocation which follows from the maximization of (6) with respect to y, q, and α. Then, the first-order conditions are obtained as

$$\beta - \delta y^* = F\left(q^*\right) + G\left(q^*, \alpha^*\right) + \left(c^w + c^d\right)\left(1 - \alpha^*\right) - \alpha^* p^r, \tag{7}$$

$$F_q + G_q = 0, \tag{8}$$

$$G_\alpha = c^w + c^d + p^r. \tag{9}$$

where y^*, q^*, and $\alpha^*$are those of optimal values. If $G(q, \alpha)$ is convex for (q, α), the second-order condition is satisfied. (See Appendix for this.)

The efficient allocation of the consumption good is determined by Eq. (7). It means that the consumers' marginal payment for the consumption good which is the LHS of (7) equals the sum of its unit production cost, the net unit recycling cost $(G(q^*, \alpha^*) - \alpha^* p^r)$, the marginal landfilling cost, and the marginal environmental damage. Equation (8) shows that, for the recycling activity, the marginal cost of the design expressed by F_q should be equal to the marginal benefit from saving the recycling cost exhibited by $-G_q$. Equation (9) implies that the marginal cost to raise the recycling ratio is equal to the sum of the marginal landfilling cost, the marginal environmental damage, and the price of the recycled materials.

3 Market Equilibrium

In this section we investigate the market equilibrium. Our model introduces the concept that the consumption good producers have a responsibility to collect the-end-of life consumption good from households after consumption and to bring it to the recycling firm. When the collected end-of-life consumption good is brought into the recycling firm, the consumption good producers must pay a fee to the recycling firm for recycling service provided by the recycling firm. Japan and some countries in Europe, for example, adopt this system.

Since perfect competition prevails in the consumption good market, the profit-maximizing behavior of a typical consumption good producer is formulated as

$$\max_{y,q} \Pi^y = (p^y - p)\, y - yF(q) + \sigma^m qy, \tag{10}$$

where p^y is the price of the consumption good, p is the price of the wasted good brought into the recycling firm, and σ^m is a product design subsidy. The first-order conditions are given by

$$p^y - p - F(q) + \sigma^m q = 0, \tag{11}$$

$$F_q = \sigma^m. \tag{12}$$

The second-order condition also holds. The amount of the produced consumption good and the quality of product design are determined from (11) and (12). Especially the level of product design is determined as $q^m \equiv q\,(\sigma^m)$ by (12). Then, in view of (11) and the demand equation $p^y = \beta - \delta y$, the price of the recycling service is determined as

$$p = \beta - \delta y - F\,(q^m) + \sigma^m q^m \equiv P\,(y, q^m)\,. \tag{13}$$

Next we consider the behavior of the recycling firm as a monopolist. The behavior of the firm is to maximize its profit with respect to y and α subject to (13), so that the optimization problem of the firm is described as

$$\begin{aligned} \max_{y,\alpha} \Pi^r = {} & [(P\,(y, q^m) - \tau^y]\, y - yG\,(q, \alpha) \\ & - (p^w + \tau^w)\,(1 - \alpha)\, y + p^r \alpha y, \end{aligned} \tag{14}$$

where p^w is a landfilling charge, τ^y is a subsidy for recycling service, and τ^w is a waste tax. Local government plays a role of discarding the non-recycled wastes by landfilling, so that the government charges p^w to the recycling firm for this one unit of cost. This means $p^w = c^w$. The first-order conditions for maximizing profit of the recycling firm are given by

$$\begin{aligned} \beta - 2\delta y = {} & F\,(q^m) + G\,(q^m, \alpha) + \tau^y - \sigma^m q^m \\ & + (p^w + \tau^w)\,(1 - \alpha) - p^r \alpha, \end{aligned} \tag{15}$$

$$G_\alpha = p^w + \tau^w + p^r. \tag{16}$$

By virtue of (16), α is determined. This, together with (15), determines y. Then, p^y is obtained from (11).

In this market equilibrium, there are three types of external diseconomies. First is the monopoly power of the recycling firm. Second is the environmental damage caused by landfilling the non-recycled waste. Third is the low quality of the product design to reduce the production cost. These three types of failures reveal that production, y, the level of product design, q, and the recycling ratio, α, tend to be lower under the market equilibrium than the socially optimal levels. In order to attain the socially optimal levels of these variables under the decentralized economy, we can use three policy instruments. They are a subsidy τ^y for the recycling service, a product design subsidy σ^m, and a waste tax τ^w to reduce the landfilling of the waste good. If these policies are appropriately introduced, economic efficiency is achieved in the decentralized economy. The following proposition presents the levels of these policies for the market equilibrium to be efficient.

Proposition 1 *If we set*

$$\tau^y = \delta y - G_q q^m - \alpha p^r,$$
$$\tau^w = c^d > 0,$$
$$\sigma^m = -G_q > 0,$$

then the market equilibrium becomes efficient, implying that the welfare can be maximized.

Proof Making use of $\tau^y = \delta y - G_q q^m - \alpha p^r$, $\tau^w = c^d$, and $\sigma^m = -G_q$, we can reduce Eqs. (7), (8), and (9), respectively, to (15), (12), and (16) which are the optimal conditions for welfare maximization. *Q.E.D.*

We should notice that a waste tax τ^w and a material subsidy σ^m are positive, whereas a subsidy τ^y for the monopolistic recycling firm is not always positive. If the government does not adopt these policies at all, the market equilibrium conditions become

$$F_q = 0, \tag{17}$$

$$\beta - 2\delta y = F(q) + G(q, \alpha) + p^w (q - \alpha) - p^r \alpha, \tag{18}$$

$$G_\alpha = p^w + p^r. \tag{19}$$

Let the solutions of competitive equilibrium Eqs. (16), (17), and (18) be denoted by y^m, q^m, and α^m. From G_q <0 and F_{qq} >0, we have $q^* > q^m$. In order to reduce the production cost, the consumption good producers choose a lower quality of the product design. Equation (19) determines the recycling ratio α^m under a given q^m. Suppose $G_{\alpha q} \leq 0$, because the marginal recycling cost seems to fall by a rise in the level of product design. Then, we have

$$G_\alpha\left(q^m, \alpha^*\right) \geq G_\alpha\left(q^*, \alpha^*\right) > G_\alpha\left(q^m, \alpha^m\right),$$

because $q^* > q^m$, $G_{\alpha\alpha} > 0$, and $G_\alpha\left(q^*, \alpha^*\right) > G_\alpha\left(q^m, \alpha^m\right)$. This implies that $\alpha^* > \alpha^m$. Thus, we have

Proposition 2 *The market equilibrium level of the product design is lower than that that of the social optimal level. And, if* $G_{\alpha q} \leq 0$, *the market equilibrium recycling ratio is lower than that of the social optimum.*

Thus, the government can use a product design subsidy $\sigma^m > 0$ for the consumption good producers and a waste tax $\tau^w > 0$ for the recycling firm in order to recover economic efficiency in the market economy.

We proceed to the examination of a production subsidy τ^y for the recycling monopoly firm by a comparison of (18) with (7). We cannot show which is larger between y^* and y^m. In general a monopoly firm puts a higher price to the produced good than a competitive firm because of a full use of monopoly power, which results in a smaller amount of production in monopoly case than the socially optimal level. But this does not mean to be a negative impact for economic efficiency in the present case. This is because a smaller supply of the recycling service by raising the price of the service implies the smaller burden on the environment by lessening the amount of landfilling. Thus, we can conclude that whether τ^y should be a subsidy or a tax is dependent on which is larger, undersupply due to monopoly power or oversupply due to free riding on the environment in the recycling service and landfilling. We assert this in the following proposition.

Proposition 3 *For the market economy to be efficient*, τ^y *should be a subsidy* (*tax*) *when the undersupply due to monopoly power is larger* (*smaller*) *than the oversupply due to free riding on the environment in the recycling service and landfilling*.

4 Comparative Statics Analysis

In this section we examine the effects of changes in the landfilling cost of the waste c^w, the environmental damage c^d, and the price of recycled material p^r to the optimal as well as equilibrium values of endogenous variables such as the amount of the consumption good, the quality level of the product design, and the recycling ratio of the end-of-life consumption good.

4.1 The Effects of c^w, c^d, and p^r on the Social Optimal Levels of the Consumption Good Supply, Product Design, and Recycling Ratio

Total differentiation of (7), (8), and (9) yields the following equation system:

$$\begin{bmatrix} \delta & F_q + G_q & G_\alpha - \left(c^w + c^d + p^r\right) \\ 0 & F_{qq} + G_{qq} & G_{q\alpha} \\ 0 & G_{\alpha q} & G_{\alpha\alpha} \end{bmatrix} \begin{bmatrix} dy^* \\ dq^* \\ d\alpha^* \end{bmatrix} = \begin{bmatrix} -(1-\alpha)\, d\left(c^w + c^d\right) + \alpha dp^r \\ 0 \\ d\left(c^w + c^d\right) + dp^r \end{bmatrix}. \tag{20}$$

The determinant of the square matrix in the LHS of (20), which is defined as Δ^*, is

$$\Delta^* = \delta\left(F_{qq}G_{\alpha\alpha} + G_{qq}G_{\alpha\alpha} - G_{q\alpha}^2\right) > 0,$$

where G is assumed to be convex with respect to (q, α). We solve (20) in the case where $dp^r = 0$. Then, we have

$$\frac{dy^*}{d\left(c^w + c^d\right)} = -\frac{1}{\Delta^*}\left(1 - \alpha^*\right)\left[G_{\alpha\alpha}\left(F_{qq} + G_{qq}\right) - G_{q\alpha}^2\right] < 0, \tag{21}$$

$$\frac{dq^*}{d\left(c^w + c^d\right)} = -\frac{1}{\Delta^*}\delta G_{q\alpha} > 0, \quad \text{where } G_{q\alpha} < 0, \tag{22}$$

$$\frac{d\alpha^*}{d\left(c^w + c^d\right)} = \frac{1}{\Delta^*}\delta\left(F_{qq} + G_{qq}\right) > 0. \tag{23}$$

By (21) to (23), we can derive the following proposition:

Proposition 4 *Concerning the socially optimum, increases in the landfilling cost and the environmental damage lessen the production level of the consumption good y^* and raise the level of the product design q^* and the recycling ratio α^*.*

Rises in the landfilling cost and the environmental damage expand the social production cost. Then, the optimal level of the consumption good production shrinks. To lessen the total cost of landfilling and the environmental damage, the recycling ratio and the level of product design should be raised in order to promote the recycling activity.

Next, we investigate the effect of material price, p^r. Solving equation system (20) with $d\left(c^w + c^d\right) = 0$, we obtain

$$\frac{dy^*}{dp^r} = -\frac{1}{\Delta^*}\alpha\left[G_{\alpha\alpha}\left(F_{qq} + G_{qq}\right) - G_{\alpha q}^2\right] > 0, \tag{24}$$

$$\frac{dq^*}{dp^r} = -\frac{1}{\Delta^*}\delta G_{\alpha q} > 0, \tag{25}$$

$$\frac{d\alpha^*}{dp^r} = \frac{1}{\Delta^*}\delta\left(F_{qq} + G_{qq}\right) > 0. \tag{26}$$

Thus, we have

Proposition 5 *At the social optimum, a rise in the price of the recycled material enhances the consumption good production* y^**, the level of the product design* q^**, and the recycling ratio* α^**.*

Proposition 5 is also easy to understand intuitively. A rise in the price of recycled material promotes the recycling activity of the recycling firm, so that the recycling service supply and recycling ratio increase. An increase in the recycling service supply means an increase in the consumption good supply. An increase in the recycling ratio implies an increase in the marginal cost of recycling, so that the level of the product design should be raised up to mitigate the increase of the marginal cost of recycling.

4.2 The Effects of c^w and p^r on the Market Equilibrium Levels of the Consumption Good Supply, Product Design, and Recycling Ratio

Totally differentiation of (17), (18), and (19) yields the following equation system:

$$\begin{bmatrix} 2\delta & 0 & 0 \\ 0 & F_{qq} & 0 \\ 0 & G_{\alpha q} & G_{\alpha\alpha} \end{bmatrix} \begin{bmatrix} dy^m \\ dq^m \\ d\alpha^m \end{bmatrix} = \begin{bmatrix} -(1-\alpha)\,dc^w + \alpha p^r \\ 0 \\ dc^w + dp^r \end{bmatrix}. \tag{27}$$

The determinant of the square matrix in (27), which is denoted by Δ^m, is calculated as

$$\Delta^m = 2\delta F_{qq} G_{\alpha\alpha} > 0.$$

Assuming that $dp^r = 0$, we solve (26) and obtain

$$\frac{dy^m}{dc^w} = -\frac{1}{\Delta^m}(1-\alpha) F_{qq} G_{\alpha\alpha} < 0, \tag{28}$$

$$\frac{dq^m}{dc^w} = 0, \tag{29}$$

$$\frac{d\alpha^m}{dc^w} = \frac{2}{\Delta^m}\delta F_{qq} > 0. \tag{30}$$

Hence, we assert

Proposition 6 *In the market equilibrium, an increase in the landfilling cost of the waste decreases the amount of the consumption good y^m and increases the recycling ratio α^m, but does not affect the quality of product design q^m.*

Proposition 6 can be interpreted as follows: First of all, we should notice that the profit-maximizing firms try to set the quality of the product design to minimize the marginal cost. The marginal cost of the consumption good has nothing to do with the landfilling cost, so the landfilling cost does not affect the quality of the product design of the profit-maximizing producers. Naturally, the recycling firm raises the recycling ratio according to an increase in the landfilling cost. Moreover, this monopolist reduces the recycling service supply, which is the consumption good amount, to raise the price to cover the increasing cost of landfilling.

Finally, we solve (27) with $dc^w = 0$. Then, we have

$$\frac{dy^m}{dp^r} = \frac{1}{\Delta^m} F_{qq} G_{qq} > 0, \tag{31}$$

$$\frac{dq^m}{dp^r} = 0, \tag{32}$$

$$\frac{d\alpha^m}{dp^r} = \frac{2}{\Delta^m}\delta F_{qq} > 0 \tag{33}$$

These results establish

Proposition 7 *In the market equilibrium, a rise in the price of the recycled material expands the consumption good supply y^m, as well as the recycling ratio α^m, but does not influence the level of product design q^m.*

We omit the intuitive explanation of this proposition since it is similar to that of Proposition 6. Comparing the market equilibrium solution with the socially optimal solution, we easily see that the marginal landfilling cost and the price of the recycled materials have no effect on the level of product design in the decentralized economy. This is because the profit-maximizing producers adopt the design which minimizes production cost which does not relate to either the marginal landfilling cost or the price of the recycled materials. Accordingly, the market equilibrium level of product design becomes lower to the socially optimal level.

5 Conclusion

In our paper, we construct a model where the perfectly competitive producers of the consumption good choose the product design which affects the recycling cost and the monopolistic recycling producer determines the volume of the recycling service and recycling ratio of the used consumption good. Economic efficiency cannot be attained since there are three types of market failures which are the lower level of the product design, the smaller recycling ratio, and the over- or undersupply of the recycling service. Thus, we introduced three types of policy instruments, each of which corresponds to each type of the market failures and investigated how these market failures are solved by these policy instruments.

Then, we examined the comparative statics analysis on how changes in the recycling cost, the landfilling cost, and the price of the recycled materials affect the consumption good supply, the recycling ratio, and the level of the product design. By the analysis, we showed that increases in the landfilling cost and the environmental damage by the waste reduce the socially optimal amount of the consumption good, while an increase in the price of the recycled material expands it. We also showed that the increases of these exogenous variables necessarily raise the socially optimal levels of the recycling ratio and the product design. In the market equilibrium, the environmental damage by the waste has no effect on the equilibrium. The effects of the landfilling cost and the recycled material price are the same to those of the consumption good supply and the recycling ratio as in the case of the social optimum. However, these exogenous variables have no impact on the level of product design.

We can extend the present analysis to a various cases. For example, we consider the case where the consumption good producer is a monopolist and the case where there is a cost of the collection of the used up consumption good and thus only a part of the consumed amount of the consumption good is collected. More importantly, we should extend the model to a general equilibrium framework. These are our future topics.

Appendix

The first-order conditions for maximizing the social welfare are

$$\begin{aligned}
&\beta - \delta y^* - F\left(q^*\right) - G\left(q^*, \alpha^*\right) - \left(c^w + c^d\right)\left(1 - \alpha^*\right) + \alpha^* p^r = 0,\\
&-yF_q - yG_q = 0,\\
&-yG_\alpha + yc^w + yc^d + yp^r = 0.
\end{aligned}$$

The Jacobian matrix of (y, q, α) of these equations is

$$\begin{bmatrix} -\delta & -F_q - G_q & -G_\alpha + c^w + c^d + p^r \\ -F_q - G_q & -yF_{qq} - yG_{qq} & -yG_{\alpha q} \\ -G_\alpha + c^w + c^d + p^r & -yG_{\alpha q} & -G_{\alpha\alpha} \end{bmatrix}$$

$$= \begin{bmatrix} -\delta & 0 & 0 \\ 0 & -yF_{qq} - yG_{qq} & -yG_{\alpha q} \\ 0 & -yG_{\alpha q} & -G_{\alpha\alpha} \end{bmatrix}$$

Assume that $G_{\alpha\alpha} > 0$, $Gqq > 0$, $Fqq > 0$, and the convexity of G(q, α) w.r.t. (q, α).

Then, in this Jacobian matrix, all principal minors of orders of 1 and 3 are negative and all second-order principal minors are positive. Thus, the second-order optimal condition is satisfied.

References

Calcott K, Walls M (2000) Can downstream waste disposal policies encourage upstream design for environment? Am Econ Rev 90:233–237

Choe C, Fraser I (1999) An economic analysis of house hold waste management. J Environ Econ Manag 38:234–246

Einchner T (2005) Imperfect competition in the recycling industry. Metroeconomica 56:1–24

Einchner T, Pething R (2001) Product design and efficient management of recycling and waste treatment. J Environ Econ Manag 41:109–134

Fullerton D, Wu W (1998) Policies for green design. J Environ Econ Manag 36:131–148

Optimal Policy and the Threat of Secession

Moriki Hosoe

Abstract In this paper, we analyze the possibility of integration and secession between a majority region and a minority region. There is assumed to be a different preference for public policy between two regions, and a government is assumed to have to offer a constant level of public goods. We introduce two forms of governance, i.e., centralized integration and decentralized integration. Then, when small level of public good is necessary, the form of governance is shown to change from centralized integration to secession and to decentralized integration as the size of the minority region becomes large. And when large level of public good is necessary, the form of government is shown to change from centralized integration to decentralized integration as the size of the minority region becomes large.

Keywords Secession • Decentralization • Policy conflict

JEL-Code: D720, D740.

1 Introduction

In this paper, we investigate the mechanism of integration and secession among regions, focusing on the policy decision. In particular, we take a policy-preference approach in the situation where there are policy conflicts between two regions. Under the threat of secession, the optimal policy of a majority region is obtained, and the possibility of secession is shown to depend on the policy gap and population gap between two regions. By considering incentives of policy decisions in each region, we show the possibility of integration and secession and how the welfare of each region is realized through strategic determination of policy.

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So far regional economic analyses of integration and secession have been done from several perspectives. Several decades ago, Oates (1972) and Buchanan and Faith (1987) pointed out that regional integration is often subject to rent-seeking by a dominant region. From the point of public economics, Inman and Rubinfeld (1997) and Besley and Coate (2003) discussed about fiscal federalism. Recently Bolton and Roland (1997), Alesina et al. (2000), Alesina and Spolaore (2003), and Gradstein (2004) discussed about regionalism, integration, and the size of nations. In particular, Gradstein analyzed the efficiency of production of public goods under an election model of the representative in each region considering integration bargaining about secession term. Alesina and Spolaore (1997) showed a model of endogenous determination on the scale of nation and the number of nation on the basis of the preference of people for the allocation of public goods, and Alesina and Spolaore (2005), Spolaore (2008), and Deiwiks et al. (2012) obtained many fruitful results theoretically and empirically.

On the other hand, from the point of view of political economics or political science, we have several papers on political delegation between politicians and bureaucrats, represented by Epstein and O'Halloran (1998). They take a bliss point approach where the utility of each citizen depends on the distance between his most favorable policy and the actual policy and analyze the optimal degree of delegation of policy decision to bureaucrats from politicians. It is interesting to apply this policy-preference model to the integration and secession problem.

In this paper, we develop a two-region model with preference of public policy and policy adjustment cost. Integration gives the scale of economy to two regions. However, under integration, a minority region accepts a common policy of a majority region, which brings the conflict of policy between two regions. Here the public policy may be a religious policy or an official language policy. The ideal point of public policy in a region depends on the type of culture or ethnics. Therefore, introducing a common policy under integration between two regions will result to a conflict of policy. We discuss the decision on secession and integration between two regions, considering the policy conflict and the scale of economy. This is a selection of governance form between two regions.

2 Model

2.1 Two-Region Model

We assume that there are two regions A and B, with the population N_A and $N_B (N_A > N_B)$, respectively. Region A is called a majority region and region B is called a minority region. Each region is facing the decision of a single and common public policy. For example, a region may take a conservative or liberal stance about religious policy or education policy. For the simplicity, the stance X of the common public policy is located on the interval [0, 1]. Then the most preferable policies, that is, bliss points of the citizen, are assumed to be $\bar{X}_A, \bar{X}_B$, respectively. As the actual policy becomes remote from the bliss point, the utility of the citizen decreases. If the policies that their regions implement for a common policy issue are different, a political friction for the regional economy may occur. This is called a policy externality, which causes the utility loss in each region. We also assume that a constant level g of a public good is needed to manage an independent country and the level g is same, irrespective of the size of population, as in Alesina and Spolaore (1997). Of course the public good is assumed to be of non-rivalry.

2.2 Secession Between Two Regions

Let us consider the situation of secession between two regions. In region i, per capita income tax τ_i is levied to produce the level g of a public good, namely, a governmental service. Then $g = N_i \tau_i y_i$ $(i = A, B)$ is held. $y_i(1 - \tau_i)$ goes to private consumption. Let us denote the utilities U_A and U_B of the representative citizen for each region as follows, when each region implements a policy X_A, X_B:

$$U_A = -a\left(\bar{X}_A - X_A\right)^2 + y_A(1 - \tau_A) + g \tag{1}$$

$$U_B = -b\left(\bar{X}_B - X_B\right)^2 - s\left(X_B - X_A\right)^2 + y_B(1 - \tau_B) + g \tag{2}$$

Here the utility at the bliss point is normalized to be zero. We assume that when there is a policy conflict between the majority region and minority region, the minority region incurs a policy external cost s, while the majority region does not. Furthermore, we assume that the policy difference between two regions does not influence the utility of the majority region, but not that of the minority region, reflecting the difference of the population.

2.3 Policy Decision Under Secession

Now let us seek the equilibrium policy that each region makes under secession. The optimal policy for region B, given the policy X_A for region A, is shown by

$$X_B^O = \frac{b\bar{X}_B + sX_A}{b + s}$$

On the other hand, the optimal policy for region A is obviously the bliss point $\bar{X}_A$, whatever the policy for region B may be. Therefore, the optimal public policy in region B is shown as follows:

$$X_B^{O*} = \frac{b\bar{X}_B + s\bar{X}_A}{b + s} \tag{3}$$

As a result, the utility of region B is

$$\begin{aligned} U_B^{O*} &= -b\left(\bar{X}_B - \bar{X}_A\right)^2 + y_O - \frac{g}{N_B} + g \\ &= -\left(\bar{X}_B - \bar{X}_A\right)^2 \frac{bs}{(b+s)} + y_B - \frac{g}{N_B} + g \end{aligned} \tag{4}$$

Then the utility of region A is

$$U_A^{O*} = y_A - \frac{g}{N_A} + g \tag{5}$$

2.4 Policy Decision Under Centralized Integration

Let us consider the case that two regions integrate. Here there are two forms of integration. One is a centralized integration (CI). The other is a decentralized integration (DI). Under the centralized integration, the same level of public policy is implemented. Under the decentralized integration, there is a room to implement different levels of the public policy for two regions. In this subsection, we consider the case of centralized integration. In this case, the first effect of regional integration on the majority region is in general a policy effect. By integration, the majority region can dominate the policy in the minority region. But in this two-region model, the policy effect for the majority region is neglected. The second effect is a scale effect. By integration, the population increases and the tax burden decreases. So when region A and region B integrate and a policy X_A is implemented, the utilities of the representative citizen for regions A and B are

$$\begin{aligned} U_A^{CI} &= -a\left(\bar{X}_A - X_A\right)^2 + y_A(1-\tau_A) + g \\ U_B^{CI} &= -b\left(\bar{X}_B - X_A\right)^2 + y_B(1-\tau_B) + g, \end{aligned}$$

where $\tau_A y_A N_A + \tau_B y_B N_B = g$ is held. We have the three effects of integration for the minority region. One is the deletion of the policy conflicts, which is positive for the minority region. Second is the delegation of policy decision, which is negative. And the third is of course a scale effect.

The region A proposes a pair of public policy X_A and tax policy (τ_A, τ_B) to the region B. Region B can refuse the proposal if it makes region B worse than in the secession. Therefore, region A has to propose the policies so as to satisfy the following integration-acceptance condition:

$$-b\left(\bar{X}_B - X_A\right)^2 + y_B(1-\tau_B) + g \geq U_B^{O*} \tag{6}$$

Region A decides the policies to maximize the utility of the representative citizen for region A. By making this integration-acceptance condition equal and considering (4), we obtain

$$-b\left(\bar{X}_B - X_A\right)^2 - y_B(1-\tau_B) + g = -b\left(\bar{X}_B - \bar{X}_A\right)^2 \frac{bs}{(b+s)} + y_B - \frac{g}{N_B} + g$$

Then using the fiscal balance $\tau_B y_B N_B = g - \tau_A y_A N_A$, the integration-acceptance condition is

$$\frac{\tau_A y_A N_A}{N_B} = b\left(\bar{X}_B - X_A\right)^2 - \frac{sb}{(s+b)}\left(\bar{X}_B - \bar{X}_A\right)^2 \tag{7}$$

From this equality, the utility of representative citizen in region A is

$$-a\left(\bar{X}_A - X_A\right)^2 + y_A - b\left(\bar{X}_B - X_A\right)^2 \frac{N_B}{N_A} + \frac{sb}{(s+b)}\left(\bar{X}_B - \bar{X}_A\right)^2 \frac{N_B}{N_A} + g$$

Therefore using the first-order condition, we have the optimal public policy

$$X_A^{CI*} = \frac{aN_A\bar{X}_A + bN_B\bar{X}_B}{aN_A + bN_B} \tag{8}$$

This is obviously the efficient public policy.

Proposition 1. *Under centralized integration, the optimal public policy becomes efficient.*

By substituting the value of the optimal public policy into (7), we have the maximum utility of representative citizen in region A under integration as follows:

$$U_A^{CI*} = -a\left(\frac{bN_B\left(\bar{X}_B - \bar{X}_A\right)}{aN_A + bN_B}\right)^2 + y_A - b\left(\frac{aN_A\left(\bar{X}_B - \bar{X}_A\right)}{aN_A + bN_B}\right)^2 \frac{N_B}{N_A} + \frac{sb\left(\bar{X}_B - \bar{X}_A\right)^2}{s+b}\frac{N_B}{N_A} + g$$

Once we obtain the maximum utility in region A under integration, let us examine whether the region A has the motivation of integration or not. We compare the utility in region A under integration with the utility in region A under secession. If the following condition is held, the integration will occur:

$$U_A^{CI*} \geq U_A^{O*} \tag{9}$$

This condition is shown as follows:

$$\frac{g}{N_A} - \left(b\left(\frac{aN_A}{aN_A + bN_B}\right)^2 - \frac{sb}{s+b}\frac{N_B}{N_A}\right)\left(\bar{X}_B - \bar{X}_A\right)^2 \geq a\left(\frac{bN_B}{aN_A + bN_B}\right)^2\left(\bar{X}_B - \bar{X}_A\right)^2 \tag{10}$$

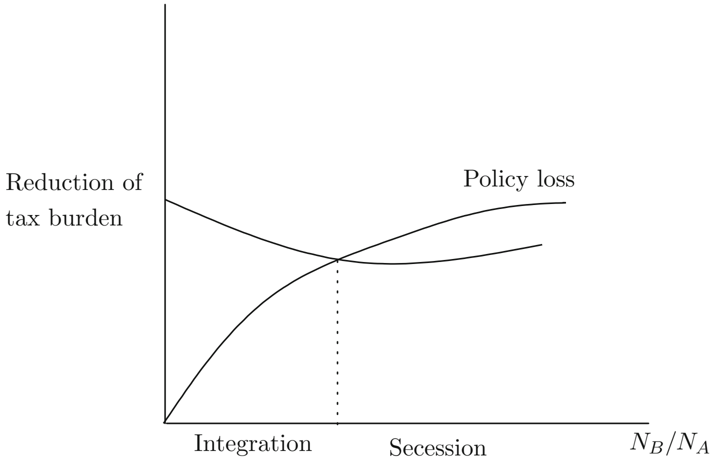
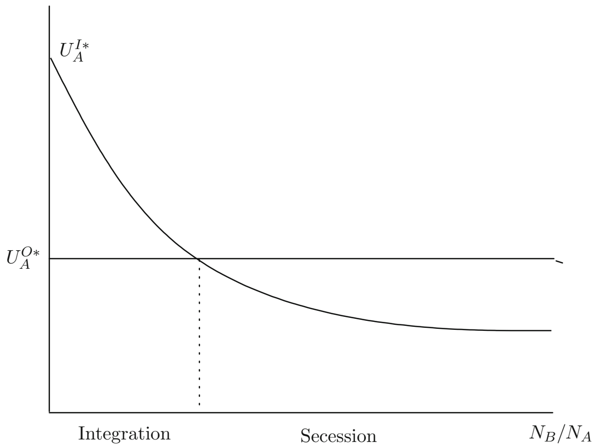


Fig. 1 Integration condition 1

Fig. 2 Integration condition 2



The right-hand side of this equality shows the merits of the decrease in per capita tax burden in the minority region due to the scale merit of integration. The left-hand side shows policy adjustment loss in the minority region due to integration. Therefore, the integration will be implemented if the former effect is larger than the latter effect. In Fig. 1, these effects are shown as the function of relative population in region *B*.

As the relative population in the minority region increases, the optimal public policy becomes close to the ideal point for the minority region. This implies the increase of policy adjustment cost for the majority region. Figure 2 shows this situation.

Proposition 2. *While centralized integration will occur in the case of small relative population in the minority region, secession will occur when the relative population becomes larger than the certain level.*

On the other hand, the per capita tax in the majority region is smaller than in the case of secession due to scale merits of integration. Since the effect of the scale merits on the per capita tax in the majority region is larger than the effect of the increase of the threat point in the bargaining with the minority region on the per capita tax in the majority region when the relative population in the minority region is small, the per capita tax decreases as the relative population in the minority region becomes large. Therefore, Proposition 2 is held, which is shown in Fig. 2.

Using (10), let us compare the utility on region A under integration with that under secession. From the comparison, we show the integration condition in Fig. 2. And since the decreasing effect of per capita tax in the majority region increases as the level of public goods increases, we obtain the following propositions:

Proposition 3. *As the level of public goods becomes high, the possibility of integration becomes high. In the case of low level of public goods, when the relative population of the majority region is low, the possibility of integration is high, and when the relative population of the majority region becomes high, the possibility of secession becomes high.*

Proposition 4. *Let us consider the case of middle size of public goods and high policy conflict cost. Then the possibility of integration is large, when the relative population of the majority region is small. However, as the relative population of the majority region increases, the possibility of secession increases, and as the relative population of the majority region increases more, the possibility of integration will occur again.*

We also obtain the following proposition regarding the ideal point gap between two regions:

Proposition 5. *As the ideal point gap of public policy between two regions becomes large, the possibility of secession becomes large.*

In this paper, the level of public goods is assumed to be given. This assumption implies that the level of public goods (civil engineering, armaments, etc.) in a country may depend on the natural environment or geopolitical situation. For example, it may be important that the country is vulnerable or not to natural calamity or invasion from a third strong country.

The integration-acceptance condition is rearranged as follows:

$$\frac{g}{N_A} \geq \left(a \left(\frac{bN_B}{aN_A + bN_B} \right)^2 + b \left(\frac{aN_A}{aN_A + bN_B} \right)^2 - \frac{sb}{s+b} \frac{N_B}{N_A} \right) \left(\bar{X}_B - \bar{X}_A \right)^2$$

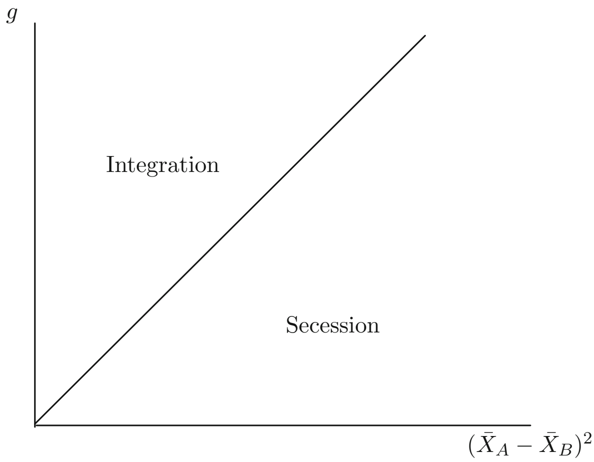


Fig. 3 Integration and secession

From this inequality, the possibility of secession increases as the ideal point gap of public policy between two regions becomes large and the cost of public goods becomes large, as shown in Fig. 3.

2.5 Tax Policy Under Centralized Integration

Let us examine the tax policy for each region under integration. The total amount of tax in *A* is shown as follows:

$$\tau_A y_A N_A = N_B \left(b \left(\frac{aN_A}{aN_A + bN_B} \right)^2 - \frac{sb}{s+b} \right) \left(\bar{X}_B - \bar{X}_A \right)^2 \tag{11}$$

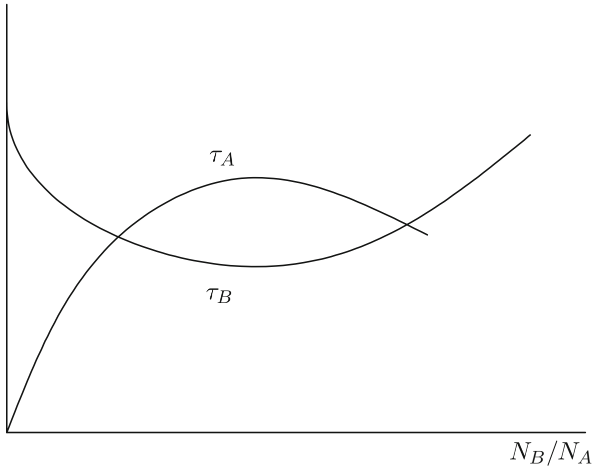
From this equation, the total amount of tax and the tax rate in the majority region become large as the ideal point gap becomes large. And when the cost of policy adjustment is small, the total amount of tax and the tax rate in the majority region increase with the relative population in the minority region. On the other hand, the total volume of tax and the tax rate in the majority region are convex functions of the level of the relative population in the minority region.

The total volume of tax in the minority region is written as

$$\tau_B y_B N_B = g - \tau_A y_A N_A$$

Therefore the tax amount becomes small as the ideal point gap of public policy becomes large. The total amount of tax in each region is written as a function of the relative population in the majority region. In Fig. 4, each tax rate is described as a function of the population rate of the majority region.

Fig. 4 Tax rate in high policy conflict cost case



3 Decentralized Integration Policy

3.1 Decentralized Integration Model

So far we assumed the public policy under integration is universal between two regions. However even under the integration, different contents of public policy may be allowed. We call an integration allowing different policies in different regions a decentralized integration (DI). For example, in a minority region, the native language may be allowed as an official language with a common language. Then, under a decentralized integration, the utility of the representative citizen in the majority region is shown as follows:

$$-a\left(\bar{X}_A - X_A\right)^2 - c(X_A - X_B)^2 - y_A(1 - \tau_A) + g,$$

where c is a policy conflict cost in the majority region. Then the optimal policies can be obtained by solving the following maximization problem:

$$\max_{X_A} -a\left(\bar{X}_A - X_A\right)^2 - c(X_A - X_B)^2 - y_A(1 - \tau_A) + g$$

$$s.t. \max_{X_B} -b\left(\bar{X}_B - X_B\right)^2 - s(X_B - X_A)^2 + y_B(1 - \tau_B) + g \geq U_B^{O*}$$

The optimal public policy of the minority region as an optimal response is shown as follows:

$$X_B = \frac{b\bar{X}_B + sX_A}{b + s}$$

From this, we can get the optimal public policy of the majority region:

$$X_A^{DI*} = \frac{aN_A\bar{X}_A + \frac{bs}{b+s}N_B\bar{X}_B + c\left(\frac{b}{b+s}\right)^2 N_A\bar{X}_B}{aN_A + \frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A} \tag{12}$$

Proposition 6. *Under the decentralized integration, the public policy of the majority region becomes close to the ideal point of public policy in the minority region.*

Let denote s satisfying the following equation as $s*$:

$$\frac{N_B}{N_A} - \frac{2c}{b+s} = 0$$

Then the effect of policy conflict s on the distance of public policies between the two regions is shown as follows:

Proposition 7. *In the case that $s < s*$, as s becomes large, the public policy of the majority region under secession becomes remote from the ideal point of the minority region. And in the case that $s > s*$, as s becomes large, the public policy of the majority region under secession becomes close to the ideal point of the minority region.*

This comes from that, as the policy conflict s becomes large, the minority region has to take the public policy of the majority region into consideration, which makes the policy conflict cost of the majority region small, while, as the policy conflict becomes large, the tax burden on the majority region as said above becomes large:

$$X_B^{DI*} - X_A^{DI*} = \frac{b}{b+s}\frac{aN_A}{aN_A + \frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A}\left(\bar{X}_B - \bar{X}_A\right) \tag{13}$$

Since this equation is held, we have the following proposition:

Proposition 8. *The regional distance between two public policies under decentralized integration becomes large with the distance of ideal points between two regions.*

We also see the following proposition with respect to the change of population rate of two regions:

Proposition 9. *The distance of public policies under decentralized integration becomes small as the population rate of the minority region becomes large. On the other hand, as the population rate of the minority region becomes large, the public policy of the majority region becomes remote from the bliss point.*

From the above discussion, the utility of the majority region is shown as follows:

$$U_A^{DI*} = -\left(a + \frac{bs}{b+s}\frac{N_B}{N_A}\right)\left(\frac{\left(\frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A\right)\left(\bar{X}_A - \bar{X}_B\right)}{aN_A + \frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A}\right)^2$$
$$-c\left(\frac{b}{b+s}\right)^2\left(\frac{aN_A\left(\bar{X}_A - \bar{X}_B\right)}{aN_A + \frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A}\right)^2$$
$$+\frac{N_B}{N_A}\frac{sb}{s+b}\left(\bar{X}_A - \bar{X}_B\right)^2 + y_A + g \tag{14}$$

Let us consider the effect of the increase of population rate of the minority region on the utility of the majority region under decentralized integration. As Proposition 9 shows, the increase of population rate of the minority region makes the distance of two public policies small, which increases the utility of the majority region, as the increase of population rate of the minority region decreases the policy conflict of the minority region and raises the utility of the majority region via the decrease of tax burden in the majority region. On the other hand, as the population rate of the minority region increases, the public policy of the majority region becomes remote from the ideal point, and the utility of the majority region decreases. Therefore, the effect of the population rate of the majority region on the utility of the majority region has two opposite directions. However, as the result of a simulation, the utility of the majority region is shown to increase in the case that the distance between values *a* and *b* of public policy in two regions is not so large.

Proposition 10. *Under decentralized integration, the utility of the majority region increases with the increase of population rate of the minority region when the distance between values a and b of public policy in each region is not so large.*

3.2 Tax Policy Under Decentralized Integration

Let us examine the tax policy under decentralized integration. From participation condition (12),

$$\tau_B y_B = \frac{g}{N_B} + \frac{sb}{s+b}\left(\left(\bar{X}_B - \bar{X}_A\right)^2 - \left(\bar{X}_B - X_A\right)^2\right)$$

is obtained. Since the optimal public policy X_A^{DI*} of the majority region under decentralized integration is a dividing point of two ideal points,the second term on the right-hand side of the above equation is positive. Therefore, per capita tax level under decentralized integration is larger than that under secession. This holds because the decision of public policy under secession is better for the majority region than that under decentralized integration. Then the tax level in the minority region under decentralized integration can be larger than that under secession. From the optimal public policy X_A^{DI*} in (14), the tax level of the minority region under decentralized integration is shown as

$$\tau_B y_B = \frac{g}{N_B} + \frac{sb}{s+b}\left(\bar{X}_B - \bar{X}_A\right)^2 \left(1 - \left(\frac{aN_A}{aN_A + \frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A}\right)^2\right) \tag{15}$$

Therefore, the tax level becomes negative, which means that the majority region can enjoy a subsidy:

$$\tau_A y_A = -\frac{N_B}{N_A}\frac{sb}{s+b}\left(\bar{X}_B - \bar{X}_A\right)^2 \left(1 - \left(\frac{aN_A}{aN_A + \frac{bs}{b+s}N_B + c\left(\frac{b}{b+s}\right)^2 N_A}\right)^2\right) < 0 \tag{16}$$

From these discussions, the following proposition is shown about the tax policy under decentralized integration:

Proposition 11. *Since, under decentralized integration, the minority region can enjoy a merit on the decision of public policy, the minority region has a room to bear an excess tax level, and the majority region can receive a merit of a subsidy.*

3.3 Selection Between Integration and Secession

Figure 5 shows the utility of the majority region as a function of the relative population in the minority region in the case of centralized integration and decentralized integration, respectively.

In this figure, centralized integration is selected when the population rate of the minority region is small, and decentralized integration is selected when the population rate of the minority region exceeds a level of population rate on the minority region.

Proposition 12. *As for the type selection of integration, the majority region wants centralized integration when the population rate of the minority region is small and wants decentralized integration when the population rate of the minority region exceeds a level of the population rate.*

Two utility levels of the majority region are written as horizontal lines in Fig. 5. The upper line corresponds to the utility with low level of pubic goods, and the

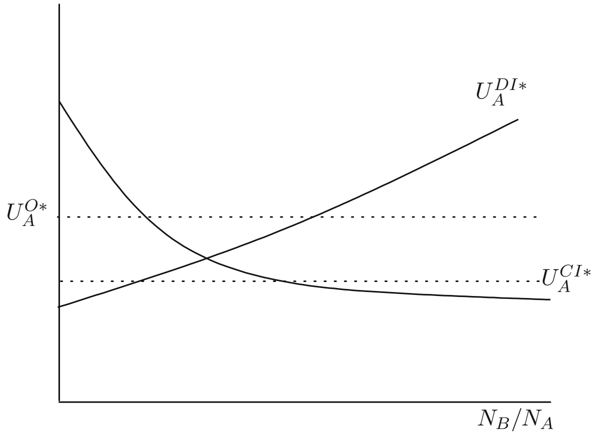


Fig. 5 Two types of integration

lower line corresponds to that with high level of public goods. In the case of low level of public goods, centralized integration is realized when the population rate of the minority region is small, secession is realized when the population rate of the minority region exceeds a certain level, and decentralized integration is realized when the population rate of the minority region increases much more. On the other hand, in the case of high public goods, centralized integration is realized when the population rate of the minority region is small, and decentralized integration is realized when the population rate of the minority region exceeds a certain level without the realization of secession. Therefore the following proposition is obtained:

Proposition 13. *As the population rate of the minority region increases, depending on the level of public goods, there are the process from centralized integration to decentralized integration and the process from centralized integration to decentralized integration via secession.*

4 Commitment Effect of Public Policy

4.1 Deviation from Centralized Public Policy

So far we have assumed that a single and common public policy is feasible under centralized integration. Here, we investigate about the feasibility of the common public policy under centralized integration. There may be a possibility of deviating from the optimal public policy by the minority region. Let us denote a public policy under centralized integration as X_A^{CI}. Then, if the minority region implements an original public policy X_B, the utility of the minority region is

$$-b\left(\bar{X}_B - X_B\right)^2 - s\left(X_B - X_A^{CI}\right)^2 + y_B(1-\tau_B) + g$$

Therefore the optimal public policy of the minority region in the case of deviation is obtained as follows:

$$X_B = \frac{b\bar{X}_B + sX_A^{CI}}{b+s}$$

Generally this public policy is not equal to X_A^{CI}. Let us seek a deviation-proof centralized public policy. We can get it by solving $X_A^{CI} = X_B$ in the above equation. Obviously the deviation-proof centralized public policy is shown to be $X_A^{CI} = \bar{X}^B$. This public policy is the ideal point for minority, which is trivial. It is impossible for the majority region to select the ideal point of the minority region as a common public policy under centralized integration.

If the majority region is almighty, any common public policy is feasible. This is a problem of power. Spolaore (2008) discusses about the power of army as a commitment device of centralized public policy. What is interesting is that the power of army itself is a kind of public goods. Of course, the power of army is not all. A democratic and mature society itself may be a commitment device in order to implement a common public policy. However, as shown in the previous section, the majority region has a possibility of voluntarily selecting a decentralized integration regime in the case of low level of public goods and relatively high population rate of the minority region. Therefore, in the case of high level of public goods and small population rate of the minority region, we need a commitment device in order to implement a single and common policy.

4.2 A Commitment of the Minority Region

Decentralized integration which was examined in the previous section is a game where the majority region is the first mover and the minority region is the second mover. So, in that case, it is impossible for the minority region to deviate from their public policy. In this subsection, we examine the case of the minority region as the first mover. This is a kind of commitment device. In reality, it may be possible that the minority region commits itself to implement the ideal point of public policy. So we think about the integration problem in the case that the minority region commits itself to implement the ideal point $\bar{X}_B$. Then the problem for the majority region is formalized as follows:

$$\text{Max} - a\left(\bar{X}_A - X_a\right)^2 - c\left(X_A - \bar{X}_B\right)^2 + y_A(1-\tau_A) + g$$
$$s.t. - s\left(X_A - \bar{X}_B\right)^2 + y_B(1-\tau_B) + g \geq U_B^{O*}$$

This constraint condition is necessary to be held as an equality. From this equality and the fiscal balance condition, the total amount of tax in the majority region is shown as follows:

$$\tau_A y_A = \frac{N_B}{N_A} s \left(\bar{X}_A - X_A\right)^2 - \frac{N_B}{N_A} \frac{sb}{s+b} \left(\bar{X}_B - X_A\right)^2$$

By substituting this equation for the utility of the majority region, our problem is rearranged:

$$\text{Max} - a\left(\bar{X}_A - X_a\right)^2 - c\left(X_A - \bar{X}_B\right)^2 + y_A - \left(\frac{N_B}{N_A} s \left(\bar{X}_A - X_A\right)^2 - \frac{N_B}{N_A} \frac{sb}{s+b} \left(\bar{X}_B - X_A\right)^2\right) + g$$

As the first-order condition, we obtain

$$X_A^{C*} = \frac{aN_A \bar{X}_A + (sN_B + cN_A)\bar{X}_B}{aN_A + sN_B + cN_A} \tag{17}$$

Then the total amount of tax in the majority region is

$$\tau_A y_A N_A = N_B s \left(\left(\frac{aN_A}{aN_A + sN_B + cN_A}\right)^2 - \frac{b}{s+b}\right)\left(\bar{X}_B - \bar{A}_X\right)^2 \tag{18}$$

This amount may be negative since the optimal public policy of the majority region is close to the ideal point of the minority region; as a result, the minority region commits itself to the ideal point. This means that the majority region can get a subsidy instead of a tax burden in exchange for giving the favorable policy to the minority region.

Lastly, under the commitment policy of the minority region, the maximum utility for the majority region is obtained by using (18) and (19):

$$U_A^{C*} = \left(-a\left(\frac{sN_B + cN_A}{aN_A + sN_B + cN_A}\right)^2 - \frac{cN_A + sN_B}{N_A}\left(\frac{aN_A}{aN_A + sN_B + cN_A}\right)^2\right. \tag{19}$$

$$\left. + \frac{N_B}{N_A}\frac{sb}{s+b}\right)\left(\bar{X}_B - \bar{X}_A\right)^2 + y_A + g \tag{20}$$

Figure 6 shows the utilities of the majority region in three cases, that is, centralized integration, decentralized integration, and the integration with the policy commitment by the minority region as a result of simulation. From this figure, sticking to the ideal point for the minority region brings the majority region a higher utility via giving a subsidy to the majority region.

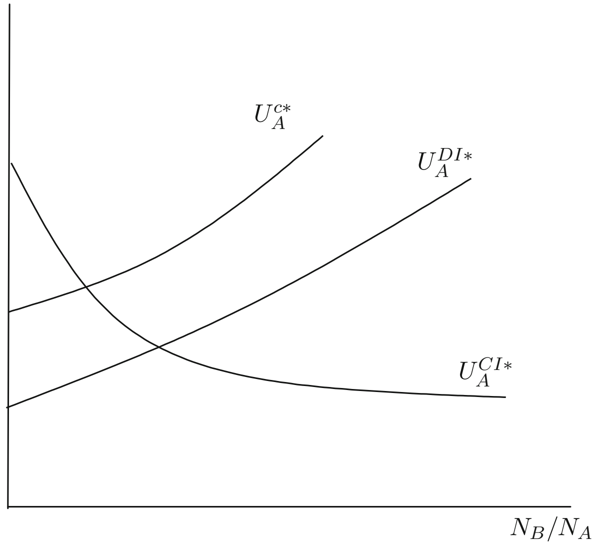


Fig. 6 Comparison of three integrations

5 Conclusion

In this paper, we analyzed the mechanism of integration and secession between two regions, using the policy-preference model with the cost of policy conflict. In particular, we showed that centralized integration will occur when the relative population in the minority region is small and secession will occur when the relative population in the minority region is larger than a certain level. And it was shown that integration will occur when the policy preference in two regions is similar and that secession will occur when the cost of policy adjustment is large. Lastly we investigated about the two types of integration, centralized integration and decentralized integration. Then, we showed that, depending on the cost level of public goods, the two dynamic processes of going from centralized integration to decentralized integration, via secession, and of going directly from centralized integration to decentralized integration will occur with the increase of the relative population in the minority region.

References

Alesina A, Spolaore E (1997) On the number and size of nations. Q J Econ 112(4):1027–1056
Alesina A, Spolaore E (2003) The size of nations. MIT Press, Cambridge
Alesina A, Spolaore E (2005) War, peace, and the size of countries. J Public Econ 89(7):1333–1354
Alesina A, Spolaore E, Wacziarg R (2000) Economic integration and political disintegration. Am Econ Rev 50(1):1276–1296

Besley T, Coate S (2003) Centralized versus decentralized provision of local public goods: a political economy approach. J Public Econ 87:2611–2637

Bolton P, Roland G (1997) The breakups of nations: a political economy analysis. Q J Econ 112(4):1057–1089

Buchanan JM, Faith RL (1987) Secession and the limits of taxation: toward a theory of internal exit. Am Econ Rev 77:1023–1031

Deiwiks C, Cederman L-E, Weber KS (2012) Inequality and conflict in federations. J Peace Res 49(2):289–304

Epstein D, O'Halloran S (1998) Delegating powers: a transaction cost politics approach to policy making. Cambridge University, Cambridge

Gradstein M (2004) Political bargaining in a federation: buchanan meets coase. Eur Econ Rev 48:983–999

Inman R, Rubinfeld D (1997) The political economy of federalism. In: Mueller DC (ed) Perspectives on public choice: a Handbook. Cambridge University Press, Cambridge, pp 73–105

Oates W (1972) Fiscal federalism. Harcourt Brace, New York

Spolaore E (2008) Civic conflict and secessions, Econ Gov 9(1):45–63. Springer, Berlin/Heidelberg

Economic Impact of CO_2 Emissions and Carbon Tax in Electric Vehicle Society in Toyohashi City in Japan

Yuzuru Miyata, Hiroyuki Shibusawa, and Tomoaki Fujii

Abstract In this paper, we explore the economic impact of promotion and realization of an electric vehicle society (EVS) in Toyohashi City in Japan. More concretely, this paper emphasizes a computable general equilibrium (CGE) modeling approach to evaluate the following issues: economic impacts of subsidies for the promotion of an EVS, economic impacts of carbon tax in order to reduce CO_2 emissions, a change of industrial structure toward an EVS, and modal shift toward an EVS.

Our simulation results demonstrate that after applying 5–25 % up subsidies to five industries including electric vehicle (EV) manufacturing, EV transport, solar power, cogeneration, and other transports, the total industrial output and city GDP increase. A large growth rate is found in industries where subsidies are introduced, but a growth can be seen in nonferrous metal industry without subsidies as well due to a repercussion effect. Moreover, it is interesting that decreasing proportions are found in coal and petroleum, mining, heat supply, and gasoline vehicle (GV) transport industries. However, an increase in the total CO_2 emission in Toyohashi City is interpreted as a rebound effect.

All the commodity prices decrease since subsidies are given to some industries. Hence, Toyohashi City's economy shows a direction where the demands for conventional vehicles and energy use are decreasing; conversely, the demands for EVs and renewable energy are increasing illustrating a different lifestyle from the current one.

Regarding CO_2 emissions, we introduced a carbon tax of 1000 yen/t-CO_2 for industries except the five industries mentioned above. As a result, the total CO_2 emission decreases, and the equivalent variation shows a positive value as compared with the base case. Thus, introducing 5–25 % subsidies and the carbon tax can really represent a realistic alternative society to EVS in Toyohashi City.

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Keywords CGE model • Electric vehicle society • Electric vehicle • Solar power • Toyohashi City • Japan

1 Introduction

Recently CO_2, which mostly forms the largest and growing fraction of greenhouse gas (GHG) emissions from transportation sector, presents a major challenge to global climate change mitigation efforts (Valerie 2010). Worldwide transportation ranks second following electric power as the largest source of emissions, contributing about 20 % of the total CO_2 in recent trends and future projections (IEA 2006).

In the case of Japan, similar to the world trend in transportation, Japan's transportation sector accounts for more than one-fifth of CO_2 emissions (MOE 2007). Especially, emissions generated from passenger and freight cars dominate 90 % of the sector (MOE 1997), while personal vehicles alone contribute 50 % of transportation CO_2 emissions in Japan (GGIOJ 2008). In addition, it is expected that CO_2 emissions will be increasing because of expanding personal vehicle fleets, particularly in the suburban areas like Toyohashi City in Japan (see Table 1).

Thus, it is imperative to introduce a new society which is based on environment-friendly transportation and renewable energy sources that does not negatively affect the environment. In this study, we aim to introduce an EVS hoping to shift the social demand to EVs and solar power to reduce CO_2 emissions. The study of EVS has been a considerably unexplored field in environmental economics despite the fact of potentially attractive and important theme though there have been little attempts for this topic in environmental economics.

For example, it would be significantly worth to examine the economic impact of both production and policy implementation for promotion and realization of an EVS. From this point, previously we applied a CGE model to investigate the economic impacts of EV production. However, promotion of an EVS does not depend on only EV production, but it is also required to acquaint citizens with new industries like EV transport in which small mileage is the main problem of EVs. It is expected that the spread of EVs would greatly reduce the CO_2 emissions;

Table 1 Increase in the number of personal vehicles and CO_2 emissions in Toyohashi City in Japan

Year	Increase in number of personal vehicles	Increase in total emissions mt/CO2
1990	189,413	58
1995	226,839	69
2000	251,433	70
2005	264,169	71

Source: Statistical data of Toyohashi City 2005 however, it only depends on internalizing electricity generated from renewable sources of energy like solar. Thus, it is also imperative to consider industries like solar power generation in constructing an EVS. Moreover, cogeneration is also important to shift the energy demand to renewable energies from the conventional one. Besides, beforehand, we did not consider subsidies, but subsidies may be required to overcome the initial price difference of the new industrial productions.

Taking these backgrounds into account, this article aims to apply a CGE model similar to author's previous study concerning this field (Khanam and Miyata 2012) to evaluate the possibility and economic impacts of an EVS taking Toyohashi City in Japan as a study region. More concretely, this paper emphasizes a CGE modeling approach to evaluate the following contents: entire impacts of subsidies for promotion of an EVS, CO_2 reduction by carbon tax, the possibility of price reduction, modal shift toward an EVS, and a change of industrial structure toward an EVS.

Toyohashi City is considered as a study region by three reasons: (1) The number of vehicles in the city is increasing rapidly; thus, CO_2 emissions show an increasing trend. (2) The city has many motor vehicle manufacturers that include the Toyota Motor Company, which is one of the world's largest automobile manufacturers by production. (3) This city has potential to generate solar energy.

The rest of the paper is organized as follows. In Sect. 2, the study area and method of the study are described. Section 3 explains the assumptions of the model and behaviors of the economic agents. In Sect. 4, simulation cases and simulation results are presented. Finally, Sect. 5 summarizes the conclusion.

2 Study Area

Toyohashi City (see Fig. 1) is located in the central part of Japan and falls in the prefectural boundary of Aichi. The Pacific Ocean is in the south of the city and the city opens onto Mikawa Bay in the west. Mikawa Port is a major port for worldwide trade, and its presence has made Toyohashi an important city as the biggest import and export hub in Japan for automobile in volume term. The area and population size of the city at founding in 1906 were 19.69 km^2 and 9900 persons (Toyohashi City 2011a). At present the size of the city is 261.35 km^2 with the population of 381,977 (density stands at 1462 persons per km^2) (Toyohashi City 2011b). Attractive economic activities, especially heavy industries and a large-scale seaport, are attracting migration to the city, and the data of Statistics Bureau in Japan provides that 10,749 persons migrated to Toyohashi in 2008, 9779 persons in 2009, and 8577 persons in 2010. As a result, the city is experiencing vertical expansion as the land area has remained unchanged since 1960 (Toyohashi City 2011b). There are many motor vehicle manufacturers in Toyohashi City, including Toyota Motor Company (one of the world's largest automobile manufacturers by production) and Mitsubishi and Suzuki Motors.

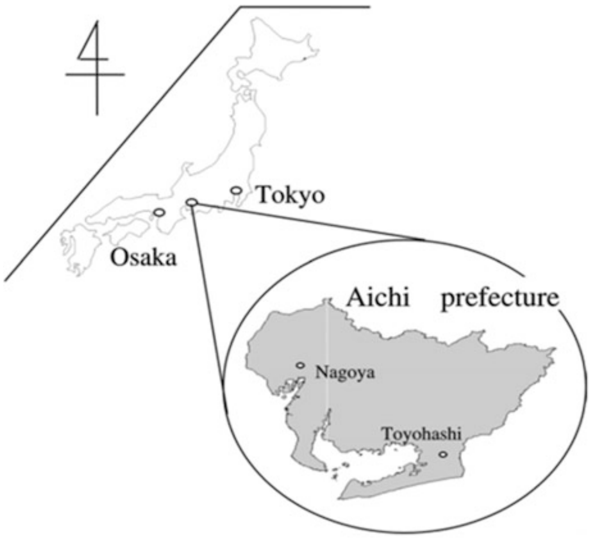

Fig. 1 Location of Toyohashi City in Japan

3 The Method

The underlying approach of this study is a CGE model. In this study we apply a CGE model similar to our previous study (2012) to investigate the economic impact of EVS in Toyohashi City in Japan. In constructing the model, the authors refer to the literature of Miyata and Shibusawa (2008), Shoven and Whalley (2007), and Shibusawa and Sugawara (2011).

3.1 Main Assumptions

The main assumptions made in our model are as follows:

1. Toyohashi City's economy in 2005 is examined. The economic agents are the households, the firms in 38 industries (see Table 2), the government, and the external sector.
2. Forty markets are considered. They are 38 commodity markets (see Table 2), one labor market, and one capital market. These are assumed to be perfectly competitive and in equilibrium in 2005.

Table 2 Classification of industries

Industries
1. Agriculture, forestry, and fishery
2. Mining
3. Food processing
4. Textile product
5. Pulp, paper, and wooden product
6. Chemical
7. Coal and petroleum product
8. Plastic product
9. Ceramic
10. Stone and clay product
11. Iron and steel product
12. Nonferrous metal
13. Metal product
14. General machinery
15. Electrical machinery
16. Information and communication electronic equipments
17. Electronic component
18. Gasoline vehicle (GV)
19. Electric vehicle (EV)
20. Aircraft
21. Other transportation equipments
22. Precision equipment
23. Other manufacturing
24. Construction
25. Electric power
26. Solar power
27. Gas supply
28. Heat supply
29. Cogeneration
30. Water supply and sanitary service
31. Commerce
32. Financial and insurance service
33. Real estate
34. GV transport
35. EV transport
36. Other transports
37. Telecommunication and broadcasting
38. Service

3.2 *Behavior of the Economic Agents*

3.2.1 Industries

In industries, intermediate goods, labor, and capital are inputted to produce goods. Industries have the Cobb-Douglas technology with respect to intermediate input and labor and capital inputs and Leontief technology for value-added inputs (see Fig. 2). Each firm is assumed to maximize the profit; however, cost minimization is considered due to the linear homogeneity of degree 1 in firm's technology. Cost minimization problem can now be written with the main assumptions made in our model as follows:

$$\min \sum_{i=1}^{38} p_i x_{ij} + \left(1 + tp_j\right)\left(wL_j + rK_j\right) (j = 1, \ldots, 38) \tag{1}$$

with respect to x_{ij}, L_j, and K_j
subject to

$$X_j = \min \left[\frac{1}{a_{10j}} f_j\left(L_j, K_j\right), \frac{x_{1j}}{a_{1j}}, \ldots, \frac{x'_{ij}}{a'_{ij}}, \ldots, \frac{x_{38j}}{a_{38j}} \right] \tag{2}$$

$$x'_{18j} = x_{18j}^{\alpha_{18j}} x_{19j}^{\alpha_{19j}} \left(\alpha_{18j} + \alpha_{19j} = 1\right) \tag{3}$$

$$x'_{25j} = x_{25j}^{\alpha_{25j}} x_{26j}^{\alpha_{26j}} \left(\alpha_{25j} + \alpha_{26j} = 1\right) \tag{4}$$

$$x'_{27j} = x_{27j}^{\alpha_{27j}} x_{28j}^{\alpha_{28j}} x_{29j}^{\alpha_{29j}} \left(\alpha_{27j} + \alpha_{28j} + \alpha_{29j} = 1\right) \tag{5}$$

$$x'_{34j} = x_{34j}^{\alpha_{34j}} x_{35j}^{\alpha_{35j}} x_{36j}^{\alpha_{36j}} \left(\alpha_{34j} + \alpha_{35j} + \alpha_{36j} = 1\right) \tag{6}$$

$$f_j\left(L_j, K_j\right) \equiv A_{1j} L_j^{a_j} K_j^{\left(1-a_j\right)} \tag{7}$$

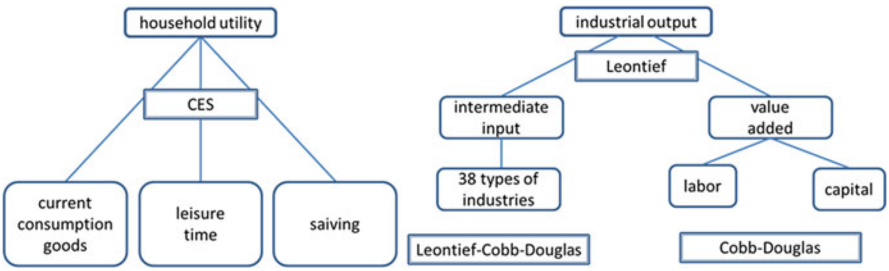

Fig. 2 Hierarchical structure of the CGE model

where:

p_i: price of commodity i
x_{ij}: intermediate input of industry i's product in industry j
tp_j: net indirect tax rate imposed on industry j' s product (indirect tax rate – subsidy rate)
w: wage rate
r: capital return rate
L_j: labor input in industry j
K_j: capital input in industry j
X_j: output in industry j
a_{0j}: value-added rate in industry j
a_{ij}: input coefficient
A_{ij} and α_{ij}: technological parameters in industry j

Conditional demands for intermediate goods, labor, and capital in the production process are as follows:

$$x_{ij} = a_{ij} X_j \tag{8}$$

$$x_{18j} = \frac{\alpha_{18j}}{p_{18}} \left[\frac{p_{18}}{\alpha_{18j}}\right]^{\alpha_{18j}} \left[\frac{p_{19}}{\alpha_{19j}}\right]^{\alpha_{19j}} a'_{18j} X_j \tag{9}$$

$$x_{19j} = \frac{\alpha_{19j}}{p_{19}} \left[\frac{p_{18}}{\alpha_{18j}}\right]^{\alpha_{18j}} \left[\frac{p_{19}}{\alpha_{19j}}\right]^{\alpha_{19j}} a'_{18j} X_j \tag{10}$$

$$x_{25j} = \frac{\alpha_{25j}}{p_{25}} \left[\frac{p_{25}}{\alpha_{25j}}\right]^{\alpha_{25j}} \left[\frac{p_{26}}{\alpha_{26j}}\right]^{\alpha_{26j}} a'_{25j} X_j \tag{11}$$

$$x_{26j} = \frac{\alpha_{26j}}{p_{26}} \left[\frac{p_{25}}{\alpha_{25j}}\right]^{\alpha_{25j}} \left[\frac{p_{26}}{\alpha_{26j}}\right]^{\alpha_{26j}} a'_{25j} X_j \tag{12}$$

$$x_{27j} = \frac{\alpha_{27j}}{p_{27}} \left[\frac{p_{27}}{\alpha_{27j}}\right]^{\alpha_{27j}} \left[\frac{p_{28}}{\alpha_{28j}}\right]^{\alpha_{28j}} \left[\frac{p_{29}}{\alpha_{29j}}\right]^{\alpha_{29j}} a'_{27j} X_j \tag{13}$$

$$x_{28j} = \frac{\alpha_{28j}}{p_{28}} \left[\frac{p_{27}}{\alpha_{27j}}\right]^{\alpha_{27j}} \left[\frac{p_{28}}{\alpha_{28j}}\right]^{\alpha_{28j}} \left[\frac{p_{29}}{\alpha_{29j}}\right]^{\alpha_{29j}} a'_{27j} X_j \tag{14}$$

$$x_{29j} = \frac{\alpha_{29j}}{p_{29}} \left[\frac{p_{27}}{\alpha_{27j}}\right]^{\alpha_{27j}} \left[\frac{p_{28}}{\alpha_{28j}}\right]^{\alpha_{28j}} \left[\frac{p_{29}}{\alpha_{29j}}\right]^{\alpha_{29j}} a'_{27j} X_j \tag{15}$$

$$x_{34j} = \frac{\alpha_{34j}}{p_{34}} \left[\frac{p_{34}}{\alpha_{34j}}\right]^{\alpha_{34j}} \left[\frac{p_{35}}{\alpha_{35j}}\right]^{\alpha_{35j}} \left[\frac{p_{36}}{\alpha_{36j}}\right]^{\alpha_{36j}} a'_{34j} X_j \tag{16}$$

$$x_{35j} = \frac{\alpha_{35j}}{p_{35}} \left[\frac{p_{34}}{\alpha_{34j}}\right]^{\alpha_{34j}} \left[\frac{p_{35}}{\alpha_{35j}}\right]^{\alpha_{35j}} \left[\frac{p_{36}}{\alpha_{36j}}\right]^{\alpha_{36j}} a'_{34j} X_j \tag{17}$$

$$x_{36j} = \frac{\alpha_{36j}}{p_{36}} \left[\frac{p_{34}}{\alpha_{34j}} \right]^{\alpha_{34j}} \left[\frac{p_{35}}{\alpha_{35j}} \right]^{\alpha_{35j}} \left[\frac{p_{36}}{\alpha_{36j}} \right]^{\alpha_{36j}} d'_{34j} X_j \tag{18}$$

$$LD_j = \left[\frac{(1 - \alpha_j)\, r}{\alpha_j w} \right]^{\alpha_j} \frac{a_{0j} X_j}{A_j} \tag{19}$$

$$KD = \left[\frac{a_j w}{(1 - a_j)\, r} \right]^{(1-a_j)} \frac{a_{0j} X_j}{A_j} \tag{20}$$

where

LD_j: conditional demand for labor in industry j
KD_j: conditional capital demand in industry j

Zero-profit condition is realized in the industries under the perfect competition:

$$\text{profit} = p_j X_j - \sum_{i=1}^{38} p_i x_{ij} - (1 + tp_j) \left[w \cdot LD_j + r \cdot KD_j \right] = 0 \tag{21}$$

3.2.2 Households

Households in Toyohashi City are assumed to be homogeneous with the fixed number of households. Thus one can consider that households share an aggregate single utility function. Households share a CES utility function of the current and future goods. Here, the current good is defined as a CES composite of current consumption goods and leisure time, while the future good is derived from saving.

Each household chooses a bundle of the current and future goods so as to maximize the utility function with a budget constraint. Then the current good is divided into a composite consumption good and a leisure time (labor supply).

Household income consists of full-wage income, which is obtained when households supply their full labor endowment, capital income after capital depreciation, current transfers from the government, labor income, property income, and other current transfers from the external sector. A part of household wage income and capital income is transferred to the external sector.

Household direct tax is imposed on the after-current-transfer income. Then households are assumed to allocate their after-direct-tax income on current and future goods. Here direct tax is supposed to include all current transfers from households to the government for simplicity.

To explain the household behavior, first, derivation of future good is described here. The future good implies the future consumption which derived from household saving; however, the saving formulates capital investment. Therefore capital good can be regarded as saving good. Investment is made by using produced goods, and let their portions in investment be denoted by b_i. Denoting the price of investment good by $p_I, p_I I = \sum_{i=1}^{38} p_i I_i$ is realized. Then the price of investment good is expressed as $p_I = \sum_{i=1}^{38} b_i p_i$. This can be regarded as the price of saving good ps.

Since the capital returns after direct tax by a unit of capital injection are expressed by $(1-ty)(1-k_o)(1-k_r)r\delta$, the expected return rate of the price of saving good ps, that is, the expected net return rate of household saving rs, is written as follows:

$$r_s = (1 - ty)(1 - k_o)(1 - k_r) r\delta / p_s \tag{22}$$

where:

t_y: direct tax rate imposed on households
k_o: rate of transfer of property income to the external sector
k_r: capital depreciation rate
δ: ratio of capital stock measured by physical commodity unit to that by capital service unit

It is assumed that the expected returns of saving finance the future consumption. Regarding the price of the current consumption good as the price of future good under the myopic expectation and denoting the household real saving by S, the following equation holds:

$$p \cdot H = (1 - ty)(1 - k_o)(1 - k_r) r\delta \cdot S \tag{23}$$

This yields $\left[p_s p / \left(1 - t_y\right)(1 - k_o)(1 - k_r) r\delta\right] H = p_s S$, and we set the price of future good p_H associated with the real saving S as

$$p_H = p_s p / (1 - ty)(1 - k_o)(1 - k_r) r\delta \tag{24}$$

Then $p_S\ S = p_H\ H$ is realized. Employing the abovementioned future good and its price, household utility maximization problem is now specified in the following. Regarding the current good, it will be described in a later part:

$$\max_{G,H}\ u(G,H) \equiv \left\{\alpha^{1/v_1} G^{(v_1-1)/v_1} + (1-\alpha)^{1/v_1} H^{(v_1-1)/v_1}\right\}^{v_1/(v_1-1)} \tag{25}$$

$$\begin{aligned}&\text{subject to}\\ &p_G \cdot G + p_H \cdot H = (1 - ty) FI - TrHO\end{aligned} \tag{26}$$

$$FI \equiv (1 - l_o) w \cdot E + LI + (1 - k_o)(1 - k_r) r \cdot KS + KI + TrGH + TrOH \tag{27}$$

where:

α: share parameter.
v_1: elasticity of substitution between the current good and future good.
G: household present consumption.

H: household future consumption.
p_G: price of current good.
p_H: price of future good.
FI: household full income.
$TrHO$: current transfers from households to the external sector.
l_o: rate of labor income transferred to the external sector.
E: household initial labor endowment, which is set up as the double of real working time. This is based on the actual working time and leisure time in Toyohashi City.
LI: labor income transferred from the external sector to households (exogenous variable).
KS: initial capital stock endowed by households.
KI: property income transferred from the external sector to households (exogenous variable).
$TrGH$: current transfers from the government to households.
$TrOH$: current transfers from the external sector to households.

Solving this utility maximization problem, demand functions for current and future goods are obtained yielding a household saving function:

$$G = \frac{\alpha\left[(1-ty)\,FI - TrHO\right]}{p_G^{v_1}\cdot\Delta} \tag{28}$$

$$H = \frac{(1-\alpha)\left[(1-ty)\,FI - TrHO\right]}{p_H^{v_1}\cdot\Delta} \tag{29}$$

$$S = p_H H/p_s \tag{30}$$

$$\Delta \equiv \alpha p_G^{1-v_1} + (1-\alpha)\,p_H^{1-v_1} \tag{31}$$

Then we describe the derivation of demands for composite consumption and leisure time from the current good G. The current good G is a composite of consumption and leisure time, and G is obtained from the following optimization problem:

$$\max_{C,F}\ G \equiv \left\{\beta^{1/v_2}C^{(v_2-1)/v_2} + (1-\beta)^{1/v_2}F^{(v_2-1)/v_2}\right\}^{v_2/(v_2-1)} \tag{32}$$

$$\begin{gathered}\textit{subject to}\\ \mathrm{p}\times\mathrm{C} + (1-\mathrm{ty})\,(1-\mathrm{l_o})\,w\times\mathrm{F} = (1-\mathrm{ty})\,\mathrm{FI} - \mathrm{TrHO} - \mathrm{SH}\end{gathered} \tag{33}$$

where:

β: share parameter
v_2: elasticity of substitution between composite consumption and leisure time
C: composite consumption
F: leisure time

p: price of composite consumption good
SH: household nominal saving ($= P_S \bullet S$)

Solving this utility maximization problem, demand functions for composite consumption, leisure time, and labor supply are obtained:

$$C = \frac{\beta\,[(1-ty)\,FI - TrHO - SH]}{p^{v_2} \cdot \Omega} \tag{34}$$

$$F = \frac{(1-\beta)\,[(1-ty)\,FI - TrHO - SH]}{[(1-ty)\,(1-l_o)\,w]^{v_2} \cdot \Omega} \tag{35}$$

$$LS = E - F \tag{36}$$

$$\Omega = \beta p^{(1-v_2)} + (1-\beta)\,[(1-ty)\,(1-l_o)\,w]^{(1-v_2)} \tag{37}$$

where LS is the household labor supply.

Substituting composite consumption (34) and leisure time (35) into (32), the price index of the current good is derived as follows:

$$p_G = \left\{\beta\, p^{1-v_2} + (1-\beta)\,[(1-ty)\,(1-l_o)\,w]^{1-v_2}\right\}^{1/(v_2-1)} \tag{38}$$

Moreover, composite consumption good is disaggregated into produced goods through the maximization of a Cobb-Douglas sub-sub-utility function given the household income and leisure time:

$$\max\ C \equiv \prod_{i=1}^{38} C_i^{\gamma_i} \left(\sum_{i=1}^{38} \gamma_i = 1\right) \tag{39}$$

subject to

$$\sum_{i=1}^{38} p_i \cdot C_i = (1-ty)\,Y - TrHO - SH \tag{40}$$

where:

C_i: household consumption good produced by industry i
p_i: price of good i
Y: household income ($= (1-l_o)w \bullet LS + LI + (1-k_o)(1-k_r)r \bullet KS + KI + TrGH + TrOH$)

From this optimization problem, consumption good i is derived:

$$C_i = \frac{\gamma_i}{p_i}\,[(1-ty)\,Y - TrHO - SH]\,(i = 1, \cdots, 38) \tag{41}$$

The price of composite consumption is calculated as follows:

$$p = \prod_{i=1}^{38} \left[\frac{p_i}{\gamma_i} \right]^{\gamma_i} \tag{42}$$

3.2.3 The Government

The government sector in this study consists of the national and local governmental activities in Toyohashi City. Thus, the concept of the government corresponds to the definition of SNA framework. The government obtains its income from direct and net indirect taxes of Toyohashi City and current transfers from the external sector, and then it spends the income on government consumption, current transfers to households, and current transfers to the external sector. The difference between income and expenditures is saved. Nominal consumption expenditures on commodities/services are assumed to be proportional to the government revenue with constant sectorial share. These are denoted by the following balance of payment:

$$\sum_{i=1}^{38} p_i \cdot CG_i + TrGH + TrGO + SG = ty \cdot Y + \sum_{i=1}^{38} tp_i \left(w \cdot LD_i + r \cdot KD_i \right) + TrOG \tag{43}$$

where:

CG_i: government consumption expenditures on commodity i
$TrGH$: current transfers to households
$TrGO$: current transfers to the external sector
SG: government savings
$TrOG$: current transfers from the external sector

3.2.4 The External Sector

The external sector gains its income from Toyohashi City's imports, current transfers from the government, labor income transfers, and property income transfers. Then, it spends the income on Toyohashi City's exports, current transfers to households, and the government, labor, and property income transfers. These are also expressed by the following balance of payment:

$$\sum_{i=1}^{38} p_i \cdot EX_i + TrOH + TrOG + KI + LI + SO = \sum_{i=1}^{38} p_i \cdot EM_i + TrHO + TrGO + KIO + LIO \tag{44}$$

where:

EX_i: export of commodity i
EM_i: import of commodity i
SO: savings of the external sector (= city current surplus)
LIO: labor income transfers to the external sector ($= l_o \bullet w \bullet LS$)
KIO: property income transfers to the external sector ($= k_0 \bullet r \bullet KS$)

3.2.5 Balance of Investment and Savings

Household, government, the external sector's savings, and the total capital depreciation determine the total investment:

$$\sum_{i=1}^{38} p_i \cdot I_i = SH + SG + SO + \sum_{i=1}^{38} DR_i \tag{45}$$

where:

I_i: demand for commodity i by investment
DR_i: capital depreciation in industry i

3.2.6 Commodity Prices

From the zero-profit condition in the industries, commodity prices can be determined by the following equation:

$$p_j X_j = \sum_{i=1}^{38} p_i x_{ij} + \left(1 + tp_j\right)\left[w \cdot LD_j + r \cdot KD_j\right] \tag{46}$$

Given the wage and capital return rates, we can calculate the commodity prices as follows:

$$P = \left(I - A'\right)^{-1}\left[\left(1 + tp_j\right)\left(w.ld_j + r \cdot kd_j\right)\right] \tag{47}$$

where:

P: vector of commodity prices
A': transposed matrix of industries' input coefficients
[•]: column vector whose elements in the brackets are $ld_j \equiv LD_j/X_j$and $kd_j \equiv KD_j/X_j$

3.2.7 Derivation of Equilibrium

The equilibrium condition in the model can be summarized as follows:

3.3 Commodity Market

$$\begin{bmatrix} X_1 \\ \vdots \\ X_{38} \end{bmatrix} = \begin{bmatrix} a_{11} \cdots a_{138} \\ \vdots \quad \ddots \quad \vdots \\ a_{381} \cdots a_{3838} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_{38} \end{bmatrix} + \begin{bmatrix} C_1 \\ \vdots \\ C_{38} \end{bmatrix} + \begin{bmatrix} CG_1 \\ \vdots \\ CG_{38} \end{bmatrix} + \begin{bmatrix} I_1 \\ \vdots \\ I_{38} \end{bmatrix} + \begin{bmatrix} EX_1 \\ \vdots \\ EX_{38} \end{bmatrix} - \begin{bmatrix} EM_1 \\ \vdots \\ EM_{38} \end{bmatrix} \tag{48}$$

3.4 Labor Market

$$LS = \sum_{j=1}^{38} LD_j \tag{49}$$

3.5 Capital Market

$$KS = \sum_{j=1}^{38} KD_j \tag{50}$$

4 Simulation Cases and Simulation Results

4.1 Simulation Cases

First of all, base case is defined as a case which assumes the existence of electric vehicle production, solar power generation, cogeneration, and EV transport in Toyohashi City. The penetration rates of these activities are as follows:

1. EV production: 15 % of the total vehicle production
2. Solar power generation: 10 % of the electric power generation
3. Cogeneration: 10 % of gas and heat supply
4. EV transport: 15 % of road transport

Table 3 Simulation cases

	Net indirect tax rate (%)
Case 1	95
Case 2	90
Case 3	85
Case 4	80
Case 5	75

	Carbon tax	Net indirect tax rate
Case 1	¥ 1.000/t-CO_2	No subsidy
Case 2	¥ 1.000/t-CO_2	95 %
Case 3	¥ 1.000/t-CO_2	90 %
Case 4	¥ 1.000/t-CO_2	85 %
Case 5	¥ 1.000/t-CO_2	80 %
Case 6	¥ 1.000/t-CO_2	75 %

Simulation cases are set up as in Table 3 to analyze economic impacts of additional subsidies (net indirect tax rate) and the introduction of carbon tax.

4.2 Simulation Results

In this section, we explain the simulation results by referring to some important economic variables as mentioned below.

4.2.1 Industrial Outputs

The change rates in industrial outputs in cases relative to base case are shown in Figs. 3 and 4. In the cases where only the subsidies are introduced, industries with large output are found in service, commerce, GV manufacturing, and construction sectors. Large industrial outputs can be seen in automobile-related industries in Toyohashi City because Toyota Motor Company (one of the world's largest automobile manufacturers by production) is located in the neighboring area. The shares of outputs in the new industries are small. Large increments are found in industries including solar power generation (0.35–1.79 % in Case 1–Case 5), cogeneration (0.21–1.07 %), EV transport (0.20–1.00 %), other transports (0.18–0.91 %), nonferrous metal (0.14–0.68 %), and EV manufacturing (0.11–0.58 %).

Growth rates in industrial outputs depend on the subsidy policy. The reason behind large increment in nonferrous metal is the high demand for producing batteries used in EV, since nonferrous metal is necessary to produce batteries used in EV. Thus, the rise in nonferrous metal production is indirectly caused by the subsidy policy on EV production. Decreasing tendency is found in some industries, for instance, coal and petroleum product (−0.03 to −0.16 %), mining

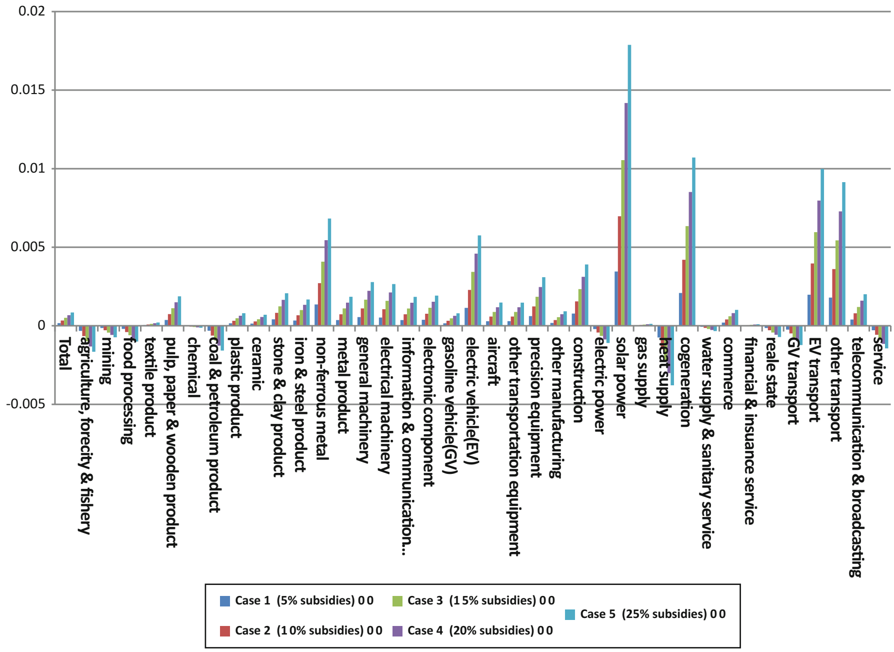

Fig. 3 Change rates in industrial outputs (Case 1 to Case 5)

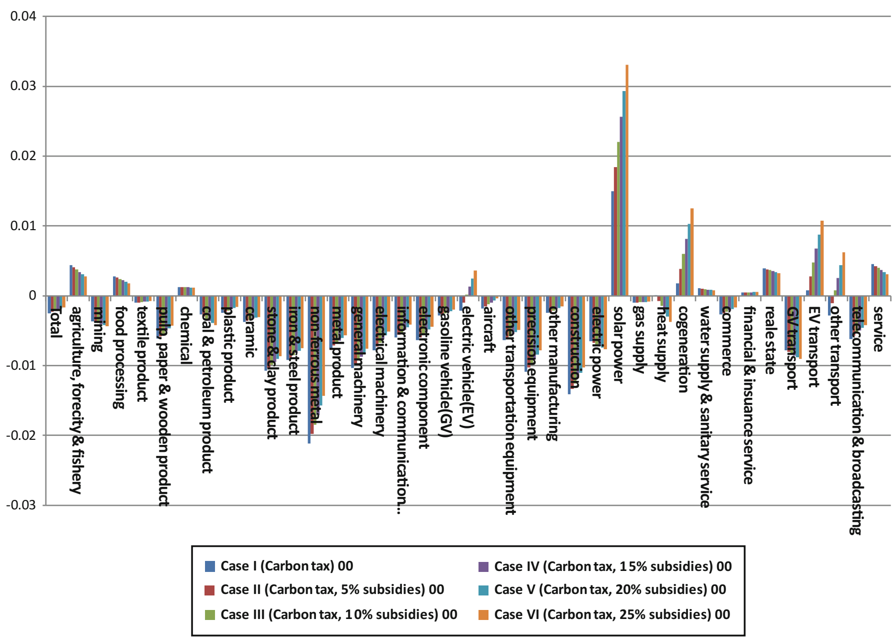

Fig. 4 Change rates in industrial outputs (Case 1 to Case 6)

(−0.01 to −0.07 %), heat supply (−0.07 to −0.38 %), and the GV transport (−0.02 to −0.12 %). And these results are considered as a positive factor for realization of an environment-friendly city. The reason behind the large decrease in coal and petroleum product industry is due to an increase in share of EV, solar power, and cogeneration. Moreover, falling trend in mining relates to a reduction in coal and petroleum production. And a decline in the heat supply industry is found because of growing share of cogeneration. The total industrial output increases ranging from 0.02 to 0.08 % across different cases.

Figure 4 shows the results where the carbon tax is introduced. In Case 1 that does not take additional subsidies into account, the outputs in industries of EV manufacturing, EV transportation, and other transportations decrease even if the carbon tax is not imposed. However, some industrial outputs are increased by introducing additional subsidies. Large increase rates are found in industries including solar power generation (1.50–3.31 % in Case 1 to Case 6), EV transport (0.08–1.08 %), other transports (−0.28–0.62 %), and EV manufacturing (−0.21–0.36 %). The total industrial output decreases by −0.16 % (5.344 billion yen) in Case 6.

4.2.2 City GDP

Figures 5 and 6 show the change rates in city GDP in cases relative to base case. Net indirect taxes are reduced by the subsidy policy. Industrial GDP with high decrease rates is found in solar power generation (−0.43 to −2.24 % in Case 1–Case 5), EV manufacturing (−0.23 to −1.14 %), cogeneration (−0.12 to −0.62 %), EV transport (−0.22 to −1.10 %), other transports (−0.25 to −1.27 %), and heat supply (−0.07 to −0.38 %) where additional subsidies are introduced. Conversely, an increasing trend is found in industries including nonferrous metal (0.14 to 0.68 %) and construction

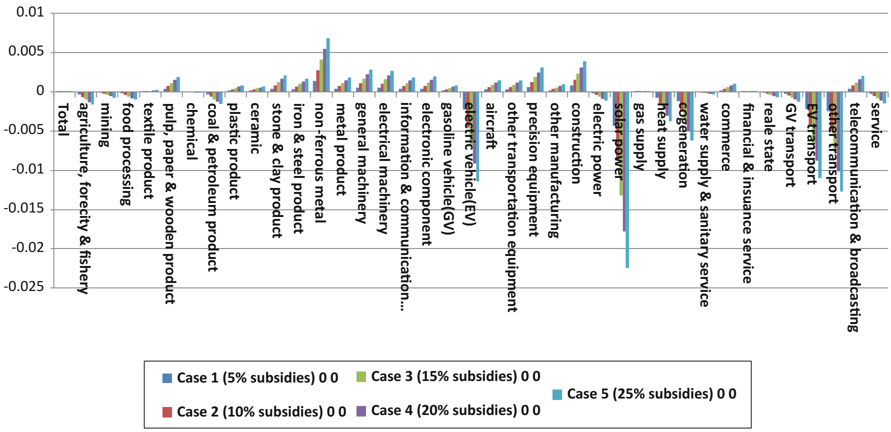

Fig. 5 Change rates in city GDP (Case 1 to Case 5)

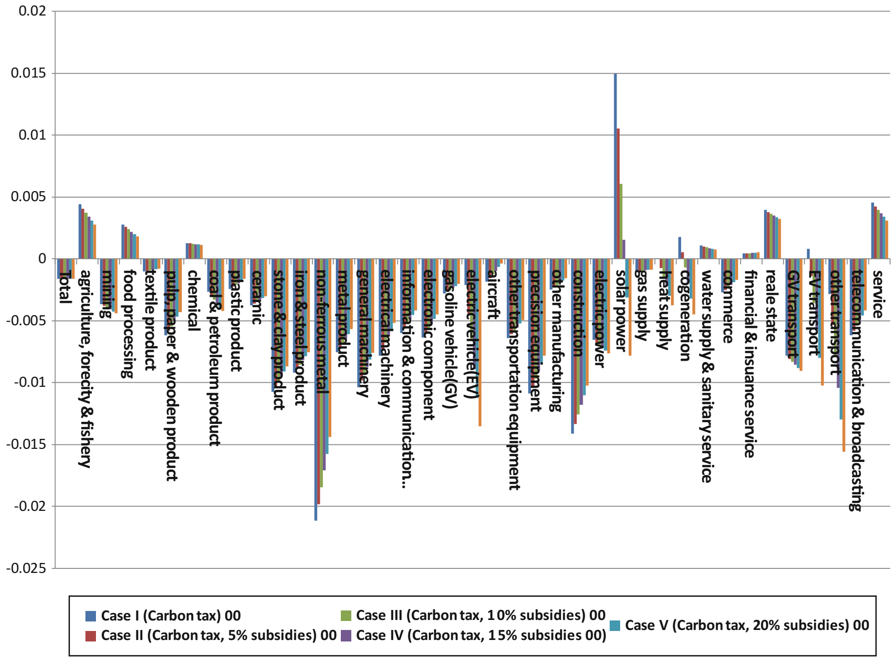

Fig. 6 Change rates in city GDP (Case 1 to Case 6)

(0.08 to 0.39 %). Moreover from Case 1 to Case 6, GDP with high decrease rates is found in solar power (1.49 to −0.784 %), other transports (−0.28 to 1.56 %), EV manufacturing (−0.21 to −1.35 %), and EV transport (−0.08 to −1.02 %). Large increase rates are found in industries including real estate (0.39–0.32 %), service (0.45–0.31 %), and so on.

4.2.3 Commodity Prices

The commodity prices are determined by the prices of the production factors. Since the numerare is set up as labor in this model, the capital return rate is adjusted to equilibrate the capital market. Because the benchmark data set is not equilibrated in this model, all prices do not become unity in base case. The capital return rate is determined so as to equilibrate the total capital supply and demand. Commodity prices decrease with additional subsidies. That is, the prices of solar power generation (−0.38 to −1.92 %), other transports (−0.27 to −1.36 %), EV manufacturing (−0.11 to −0.53 %), EV transport (−0.25 to −1.25 %), and cogeneration (−0.23 to −1.15 %) largely decrease in Figs. 7 and 8. The price of GV transport decreases by −0.03 to −0.15 % due to a fall in the price of other transports. The decreasing trends in all commodity prices are found due to introduction of subsidies in some industries, leading to a fall in the consumer price index. In the cases with

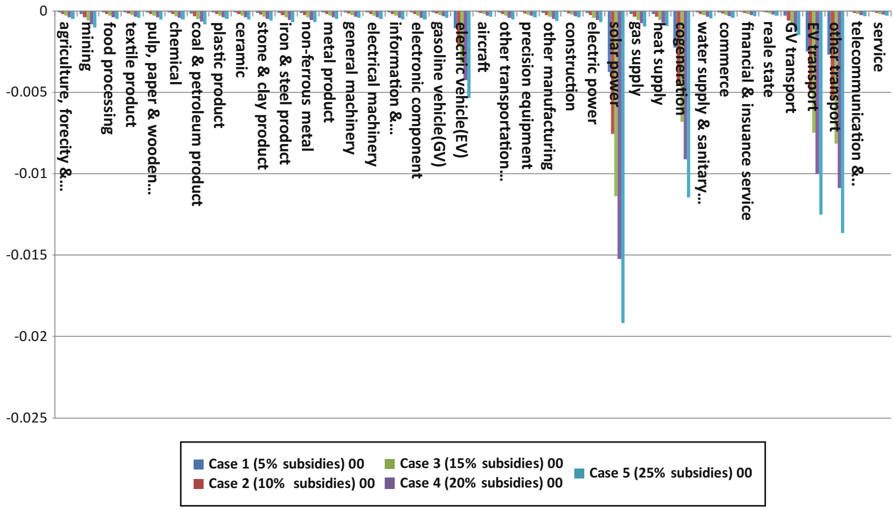

Fig. 7 Change rates in commodity prices (Case 1 to Case 5)

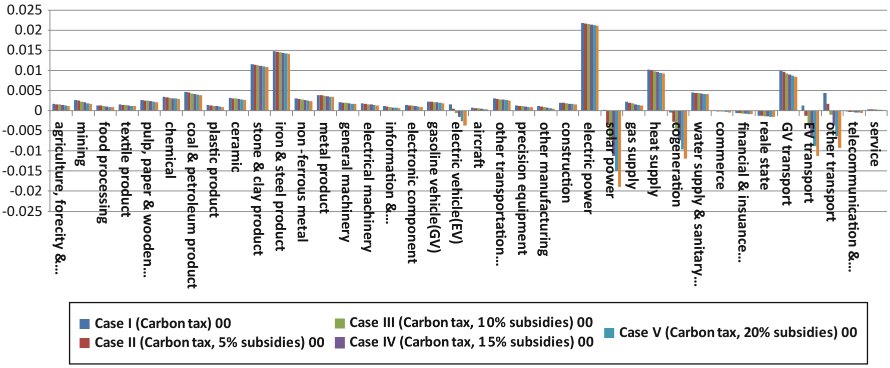

Fig. 8 Change rates in commodity prices (Case 1 to Case 6)

carbon tax, the commodity prices in the industries emitting large amount of CO_2 increase. For instance, it is observed that 2.18–2.11 % in electricity (Case 1 to Case 6), iron and steel product (1.48–1.42 %), and stone and clay product (1.15–1.09 %).

Looking at the changes in CO_2 emissions by sector in Figs. 9 and 10, it can be seen that changes in CO_2 emissions by industries correspond to the expense of the public subsidies. As a result, decreasing trends in CO_2 emissions are found in heat supply (−0.07 to −0.38 % in Case 1–Case 5), coal and petroleum product (−0.03 to −0.16 %), and GV transport (−0.02 to −0.12 %). Decreases in CO_2 emissions in these industries is attributed to increases in industrial outputs including cogeneration, solar power, and EV transport. However, large increase

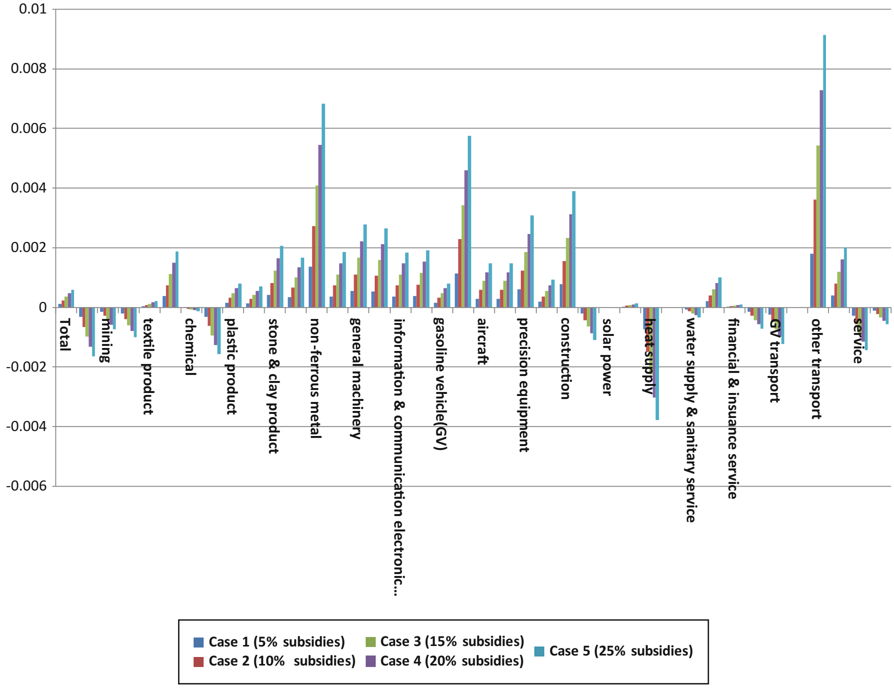

Fig. 9 Change rates in CO_2 emissions (Case 1 to Case 5)

rates in CO_2 emissions are seen in other transports (0.18–0.91 %), nonferrous metal (0.14–0.68 %), EV manufacturing (0.11–0.58 %), and construction (0.08–0.39 %). These industries correspond to the industries where industrial outputs increase. The total CO_2 emission eventually increases by 2323 t-CO_2 (0.06 %) in Case 5. By popularization of EV, CO_2 emissions by heat supply and coal and petroleum product were reduced, but the industrial productions which emit more CO_2 such as other transports and nonferrous metal increase. Thus the total CO_2 emission is increased.

This can be interpreted as a rebound effect. The rebound effect implies a secondary effect caused by improvement of energy and/or production efficiency. The rebound effect is a phenomenon to cancel a part of or all of CO_2 reduction expected by improvement of energy and/or production efficiency.

CO_2 emissions decrease in many industries after imposition of carbon tax in Case 1 to Case 6. Industries reducing much CO_2 emissions include, for example, nonferrous metals (−2.12 to 1.44 % in Case 1 to Case 6), construction (−1.41 to 1.03 %), and stone and clay (−1.07 to 0.87 %). The total CO_2 emission is decreased by 23,041 t-CO_2 (−0.58 %) in Case 6. This is attributed to the fact of decreases in industrial outputs with large CO_2 emissions.

Moreover, CO_2 emissions from EV manufacturing and other transports decrease in Case 1 where additional subsidies are not introduced, but CO_2 emissions from those industries increase as the subsidy rate rises. Industries with a large increment

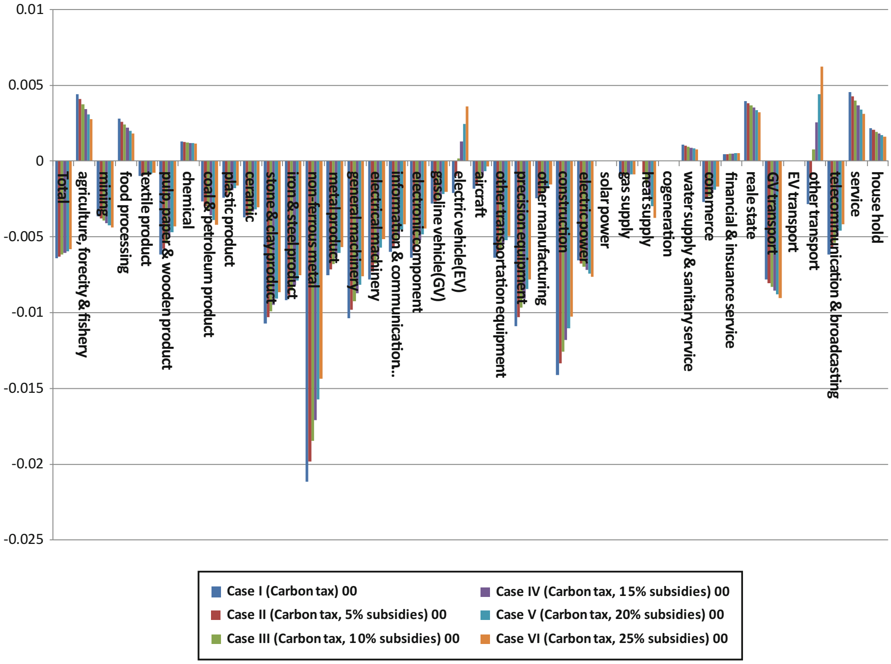

Fig. 10 Change rates in CO_2 emissions (Case 1 to Case 6)

in CO_2 emissions include other transports (−0.28 to 0.62 %), EV manufacturing (−0.21 to 0.36 %), and services (0.45–0.31 %). It is observed that CO_2 emissions from coal and petroleum decrease as the subsidy rate increases.

Comparing the total CO_2 emissions in Cases 1 and 6 with that in base case, decreases of −25,348 t-CO_2 (−0.64 %) and −23,041 t-CO_2 (−0.58 %) are observed, respectively.

4.2.4 Other Variables

Looking at Figs. 11 and 12 to see changes in other variables comparing with those in base case, large increase rates are found in EV purchase by households (0.08–0.42 % in Cases 1–5), the total investment (0.07–0.36 %), and labor supply (0.02–0.11 %). Many variables decrease in other variables. A decrease in net indirect tax revenue in the government sector results in reduction in government income, government consumption expenditure, and government saving. This decrease also causes a fall in the current transfers from the government to households resulting in a decline in household income.

On the other hand, in Cases 1 to 6, government income, government consumption expenditure, and government saving show increases since the carbon tax is

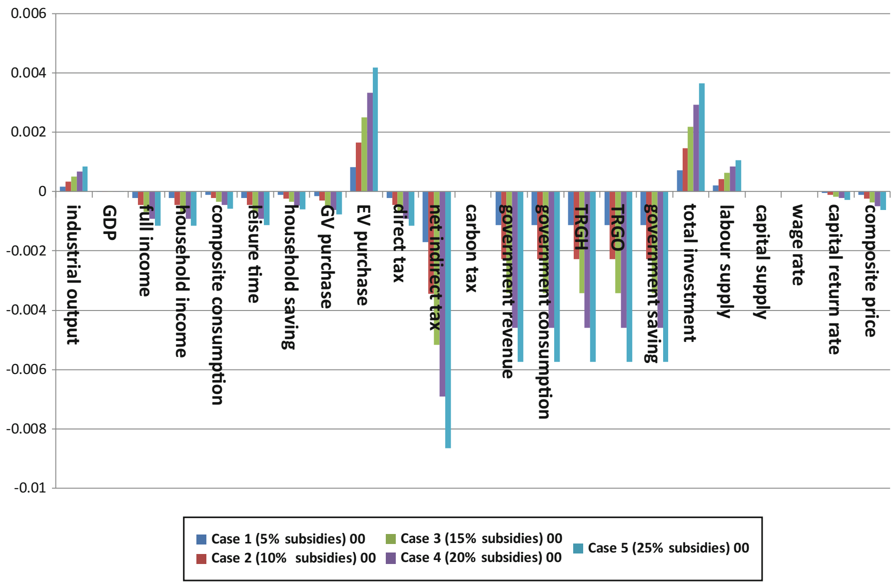

Fig. 11 Change rates in other variables (Case 1 to Case 5)

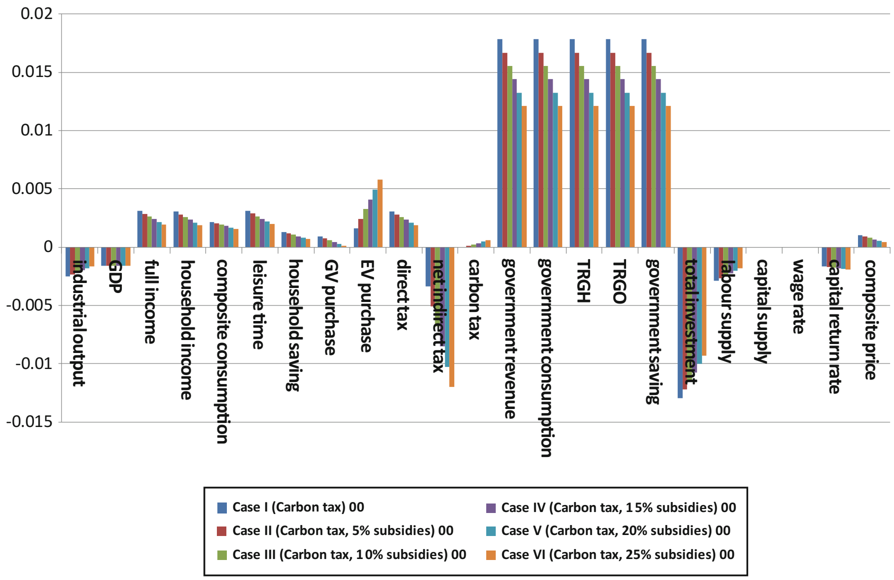

Fig. 12 Change rates in other variables (Case 1 to Case 6)

introduced. Household income also grows because the current transfers from the government to households are expanded.

The equivalent variation shows a negative value of −1255 million yen in Case 5 as base case is set up as the baseline. This value implies the per capita equivalent variation of −3354 yen in Toyohashi City. In Case 6, the equivalent variation depicts a welfare gain of 2208 million yen meaning the per capita equivalent variation of 5901 yen.

5 Concluding Remarks

The conversion of Toyohashi City toward the electric vehicle society by subsidy policy illustrates the result of expansion in outputs in electric vehicle manufacturing, solar power generation, cogeneration, electric vehicle transport, and other transports. The outputs in mining and coal and petroleum industries shrink by substitution effect. Moreover, electric vehicle purchase increases in household sector. However, the total CO_2 emission slightly increases due to the fact of increases in outputs in industries generating much CO_2. This is interpreted as a rebound effect by the spread of electric vehicles that are characterized by energy and parts saving type.

On the other hand, in the cases with a carbon tax, outputs in industries generating much CO_2 including iron and steel, electricity, and clay and stones decrease, while outputs in industries with additional subsidies grow resulting in a reduction in the total output and CO_2 emission. It can be said that this result comes from the price incentive effect which implies decreases in outputs in industries generating much CO_2 emissions due to rises in prices of products of such industries.

When the subsidy rate is raised, then the total industrial output increases leading to an increase in the total CO_2 emission. When the carbon tax is imposed on industrial outputs, outputs in industries generating much CO_2 emissions decrease resulting in a reduction in the total output and CO_2 emission. In this study, the additional subsidies are assumed to increase by 5 % leading to a proportional increase in the industrial outputs. Among others the expansions in industrial outputs with the additional subsidies are larger as compared with other outputs.

When the additional subsidies are introduced, the equivalent variation shows a negative value implying Toyohashi City's welfare loss. Although there is an income effect resulting from a fall in consumer price index, decreases in household income and leisure time are over the income effect. However if the carbon tax is introduced, current transfers from the government to households expand resulting in increases in household income and leisure time showing a positive equivalent variation.

This study has shown a solution for the problem of the rebound effect in CO_2 emissions raised in the authors' previous literature by introducing the carbon tax. This study has also illustrated a path to an environment-friendly society in Toyohashi City with more spread of electric vehicles, CO_2 reduction, and an increase in household utility due to introduction of appropriate subsidies and carbon tax. In the near future, Aichi Prefecture IO table will be published; hence, areas worth examining include improvement of estimation accuracy of the model.

References

GGIOJ (Greenhouse Gas Inventory Office of Japan) (2008) National GHGs inventory report of Japan

IEA (International Energy Agency) (2006) World energy outlook, Paris, France

Khanam S, Miyata Y (2012) New industrial structure coping with the economic impacts of shifting production to battery based on electric vehicles in Toyohashi City in Japan – a CGE modeling approach -, regional science inquiry, vol. IV, no 3, Special Issue, Dec 2012, pp 85–100

Miyata Y, Shibusawa H (2008) Does a decrease in the population prevent a sustainable growth of an environmentally friendly city?-A comparison of cases of decreasing and increasing populations of Obihiro Metropolitan area in Japan by an Intertemporal CGE Modeling Approach. Interdiscip Inf Sci 14(1):1–24

MOE (Ministry of Environment, Japan) (1997) Kankyo Hakusho (Environmental White Paper of Japan) (in Japanese)

MOE (Ministry of Environment, Japan) (2007) National greenhouse gas inventory Report of Japan

Shibusawa H, Sugawara T (2011) Evaluating the economic impacts of the production of new generation automobiles with technological innovations. Stud Reg Sci 41(1):127–146. (in Japanese)

Shoven JB, Whalley J (2007) Applying general equilibrium, Cambridge survey of economic literature. Cambridge University Press, New York

Toyohashi City, Toyohashi City Statistics (2011a) http://www.citypopulation.de/php/japan-aichi.php?cityid=23201

Toyohashi City, home page (2011b) http://www.city.toyohashi.aichi.jp/en/index.html

Valerie JK (2010) Prospects for plug-in hybrid electric vehicles in the United States and Japan: a general equilibrium analysis, Elsevier. Transp Res A 44:620–641

Initial Explorations into the Spatial Structure of the Japanese Regional Economies

Geoffrey J. D. Hewings and Michael Sonis

Abstract Comparative analysis of economies has usually focused on the share of production activities accounted for by specific sectors. In this paper, attention is directed to comparative analysis of the economic structure of a set of Japanese regional economies. Using the concept of the multiplier product matrix applied to input-output tables, a visualization the economic structure can be obtained. By specifying one structure as a *numeraire*, comparative analysis can reveal the nature of similarities and differences. A further elaboration in the form of feedback loops provides insights in the nature and strength of interregional interdependencies. Hence, both internal and external interdependencies can be revealed and changes in these structures over time can be highlighted.

Keywords Multiplier product matrix • Feedback loops • Structural decomposition • Japanese regional economies

1 Introduction

Regional growth theory has a great deal to say about the contributions of various factors that propel a region forward, that explain why some regions grow, why other regions grow more rapidly, and why some regions decline. However, very little attention has been directed to the role of economic structure and structural changes, even though these are elements of the regional economy that play an important role in conditioning growth, establishing the competitiveness of a region's economy and its potential for future expansion. While the development of the new economic

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geography and the inclusion of space in the new trade theory have drawn attention once again to regional economies, regional structure is still not addressed (see Fujita et al. 1999).

Not only is regional structure not evaluated, but there has been, in addition, an absence of any form of comparative analysis. On the one hand, this is surprising given the volume of work that has been directed to regional modeling; on the other hand, many of the models have been developed using assumptions, data, and classification systems that render comparison difficult if not impossible. Part of the stimulation for this present paper originated in two papers, one sadly never revised and published before the author's death. The first paper, by Simpson and Tsukui (1965), explored the structure of the US and Japanese economies using input-output tables. Although forced to aggregate to a level of sectoral detail that was in some ways unfortunate but dictated by classification conformity problems, they did provide insights into what they referred to as the *fundamental structure of production*. This skeletal structure exhibited strong common tendencies between the two countries and revealed an underlying similarity in the way activities interacted with each other. The skeletal structure was extracted by discarding transactions that were, in order of magnitude terms, relatively small. However, these ideas were never pursued further until Okawzaki (1989) presented some empirical work that highlighted what he referred to as the *hollowing out* of the Japanese economy. His research suggested that, over time, the average sector in Japan was becoming less dependent on domestic sources of inputs and on the domestic market as a source of demand for its outputs.

Taken together, these two contributions established a set of testable hypotheses about the nature of economic structure and structural change over time. Could there be a common regional structure of production – across regions within a country or even across regions in different countries? Could one expect the structural evolution of these economies to exhibit similar patterns of change over time? Is the process of hollowing out a common phenomenon across regional economies? If hollowing out is occurring, where is the source (location) of the new dependencies for a region's economy – other regions within the same country or other countries? These are fascinating questions that require considerable research effort to be directed to answering them since the information is not readily available.

The process was initiated at the regional level in the late 1980s. Hewings and Jensen (1986) noted that by the mid-1980s, there had been a redirection of research efforts in regional input-output analysis away from preoccupation with input-output table compilation to issues associated with structure and structural change. In Jensen et al. (1988, 1991), the concept of *fundamental economic structure* was introduced. Drawing on the approach of Simpson and Tsukui (1965), an attempt was made to explore the degree to which a region's economic structure (in input-output terms) could be divided into sets of transactions – those that were predictable, but whose level and intensity might reflect the size of the economy in question, and those that were not predictable and might reflect region-specific comparative or competitive advantages.

These initial steps awaited the development of methodology that could identify components that were similar or different; in the decade of the 1990s, this methodology has evolved significantly and has made possible the comparative analyses that are described in this paper. Of course, there are still many gaps and even more opportunities to contribute to methodology as well as insights and interpretations of the differences and similarities that have been uncovered.

The paper is organized as follows. In the next section, the analytical approaches will be presented, focusing on the important issue of extraction of economic structure (input-output tables) over time and the methods developed to visualize and compare economic structure. Section 3 sets out a series of expectations that underpin the research agenda. The next section presents the empirical findings for Japan. Section 5 provides a summary and the final section reviews some current, continuing research.

2 Analytical Approaches

2.1 Visualizing Economic Change: The Multiplier Product Matrix[1]

Comparing a set of matrices over time or across space presents a daunting problem; while there are many summary measures that could be applied, many fail to provide a holistic sense of the changes that may have occurred. In this regard, some new methodology, the multiplier product matrix (MPM), was developed to enhance the visualization of economic structure. The method, as will be described below, provides a strong link to key sector analysis and offers a first step in the more detailed process that will be required to uncover trends.

The definition of the multiplier product matrix is as follows: let $A = \|a_{ij}\|$ be a matrix of direct inputs in the usual input-output system, $B = (I - A)^{-1} = \|b_{ij}\|$ be the associated Leontief inverse matrix, and $B_{\bullet j}$ and $B_{i\bullet}$ be the column and row multipliers of this Leontief inverse. These are defined as

$$B_{\bullet j} = \sum_{i=1}^{n} b_{ij}, \quad B_{i\bullet} = \sum_{j=1}^{n} b_{ij} \tag{1}$$

[1]This section draws on Sonis et al. (1996).

Let V be the global intensity of the Leontief inverse matrix:

$$V = \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \tag{2}$$

Then, the input-output multiplier product matrix (MPM) is defined as

$$M = \frac{1}{V} \left\| B_{i\bullet} B_{\bullet j} \right\| = \frac{1}{V} \begin{pmatrix} B_{1\bullet} \\ B_{2\bullet} \\ \vdots \\ B_{n\bullet} \end{pmatrix} \begin{pmatrix} B_{\bullet 1} & B_{\bullet 2} & \cdots & B_{\bullet n} \end{pmatrix} = \left\| m_{ij} \right\| \tag{3}$$

The properties of the MPM will now be considered in the context of the hierarchy of backward and forward linkages and their economic landscape associated with the cross-structure of the MPM.

2.1.1 Economic Cross-Structure Landscapes of MPM and the Rank-Size Hierarchies of Backward and Forward Linkages

The concept of key sectors is based on the notion of backward and forward linkages and has been associated with the work of both Rasmussen (1956) and Hirschman (1958). The major thrust of the analytical techniques, and subsequent modifications and extensions, has been toward the identification of sectors whose linkage structures are such that they create an above-average impact on the rest of the economy when they expand, or in response to changes elsewhere in the system, Rasmussen (1956) proposed two types of indices drawing on entries in the Leontief inverse:

1. Power of dispersion for the backward linkages, BL_j, is as follows:

$$\begin{aligned} BL_j &= \tfrac{1}{n} \sum_{i=1}^{n} b_{ij} / \tfrac{1}{n^2} \sum_{i,j=1}^{n} b_{ij} = \\ &= \tfrac{1}{n} B_{\bullet j} / \tfrac{1}{n^2} V = B_{\bullet j} / \tfrac{1}{n} V \end{aligned} \tag{4}$$

   and
2. The indices of the sensitivity of dispersion for forward linkages, FL_i, are as follows:

$$\begin{aligned} FL_i &= \tfrac{1}{n} \sum_{j=1}^{n} b_{ij} / \tfrac{1}{n^2} \sum_{i,j=1}^{n} b_{ij} = \\ &= \tfrac{1}{n} B_{i\bullet} / \tfrac{1}{n^2} V = B_{i\bullet} / \tfrac{1}{n} V \end{aligned} \tag{5}$$

The usual interpretation is to propose that $BL_j > 1$ indicates that a unit change in final demand in sector j will create an above-average increase in activity in the economy; similarly, for $FL_i > 1$, it is asserted that a unit change in all sectors' final demand would create an above-average increase in sector i. A key sector, K, is usually defined as one in which both indices are greater than 1. It should be noted here that similar ideas were developed by Chenery and Watanabe (1958) for the definition of backward and forward linkages based on the matrix of direct inputs, $A = \left\| a_{ij} \right\|$.

The definitions of backward and forward linkages provided by (4) and (5) imply that the rank-size hierarchies (rank-size ordering) of these indices coincide with the rank-size hierarchies of the column and row multipliers. It is important to underline, in this connection, that the column and row multipliers for MPM are the same as those for the Leontief inverse matrix:

$$\begin{aligned}\sum_{j=1}^{n} m_{ij} &= \tfrac{1}{V}\sum_{j=1}^{n} B_{i\bullet}B_{\bullet j} = B_{i\bullet}\\ \sum_{i=1}^{n} m_{ij} &= \tfrac{1}{V}\sum_{i=1}^{n} B_{i\bullet}B_{\bullet j} = B_{\bullet j}\end{aligned} \tag{6}$$

Thus, the structure of the MPM is essentially connected with the properties of sectoral backward and forward linkages.

The structure of the matrix, M, can be ascertained in the following fashion: consider the largest column multiplier, $B_{\bullet j}$, and the largest row multiplier, $B_{i\bullet}$, of the Leontief inverse. Then, the element, $m_{i_0 j_0} = \frac{1}{V} B_{i_0\bullet} B_{\bullet j_0}$, located in the place (i_0, j_0) of the matrix, M, will be the largest element in M. Moreover, all rows of the matrix, M, are proportional to the i_0^{th} row, and the elements of this row are larger than the corresponding elements of all other rows. The same property applies to the j_0^{th} column of the same matrix. Hence, the element located in (i_0, j_0) defines the center of the largest *cross* within the matrix, M. If this cross is excluded from M, then the second largest cross can be identified and so on. Thus, the matrix, M, contains the rank-size sequence of crosses. One can reorganize the locations of rows and columns of M in such a way that the centers of the corresponding crosses appear on the main diagonal. In this fashion, the matrix will be reorganized in such a way that a descending *economic landscape* will be apparent.

This rearrangement also reveals the descending rank-size hierarchies of the Hirschman-Rasmussen indices for forward and backward linkages. Inspection of that part of the landscape with indices >1 (the usual criterion for specification of key sectors) will enable the identification of the key sectors. However, it is important to stress that the construction of the economic landscape for different regions or for the same region at different points in time would create the possibility for the establishment of a taxonomy of these economies. Moreover, the superposition of the hierarchy of one region on the landscape of another region provides a clear visual representation of the similarities and differences in the linkage structure of these regions (see Sonis et al. 1996 for an application to Chinese urban areas).

2.1.2 Inner Structure of Column and Row Multipliers

While the applications of the MPM method will reveal some of the macro-level changes in the structure of the economy, it will be important to examine the finer structure of changes. For example, if a sector's multiplier value increases or decreases, how are the relative shares accounted for by supplying sectors changing, and would it be reasonable to assume that the relative rankings would also remain the same? The fine structure can be analyzed by viewing both row and column components on the Leontief inverse matrix.

In this application, attention was focused on the ordinal rankings of the elements of the row and columns of the Leontief inverse net of the initial injection:

$$[B(t) - I] \quad (7)$$

Furthermore, the relative contributions of each element were evaluated:

$$\left[b_{ij}(t)/B_{\bullet j}(t)\right] \quad \text{or} \quad \left[b_{ij}(t)/B_{i\bullet}(t)\right] \qquad \forall i, j, t \quad (8)$$

2.2 Spatial Production Cycles (Feedback Loops)

The renewed interest in international trade has drawn attention to the phenomenon of vertical specialization, the use of imported inputs for producing goods that are exported (see Brülhart and Hine 1999). Balassa (1967, p. 97) coined the term vertical specialization; in a recent paper, Hummels et al. (1998) introduced and discussed the following definition of vertical specialization:

> (1) a good must be produced in multiple sequential stages, (2) two or more countries must specialize in producing some, but not all, stages, and (3) at least one stage must cross an international border more than once . . . Thus, countries link sequentially to produce a final good.

This definition speaks to the role of sequential production or spatial production cycles and bears an important relationship with the notion of a hierarchy of feedback loops of interindustry flows elaborated by Sonis et al. (1995, 1997). The further elaboration and visualization of this approach, which is a purpose of this chapter, may be shown to be connected with an analogy between the behavior of flows of goods and hydrodynamic turbulence (see Sonis et al. 2000). A flow of energy from large to small scales is one of the main characteristics of fully developed homogeneous isotropic turbulence in three-dimensional space. Energy is pumping into the system at large scales, transferred to smaller scales through a hierarchy of eddies of decreasing sizes, and dissipates at the smallest scale (this cascade of kinetic energy generates the scaling behavior of eddies; see Sonis et al. 2000). The turbulence analogy is provided through the way in which large, aggregate interregional feedback loops (spatial production cycles) of intermediate input flows are decomposed into feedback loops between economic activities (such as resources, manufacturing, and services) and then further decomposed into the loops of flows on the scale of individual industries (interindustry production cycles). Moreover, the scaling of eddies, analogous to the hierarchy of economic subsystems, is presented with the help of the so-called "Matryoshka" principle (see Sonis and Hewings 1990). Thus, the idea rank-size hierarchy of spatial production cycles (hierarchical feedback loop analysis) can be used for structural economic analysis.

2.2.1 The Spatial Production Cycle Analysis as a Multiregional Feedback Loop Approach

Closed Feedback Loops and Block-Permutation Matrices Consider a multiregional, multi-country, interindustry system described with the help of a square block matrix, F, of interregional inputs of the following form:

$$F = \begin{pmatrix} F_{11} & F_{12} & \dots & F_{1n} \\ F_{21} & F_{22} & \dots & F_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ F_{n1} & F_{n2} & \dots & F_{nn} \end{pmatrix} \tag{9}$$

It is assumed that there are n regions in which there exist m divisions of the economy, organized into activities, and there is the subdivision of activities in the different subcategories. The central point of the feedback loop decomposition analysis is the use of spatial/functional feedback loops represented by block-permutation matrices. By definition, a block-permutation matrix includes in each block row and block column only one nonzero block.

In the two-region case

$$F = \begin{pmatrix} F_{11} & F_{12} \\ F_{21} & F_{22} \end{pmatrix} \tag{10}$$

there are only two block-permutation sub-matrices:

$$F_1 = \begin{pmatrix} F_{11} & 0 \\ 0 & F_{22} \end{pmatrix}, \quad F_2 = \begin{pmatrix} 0 & F_{12} \\ F_{21} & 0 \end{pmatrix} \tag{11}$$

and

$$F = F_1 + F_2 \tag{12}$$

The matrix $F_1 = \begin{pmatrix} F_{11} & 0 \\ 0 & F_{22} \end{pmatrix}$ represents the circulation of intermediate goods in the same geographical region, and the matrix $F_2 = \begin{pmatrix} 0 & F_{12} \\ F_{21} & 0 \end{pmatrix}$ represents the spatial production cycle mirroring the bilateral connections between the two regions.

Within a three-region system

$$F = \begin{pmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{pmatrix} \tag{13}$$

there are six block-permutation sub-matrices:

$$F_1 = \begin{pmatrix} F_{11} & 0 & 0 \\ 0 & F_{22} & 0 \\ 0 & 0 & F_{33} \end{pmatrix} \quad F_2 = \begin{pmatrix} 0 & 0 & F_{13} \\ F_{21} & 0 & 0 \\ 0 & F_{32} & 0 \end{pmatrix} \quad F_3 = \begin{pmatrix} 0 & F_{12} & 0 \\ 0 & 0 & F_{23} \\ F_{31} & 0 & 0 \end{pmatrix} \tag{14}$$

$$F_4 = \begin{pmatrix} F_{11} & 0 & 0 \\ 0 & 0 & F_{13} \\ 0 & F_{32} & 0 \end{pmatrix} \quad F_5 = \begin{pmatrix} 0 & F_{12} & 0 \\ F_{21} & 0 & 0 \\ 0 & 0 & F_{33} \end{pmatrix} \quad F_6 = \begin{pmatrix} 0 & 0 & F_{13} \\ 0 & F_{22} & 0 \\ F_{31} & 0 & 0 \end{pmatrix} \tag{15}$$

and

$$F = F_1 + F_2 + F_3 = F_4 + F_5 + F_6 \tag{16}$$

Here, the block-permutation matrices F_2, F_3, F_4, and F_5 represent the different spatial production cycles reflecting the trilateral trade connections between three regions, the block-diagonal matrix F_1 represents the "circulation" of intermediate flows within the same region, and the block-permutation F_6 represents the spatial production cycle reflecting the bilateral trade between first and third regions and the "circulation" within the second region.

In the case of n regions, there exists $n!$ different block-permutation matrices, and it is possible to prove that the number of possible additive decompositions is equal to $(n-1)!(n-2)!\ldots 2!$. Thus, the problem focuses on the appropriate choices from this very large set of possible decompositions, namely, the decompositions with the sound spatial economic meaning. This problem can be solved through the adoption of a hierarchical stepwise approach; the procedure operates at successive levels in the system, but the approach at each stage is similar. This top-down decomposition may be considered analogously to an exfoliation process in the removal of the layers of an onion or using the turbulence analogy to the construction of an hierarchy of feedback loops (whirlpools) ordered with the help of aggregated cumulative flows within the blocks belonging to the loop. The feedback loops on the inner hierarchical level of economic activities should be placed into the loops of the higher levels in the same manner as a set of *Matryoshka* dolls in which successively smaller dolls of exactly the same shape and style are nested within the larger dolls. Hence, the Matryoshka approach examines the intra- and interregional transactions in terms of the hierarchical structure of feedback effects drawing upon the superposition principle conceptual framework (see Sonis 1982). The superposition principle considers the economic system as a decentralized system that is comprised of a set of subsystems acting according to different and often conflicting and noncommensurable objectives. These objectives may be presented in the form of extreme tendencies or trends; the hierarchical viewpoint enables the analyst to extract the tendencies from the most to the least important. In this fashion, the procedure is not unlike that used in principal component analysis. A brief summary of the methodology for extracting the system of closed feedback loops may be found in Sonis et al. (1997).

One natural method for dealing with such a large amount of complete feedback loops is of course the derivation of some hierarchical structure. Essentially, the hierarchical feedback loop approach attempts to extract complete feedback loops that successively account for the most "explanation" in each stage of the selection process. The procedure continues until all transaction flows have been included. It is important to note that each block matrix F of the type (9) can be replaced by the numerical matrix T_F whose components are the sum of all economic flows in the corresponding block – the aggregated block flows. Such a sub-matrix T_F represents a complete feedback loop if it includes in each row and in each column only one nonzero entry from the matrix F and zeros elsewhere. One can define the *flow intensity* of a complete feedback loop (the *flow intensity* of a spatial production cycle) as the sum of all flows of the corresponding sub-matrix T_F.

If all nonzero entries of T_F are replaced by ones, the result is a so-called *permutation matrix* P_F. This zero-one matrix corresponds to some permutation of the sequence of numbers $1, 2, \ldots, n$. Such a permutation (of regions) represents the spatial structure of the corresponding complete feedback loop. The corresponding sub-matrices T_F are referred to as *quasi-permutation matrices*.

It is important to note that for each permutation matrix P_F, there is an integer k such that P_F^k is the unit matrix I. For that k, the corresponding quasi-permutation matrix T_F has the property that T_F^k is a diagonal matrix, implying that the corresponding feedback loop indeed represents the notion of *self-influence*.

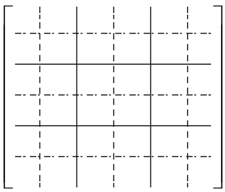
The hierarchy of all complete feedback loops is defined as the sequence of quasi-permutation sub-matrices T_F chosen according to the rank-size of their flow intensities. This means that on the top of the hierarchy, one finds the complete feedback loop with the maximal flow intensity.

The problem of the determination of the quasi-permutation sub-matrix with the maximal flow intensity is mathematically equivalent to the solution of the optimal personnel assignment of n persons (here rows) between n jobs (here columns) in such a way that one person will have one job while profit is maximized (see Sonis 1982). Here profit is defined by the size of the flows in matrix T. The procedure is summarized in Sonis et al. (1997).

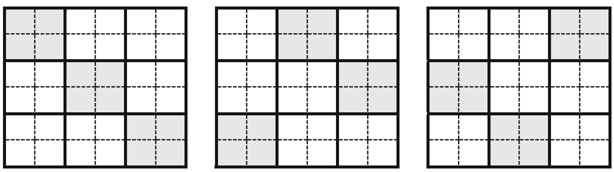
2.3 *Matryoshka Principle for the Description of the Nested Hierarchy of Spatial Production Cycles*

It is necessary and possible to combine the interregional and interactivity interdependencies. To this aim, the aggregated table needs to be replaced by the detailed table describing the interplay between the interactivity and international interdependencies. Further, it is important to stress that the flexible form of the spatio-economic feedback loop analysis employed in this analysis allows an easy extension to the spatio-sectional level. In such an extension, the analysis will relate to activities per region. Thus, the hierarchy of the feedback loops will reflect the interactivity interdependencies intertwined spatially, enabling one to distinguish the spatial extent of multiregional industrial complexes.

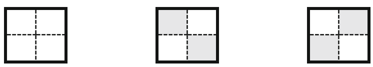
Consider, as an example, the three-region/two-activity table of the following form:

$F =$ 

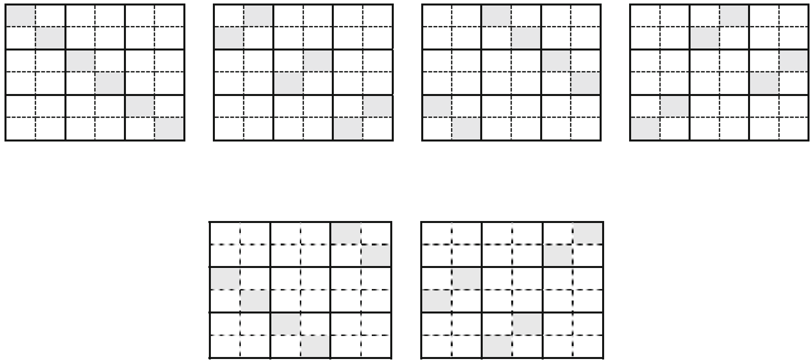
At the regional spatial scale (i.e., where interest is merely focused on the aggregate flows rather than the interactivity flows), the following hierarchical feedback loop structure can be identified:



At the activity level, the simple decomposition holds:



Therefore, the following nested hierarchical decomposition satisfies the rules of the Matryoshka principle:



A similar structure of nested feedback loop hierarchies could be extracted for the general case of an *n*-region/*m*-activity input-output system. Of course, the Matryoshka principle is applicable to the disaggregation of regions into subregions and further successive spatial and activity disaggregation.

3 Expectations

Given that the earlier findings of Simpson and Tsukui (1965) were derived from comparisons of national economic structure, the literature in regional science reveals very little in the way of insights into the comparison of regional economic structure. However, one might be able to assemble some tentative hypotheses and expectations, and some of these are articulated below.

3.1 Income Convergence

In most advanced economies, differences in levels of welfare between regions have decreased over time and there is a tendency for income convergence to occur. Could one also expect that the economic structures of these regions would also converge in the sense that differences in the sectoral distribution of activities would decrease?

3.2 The Nature of Trade I

If Okazaki's (1989) findings could be generalized, could one point to an expectation that regions should exhibit a hollowing-out phenomenon as their economies mature? In essence, intra-region dependence will be replaced by extra-region dependence; but will this occur uniformly across all regions and across all sectors?

3.3 The Nature of Trade II

Drawing on the new trade theory, one aspect of enhanced development has been the associated growth in demand for variety of products. If, as expected, regional economies are becoming more similar in structure and yet extra-regional dependence is increasing, what is being traded? Here we can test for the propositions proposed by Krugman (1990) that as economies become more similar in structure and levels of per capita income converge, comparative advantage gives way to other forces (scale economies). In this case, the nature of trade changes from domination by interindustry flows across regions to domination by intra-industry flows.

3.4 The Nature of Trade III

If external trade is increasing, with whom is it increasing – nearest neighbor regions, other regions within the same country, or increased international trade?

These are some of the ideas and hypotheses guiding the empirical explorations to be presented below. In many cases, the explorations are continuing and definitive findings cannot be presented. However, these expectations will serve as benchmarks against which continuing research can be placed.

4 Summary of Empirical Findings for Japan

The Japanese research was focused on a ten-region CRIEPI developed system for Japan; additional research was also conducted on a slightly different regionalization, the one used by MITI in the development of interregional input-output tables for Japan. The research findings will be summarized into three parts:

- Economic structure
- Changes in the nature of trade
- Examination of spatial production cycles (feedback loops)

These will be described and interpreted in turn.

4.1 Economic Structure

Research in the Midwest regions of the USA had indicated that, notwithstanding similarities in the macroeconomic structure across, there were some important differences in the internal economic structure, reflected in the presentation of the MPM economic landscapes (see Sonis et al. 2002). Figure 1 provides a summary of the macrostructure for the ten-region Japanese system.

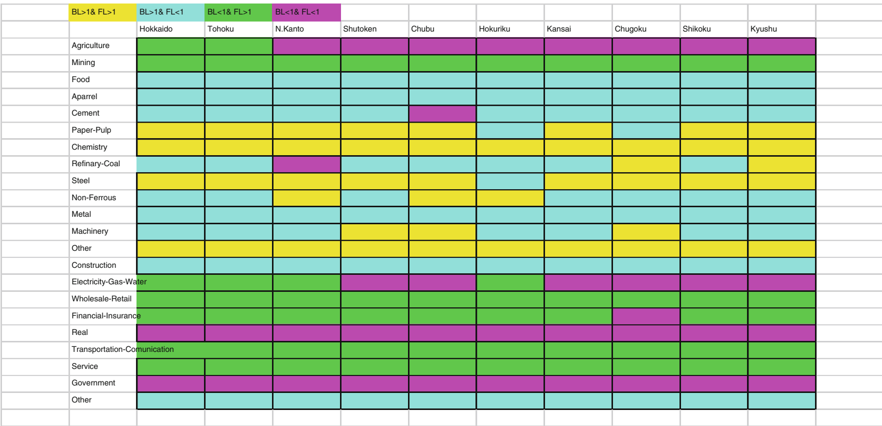


Fig. 1 Backward and forward linkage classification for Japanese regions

Sectors are classified into four sets based on the notion of backward and forward linkages introduced in Sect. 3. Key sectors are those with backward and forward linkages greater than 1.0; this implies that the purchases that they make from other sectors are larger than the average for all sectors. Furthermore, when final demand changes in other sectors, demand for inputs from the key sectors is also higher than the average for all sectors. The three other classifications are as follows:

Backward-linked sectors: those with above-average backward linkages but below-average forward linkages
Forward-linked sectors: those with above-average forward linkages but below-average backward linkages
Weakly linked sectors: those with both forward and backward linkages less than the average

Overall, the patterns were remarkably consistent across regions; key sectors tended to be key in all regions with the exception of machinery and nonferrous metals that were more spatially concentrated. Similarly, backward-, forward-, and weakly linked sectors tended to be classified as such across the regions. In all cases where a sector was not classified as key in some but not all regions, it was allocated to the backward-linked sectors in the other regions. With the exception of cement in Chubu, sector classifications were only one category apart across regions.

The findings suggest an economic structure reflecting considerable similarity across regions; however, given the findings for the US regions, the next step involved analysis of the internal structure reflected in the input-output interdependence. In the next series of figures, the 1990 MPM economic landscape for Shutoken (South Kanto) was used as the numéraire (see Fig. 2). To conserve space, only four examples of the other nine regions are shown; as before, all the vertical axes are the same, and the order of the sectors revealed in Shutoken is used for the remaining

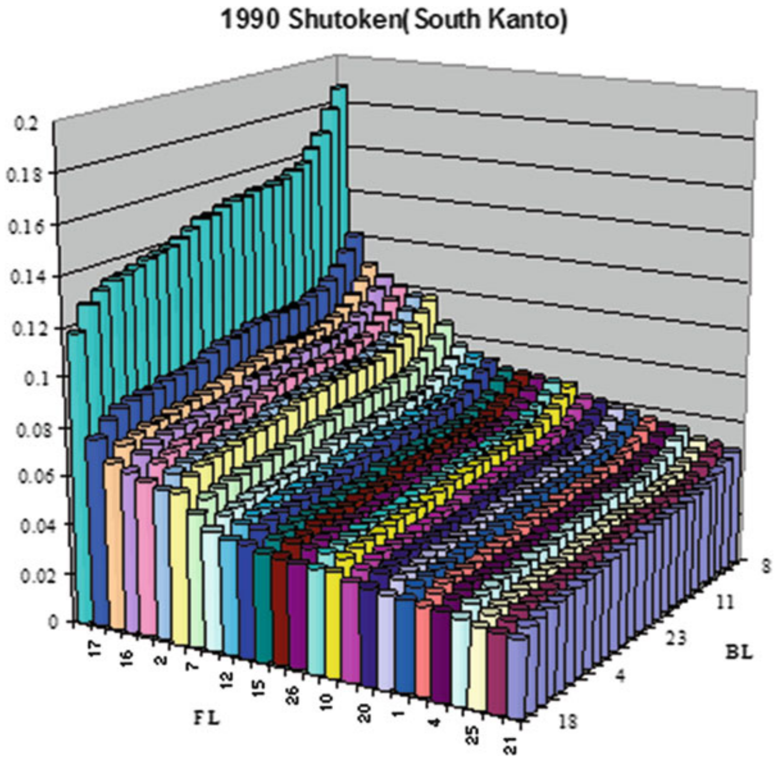
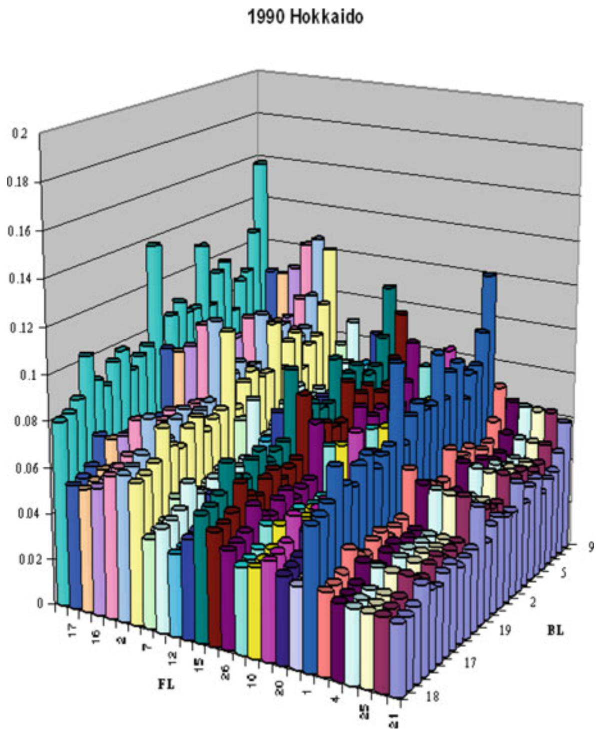


Fig. 2 The economic landscape (MPM) for Shutoken, 1990

regions. Figures 3 and 4 show the structures for the peripheral regions of Hokkaido and Kyushu/Okinawa. The pattern is clearly different from Shutoken in the sense that the hierarchical structure is less pronounced with many sectors less dominant in the Shutoken region exhibiting greater importance in these other two regions (indicated by the elevation above a hypothetical smoothly descending surface from the upper left-hand corner). In a sense, one might reflect that this pattern might reflect regions in which there are more pronounced differences between sectors. This becomes apparent when the economic structures for North Kanto and Chubu are examined (Figs. 5 and 6). These landscapes are much "flatter" with far fewer pronounced breaks in the economic structure than was evident in Figs. 3 and 4. Of the two, Chubu has a more pronounced hierarchical structure.

The findings suggest that examination of structure needs to move beyond the simple, macroeconomic descriptors since these measures often hide important differences in the ways in which sectors are linked. At this stage, the analysis has not explored the degree to which these differences reflect variations in technology or just reflect the regions' variation in competitive advantage in supplying intermediate goods. In the latter case, the technology across regions may be similar, but the

Fig. 3 MPM for Hokkaido



sources of supply vary; in the former case, differences in technology may be reflected in different mixtures of input requirements, thus leading to differences in internal structure.

In the next section, some of the aspects surrounding differences in regional structure will be explored in the context of changes in the nature of spatial dependence. In essence, this research focused on the degree to which Japanese regions were hollowing out and exchanging internal for external dependence. However, the latter dependency was further differentiated to explore interregional versus international trade.

4.2 Changes in the Nature of Trade

The analysis adopted here employed a sophisticated decomposition methodology to examine changes in the economic structure of Japanese regions.[2] In addition to exploring changes in economic structure reflecting the existence of hollowing-out

[2]This section draws on Hitomi et al. 2000.

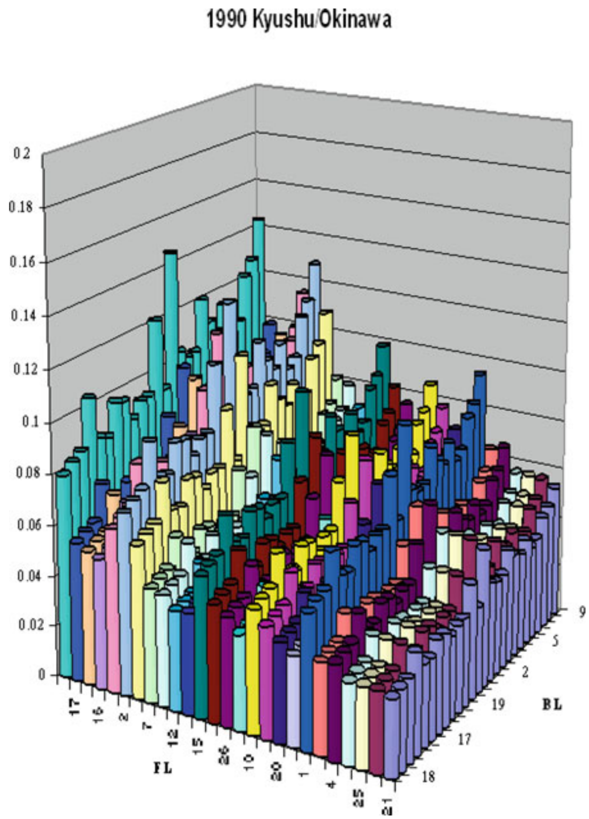
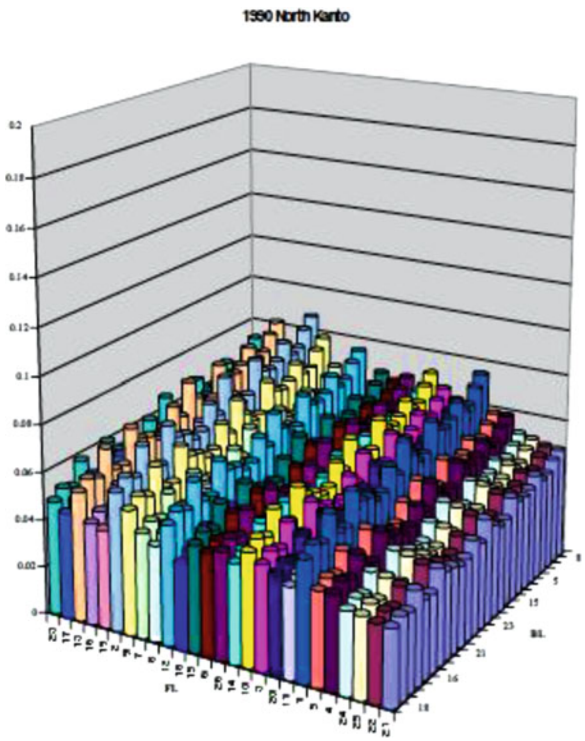


Fig. 4 MPM for Kyushu/Okinawa

phenomena, additional attention was directed to the role played by technological change and demand. Earlier research had pointed to the important role that demand changes played in explaining growth in output levels at the national level (see Sonis et al. 1996). However, little comparable research has been undertaken at the regional level.

The difference in decomposition analysis applied at the national and regional levels may be that, at national level, structural change can be decomposed into technological change, change in demand, and synergetic change, whereas, at the (inter)regional level, the attention of structural change should also include changes in intra- and interregional dependencies. In this context, interregional input coefficients can be decomposed into two factors: technical coefficients and interregional trade coefficients. The main objective of this work was to clarify the role of interregional trade and technology in the changing interregional dependency in the Japanese regional economy. Our analysis focused on the change in the interregional Leontief inverse matrix (an enlarged Leontief inverse) and identifying the factors contributing to those changes.

Fig. 5 MPM for North Kanto



The model system solves for total output using a matrix of technical coefficients, A, a matrix of domestic supply coefficients, D, and a matrix of interregional trade coefficients, T. Final demand is divided into domestic (F) and export (E) demand. The solution takes on the following form:

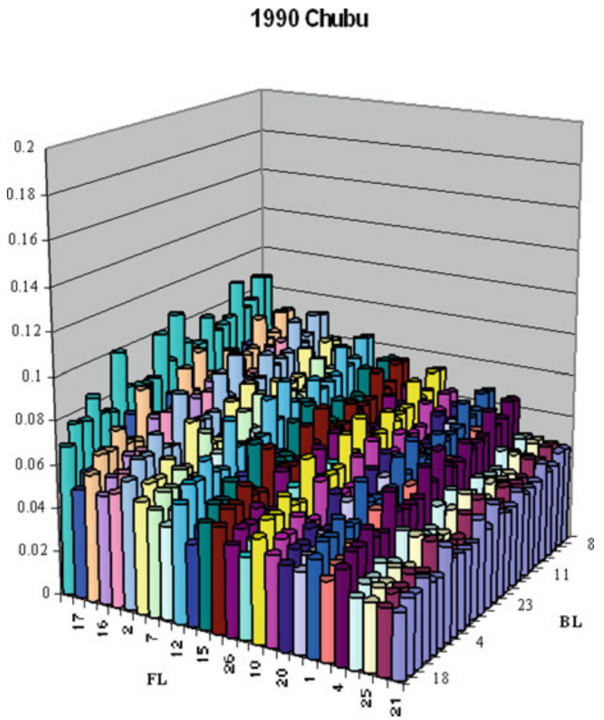
$$
\begin{aligned}
X &= [I - (D * T)\,A]^{-1}\,[(D * T)\,F + E] \\
&= [I - (D * T)\,A]^{-1}\,(D * T)\,F + [I - (D * T)\,A]^{-1}E \\
&= X^f + X^e
\end{aligned}
\qquad (17)
$$

The solution of regional output vector X is divided into two parts: production induced by domestic final demand, $[I - (D * T)\,A]^{-1}\,(D * T)\,F$, and production induced by foreign export, $[I - (D * T)\,A]^{-1}E\ [I - (D * T)\,A]^{-1}E$. We denote the former as X^f and the latter as X^e. In this model, the growth of regional output is written as

$$\Delta X = \Delta X^f + \Delta X^e \qquad (18)$$

Next, growth in output induced by domestic final demand is decomposed. Since $X^f = [I - (D * T)\,A]^{-1}\,(D * T)\,F\ X^f = [I - (D * T)\,A]^{-1}\,(D * T)\,F$, the change in X^f can be further decomposed into changes in D, T, A, and F.

Fig. 6 MPM for Chubu



Employing averaging procedures that are described in Hitomi et al. (2000), the decomposition of domestic final demand results in

$$\begin{aligned}\Delta X^F &= \overline{B}\left(\overline{D}{*}\overline{T}\right)\Delta F \\ &+ B_t^*\left(\overline{D}{*}\overline{T}\right)\Delta A B_0^* \overline{F} \\ &+ \left[\overline{B}\left(\overline{D} * \Delta T\right)\overline{F} + B_t^*\left(\overline{D} * \Delta T\right)\overline{A}B_0^*\overline{F}\right] \\ &+ \left[\overline{B}\left(\Delta D * \overline{T}\right)\overline{F} + B_t^*\left(\Delta D * \overline{T}\right)\overline{A}B_0^*\overline{F}\right] \qquad (19)\end{aligned}$$

where $\overline{B} = \left(B_t^* + B_0^*\right)/2$. As a result, the change of regional output induced by regional final demand can be decomposed into a change in four factors: (1) change in regional final demand, ΔF ΔF; (2) change in regional technical coefficient, ΔA; (3) change in interregional trade coefficient, ΔT; and (4) change in domestic purchase coefficient ΔD. Since the interregional trade coefficient and domestic purchase coefficient affect regional output through two paths – final demand and the enlarged Leontief inverse – the decomposed terms related to ΔT and ΔD in Eq. (19) are expressed as the sum of those two parts.

For export demand, a similar but simpler decomposition yields

$$\Delta X^e = \overline{B}\Delta E + B_t^* \left(\overline{D}\overline{*}\overline{T}\right) \Delta A B_0^* \overline{E} + B_t^* \left(\overline{D} * \Delta T\right) \overline{A} B_0^* \overline{E} + B_t^* \left(\Delta D * \overline{T}\right) \overline{A} B_0^* \overline{E} \tag{20}$$

where $\overline{E} = (E_t + E_0)/2$. Again, growth in regional output induced by international exports can be decomposed into four parts in similar fashion to Eq. (19).

So far, we have developed a decomposition equation of output change with regard to regional final demand and international exports. Since the total output growth is the simple sum of those two changes as shown in (18), we can derive the total output growth decomposition by summing up Eqs. (19) and (20):

$$\begin{aligned}\Delta X = {} & \overline{B}\left(\overline{D}\overline{*}\overline{T}\right) \Delta F + \overline{B}\Delta E \\ & + \left[B_t^* \left(\overline{D}\overline{*}\overline{T}\right) \Delta A B_0^* \overline{F} + B_t^* \left(\overline{D}\overline{*}\overline{T}\right) \Delta A B_0^* \overline{E}\right] \\ & + \left[\overline{B}\left(\overline{D} * \Delta T\right) \overline{F} + B_t^* \left(\overline{D} * \Delta T\right) \overline{A} B_0^* \overline{F} + B_t^* \left(\overline{D} * \Delta T\right) \overline{A} B_0^* \overline{E}\right] \\ & + \left[\overline{B}\left(\Delta D * \overline{T}\right) \overline{F} + B_t^* \left(\Delta D * \overline{T}\right) \overline{A} B_0^* \overline{F} + B_t^* \left(\Delta D * \overline{T}\right) \overline{A} B_0^* \overline{E}\right]\end{aligned} \tag{21}$$

Applying this approach to a series of Japanese nine-region input-output tables between 1980 and 1990, this research revealed that interregional trade patterns were dispersed across the regions. It also found that changes in production technology continued to decrease intermediation while interregional trade had a tendency to increase. These findings indicate that the major factor of change over time in regional output and the enlarged Leontief inverse matrix is interregional trade. While attention is often directed to the role of foreign import penetration as a cause of decreasing regional output, this study showed that changes in interregional trade within the country contributed a far greater impact. Through the analysis of decomposition by region, we found a heavy dependency of the regional economies on the Kanto region; while this dependency is decreasing in our sample period, it remains at a high level.

It will be important to analyze change in the regional economies after 1990. After the end of the so-called bubble economy, the Japanese economy has experienced a serious recession. As a result, the effect of changes in final demand, interregional trade, technology, and domestic purchasing coefficient may be altered in terms of their magnitude and relative contributions. Hence, the present study can be viewed as one exploring structural change in a regional system of economies undergoing significant growth; as the relevant data appear in the next decade, it will be important to explore a complementary approach under conditions of much more moderate growth and even decline in some years.

In the next section, attention is focused more directly on the nature of the interregional trading patterns, interpreted using the concept of spatial production cycles (feedback loops). The objective here is to explore the way in which trade flows move through the system of regions, extracting a hierarchy or production loops that begin in one region and move from part or all of the other regions before returning to the region of origin.

4.3 Examination of Spatial Production Cycles (Feedback Loops)

The methodology for this analysis was reviewed in Sect. 2. Hence, this section will present the results for the Japanese case. The data used in this analysis were derived from publications of the Ministry of International Trade and Industry of Japan, 1980–1995: “1980, 1985, 1990 Interregional Input-Output Tables.” First, these data were aggregated to the level of nine economic regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa. Sectorally, three main economic activities were considered: primary *P* (agriculture), manufacturing *M*, and services *S*. Thereafter, these aggregated activities were subdivided in the following groups: primary, *P* (agricultural activities) and *p* (nonagricultural activities); manufacturing, *M* (non-durable goods) and *m* (durable goods); and services, *S* (business services) and *s* (personal services).

It was noted in the previous section that Hitomi et al. (2000) had identified changes in interregional trade as a major contributor to regional growth in a factor decomposition of the Japanese economy. The analysis to be presented here will explore in greater detail the ways in which the regional economies of Japan are linked and whether these linkages have changed over the periods 1980 to 1985 to 1990.

4.3.1 Intra-regional Trade and Horizontal Specialization of the Japanese Trade, 1980 to 1985 to 1990

Horizontal specialization of trade refers to pure intra-regional trade, flows that do not cross the boundaries of the region, although, of course, the final product from a commodity chain of production may become part of interregional trade. Hence, horizontal specialization may be considered to be the subset of interactions that involve movements between sectors but not between regions. A further perspective may be offered by suggesting that they form part of a regional cluster of interactions; feedback loop analysis will help explore the degree to which this spatial cluster of flows strengthens or weakens over time in response to changes in regional and interregional competitiveness. An examination of the Chicago economy over the period 1970–1990 found clear evidence of a weakening or hollowing out of horizontal specialization, while the reverse was observed for a five-region division of Indonesia between 1980 and 1993 (see Hewings et al. 1998; Sonis and Hewings 2001; Sonis et al. 1997). For the Japanese case, the feedback loop analysis identified the feedbacks between the activities: primary *P* (agriculture), manufacturing *M*, and services *S*.

Table 1 Types of intra-regional feedback loops, 1980–1985–1990

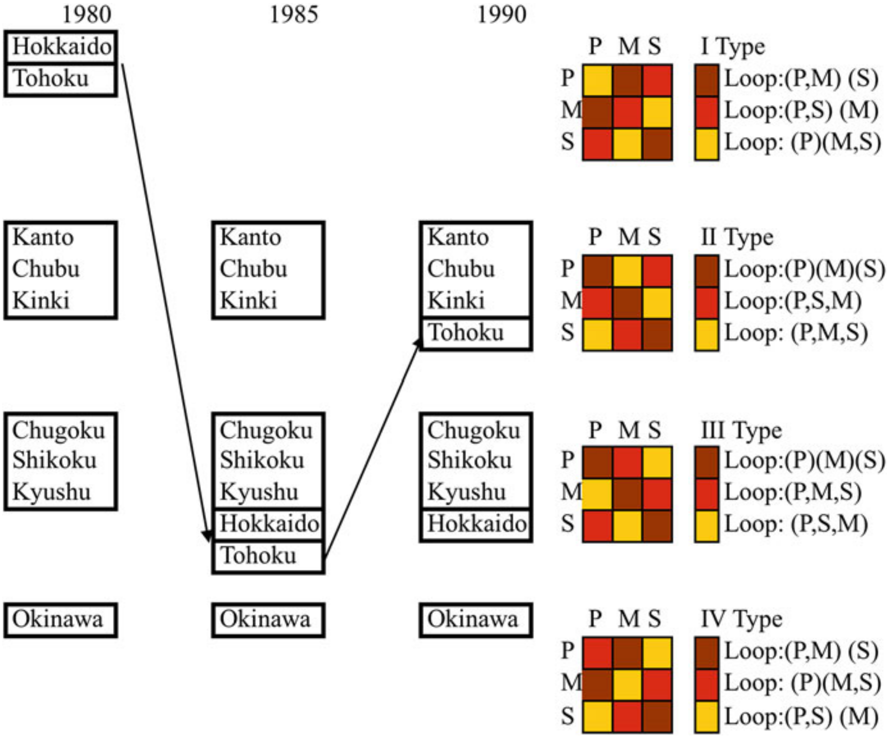
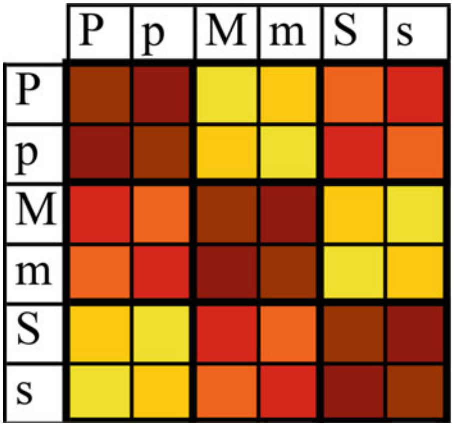


Table 1 identifies four different types of such feedbacks: the I and IV types are characterized by most intensive bilateral (dyadic) connections between activities (*P,M*), (*P,S*), or (*M,S*); the III and IV types are characterized by intensive intra-activity flows (*P*), (*S*), and (*M*) and trilateral connections between activities (*P,M,S*) and (*P,S,M*). Moreover, the most economically developed central regions, Kanto, Chubu, and Kinki, during time periods 1980 to 1985 to 1990 maintain type I intra-regional loops; the adjusted developed economic regions, Chugoku, Shikoku, and Kyushu, maintain type III of feedback loops, while the peripheral regions Hokkaido and Tohoku travel from the type I of loops to II and III, and the Okinawa region maintains throughout the period type IV of feedbacks.

The more detailed subdivision of the primary, manufacturing, and services activities into the following groups – primary, *P* (agricultural activities) and *p* (nonagricultural activities); manufacturing, *M* (non-durable goods) and *m* (durable goods); services, *S* (business services) and *s* (personal services) – reveal the fine structure of the intra-activity and inter-sub-activity feedback loops. This structure is illustrated for the case of type II of the intra-regional feedback loops in Kanto, Chubu, and Kinki economic regions, which are hierarchically stable during all periods 1980 to 1985 to 1990.

Table 2 Qualitative characterization of the horizontal specialization feedback loops in Kanto, Chubu, and Kinki economic regions, 1980–1985–1990

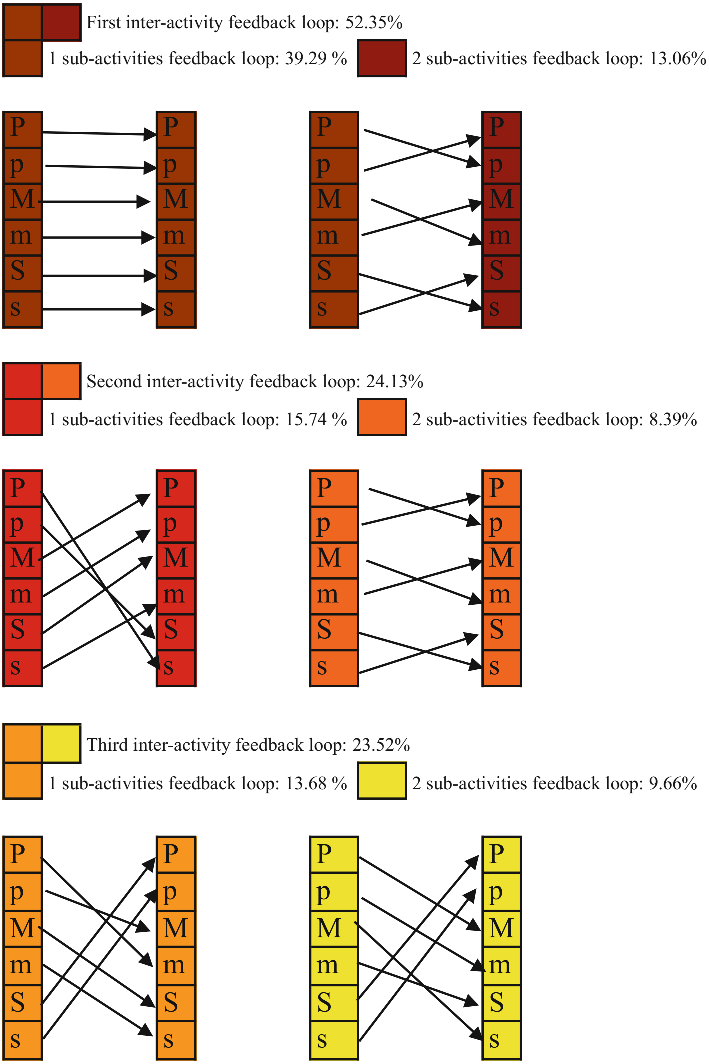


This stable hierarchy is presented in Table 2 for all the time periods and, in greater detail, for Kanto in 1990 in Table 3. Table 3 reveals the intensive intra-activity and sub-activity feedback loops accounting for 52.35 % of all intra-regional trade in these three regions, supplemented by two interactivity loops. It is important to stress that really informative feedback loop analysis of the horizontal specialization of the intra-regional trade should be done on the level of various industries, which is beyond the scope of the present report.

4.3.2 Vertical Specialization of the Japanese Trade, 1980 to 1985 to 1990

The analysis of the vertical specialization of the trade is naturally placed on three hierarchical levels of the spatial economy: *the first level* is the geographical level of different economic regions; *the second level* is the spatial macroeconomic level of interregional primary, secondary, and tertiary economic activities; and the *third level* is the interregional intra-activities, presenting the overall trade between industries belonging to different economic activities. In this paper, the same subdivisions of economic activities used earlier are employed. These three hierarchical levels of loops are connected with the help of the Matryoshka principle: the spatial feedback loops are decomposed into interregional activity loops, which, in turn, are decomposed into the interregional sub-interactivity feedback loops. On each hierarchical level within this hierarchical Matryoshka, the hierarchy of feedback loops is introduced on the basis of the overall intensity (sum) of the trade flowing through the loops.

Table 3 Kanto intra-regional interactivity and sub-activity trade flow, 1990



4.3.3 Spatial Hierarchy of Interregional Feedback Loops

The application of linear programming personnel assignment algorithm (see Sonis et al. 2001) to the tables of interregional trade in Japan, 1980 to 1985 to 1990, is presented with the help of Tables 4, 5, and 6.

The hierarchy of the spatial feedback loops is presented by the sequence of shading in such a way that trade flows in each identified feedback loop are shaded similarly. In these tables, only the two top feedback loops are shown. It is possible

Table 4 The hierarchy of Japan trade feedback loops, 1980

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,146,680	318,410	1,158,246	277,987	458,736	80,589	38,081	78,392	2,330
Tohoku	233,490	12,041,041	3,180,651	413,443	598,430	187,673	72,706	116,773	11,456
Kanto	1,388,647	3,227,078	95,002,696	4,337,311	4,753,871	1,940,187	796,930	2,013,071	119,669
Chubu	340,916	542,824	5,573,457	28,241,323	3,039,244	879,636	319,953	888,213	42,300
Kinki	412,004	720,866	5,396,792	3,194,979	39,077,234	1,841,676	1,115,650	1,657,568	81,378
Chugoku	96,787	185,127	1,767,871	1,134,057	2,047,829	18,557,969	451,872	1,117,130	27,921
Shikoku	44,440	100,565	1,024,520	376,124	930,536	368,914	6,384,438	417,708	12,614
Kyushu	89,199	198,191	1,871,359	836,664	1,297,013	724,675	260,344	18,651,512	90,371
Okinawa	10,247	2,214	128,586	18,431	40,671	59,545	10,594	35,878	1,177,886

Total intra-regional flow	228,280,779	
1 Feedback Loop: (Kanto, Kinki, Chubu) (Hokkaido,Tohoku) (Chugoku, Kyushu) (Shikoku, Okinawa)	15,939,220	23.57%
2 Feedback Loop; (Kanto, Chubu, Kinki) (Hokkaido, Okinawa) (Tohoku,Chugoku,Shikoku, Kyushu)	14,041,368	20.76%
3 Feedback Loop: (Kanto, Tohoku) (Kinki, Chugoku) (Chubu, Kyushu, Okinawa) (Hokkaido, Shikoku)	11,376,770	16.82%
4 Feedback loop; (Kanto, Kyushu) (Kinki, Shikoku) (Chubu, Hokkaido, Chugoku) (Tohoku, Okinawa)	7,499,848	11.09%
5 Feedback Loop; (Kanto,Chugoku) (Kinki, ,Kyushu, Hokkaido),Chubu, Okinawa) (Tohoku, Shikoku)	5,989,054	8.86%
6 Feedback Loop: (Kanto, Hokkaido) (Kinki, Kyushu) (Chubu, Shikoku, Tohoku) (Chugoku, Okinawa)	5,730,881	8.47%
7 Feedback Loop:(Kanto, Okinawa, Kinki, Tohoku, Chugoku< Chubu, Hokkaido, Kyushu, Shikoku)	4,014,157	5.94%
8 Feedback Loop: (Kanto, Shikoku, Kyushu, Chubu, Okinawa) (Kinki, Hokkaido, Chugoku, Tohoku)	3,038,312	4.49%
Total inter-regional flow	67,629,610	100.00%
Total Trade flows	295,910,389	

Table 5 The hierarchy of Japan trade feedback loops, 1985

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,427,904	432,670	1,478,922	330,388	488,801	98,939	40,698	106,349	3,557
Tohoku	362,347	11,992,411	5,029,436	536,249	1,024,791	175,600	59,462	209,198	10,597
Kanto	1,438,437	4,350,926	109,699,122	7,568,097	7,684,095	3,139,547	1,295,037	3,038,009	158,670
Chubu	429,829	902,237	7,112,278	31,054,977	4,438,644	1,004,597	477,845	940,143	61,540
Kinki	517,481	1,150,511	8,492,348	4,016,437	39,602,352	2,449,982	1,225,071	2,150,410	108,962
Chugoku	119,048	264,452	2,628,576	1,330,323	3,068,076	17,533,421	636,403	1,381,461	45,404
Shikoku	35,114	76,059	1,244,184	471,868	1,259,468	432,612	5,725,534	432,043	9,644
Kyushu	86,788	225,392	2,815,103	963,947	1,836,171	933,550	322,671	18,906,350	115,990
Okinawa	1,347	5,341	113,682	22,289	53,746	28,685	13,192	63,417	1,278,296

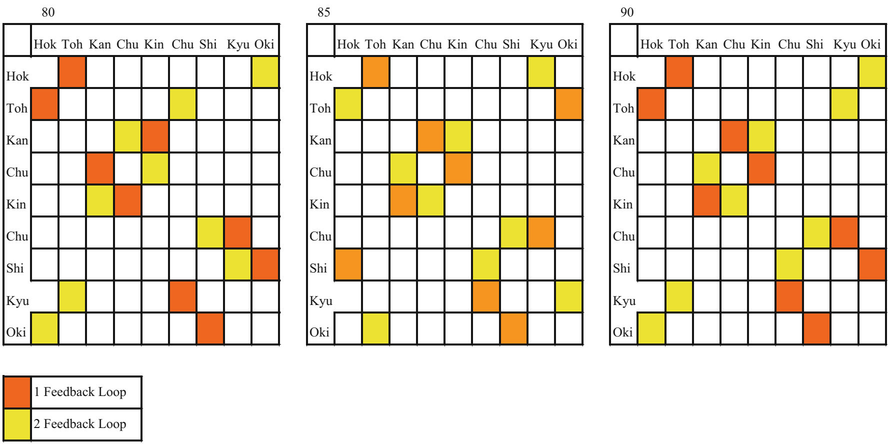
Intra-regional flows	245,220,367	
1 Feedback Loop: (Kanto,Chubu,Kinki) (Hokkaido,Tohoku, Okinawa, Shikoku) (Chugoku,Kyushu)	23,305,673	24.38%
2 Feedback Loop: (Kanto,Kinki,Chubu) (Hokkaido,Kyushu, Okinawa, Tohoku) (Chugoku, Shukoku)	20,471,852	21.42%
3 Feedback Loop: (Kanto, Tohoku) (Kinki, Chugoku) (Chubu,Kyushu) (Hokkaido,Shikoku, Okinawa)	16,854,199	17.63%
4 Feedback Loop: (Kanto, Chugoku,, Chubu, Hokkaido, Okinawa, Kinki, Kyushu) (Tohoku, Shikoku)	10,058,036	10.52%
5 Feedback Loop: (Kanto, Hokkaido) (Kinki, Tohoku) (Chubu, Chugoku, Okinawa) (Shikoku, Kyushu)	6,919,665	7.24%
6 Feedback Loop: (Kanto, Okinawa, Chugoku, Hokkaido, Chubu, Tohoku, Kyushu, Kinki, Shikoku)	6,053,652	6.33%
7 Feedback Loop: (Kanto, Kyushu, Hokkaido, Chugoku, Tohoku, Chubu, Shikoku, Kinki, Okinawa)	5,984,394	6.26%
8 Feedback Loop: (Kanto, Shikoku, Chubu, Okinawa, Kyushu, Tohoku, Chugoku) (Kinki, Hokkaido)	5,927,712	6.20%
Total Inter-regional flows	95,575,183	100.00%
Total Trade flows	340,795,550	

Table 6 The hierarchy of Japan trade feedback loops, 1990

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,998,163	430,812	1,776,470	371,324	477,711	128,120	58,052	153,149	7,550
Tohoku	406,671	13,778,391	5,910,538	795,140	1,046,758	332,722	109,854	299,941	22,690
Kanto	1,900,456	5,493,008	142,178,803	9,782,012	8,011,189	3,568,744	1,537,155	4,225,170	263,264
Chubu	516,919	1,249,460	9,485,123	38,666,020	4,595,327	1,582,695	467,947	1,229,819	54,791
Kinki	521,374	1,203,332	9,742,547	5,336,958	52,676,087	2,770,243	1,261,139	2,344,171	119,643
Chugoku	135,901	408,563	3,648,986	1,549,948	3,065,274	18,058,145	754,272	1,506,565	45,932
Shikoku	45,202	153,240	1,506,836	551,626	1,228,188	558,504	6,347,276	307,161	16,938
Kyushu	132,234	311,542	3,662,138	1,174,198	1,943,081	1,353,305	383,885	20,981,279	125,791
Okinawa	2,127	7,748	137,506	23,659	46,371	27,002	15,744	66,397	1,318,935

Total intra-regional flow	304,003,099	
1 Feedback Loop: (Kanto,Chubu, Kinki) (Hokkaido,Tohoku) (Chugoku, Kyushu) (Shikoku, Okinawa)	27,849,921	24.33%
2 Feedback Loop; (Kanto, Kinki, Chubu) (Hokkaido, Okinawa) (Chugoku, Shikoku) (Tohoku, Kyushu)	24,767,206	21.63%
3 Feedback Loop: (Kanto, Tohoku) (Kinki, Chugoku) (Chubu, Kyushu, Okinawa) (Hokkaido, Shikoku)	18,721,586	16.35%
4 Feedback loop; (Kanto, Kyushu) (Kinki, Shikoku) (Chubu, Chugoku, Hokkaido) (Tohoku, Okinawa)	12,496,993	10.92%
5 Feedback Loop; (Kanto,Chugoku) (Kinki, Okinawa,Kyushu, Hokkaido) (Chubu, Tohoku, Shikoku)	9,924,655	8.67%
6 Feedback Loop: (Kanto, Hokkaido) (Kinki, Kyushu) (Chubu, Shikoku, Tohoku) (Chugoku, Okinawa)	9,453,439	8.26%
7 Feedback Loop:(Kanto, Okinawa, Kinki, Tohoku, Chugoku< Chubu, Hokkaido, Kyushu, Shikoku)	5,956,426	5.20%
8 Feedback Loop: (Kanto, Shikoku, Kyushu, Chubu, Okinawa) (Kinki, Hokkaido, Chugoku, Tohoku)	5,315,626	4.64%
Total inter-regional flow	114,485,852	100.00%
Total Trade flows	418,488,951	

Table 7 Qualitative description of the two largest feedback interregional loops, 1980–1985–1990



to see that the spatial hierarchy of trade flows is very similar and the intensities of feedback loops diminish at the same rate. Note the similarity between the two first largest feedback loops: each of them, in each time period 1980 to 1985 to 1990, includes the very intensive triad of three central economic regions, Kanto, Chubu, and Kinki, supplemented by bilateral dyads of feedback between other regions. Moreover, the first and second interregional loops are almost symmetrical, and this symmetry is complete in the period 1990 (see Table 7).

The meaning of this growing spatial symmetry is that there is a tendency toward the intensive bilateral trade relationships between regions. In the midst of this bilateral trade, the triads (Kanto, Chubu, and Kinki and Kanto, Kinki, and Chubu) are emerging.

The prominence of these two triads has already been stressed in the recent literature. Ihara (1999) concludes that "about 66.1 % of total number of the total Japanese population are found in the Kanto, Kinki and Chubu regions, and the same three regions' product amount to 72.9 % of the total value of national products. In other words, these regions have already formed a megalopolis in Japan." Moreover, Ihara noted the essential difference between the economic intensities of flows in the triads (Kanto, Chubu, and Kinki and Kanto, Kinki, and Chubu): "... the indirect input-inducing effect derived from Chubu to Kinki via Kanto turned out to be relatively smaller than that derived from Kanto to Kinki via Chubu ... ." Further, in the special research devoted to evaluation of the role of the Kanto region in the growth of Japanese regional economies, Akita (1999) provided an extended growth-factor decomposition method based on a three-region interregional system.

Table 8 represents the qualitative characterization of vertical specialization of these three regions included in the first spatial feedback loop. The functional economic content of this feedback loop is presented in Table 9.

Revealed here is a hierarchy of three interactivity feedback loops, each of which includes two sub-activity loops. Within the first interactivity feedback loop, the most prominent is (1) the sub-activity feedback loop which includes the trade flows not

Table 8 Qualitative characterization of the vertical specialization feedback loop for the triad (Kanto-Chubu-Kinki) from the first interregional interactivity feedback loop, 1990

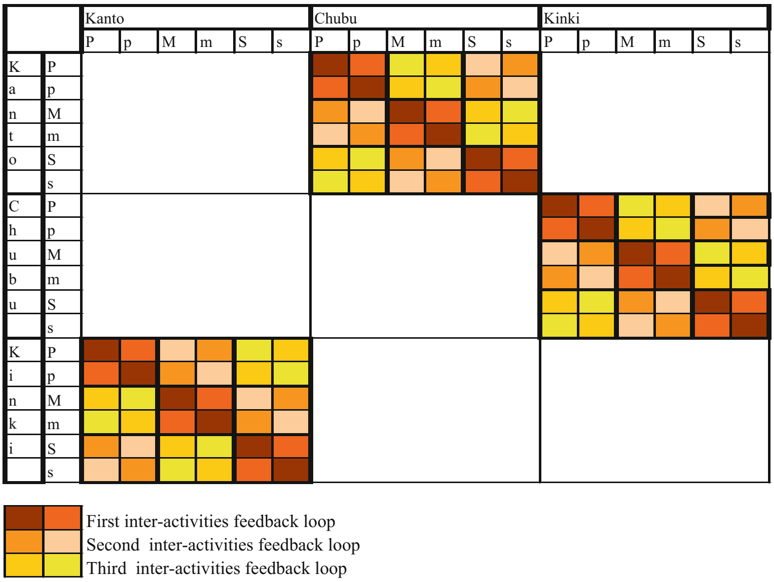
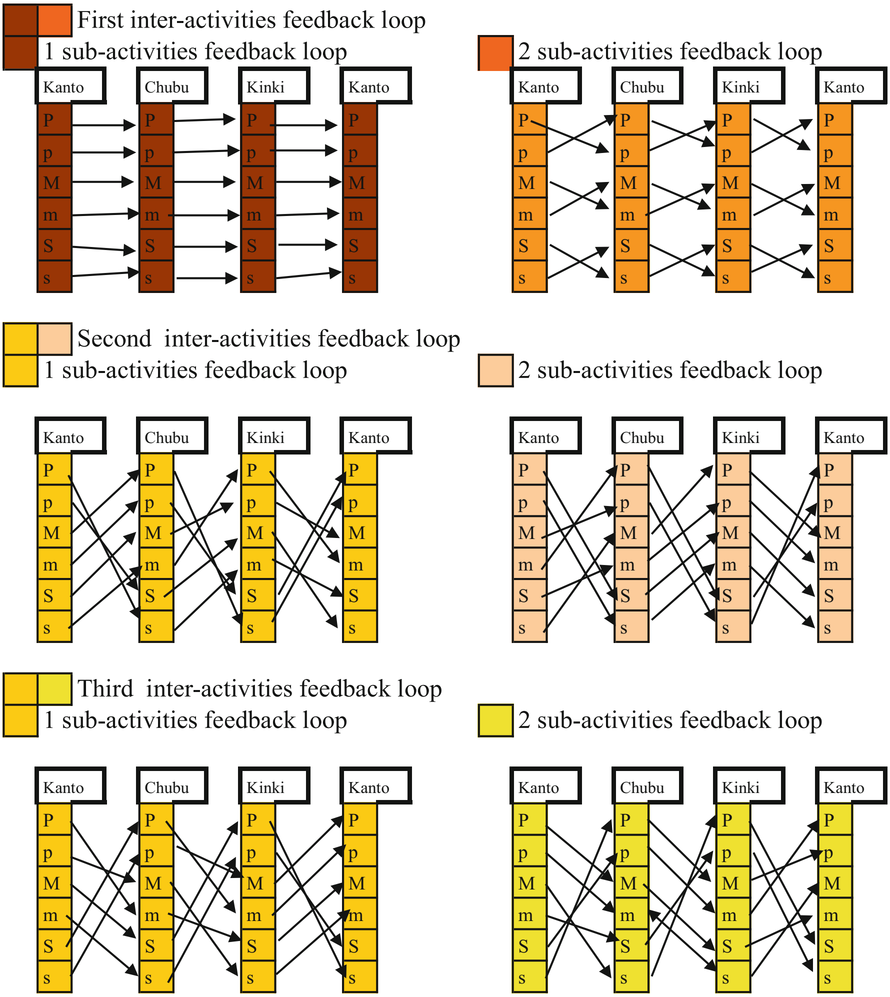


Table 9 Total interregional interactivity and sub-activity feedback loop structure for Kanto-Chubu-Kinki, 1990

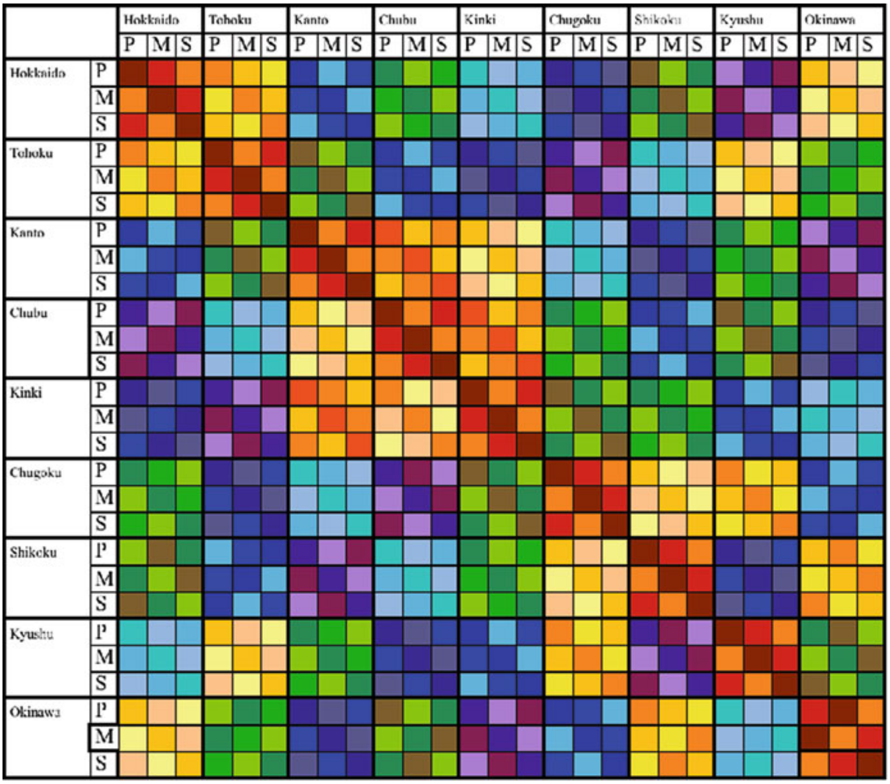


abandoning the sub-activity and (2) the sub-activity loop which flows between sub-activities within the activity; the second and third interactivity loops present the more complicated flow structure between the sub-activities.

4.3.4 Activity and Sub-activity Feedback Loop Analysis

The fine structure of the interregional economic activity and sub-activity feedback loops can be extracted from Tables 10 and 11 presenting these loops in myriad of details.

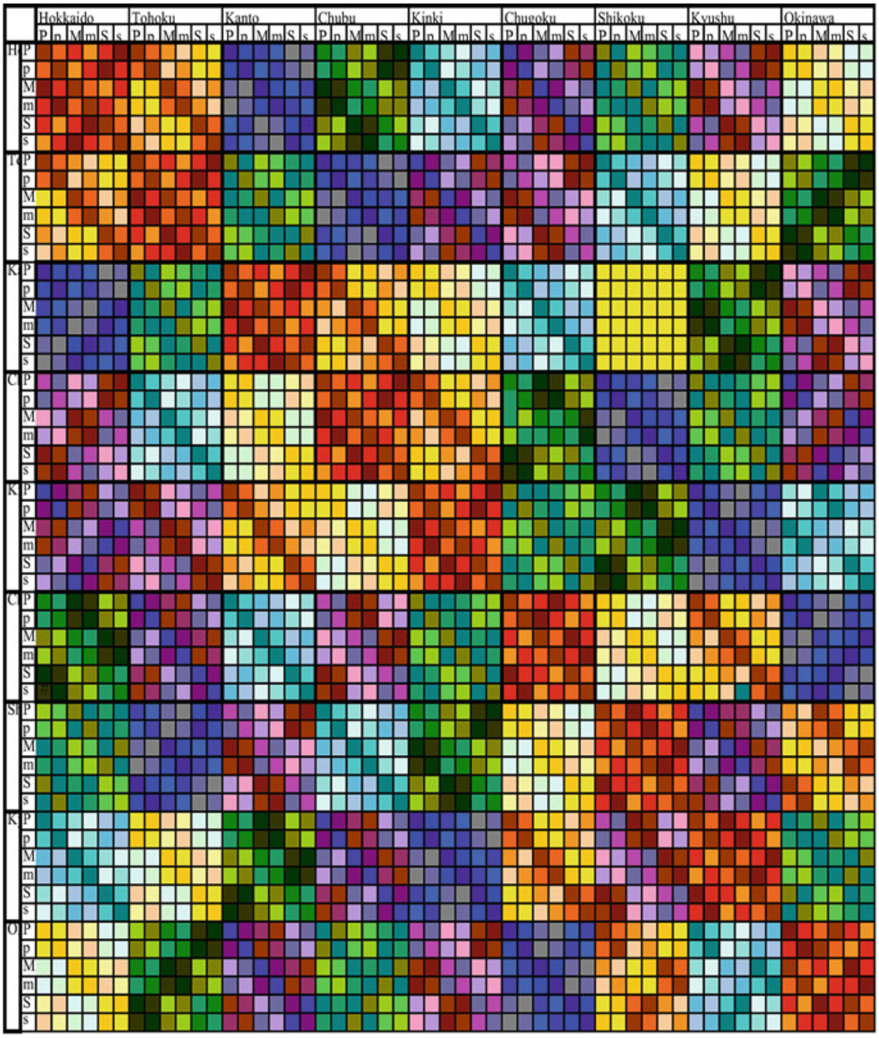
Table 10 Qualitative presentation of the interactivity feedback loops, 1990



These two tables are constructed according to the analytical and visualization procedures described earlier. Analogously, all sets of the feedback loops can be visualized, presenting the hierarchy of interregional economic activity feedbacks. In the same manner as in Tables 8 and 9, the hierarchy of interregional economic activity-sub-activity feedbacks loops can be presented (Table 8 contains only the triad of regions included in the first interregional activity-sub-activity loop).

The findings and interpretations here can now be considered in the context of the parallel analysis noted earlier that explored a factor decomposition of growth in the Japanese regional economies over the same time period (Hitomi et al. 2000). In this decomposition analysis, attention was focused on the role of international trade, technological change, and interregional trade in generating changes in the levels of output in each region. Given the role of the Kanto region in the hierarchy of feedback loops, it should not be surprising to learn that about 50 % of growth in Japan could be accounted for by the change in all factors occurring in Kanto. The dependency on the Kanto economy increased slightly from 48.7 % in 1980–1985 to 49.9 % in 1985–1990. For almost all regions, over 45 % of regional output growth can be ascribed to changes in Kanto during 1980–1985. This dependency decreased

Table 11 Trade flows of Japan, 1990



Hierarchy of interregional activity feedback loops

slightly in 1985–1990, but it is still relatively high. For example, during this period, 38 % of output growth in Chugoku and 36 % of output growth in Tohoku depend on changes in Kanto. Over these same time periods, technological changes, in contrast, played a much less role. Thus, the circulation implied in the feedback loops contains important economic signals that generate growth; the strengthening of interregional at the expense of intra-regional flows between 1980 and 1985 reflects a continuation of a hollowing-out phenomenon that has been observed at many spatial scales (see Hewings et al. 1998; Sonis et al. 1993), although there was a slight reversal between

1985 and 1990. As Hitomi et al. (2000) noted, it will be important to analyze change in the regional economies after 1990, after the end of the so-called bubble economy and Japan's entry into a period of serious recession.

The case study of Japan suggests the following simplified scheme in the emergence of the rank-size network hierarchy of feedback loops. In the two regions' context, the historical evolution of bilateral trade was characterized by asymmetric flows – with the direction of flows reflecting, in large part, regional comparative advantages and the character of flows being interindustry, reflecting a value chain of production that was relatively simple. As the structure of national economy became more complex, bilateral flows were complimented by increasing multilateral exchanges and thus to the emergence of a hierarchy of multilateral feedback loops. Further, the exchanges would come to be dominated by intra-industry rather than interindustry flows, reflecting the emergence of trends toward equalization of regional per capita incomes and the consequent demands for greater production variety. What happens next remains uncertain: will the growth of global trade and the pressures for greater economic efficiency lead back to bilateral exchanges dominating as a result of the disaggregation of the large multilateral loops into smaller dyadic and even triadic exchange?

The notion of trading blocks within nations (i.e., at regional level) requires a different qualitative interpretation than similar grouping at the international level. In most countries, like Japan and the USA, regions have severely limited abilities to introduce tariff or even nontariff instruments to gain economic power, and with ownership of plants increasingly dominated by multiregional and multinational organizations, the structure of exchange responds to difference of economic incentives.

It is important to note that consideration of feedback loops in trade theory is a relatively new approach to the detailed analysis of vertical specialization of trade flows. This approach leads the decomposition of global trade into feedback loops. Thus, the analytical technique of block-permutation matrices and the decomposition of trade into feedback loops can be utilized in trade theory (in the form of the Koopmans-Beckmann linear programming personnel assignment algorithm). Furthermore, the spatial and functional economic disaggregations of the trade offer the opportunity to apply the Matryoshka principle of hierarchical inclusion of economic activity flows into the spatial trade loops. The essential consequence of the decomposition of the overall matrix trade flow into the sum of block-permutation matrices of feedback loops is the possibility to visualize the trade feedback loops with the help of shadowing of different feedback loops. This visualization represents in fine detail the rich information about spatial and economic interdependencies within interregional trade at different levels of aggregation. In such a manner, the trade tables can be converted into shadowed spatial and functional maps of the hierarchy of trade feedback loops.

Two further developments need to be explored. Firstly, attention has to be directed to more detailed sectoral analysis to explore the role of *intra-industry* vis-à-vis *interindustry* trade (see Munroe et al. 2007). Secondly, there needs to be a formal link between international and interregional feedback loop analysis to trace the way in which international exchange signals ripple across the internal space of individual countries. Furthermore, with regional economies in countries like Japan and the USA moving toward greater uniformity in levels of welfare, the issue of trading blocks and welfare implications that is a prominent feature of debate at the international level assumes far less importance (see Spilimbergo and Stein 1998).

5 Summary

In attempting to summarize the findings of this exercise, the main results point to significant communalities in the nature of structural change at the regional level in Japan. However, while there are striking similarities in structure and structural change, it is not altogether apparent that the processes of structural change have been shared. While Japan has certainly experienced a hollow out of the economy, the spatial exchange has been different from the US regional experience. Firstly, in Japan, interregional dependence has certainly increased, but overall, external dependence for any one region has increased with international trade assuming an important role. Secondly, dependence in Japan is still heavily focused on the Kanto region; if anything, this dependence has even increased over time.

In contrast, in the USA, interregional dependence has definitely increased; however, the patterns of trade are not as concentrated or as heavily focused on one region (see Lee and Hewings 2016). There are several reasons why one might expect interregional trading patterns to differ. Firstly, the domestic US economy is so much larger; hence, there is a natural tendency for firms to orient production and location decisions with reference to this dominant domestic "pull" factor. Secondly, the significant, four-decade-long investment in interstate highways coupled with the deregulation of much of the transportation industry beginning in the 1980s has resulted in a downward pressure on transportation prices.

As a result, firms have optimized production among establishments in ways that are very different from the 1960s and 1970s. A stylized view is presented in Fig. 7; in the earlier periods, production was oriented far more to not only domestic markets

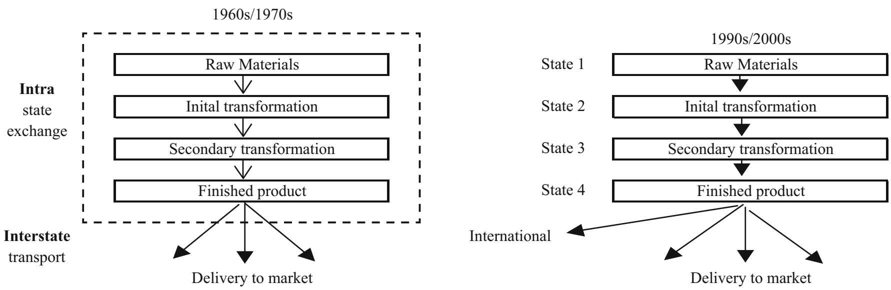


Fig. 7 Spatial organization of production, 1960s–2000s

but also regional (state) markets. Accordingly, a large percentage of the commodity chain of production took place within relatively small geographical areas. Over time, decrease in transportation costs coupled with consumer demand for greater product variety has led to a reorganization of firm production across establishments. Instead of trying to realize economies of both scale and scope within one establishment, firms have opted to specialize within establishments to yield scale economies and trade across state lines. Thus, the commodity chain of production is now spatially more sophisticated, with components moving across several states prior to resting within a final product. The two prominent effects from this process have been a significant increase in interstate trade and a concomitant decline in intra-regional interaction.

One of the more important implications for this process is the greater degree of integration it brings to regional economies. No longer can we anticipate huge disparities in the responses of regions to business cycles (see Hayashida and Hewings (2009) for Japan and Park and Hewings (2012) for the USA); the differences that remain will reflect the variations in demand for niche productions within broad, aggregated sectoral entities rather than differences across sectors. However, the findings thus far have generated more questions than answers – not surprisingly given the exploratory nature of the research effort and the considerable investment that has had to have been made in model development and calibration. The stage is now set for some continuing research activities; some of these are briefly described in the final section.

6 Continuing Research

The research began with a review of the Simpson and Tsukui (1965) analysis; however, all the data have not yet been assembled and analyzed in a way that the following question can be answered:

Is there a common "structure of production" across regions and across advanced countries?

One suspects that the general tendencies observed at the national level probably carry through to the regional level. However, of greater interest is the organization of production across regions in the sense of how an individual region is placed in commodity chains of production – does it serve a key or strategic role, or does it offer little challenge to existing linkages? In a sense, answers to this question will inform the discussion on the second problem.

How varied is the structure of trade?

The evidence assembled this far suggests that it is here that there are likely to be significant variations across regions and across countries. Little has been said thus far about the role of institutions; there is little proactive regional development policy or programming in the USA in strong contrast to the implicit and explicit policies enacted in Japan and many European Union economies. The role of these market distortions or corrections (depending on one's perspective about the visible or invisible hand) has not been fully explored. The issue is further complicated by the presence of tariff and nontariff barriers imposed on international trade. Hence, a further question that could be posed is:

What is the role of increases in international versus interregional trade on regional economies
In answering this question, as the Japanese work has elegantly revealed, one must distinguish between direct effects and indirect effects. For example, for many states, international trade may account for less than 10 % of total trade; however, much of the interregional trade may end up as part of a commodity chain that ends up in exports. These nuances need to be explored and highlighted.

Finally, on trade, there needs to be a careful evaluation of the role that organizations like the WTO and major trading partners have on the patterns of trade and the structure of regional economies. In conducting future research, analysts can now access a rich comparative data set that has been assembled (e.g., WIOD); the possibilities of focusing attention on the increasing importance of interregional/international trade (i.e., trade between regions in different countries) offers the potential for discovering the heterogeneous intra-national welfare effects of bilateral and multilateral international trade agreements.

References

Akita T (1999) The role of the Kanto Region in the growth of Japanese regional economies 1965–1985: an extended growth-factor decomposition analysis. In: Hewings GJD, Sonis M, Madden M, Kimura Y (eds) Understanding and interpreting economic structure. Springer, Berlin/New York/London/Tokyo, pp 155–166
Balassa B (1967) Trade liberalization among industrial countries. McGraw Hill, New York
Brülhart M, Hine RC (eds) (1999) Intra-industry trade and adjustment: the European experience. Macmillan Press, London
Chenery HB, Watanabe T (1958) International comparisons of the structure of production. Econometrica 26:487–521
Fujita M, Krugman P, Venables AR (1999) The space economy. University Press, Cambridge
Hayashida M, Hewings GJD (2009) Regional business cycles in Japan. Int Reg Sci Rev 32:110–147
Hewings GJD, Jensen RC (1986) Regional, interregional and multiregional input-output analysis. In: Nijkamp P, Mills ES (eds) Handbook of urban and regional economics, vol I. North-Holland, Amsterdam
Hewings GJD, Sonis M, Guo J, Israilevich PR, Schindler GR (1998) The hollowing out process in the Chicago economy, 1975–2015. Geogr Anal 30:217–233
Hirschman A (1958) The strategy of economic development. Yale University Press, New Haven
Hitomi K, Okuyama Y, Hewings GJD, Sonis M (2000) The role of interregional trade in generating change in the interregional Leontief inverse in Japan, 1980–1990. Econ Syst Res 12:515–537
Hummels D, Rapoport D, Yi K-M (1998) Vertical specialization and the changing nature of world trade. Econ Policy Rev (Federal Reserve Bank of New York), June, 79–97
Israilevich PR, Hewings GJD, Sonis M, Schindler GR (1997) Forecasting structural change with a regional econometric input-output model. J Reg Sci 37:565–590

Jensen RC, West GR, Hewings GJD (1988) The study of regional economic structure using input-output tables. Reg Stud 22:209–220

Jensen RC, Dewhurst JHLL, West GR, Hewings GJD (1991) On the concept of fundamental economic structure. In: Dewhurst JJLL, Hewings GJD, Jensen RC (eds) Regional input-output modelling: new developments and interpretations. Avebury, Aldershot

Krugman PR (1990) Rethinking international trade. MIT Press, Cambridge, MA

Lee J-S, Hewings GJD (2016) Exploring the spatial connectivity of U.S. States, 1993–2007. In: Batabayal A, Nijkamp P (eds) The region and trade: new analytical directions .World Scientific, pp 91–136

Munroe DK, Hewings GJD, Guo D (2007) The role of intraindustry trade in interregional trade in the Midwest of the US. In: Cooper RJ, Donaghy KP, Hewings GJD (eds) Globalization and regional economic modeling. Springer, Heidelberg

Okawzaki F (1989) The 'hollowing out' phenomenon in economic development. Paper presented at the Pacific Regional Science conference, Singapore

Park Y, Hewings GJD (2012) Does industry mix matter in regional business cycles? Stud Reg Sci 42:39–60

Rasmussen P (1956) Studies in inter-sectoral relations. Einar Harks, Copenhagen

Simpson D, Tsukui J (1965) The fundamental structure of input-output tables: an international comparison. Rev Econ Stat 47:434–446

Sonis M (1982) The inverted problem of multiobjective programming. In: Chiotis GP, Tsoukalas DA, Louri HD (eds) The region and the enlargement of the European economic community. Athens School of Economics and Business Science, Athens

Sonis M, Hewings GJD (1990) The 'Matrioshka Principle' in the hierarchical decomposition of multiregional social accounting systems. In: Anselin L, Madden M (eds) New directions in regional analysis: integrated and multiregional approaches. Pion, London

Sonis M, Hewings GJD (2001) Feedbacks in input-output systems: impacts, loops and hierarchies. In: Lahr M, Dietzenbacher E (eds) Input-output analysis: frontiers and extensions. Palgrave, London

Sonis M, Oosterhaven J, Hewings GJD (1993) Spatial economic structure and structural changes in the European Common Market: feedback loop input-output analysis. Econ Syst Res 5:173–184

Sonis M, Hewings GJD, Lee JK (1994) Interpreting spatial economic structure and spatial multipliers: three perspectives. Geogr Anal 26:124–151

Sonis M, Guilhoto JJM, Hewings GJD (1995) The Asian economy: trade structure interpreted by feedback loop analysis. J Appl Input-Output Anal 2:24–40

Sonis M, Hewings GJD, Okuyama Y, Guo J (1996) Japanese regional economic structure interpreted through the multiplier product matrix. Stud Reg Sci 26:1–20

Sonis M, Guo J, Hewings GJD, Hulu E (1997) Interpreting spatial economic structure: feedback loops in the Indonesian economy, 1980, 1985. Reg Sci Urban Econ 27:325–342

Sonis M, Hewings GJD, Okuyama Y (2000) Vertical specialization and interregional trade: turbulence analogy and feedback loops analysis of the Midwest economy. In: Herrmann H, Bröcker J (eds) Spatial change and interregional flows in the integrating Europe. Physica-Verlag, Heidelberg

Sonis M, Okuyama Y, Hewings GJD (2001) Feedback loops analysis of interregional trade: case study of the japanese economy, 1980-85-90. J Econ Geogr 1:341–362

Spilimbergo A, Stein E (1998) The welfare implications of trading blocks among countries with different welfare endowments. In: Frankel JA (ed) The regionalization of the world economy. University of Chicago Press, Chicago

Rural and Agriculture Development in Regional Science

Lily Kiminami and Akira Kiminami

Abstract This paper discussed the trends and the outlook of the study of rural and agriculture development in regional science. Firstly, the relationships between regional science, area study, and regional economic development are clarified. Secondly, the definition, purpose, and approach of rural and agriculture development are described. Thirdly, the analytical approaches toward rural and agriculture development issues are introduced with some comments on the roles of entrepreneurs and knowledge creation in innovation. Fourthly, the pioneering studies in rural and agriculture development in Japan based on regional science and their development to new theories are evaluated. Finally, the theoretical framework of a new approach of strategic development for regional agriculture is introduced by combing synthetically conventional urban planning, community development, strategic marketing planning, and industrial cluster strategy based on collaborative advantage. In addition, future prospects in rural and agriculture development studies are recommended such as the issues of regional heterogeneity, rural-urban partnerships, creating more effective models for rural and agriculture development, perceived agriculture and rural areas, etc. Furtherly, the cognitive changes toward agriculture and rural area from regarding them as an ailing industry and a conservative and closed society to a growth industry and an open "space" to create knowledge and innovation are thought to be urgent in Asia.

Keywords Rural and agriculture development • Regional science • Globalization • Rural-urban partnership • Innovation

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1 Introduction

In discussing trends and the outlook of the study of rural and agriculture development in regional science, it would be beneficial, first, to outline the relationships between regional science, area study, and regional economic development. According to Kohno and Higano (1980), regional science is an "extremely transformative academic discipline which aims mainly to clarify regional issues through interdisciplinary collaboration and cooperation between many areas such as modern economics, engineering, economic geography, social science and public administration study from their own specialist perspective." In contrast, according to Tsubouchi (1999), area study is characterized by (1) the fusion of studies of humanities and social science and (2) interregional comparison. Regional economic development is, according to Stimson et al. (2006), "the use of economic processes and available resources in the region to bring sustained development to the region and desirable economic results, and to meet the concept of the values and expectations of the economic operators and residents as well as visitors." Having outlined the characteristics and mutual relationships of the three academic disciplines, regional science, generally speaking, focuses on an understanding of the issues by theorizing and quantifying them to formulate a policy with a view to solve regional problems. In terms of the direction of studies, the characteristic is oriented toward the refinement and integration of methodologies. In contrast, area study focuses on the clarification of varied mechanisms in the development process in a particular area and, further, the characteristic property of regional issues while actively recognizing the differences in the historical, cultural, and natural conditions of the area. On the other hand, regional economic development study is characterized in attempting to capture the dynamism of regional development because regional issues and their characteristics change following the development of the region. Although regional economic development is multifaceted, the essence of the problem lies in the geography of welfare and its evolution in the region (Nijkamp and Abreu 2009; Capello and Nijkamp 2011).

For the purpose of this paper, we define regional development study as the clarification of regional issues and their mechanisms and a quest for policies for solutions from a global perspective. In addition, this study positions rural and agriculture development study as one of the applied areas of regional development study; however, this does not mean a simple substitution of "regional" with "rural and agriculture." This is because rural and agriculture development study is expected to solve the issue of clarifying diversity and universality which is essentially combined in regional development study, while rural and agriculture development issues are heavily related to natural resources in the region such as ecological systems, society, and culture. Therefore, rural and agriculture development study combines two aspects of (1) the clarification of local issues by approaches that are often taken in area study and (2) the refinement and theorization of analytical methods and the pursuit of measures to solve issues by approaches that are often taken in regional science.

2 Definition, Purpose, and Approach of Rural and Agriculture Development

While rural and agriculture development literally concerns issues of development within a geographical region of an "agricultural community," it also concerns issues of developing "agriculture" as an industry. Therefore, it is natural to seek theoretical underpinning of rural and agricultural development in development economics. However, despite the fact that the neoclassical theory of economic growth faced its limit and split into several directions, it is a prevalent notion in development economics that there are areas in economic development that consist of multiple dimensions. Namely, there is the dimension of "quantity and quality" in economic development first of all. The quantitative aspect includes increase in wealth, increase in the income level, and availability of assets or services. The qualitative aspect includes the realization of social welfare, creation of employment opportunities, sustainable development, and improvement in quality of life (QOL). Another dimension in economic development is "product and process." The product aspect is about producing the result to meet the aforementioned quantitative and qualitative elements, and the process aspect includes policies, plans, analysis, strategy, and resource use to achieve the desired results (Stimson et al. 2006). Therefore, regional economic development can also be treated as an issue of regional economic development with "quantity and quality" and "product and process" dimensions.

In other words, rural and agriculture development is the study of issues in the development of the "agriculture" sector and of issues in the development of "rural" areas as geographical, social, and economic space. However, agriculture development has been dealt with to modernize agriculture with the goal of productivity improvement in agriculture in developed countries, which is then implemented in developing countries via technology transfer; thus, agriculture development issues have traditionally been regarded as development issues of agriculture in developing countries (World Bank 2008). With the increased interest in sustainable agriculture and the development of resources, the areas covered by agriculture development are expanding into environmental conservation and the stabilization and invigoration of communal society, and securing sustainability is becoming a prerequisite for agricultural development. Therefore, rural and agriculture development issues concern three overlapping areas of industry policy, regional policy, and resources and environmental policy. In terms of rural and agriculture development today, geographical spatial links are strengthening as well as widening in the issues covered; thus, it is beneficial to understand issues based on the framework of sustainability. In other words, the areas covered by rural and agriculture development exist with overlapping issues of agriculture and food, resources, and the environment and regional issues. Furthermore, as globalization is rapidly reaching and penetrating even agricultural communities in developing countries, it is necessary to readdress rural and agriculture development, which has been an issue at a local level, from a global perspective (Kiminami 2009a).

Needless to say that the issue of rural and agriculture development in developed countries cannot be ignored, but the issue of rural and agriculture development in developing countries is one of the global issues that remain in the twenty-first century, and efforts should be made to identify a successful strategy that has universal quality in rural and agriculture development. Above all, existing agriculture development theory attaches too much weight to the development of agriculture that emphasizes the cultural and regional particularity of agriculture without attention to the development of agriculture as an industry (agro-industry). In addition, existing rural and agriculture development theories adopted regional economic development models (such as exogenous development, endogenous development, and a mix of exogenous and endogenous development) without any changes, or issues were discussed in isolation from regional economic development (such as rural sociology, agricultural history, rural finance, and rural planning); therefore, affinity with other areas of agronomics (such as farm management) has been low. However, as seen in Desai et al. (2011), the recognition of the role played by entrepreneurship in regional economic development and the increased interest in the study of the functions and behavior of economic entities such as entrepreneurs indicate the need for collaboration with management studies on economic entities in agriculture and agricultural communities.

3 Regional Science and Rural and Agriculture Paradigm

3.1 Shift in Reference Framework

In proceeding with the survey of rural and agriculture development study in regional science, the following perspectives are given importance. The first is the analytical approach toward rural and agriculture development issues. That is to draw attention in rural and agriculture development studies in regional science to which models they are reliant on, how each model attempts to clarify the elements and actual conditions on which the model places emphasis, and how the economic environment that surrounds agriculture and rural communities is captured. Irwin et al. (2010) think that an issue of a trade-off among scale, transport costs, and endowments in the economic location exists at the basis of regional economic issues and that its essence lies in (1) imperfect factor mobility, (2) imperfect divisibility, and (3) imperfect mobility of goods and services. Therefore, theoretically speaking, the regional science approach to rural and agriculture development can be regarded as how to apply the way of thinking regarding regional economic issues to agricultural communities. For example, regional input-output analysis is a commonly used analytical method in rural development studies in the USA, and its contribution is significant in its application, such as in the assessment of regional economic policy. However, there are also opinions that consider regional input-output analysis to be problematic as it does not sufficiently reflect the essence of the regional economic issues as above.

On the other hand, Terluin (2003) categorized recent rural development theories into three groups of (1) exogenous development, (2) endogenous development, and (3) mixed exogenous/endogenous development and outlined the relationships with regional economic growth theories. Namely, there are four types of regional economic growth theories: (1) traditional models, (2) pure agglomeration models, (3) local milieu models, and (4) territorial innovation models, and the relationships with rural development theories are shown in Table 1.

Of these types, the regional economic growth theories that rely on the regional innovation model are making rapid advancement. In terms of the theoretical aspect, theories are being developed with more attention to the roles of entrepreneurs and knowledge creation in innovation, and in terms of the empirical aspect, analyses are being made using the substitute variable of innovation and entrepreneurship, and the models need to be adjusted based on the results (Kourtit et al. 2011). At least, according to recent theories that innovations in a region are defined by expressions of entrepreneurship, the production function to be assumed in the regional economy should be the aggregation of the production functions of individual entities, instead of production functions based on aggregates. In that case, innovation is the function of entrepreneurship, in formulation (1) as follows:

$$Y = \sum fi\,(I(E),\ LM,\ L,\ K) \tag{1}$$

Y: Income or yield
L: Labor
K: Capital
LM: Local milieu (space, human capital, technology, network, trust, culture, policy)
I: Innovation
E: Entrepreneurship
i: Individual economic entity

The second is the relationship between the current status and the changes in agriculture and agricultural communities. According to existing notions of agriculture and rural communities, agriculture is a traditional and occupational industry that is supported by small family-run operations, and agricultural communities refer to the areas where agriculture is carried out, and the rural economy heavily relies on agriculture. Then the Japanese agriculture and agricultural communities experienced the issues of relative stagnation during the post-war period toward the high economic growth period. However, such notions are not appropriate when referring to different eras or regions, especially in rural and agriculture development in developed countries including the EU today. The socioeconomic reality of agriculture and rural communities has undergone significant changes, and

Table 1 Classification of theories in the rural development and regional economic growth

Approach of rural development studies	Model of regional economic growth	Production function	Theories
Traditional approach	Traditional models	$Y = f(L,K)$	Neoclassical growth theory
			Keynesian approach: export-base theory
Exogenous development	Pure agglomeration	$Y = f(AE,L,K)$	Cumulative causation theories
			Growth pole theories
			New economic geography (NEG) theories
Endogenous development approach	Local milieu models	$Y = f(LM,L,K)$	Endogenous growth models
Community-led rural development theory			Theories based on changes in the organization of labor
Bryden's theory on immobile resources			
Mixed exogenous/endogenous development approach	Territorial innovation models	$Y = f(I,LM,L,K)$	Incubator theories
			Product life cycles
			Theory of the innovative milieu
			Porter's theory on the competitive advantage of nations
			Illeris' inductive theory of regional development
			Storper's theory on the region as a nexus of untraded interdependencies

Source: Terluin (2003) p. 330, p. 333

Y income or yield, *L* labor, *K* capital, *AE* agglomeration effects (external economy and economy of scale), *LM* local milieu (space, human capital, technology, network, trust, culture, policy), *I* innovation

Table 2 The new rural paradigm

	Old approach	New approach
Objectives	Equalization, farm income, farm competitiveness	Competitiveness of rural areas, valorization of local assets, exploitation of unused resources
Key target sector	Agriculture	Various sectors of rural economies (e.g., rural tourism, manufacturing, ICT industry, etc.)
Main tools	Subsidies	Investments
Key actors	National governments, farmers	All levels of government (supranational, national, regional, and local), various local stakeholders (public, private, NGOs)

Source: OECD (2006b) p. 15

economic dependency on sectors other than agriculture has increased in rural areas following the sharp decrease in the number of farmers. In the USA, too, changes are observed, such as the elimination of disparity in income levels between urban and rural areas, a decrease in the farming population, the diversification of the rural economy, manufacturing industries being established in agricultural communities, and increased reliance on industries other than agriculture for farmers' income (Irwin et al. 2010).

Furthermore, due to the changes in the rural economy, the "new rural paradigm" (OECD 2006b), which forms the foundation in rural and agriculture development policies in developed countries today, is based on the recognition that existing rural and agricultural development policies have difficulties in driving comprehensive rural development in terms of policy content and governance (see Table 2). The Paradigm therefore seeks diversions from existing approaches. More specifically, rural and agriculture development today aims to improve the competitiveness of rural areas and to utilize unused resources through the appropriate assessment of the resources in the region. It targets various sectors in the rural economy, and the government and stakeholders at various levels implement measures by mainly using the development method of investment. Based on the above, rural and agriculture development studies in regional science today are being asked whether an appropriate analytical framework is established concerning the issues, target, methods, and assessment standards according to the current status, history, and development stage of the region.

3.2 Assessment and Position of Existing Studies

3.2.1 Regional Science Theories

There are quite a few studies on agriculture and rural communities in the area of regional science. Fujita (2006) is one of a few attempts that contribute in solving the actual issues in rural and agriculture development on the basis of theoretical underpinning and characteristics in regional science. Kohno (1988) states that "regional science in Japan has focused on regional development, especially regional industrial development and the social infrastructure development for it, i.e., the development of social overhead capital for manufacturing, and it has not address agricultural issues directly," despite the fact that agriculture in the region has been at the root of regional development. Kohno then looks at the measures to enhance the competitiveness of agriculture in Japan in market-oriented economic reform through an interdisciplinary approach based on microeconomics, dynamic optimal planning, social benefit theory, econometrics, public economics, and so on. This is followed by Morishima et al. (1989) who examined the effectiveness of the policies through simulation in small rural areas. These studies are pioneering studies in rural and agriculture development in Japan based on regional science. However, rural and agriculture development theories continue to develop from traditional theories to new theories.

3.2.2 Rural and Agriculture Issues in the Process of Economic Development

The stagnation of agriculture, the outflow of rural population to urban areas, and the resultant decline of agricultural communities in the process of economic development are fundamental rural and agriculture issues in developed countries. Hayashi (1970) analyzed the current status of the issues in mountain villages and showed that significant differences existed between mountain villages, and therefore there was a need for different development strategies. In regard to depopulation problems, Nemoto (1972) clarified the process of depopulation by including social capital and income level as determining factors in the demographic shift. In regard to the demographic shift from agricultural communities to urban areas, Nobukuni (1982) clarified its relationship with the economic cycle and also carried out factor analysis and simulation using a utility difference model. Hagihara (1984) studied depopulation problems from the perspective of optimal population distribution and analyzed the effectiveness of measures to address depopulation such as subsidies from both theoretical and empirical aspects. Katada et al. (1987) quantitatively formulated the mechanism of the demographic shift and commuting flows from the perspective of agricultural and mountainous communities and studied models to forecast the size of the demographic shift and commuting flows using the levels of the living environment and employment environment in agricultural and mountainous communities and urban areas, respectively, and the commuting transport conditions between the two areas as explanatory variables.

In addition, the changes in the supply and demand of food in the course of economic development and furthermore the changes in the food trade structure have had significant impact on rural and agriculture development in the respective and related countries, regardless of whether developed or developing. As a result, studies in food policy are receiving a considerable amount of interest in Europe and elsewhere following the recent sharp increase in food prices. In particular, emerging countries with enormous populations such as China and India are attracting attention. Kiminami (2009b) clarified the changes in food consumption behavior in the course of economic growth in China and discussed the need for harmony between food policy and other policies. In addition, Kiminami (2009c) called for food policies for sustainable rural and agriculture development in Asia, including Japan.

3.2.3 Production Structure and Production Factors in Agriculture

The restructuring of the agriculture production structure has not advanced as rapidly in Japan as in Europe and the USA, and the structural reform is especially important in land-intensive farming. One significant feature in comparing agriculture with other industries is that land plays a crucially important role as a production factor. It does not simply refer to the size of land usage area per production value, but the significant role that is played by the quality of land (form, compartment, abundance, and so on).

Kiminami and Kiminami (2005) viewed land improvement as changes in capital stock on the basis of quality of land and measured its economic effect on agricultural management. By contrast, Furuzawa and Kiminami (2006) clarified from a farmer-level analysis that the direction of land improvement projects is determined by farmers' business objectives and the assessment of land resources. On the other hand, Souma and Kiminami (2012) pointed out that it is important to support young farmers in establishing a farm business that not only tangible assets such as farmland but also intangible assets should be included in the management properties of succession. However, Cao et al. (2012) suggested to provide incentives to increase farm turnover in order to raise the competitiveness of the agricultural sector and achieve rural development. Furthermore, Kiminami et al. (2011) viewed the problems of human resource management in Japanese agricultural sector and empirically clarified the determinant factors that affect the employee turnover rates using logit model.

3.2.4 Diversification of Agriculture and the Rural Economy and Collaboration with Other Industries

The phrase "the rural economy is not the same as the agricultural economy" has several meanings in developed countries. It may refer to the fact that the continued existence of farmers and rural communities depends on employment opportunities in nonagricultural sectors in rural areas, or it may refer to the fact that new economic activities (community business; collaboration between agriculture, commerce, and industry; and so on) are intensifying as a result of the diversification of the rural economy. The relationship of mutual dependence between agriculture and related industries is not limited to the simple trading of assets and services, but also includes business collaboration in various formats. Yoshimoto et al. (2009) looked at the relationship between agriculture and tourism in Okinawa and measured the economic ripple effect of agriculture on other sectors and the employment creation effect by analyzing interindustry relationship tables.

In regard to unused organic resources, Yasunaga (2006) estimated the cyclic use flow of agricultural biomass in the region and quantified the effect of utilizing agricultural biomass on the regional economy including the chain effect. The effects of rural industrialization on the regional economy and rural and agriculture development by industrial cluster strategy are recently attracting attention in developing countries as well. Kiminami (2010) explored solutions for rural and agriculture development issues in China (improvement in agricultural productivity, increase in farm household income, poverty reduction, environmental conservation, and so on) from the perspective of industrial clusters. In addition, studies concerning the agro-industry are making advances based on the reality that agriculture today is deepening its economic ties with other related industries, and rural areas are heavily dependent on nonagricultural industries. As a study, especially in relation to the food industry, there is Kiminami et al. (2010), which looked at business collaboration.

3.2.5 Urbanization, Agriculture, and Rural Areas

The relationship between rural and urban areas and the relationship between agricultural and nonagricultural industries have often been treated as a simple binary relationship, but the clarification of the mutual interdependent relationship between rural and urban areas and cooperation between agricultural and nonagricultural industries have become important research themes in recent years.

The importance of agriculture in the rural economy has decreased in developed countries, but agriculture still plays a significant role in terms of land management. Furuzawa and Kiminami (2007) clarified the structure of the issues concerning agricultural land use and urban land use in Niigata's city planning based on an analysis of residents' awareness and explored consensus formation for plan formulation. The effect of economic activities in urban areas on the rural economy is also an important point of argument. For example, Kakimoto (1991) used the Harris-Todaro model that incorporates the relationship where agricultural products become raw materials for the urban sector and showed that employment subsidies in the urban sector have no effect on improving employment in rural areas due to factor substitution. On the other hand, Kiminami and Kiminami (2006) assessed the impact of urban agriculture on urban quality of life (QOL) and analyzed the sustainability of agriculture in Japan.

In developing countries, too, interest in food safety and environmental issues is growing, following rapid industrialization and urbanization, and as a result, the concept of urban agriculture is getting reexamined. Kiminami and Kiminami (2007a) discussed that urban agriculture in Shanghai, China, attached importance to securing food for urban residents until the reform and opening up of China, but the focus shifted after that to economic efficiency, i.e., increase in farmers' income. The paper also pointed out that environmental conservation and the safety of agricultural products are also given importance in recent years in response to the needs of residents.

3.2.6 Agriculture, Rural Area, the Environment, and Common-Pool Resource (CPR) Management

Studies concerning the relationship between agriculture, rural area, and the environment are roughly divided into two groups of those concerning a positive effect on the environment and a negative effect on the environment. The former has several different types in terms of approach to the issues. Yamamoto and Ogura (1997) adopted the method of expanding the social accounting matrix (SAM) in rural and mountainous communities into the environmental sector and examined economic settlement conditions for the people who assume the role of regional resource management and the formulation of land and resource plans. Miyata et al. (2001) created overall environmental and economic integrated accounts and carried out economic assessment on multiple functions of agriculture and forestry. An example of the latter can be found in Kiminami and Kiminami (1988), on the dispute settlement mechanism for environmental issues in a region, with a case example of pollution by livestock.

Regional resources in rural area are varied, including land, water, and unused organic resources, and these resources need to be appropriately evaluated, maintained, and managed for efficient use and application. However, as these resources have characteristics as public property, there is a danger of undersupply if left to the market. Hayami (1997) regarded that an economic system consists of the three economic organizations of market, nation, and collective from the perspective of development economics and pointed out that collectives have comparative advantages in the supply of public property in the region, such as common-pool resource management. In addition, Ostrom (1990) presented conditions under which self-governance of common-pool resources by users would work. Concerning these points of argument, Furuzawa and Kiminami (2010) looked at the issue of maintaining and managing agricultural drainage and clarified the management mechanism of common-pool resources in the region in relation to consensus building between diversifying stakeholders, while Furuzawa and Kiminami (2009) clarified determining factors in resident participation in the collective management of common-pool resources in rural areas and the effect of resident participation on the accumulation of social capital.

3.2.7 Globalization, Regional Integration, and Agriculture/Rural Area

A decrease in the cost of transporting assets, services, money, people, and information are thought to be the driving forces for rapid changes in the global economic system today. However, such decreases in the "transportation cost" in the broad sense of the term lessen the meaning of national borders, and thus the importance of cities and regions is increasing. This means globalization and localization occur at the same time (Fujita 2007). However, the elimination of measures at borders is a politically sensitive issue, and thus WTO negotiations are facing difficulties. In particular, the agricultural sector tends to be seriously affected by trade liberalization; thus, it is one of the most sensitive areas in the negotiation process. Studies on regional integration are roughly grouped into studies concerning regionalization of the economy and studies concerning regional trade agreements.

In the studies concerning regionalization, studies on the aspects of economics and trading are advanced, and these are divided into those concerning the production network and spatial economics such as industry accumulation. Empirical studies are abundant, such as studies on the economic effect of economic partnerships in East Asia, as represented by WTO-IDE-JETRO (2011), and studies concerning location and agglomeration, such as Jin and Tokunaga (2008) and Lu and Tokunaga (2008), but studies on mutual dependence through the trading of agricultural products and food are scarce. Kiminami and Kiminami (1995, 1998, 1999) analyzed the trend in economic integration in East Asia by clarifying intra-industry trade mechanism through the typification of trade patterns and in terms of the relationship with direct investment and clarified the international division of labor in the food industry. In contrast, in regard to the liberalization of agricultural trade, Sakuyama (2010) empirically clarified the determination factors in the custom duty reliance in agricultural protection in developed countries, and Kiminami and Kiminami (2007b) clarified domestic and bilateral consensus formation in Japan and China for achieving FTA including agriculture.

In addition, in the studies concerning regional cooperation, Kiminami and Furuzawa (2013) theoretically examined the possibility in knowledge creation (including development of human resources) through international cooperation in agriculture from the perspectives of food system. More specifically it integrated the knowledge creation theory and the industrial life cycle theory using the concept of "proximity" to explain the knowledge creation mechanism in international agricultural cooperation. Furthermore, Kiminami (2015) pointed out that the policy design for improving the capability of collaboration among entities and accepting the diversified and pluralistic nature of entities in the network is an urgent necessity for solving the problem of food security in Northeast Asia and realizing a sustainable development of the region since the type of knowledge, the optimal timing, and the combination of network in the clustering change dynamically.

3.2.8 New Approaches of Strategic Development for Regional Agriculture

Until now these are mainly the following approaches about regional economic development: community development (Nitagai et al. 2008), urban planning (Higasa and Hibata 1993), economic development (Bailey 1989), and strategic marketing planning (Kotler et al. 1993. These approaches are not mutually exclusive but relevant to each other, and some of them have finished original development. However, a strategy is a plan of action designed to achieve a long-term or overall aim

(Oxford Dictionary of English). The success of a strategy depends on doing many things well—not just a few—and integrating among them. If there is no fit among activities, there is no distinctive strategy and little sustainability (Porter 1996).

As for the sustainability of agriculture, it is considered to be composed of three aspects: economic efficiency, sociality, and environmental protection. The relative importance among three aspects varies depending on the place and time, and an appropriate balance between the three aspects is always required (Kiminami and Kiminami 2006). Furthermore, since a "region" is regarded as an economic, social, cultural, and historical place rather than as a space of mere economic activity, the role of rural and agriculture development studies in regional science is regarded to draw policy implication from theoretical and empirical analysis on the sustainability of regional development.

Here, the relationship between regional development and sustainability is described as Fig. 1. The frontier area ($A_{t0}B_{t0}$) is assumed as the total value of economy, social, and environment created by the activities in a region at time of t_0. In terms of the sustainability of a region, the minimum level of economy, sociality, and environmental protection is set at Am and Bm. Although both P_0 and P_0' are efficient within the area of sustainability, there exists the optimal point P_{t0}^* with the best balance between economic efficiency, sociality, and environmental protection in the region. Next, the innovations in the region are supposed to be created at the

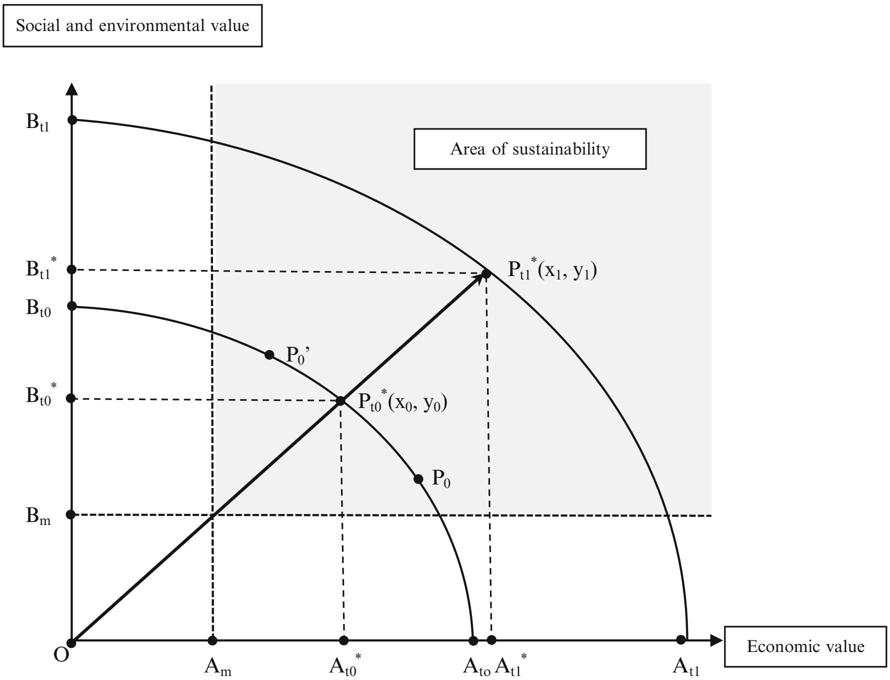

Fig. 1 Regional development and sustainability

time of t_1, then the frontier area would be enlarged to $A_{t1}B_{t1}$, and a higher level of sustainability would be shifted to P_{t1}^* which means that a sustainable development would be realized in the region.

On the other hand, in terms of innovation creation in a region, one of the approaches which attract attention most in the theory of regional economic development is the approach so-called cluster strategy (Stimson et al. 2006). Cluster strategy is characterized by its focus on the competitive and cooperative relationships among the economic entities in a region, with a view to achieve regional economic development by facilitating agglomeration and collaboration among economic entities to generate innovation and hence to achieve competitive advantages for the region (Porter 1998).

Cluster strategy attracts attention increasingly also in the field of agriculture and rural development (Kiminami 2010; Kiminami and Kiminami 2009). However, it was rare for agriculture and rural area to serve as main objects in a strategic marketing planning. This is related to the facts that agriculture and rural development have been traditionally separated from the development of region and the position of agriculture existing in the region was not always clear. Therefore, while the recognition to the role of agriculture including multifunctionality is changing, a new approach is called for in regional science.

This research presents a new approach so-called strategic development for regional agriculture by combining synthetically conventional urban planning, community development, strategic marketing planning, and industrial cluster strategy (see Fig. 2) in formulation (2) as follows. Therefore, it is thought that the

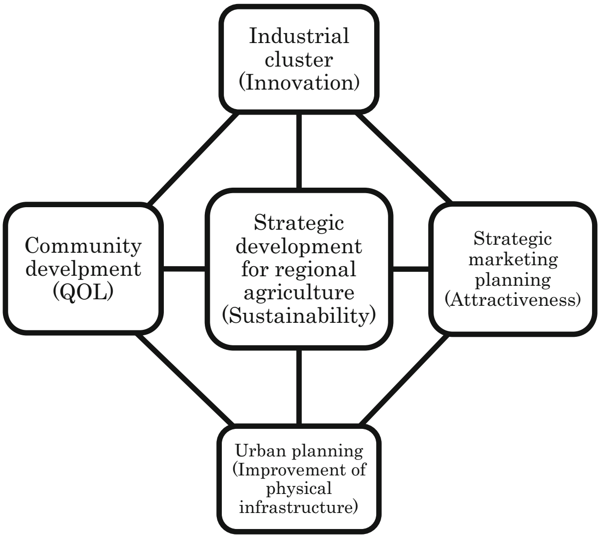

Fig. 2 Concept of strategic development for regional agriculture (Source: Kiminami et al. (2013))

sustainability of regional development (S) is defined as the objective function of the innovation created by industrial clustering, the attractiveness through strategic marketing planning, physical infrastructure improved by urban planning, and the QOL through community development in the region.

$$S = fs\,(I(C), M, P, Q) \tag{2}$$

S: Index of the sustainability in the development of region
I: Innovation
C: Industrial clustering
M: Attractiveness through strategic marketing planning
P: Physical infrastructure
Q: QOL through community development

4 Future Prospects

As pointed out by OECD (2014) that focusing on the two pillars critical to revitalizing rural areas – innovation and modernization – is one way to identify factors that can trigger or facilitate improved economic performance and identify those that tend to weaken it. In conclusion to the aforementioned analytical results, the following are listed for future tasks in rural and agriculture development studies.

Firstly, there is an issue of regional heterogeneity. This issue is especially important in the discussion of the effectiveness of rural and agricultural policies. OECD (2006a) concluded that the development of frameworks for the monitoring and assessment of the effectiveness of cross-sectional policies for industries relating to rural and agriculture development and the implementation of detailed case studies are necessary. Many developed countries are introducing people-based policies (to develop regions through human resource development) and region-based policies (to set a regional range and develop the region) as a result of problems in industry-based policies (which is to develop regions through industry promotion). However, there are also claims that pan-region people-based policies do not function effectively due to regional heterogeneity (Kilkenny 2010). Regarding region-based policies, policies that consider regional characteristic (place-tailored policies) rather than blanket policies are thought to be more effective, but these are problematic in terms of high policy cost. Therefore, discussion on effective policies continues. This is why it is important to consider the way of accurately capturing regional heterogeneity and reflecting it on policy formation and governance.

Secondly, there is an issue of rural-urban partnerships. As noted by OECD (2013), urban and rural areas are increasingly integrated, and this integration covers a complex set of linkages (e.g., population and labor market flows, public service provision, transport network, environmental services, etc.). Therefore, rural-urban partnership is thought as the mechanism of cooperation that manages these linkages to reach common goals and enhance rural-urban relationships.

Thirdly, there is an issue of creating more effective models for rural and agriculture development. Recent changes in the environment that surrounds agriculture and rural areas have certainly introduced more factors into the consideration in development models, and therefore the matter becomes complicated. However, on the other hand, the potential to create new development models has also increased. For example, McGranahan and Wojan (2007) and McGranahan et al. (2011) proposed a new growth model by combining Florida's (2002) regional development model based on creative class with the shift of creative class to rural areas as a result of amenity factors in rural areas and conducted empirical analysis.

Fourthly and most importantly, there is an issue of how agriculture and rural areas are perceived. In other words, it is urgent to make cognitive change in regarding agriculture and rural area from an ailing industry to a growth industry and from a conservative and closed society to an open "space" to create knowledge and innovation. Studies on innovations and knowledge creation in rural and agriculture development in Asia have only just started. The accumulation of case studies on innovation and knowledge creation from the activities of individual economic entities, the large-scale surveys at an individual management level, and the construction of databases for management results are called for.

Note This paper is revised from Kiminami L, Kiminami A, Furuzawa S (2012) Agricultural and rural development. In: The Japan Section of Regional Science Association International (ed) The progress and perspectives of regional science in Japan: golden 50th anniversary. Sasaki Shuppan, pp 409–428 (in Japanese).

References

Bailey JT (1989) Marketing cities in the 1980s and beyond: new patterns, new pressures, new promise. American Economic Development Council, Chicago

Cao W, Kiminami L, Kiminami A (2012) Analysis on the attitude of employed Japanese farmers from the viewpoint of human resource management. J Rural Econ (Special Issue):53–60

Capello R, Nijkamp P (2011) Regional growth and development theories revisited. In: Stimson R, Stough RR, Nijkamp P (eds) Endogenous regional development: perspectives, measurement and empirical investigation. Edward Elgar, Cheltenham, pp 301–324

Desai S, Nijkamp P, Stough RR (2011) New directions in regional economic development: the role of entrepreneurship theory and methods, practice and policy. Edward Elgar, Cheltenham

Florida R (2002) The rise of creative class. Basic Books, New York

Fujita M (2006) Economic development capitalizing on brand agriculture: turning development strategy on its head. IDE Discuss Paper 76:1–50

Fujita M (ed) (2007) Regional integration in east Asia; from the viewpoint of spatial economics. Palgrave Macmillan, London

Furuzawa S, Kiminami L (2006) Perception formation and choice of farm households about land improvement projects: an empirical study on Niigata Prefecture, Japan. Stud Reg Sci 36(4):839–852 (in Japanese)

Furuzawa S, Kiminami L (2007) Structure of resident consciousness about urban planning: a case study of the master plan for the New Niigata city, Japan. Stud Reg Sci 37(4):1109–1126 (in Japanese)
Furuzawa S, Kiminami L (2009) Study on collective management of rural common-pool resources and social capital. J Rural Econ (Special Issue):53–60
Furuzawa S, Kiminami L (2010) Policy for activities to manage common-pool resources in Niigata Prefecture. Stud Reg Sci 40(1):173–187 (in Japanese)
Hagihara K (1984) An economic study of the depopulation problem. Stud Reg Sci 15:185–211 (in Japanese)
Hayami Y (1997) Development economics: from the poverty to the wealth of nations. Clarendon, Oxford
Hayashi K (1970) Structural problems in mountainous areas. Stud Reg Sci 1:63–77 (in Japanese)
Higasa T, Hibata Y (1993) Urban planning, 3rd edn. Kyoritsu Shuppan, Tokyo (in Japanese)
Irwin EG, Isserman AM, Kilkenny M, Partridge MD (2010) A century of research on rural development and regional issues. Am J Agric Econ 92(2):522–553
Jin S, Tokunaga S (2008) Effects of agglomeration on production in the Chinese food industry: a panel data analysis. Stud Reg Sci 38(4):1021–1026
Kakimoto S (1991) A note on agro-based industry, rural-urban migration and factor substitution. Stud Reg Sci 21(2):62–66
Katada T, Aoshima N, Higano Y (1987) Life cycle-simultaneous choice model of dwelling and work places in the rural and urban areas. Stud Reg Sci 18:1–18 (in Japanese)
Kilkenny M (2010) Urban/regional economics and rural development. J Reg Sci 50(1):449–470
Kiminami L (2009a) International food system. Agriculture and Forestry Statistics Publishing, Tokyo (in Japanese)
Kiminami L (2009b) Food consumption and food policy under the economic development of China. Stud Reg Sci 38(4):921–938 (in Japanese)
Kiminami L (2009c) Food security and sustainability policy in Asia. Int J Agric Res Gov Ecol 8(2–4):318–333
Kiminami L (2010) Agriculture and rural development through cluster-based strategy in China. Agriculture and Forestry Statistics Publishing, Tokyo (in Japanese)
Kiminami L (2015) Food security and collaborative advantage: scoping the scene. In: Kiminami L, Nakamura T (eds) Food security and industrial clustering in Northeast Asia, new frontiers in regional science, vol 6, Asian Perspectives. Springer, Tokyo, pp 1–18
Kiminami L, Furuzawa S (2013) Knowledge creation through international cooperation in agriculture. Stud Reg Sci 43(1):79–87
Kiminami A, Kiminami L (1988) Regional conflict solution to environmental pollution: a case study of the Japanese livestock industry. Stud Reg Sci 29(3):249–262 (in Japanese)
Kiminami L, Kiminami A (1995) Regional integration and specialization: an empirical note. In: Iwasaki M (ed) Varieties of regional integration. LIT, Münster, pp 92–116
Kiminami L, Kiminami A (1998) The structure of trade and international specialization in Asia: a case study on Japanese food industry. Stud Reg Sci 28(1):257–267 (in Japanese)
Kiminami L, Kiminami A (1999) Intra-Asia trade and foreign direct investment. Pap Reg Sci 78(3):229–242
Kiminami A, Kiminami L (2005) Panel data analysis on economic effects of land improvement. Stud Reg Sci 35(2):415–425 (in Japanese)
Kiminami L, Kiminami A (2006) Sustainability of agriculture and urban quality of life in Japan: economic efficiency, sociality and environment protection. Stud Reg Sci 36(2):305–321
Kiminami L, Kiminami A (2007a) Sustainability of urban agriculture: a comparative analysis of Tokyo and Shanghai. Stud Reg Sci 37(2):585–597
Kiminami L, Kiminami A (2007b) Consensus formation on the economic partnerships in East Asian agriculture. J Rural Econ (Special Issue):382–389
Kiminami L, Kiminami A (2009) Agricultural industry clusters in China. Paper presented at the 27th international association of agricultural economists conference, International Convention Center, Beijing, China, 16–22 August 2009

Kiminami L, Kiminami A, Furuzawa S, Nakamura T, Zhu Y (2010) An analysis on the business alliance in food-related industries: international comparison between Niigata Prefecture of Japan and Heilongjiang Province of China. Stud Reg Sci 40(2):449–471 (in Japanese)
Kiminami A, Kiminami L, Furuzawa S (2011) Human resource management challenges for the Japanese agricultural sector: an empirical analysis of employee turnover rates in agricultural corporations. Jpn J Farm Manag 49(1):13–21 (in Japanese)
Kiminami L, Kiminami A, Furuzawa S (2013) Factors of attractiveness in strategic regional agricultural development: case study from Seiro-machi, Japan. Stud Reg Sci 43(2):241–257
Kohno H (1988) To what direction should we orient the Japanese agriculture?: survey and personal views I: a prescription toward the market-economy oriented and international competitive power-holding agriculture. Stud Reg Sci 19:65–107 (in Japanese)
Kohno H, Higano Y (1980) The regional science in Japan; a survey II. Stud Reg Sci 11:221–330 (in Japanese)
Kotler P, Haider DH, Rein I (1993) Marketing places. The Free Press, New York
Kourtit K, Nijkamp P, Stough RR (eds) (2011) Drivers of innovation, entrepreneurship and regional dynamics. Springer, Berlin
Lu J, Tokunaga S (2008) Market potential and location choice for the Japanese food industry in east Asia: an approach of new economic geography. Stud Reg Sci 38(1):109–119
McGranahan D, Wojan T (2007) Recasting the creative class to examine growth processes in rural and urban counties. Reg Stud 41(2):197–216
McGranahan DA, Wojan TR, Lambertz DM (2011) The rural growth trifecta: outdoor amenities, creative class and entrepreneurial context. J Econ Geogr 11:529–557
Miyata Y, Fukuoka K, Ariyoshi N, Liu Q (2001) Environmental valuation of agriculture and forest based on a system for integrated environmental and economic accounting. Stud Reg Sci 32(1):115–137 (in Japanese)
Morishima T, Ide M, Yanai T, Kohno H (1989) What should Japanese agriculture be? II: simulation of agricultural management program to dynamic development for small rural village: in case of Asoda Area, Saita-Town, Kagawa-Prefecture. Stud Reg Sci 20(1):181–115 (in Japanese)
Nemoto K (1972) Analysis of under-agglomeration process. Stud Reg Sci 3:89–113 (in Japanese)
Nijkamp P, Abreu M (2009) Regional development theory. Serie Research Memoranda 0029, VU University Amsterdam, Faculty of Economics, Business Administration and Econometrics
Nitagai K, Ohono H, Koizumi H, Hayashi Y, Moritan A (eds) (2008) Encyclopedia of town planning. Maruzen Publishing, Tokyo (in Japanese)
Nobukuni M (1982) Rural-urban-migration and business cycle. Stud Reg Sci 13:141–151
OECD (2006a) The development dimension: coherence of agricultural and rural development policies. OECD Publishing, Paris
OECD (2006b) The new rural paradigm: policies and governance. OECD rural policy reviews. OECD Publishing, Paris
OECD (2013) Rural-urban partnerships: an integrated approach to economic development. OECD Publishing, Paris
OECD (2014) Innovation and modernizing the rural economy. OECD Publishing, Paris
Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge
Porter M (1996) What is strategy? Harvard Bus Rev 74(6):61–78
Porter M (1998) Clusters and competition: new agendas for companies, governments, institutions. In: Porter M (ed) On competition. Harvard Business School Publishing, Boston, pp 155–196
Sakuyama T (2010) Determinants of tariff dependence in agricultural protection in developed countries: an empirical analysis using panel data. Stud Reg Sci 40(3):679–694 (in Japanese)
Souma T, Kiminami L (2012) Studies on knowledge management in agricultural succession. Stud Reg Sci 41(4):943–955 (in Japanese)
Stimson RJ, Stough RR, Roberts BH (2006) Regional economic development: analysis and planning strategy. Springer, Berlin
Terluin IJ (2003) Differences in economic development in rural regions of advanced countries: an overview and critical analysis of theories. J Rural Stud 19:327–344

Tsubouchi Y (1999) Toward integrated area studies. In: Tsubouchi H (ed) Seeking integrated area studies: with the image of Southeast Asia as a clue. Kyoto University Press, Kyoto, pp 1–18 (in Japanese)
World Bank (2008) World Development Report 2008: agriculture for development, The World Bank, Washington
WTO-IDE-JETRO (2011) Trade patterns and global value chains in East Asia: from trade in goods to trade in tasks, WTO, Geneva
Yamamoto N, Ogura N (1997) The potential applications of rural area social accounting matrices: the extension to the environmental sector and the public sector. Stud Reg Sci 28(1):231–241 (in Japanese)
Yasunaga N (2006) Recycling of farm organic resources and the environmental evaluation in local economy: an estimation of linkage effect in Hokkaido region. Stud Reg Sci 36(3):611–621 (in Japanese)
Yoshimoto S, Oshiro T, Hara I (2009) Quantitative analysis of the multilateral value of Okinawa agriculture: estimation of the contribution to Okinawa sightseeing and economic effect. Stud Reg Sci 39(4):1013–1025 (in Japanese)

Impact of Climate Change on Regional Economies Through Fluctuations in Japan's Rice Production: Using Dynamic Panel Data and Spatial CGE Models

Suminori Tokunaga, Mitsuru Okiyama, and Maria Ikegawa

Abstract The agriculture industry would be most affected by global warming-induced climate change. Based on the assumption that only rice is affected by global warming, this study examines the impact of global warming on regional economies based on the spillover effects from other agricultural products and the industrial sector having an input–output relationship with agriculture. Our findings show that global warming-induced climate change has different impacts on each region, and it creates regional economic disparities. For example, global warming has a positive impact on regional economies in Hokkaido and Tohoku. In addition to increasing rice production, the gaps in rice prices in Kanto and the region west of Kanto will increase outflow, which in turn further increases production. Meanwhile, global warming will reduce production in Kanto and the region west of Kanto, and it will have a negative impact on regional economies. Furthermore, other agricultural products will be negatively affected in all the regions due to changes in rice production, while production in the food and beverage industries will be negatively affected in Kanto and the region west of Kanto. However, when the impact of global warming becomes greater, production in the food and beverage industries will increase in Hokkaido and Tohoku. Finally, we find that there is the good impact of adaptation technologies on the production of rice in Kanto and the region west of Kanto from simulation results of the development of adaptation technologies such as high-temperature-tolerant rice varieties in regions affected by global warming. Thus, the promotional policy of adaptation technologies such as

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high-temperature-tolerant rice varieties and public support for industrial clusters based on rice are necessary in order to eliminate the disparities in regional economic welfare caused by global warming.

Keywords Global warming-induced climate change • Dynamic panel data model • Spatial CGE model • High-temperature-tolerant rice • Adaptation technology • Industrial cluster

1 Introduction

The debate on the problem of global warming was begun by many scholars in the 1980s. In 1988, governments set up the "Intergovernmental Panel on Climate Change" (IPCC) as a forum to study global warming and discuss measures to reduce greenhouse-gas (GHG) emissions, a major cause of global warming. The agriculture industry would be most affected by global warming-induced climate change. Thus, the food and beverage industries that receive materials from the agriculture industry will also be affected by climate change. In 2013, the Japan Meteorological Agency (JMA) projected Japan's climate change based on the non-hydrostatic regional climate model using IPCC GHG emission scenario A1B. According to the projection, the annual mean temperature is projected to increase by about 3 °C in each region by the end of the twenty-first century (2076–2095 average) based on the average from the end of the twentieth century (1980–1999 average). In particular, the increase in temperature is projected to be larger in the northern part of Japan than in the southern part of Japan and greater in the winter than in the summer. The JMA's projection corresponds to the A1B scenario (3.2 °C) among the results of three scenarios (A2, A1B, and B1) presented by the Ministry of Education, Culture, Sports, Science, and Technology, the JMA, and the Ministry of the Environment (2009). In this case, Japan's temperature increase was extracted from the results of global mean temperature increase projections based on GHG emission scenarios used in the IPCC Fourth Assessment Report (AR4). The A2 and B1 scenarios predicted that Japan's temperature would increase by 4.0 °C and 2.1 °C, respectively, by the end of the twenty-first century.

In previous studies, Kuroda (1979, 2013), Egaitsu and Shigeno (1983), Kako (1984), Kusakari (1985), and Godo (1991) have analyzed using production, profit, and cost functions without the climate change variables. Some studies have produced some findings related to the impact of these climate changes on the production of agricultural products in Japan (Nishimori and Yokozawa 2001; Shimono 2008; Yokozawa et al. 2009; Kunimitsu et al. 2013, 2015; Okiyama and Tokunaga 2016). The majority of these studies focused on rice and derived their findings based on models that reflected actual rice growth conditions, changes in annual yield, and regional differences in climate conditions. These studies identified the impact of climate change on rice yield and quality as well as regional differences by using chronological regional panel data and incorporating climate variables, such as specific periods after the rice-heading season, minimum and maximum daily temperatures, and solar radiation. For example, Yokozawa et al. (2009) estimated that the average national rice yield was expected to increase slightly or remain at the same level until the temperature rose by approximately 3 °C during the warm season from May to October. In addition, if the rise were to exceed 3 °C, the rice yield might decline in various regions, except for Hokkaido and Tohoku. Furthermore, Kunimitsu et al. (2013) estimated the total factor productivity (TFP) of Japanese rice production including several causative factors, such as socioeconomic factors and climate conditions, and they predicted the TFP of rice production in nine regions of Japan until 2100. Their results showed that climate change will have a positive effect on TFP in Hokkaido and Tohoku until 2100. Climate change will also have a positive effect on other regions until 2050, but it will decrease TFP after 2050.

In response to these previous studies, Okiyama et al. (2013) created panel data for nine regions, except Okinawa, and estimated the yield of rice, vegetables and potatoes (the sum of nine varieties including fruit vegetables, leaf and stem vegetables, root vegetables, and potatoes), and fruits (the sum of five varieties of fruits including tangerines and apples), respectively. They used climate variables, such as the annual mean temperature, precipitation, and solar radiation, in addition to the total work time spent on each agricultural product based on the Cobb–Douglas production function. Moreover, using the same panel data as Okiyama et al. (2013), Tokunaga et al. (2015) measured the yield of rice, vegetables, and potatoes based on a dynamic panel data model including climate variables, which added the lagged output variable in the explanatory variables. Their results indicated that when the average annual temperature increased by 1 %, the rice production decreased in the long run by approximately 0.55 %, while vegetable and potato production decreased in the long run by 1.2 %.

Based on these previous studies, we focus on the point that global warming-induced climate change affects Japan's agriculture differently depending on the region. Similar to the previous studies, this chapter focuses on rice, Japan's main agricultural product, with the aim of not only identifying the impact of global warming on rice and its subsequent impact on regional economies but also identifying the overall impact on regional economies, including the impact of rice production fluctuations on the production of other agricultural products and the spillover effects on the industrial sector, which has an input–output relationship with agriculture. Therefore, this chapter utilizes a dynamic panel data and the spatial computable general equilibrium (SCGE) models to analyze changes in rice production. The SCGE model is capable of reflecting the impact of global warming, such as the crop models used in the aforementioned studies and the production functions of agricultural products. As this is also a general equilibrium model, it is capable of reflecting the impact of interregional differences by global warming on changes in interregional exports and imports as well as differences in the prices of agricultural products. In addition, the model is capable of reflecting the point at which changes in the production of agricultural products affect production in other industries, especially the food-processing industry (which uses agricultural products). Consequently, it indirectly affects the production of agricultural products through the impact on regional economies. Furthermore, the impact of global warming on regional economies can be quantified for each region's economic welfare through the equivalent variation (EV) indicator. This chapter first constructs a social accounting matrix (SAM) for six regions, which are subdivided into the agriculture, forestry, and fishery and food and beverage industries based on the interregional input-output table for nine regions (2005) developed by the Ministry of Economy, Trade, and Industry. Next, we will develop a CGE model for six regions (the 6SCGE model) based on the SAM. Using data based on the JMA's future temperature projections and the SCGE model, the impact of global warming-induced climate change in Japan on regional economies will be measured.

This chapter proceeds as follows. Section 2 explains how we compiled the panel data and outlines the rice production and temperature-change trends. Section 3 estimates the production function of rice yield, which incorporates climate variables using a dynamic panel data for nine regions and examines regional changes in rice yield based on the JMA's future temperature projections. Section 4 provides an overview of the six regional SAMs and the 6SCGE model. Section 5 explains the data, which includes the premise of simulations, and analyzes the results of the simulation. Finally, Sect. 6 concludes this chapter and presents policy implications.

2 Changes in Rice Production and Temperatures for 1993–2009

We first explain how the panel data was compiled. The regional divisions comprised nine regions used in various statistics by the Ministry of Agriculture, Forestry, and Fisheries: Hokkaido, Tohoku, Hokuriku, Kanto–Tosan, Tokai, Kinki, Chugoku, Shikoku, and Kyushu (excluding Okinawa). The one agricultural product category selected to investigate the extent to which climate change is affecting agricultural production in Japan was rice and crop yield data was compiled from 1995 to 2009 (Okiyama et al. 2013; Tokunaga et al. 2015).

Figure 1a shows movements of the agricultural production (consisting of rice, wheat and potatoes, vegetables, and fruits) for 1993–2009. According to Fig. 1a, the production of vegetables and fruits flattened from 1995 to 2009. On the other hand, production of rice, wheat, and potatoes decreased slightly for 1993–2009. Reflecting a slightly decrease in rice production, we examine changes in the regional rice production. Figure 1b depicts the variation in total rice production for 1993–2009, reflecting phenomena such as the national crop failure of 1993 and regional crop failures of 2003 and 2006, both of which appear attributable to abnormal weather patterns at national and regional levels. Further, we see that rice production of Tohoku trends downward yearly compared with other regions.

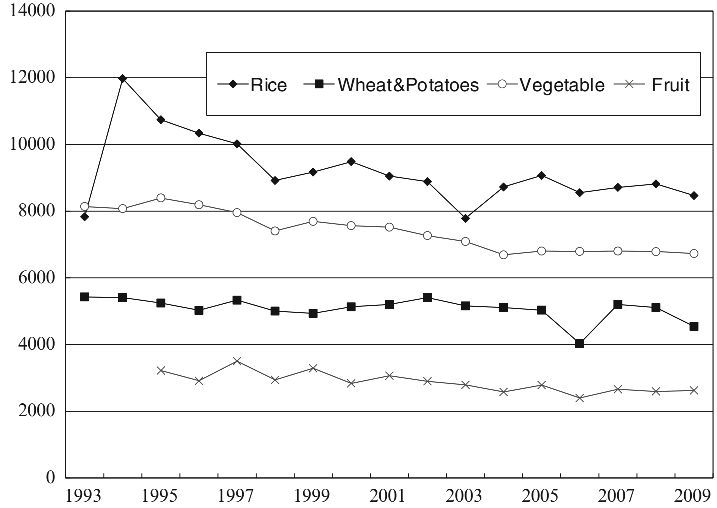

Fig. 1a Changes in the agricultural production from 1993 to 2009
Note: Unit in 1000 tons. The definition of agricultural production is as follows: rice (paddy rice and dryland rice), wheat and potatoes (wheat, soybean, sweat potato, and potato), vegetable (Japanese white radish, carrot, Chinese cabbage, cabbage, long green onion, cucumber, eggplant, tomato), and fruit (mandarin (orange, mikan), apple, pear, persimmon, and grape)
Source: The Ministry of Agriculture, Forestry, and Fisheries (MAFF)

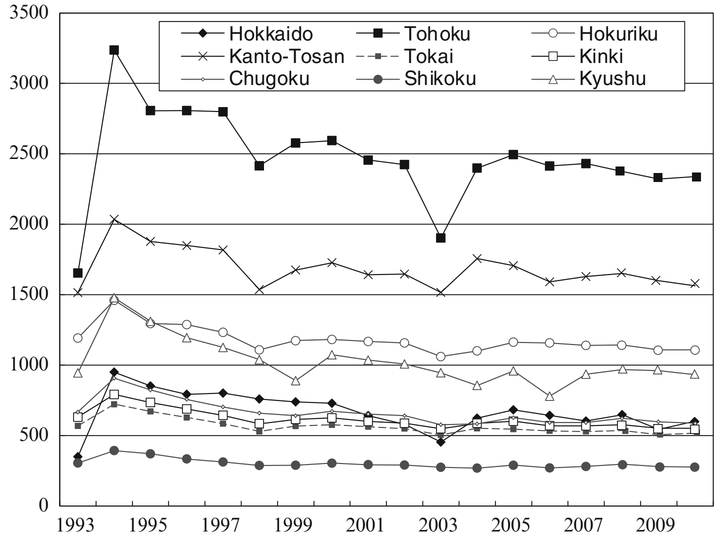

Fig. 1b Changes in the rice production by nine regions from 1993 to 2009
Note: Unit in 1000 tons. The definition of rice is paddy rice and dryland rice
Source: The Ministry of Agriculture, Forestry, and Fisheries (MAFF)

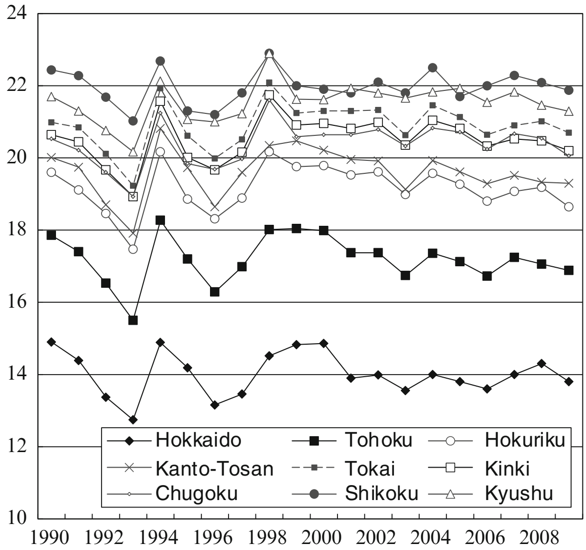

Fig. 1c Changes in the April to October average temperature by nine regions from 1990 to 2009
Note: Unit in °C
Source: AMeDAS

Finally, we explain the temperatures variables. For meteorological data, figures from 1990 to 2009 were provided by AMeDAS.[1] The data was cross-sectioned by municipality and monthly figures for temperature in a fixed interval averages. Figure 1c depicts the variation in mean temperature from April to October by region. Even when examining variations in regional temperatures over a decade, no clear upward trend could be determined. However, temperature variations from 1993 to 1994 and in 1998 and 2004 significantly exceeded normal values by roughly 1 °C, thus constituting abnormal weather.

3 Estimation of a Dynamic Panel Data Model on Rice Yield and Temperatures

3.1 GMM Estimation of a Dynamic Panel Data Model on Rice Production

In this section, we conduct a dynamic panel data analysis to examine the impact of long-term climate change on rice production in Japan and add the lagged output and temperature variables. We estimate the dynamic panel data model for rice yield, which is the production per cultivated land, for a sample period from 1996

[1] We were using prefectural data processed by Dr. Nishimori, who belongs to the National Institute for Agro-Environmental Sciences, according to specific observatory data of AMeDAS. We are grateful to him for his cooperation.

to 2009 in the nine regions (Hokkaido, Tohoku, Hokuriku, Kanto–Tosan, Tokai, Kinki, Chugoku, Shikoku, and Kyushu). This regional classification was performed by the Ministry of Agriculture, Forestry, and Fisheries and was used by Okiyama et al. (2013) and Tokunaga et al. (2015). We formulated the production function for rice yield by incorporating the point that when the temperature exceeds a certain level, the impact of high-temperature injury becomes larger, and as pointed out by Yokozawa et al. (2009), "yield decreases when temperature exceeds a certain point." We then estimated the production function for rice yield with the mean temperature in Eqs. (1) and (2) using the Arellano and Bond (1991) GMM[2]:

$$\frac{Y_{it}}{\text{Land}_{it}} = \alpha + \beta_1 \cdot \frac{Y_{it-1}}{\text{Land}_{it-1}} + \beta_2 \cdot \frac{K_{it}}{\text{Land}_{it}} + \beta_3 \cdot \text{tems}_{it} + \beta_4 \cdot \text{tems}_{it}^2 + \beta_5 \cdot D_{2003} + \varepsilon_{it} \tag{1}$$

$$In\left(\frac{Y_{it}}{\text{Land}_{it}}\right) = \alpha + \beta_1 \cdot In\left(\frac{Y_{it-1}}{\text{Land}_{it-1}}\right) + \beta_2 \cdot In\left(\frac{K_{it}}{\text{Land}_{it}}\right) + \beta_3 \cdot \text{tems}_{it} + \beta_4 \cdot \text{tems}_{it}^2 + \beta_5 \cdot D_{2003} + \varepsilon_{it} \tag{2}$$

where Y_{it} and Y_{it-1} represent the production of region i in year t and year $t-1$, respectively (unit in tons); Land_{it} and Land_{it-1} represent the cultivated area of region i in year t and year $t-1$, respectively (unit in hectares); K_{it} represents the total real amount of fixed capital expended by all rice-farming households of region i in year t (unit in million yens); tems_{it} represents the mean temperature from April to October for region i in year t; and D_{2003} represents the dummy variable of 2003 because of a lean year in all parts of Japan. temp_{it}^2 represents the square of the temperature variable, and it is reflected in high-temperature injury. We excluded the labor variable from the above equations due to its insignificance when adding the total labor time expended by all rice-farming households to these equations. Table 1a provides detailed description of explanatory variables used in these models.

The results are shown in Table 1b. In specifications for Eqs. (1) and (2), the coefficients of capital stock per cultivate land and lagged rice production per cultivate land variables are both positive and statistically significant for both equations. The coefficients of the mean temperature from April to October variable are positive and statistically significant for both equations, while the coefficients of square of the mean temperature from April to October variable are negative and statistically significant for both equations. From these results, we found that the impact of high-temperature injury becomes larger and "yield decreases when temperature exceeds a certain point" as pointed out in previous studies. Thus, given that rice yield is affected by temperature during the ripening period, we used the

[2]For efficient estimation of dynamic panel data models using GMM, see Green (2012) and Baltagi (2013).

Table 1a Summary statistics of explanatory variables for the rice production function

Variable	Definition	Unit	Mean	Standard deviation
Y/Land	Rice production per cultivate land (ha)	(1000 tons)	5.0680	0.3381
ln(Y/Land)	Logarithm of rice production per cultivate land (ha)		1.6207	0.0687
K/Land	Capital stock per cultivate land (ha)	(1000 yens)	1.0065	0.4295
ln(K/Land)	Logarithm of capital stock per cultivate land (ha)		–0.0953	0.4755
tems	Mean temperature from April to October	(°C)	19.5311	2.4245
$tems^2$	Square of mean temperature from April to October	(°C)	387.2989	87.8461
D2003	Dummy variable of year 2003		0.0296	0.1702

Table 1b Estimated results of a dynamic panel data model on rice production

	Rice production function (GMM estimation)	
Variables	Equation (1) $Y_{it}/Land_{it}$	Equation (2) ln $(Y_{it}/Land_{it})$
$Y_{it-1}/Land_{it-1}$	0.1179***	
	(4.00)	
ln $(Y_{it-1}/Land_{it-1})$		0.1099***
		(4.21)
$K_{it}/Land_{it}$	0.2312***	
	(2.87)	
ln $(K_{it}/Land_{it})$		0.0515**
		(2.21)
$tems_{it}$	0.6634***	0.1429***
	(2.75)	(2.65)
$(tems_{it})^2$	–0.0174***	–0.0037***
	(–2.74)	(–2.63)
D2003	–0.7739***	–0.1614***
	(–3.43)	(–3.16)
Constant term	–1.9687	0.1043
	(–0.88)	(0.20)
Wald χ^2	136.54	67.90
Prob > χ^2	0.000	0.000
Current sample period	1995–2009	1995–2009
Number of regions	9	9
Number of observations	117	117

Note 1: *** < 0.001, ** < 0.05, * < 0.1, z-statistics in parentheses
Note 2: Arellano–Bond dynamic panel data estimation. Instruments for differenced equation are GMM-type, L(2/6).y_land; standard, D.capital_land D.tems D.tems_2 D.D2003
Note 3: Without taking log for Eq. (1) and with taking log for Eq. (2)

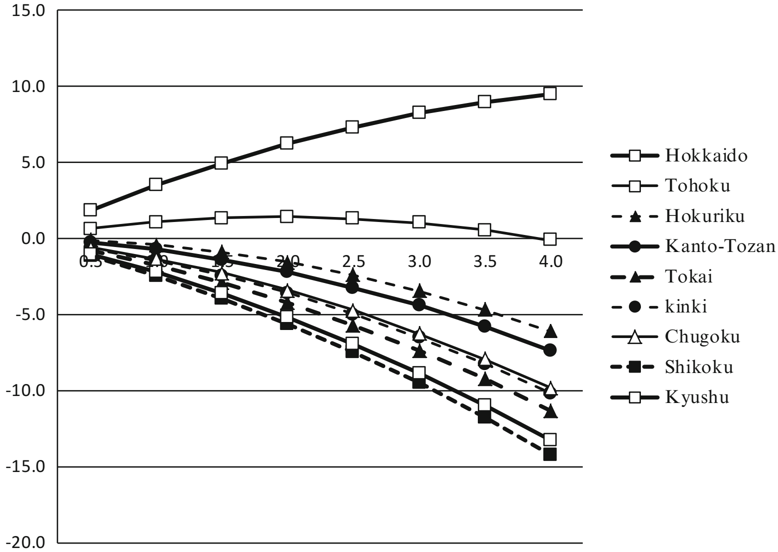

Fig. 2 Changes in the regional rice yield by a rise in temperature
Note: Unit in % of (Yit/Landit-Yit-1/Landit-1)/(Yit-1/Landit-1) in vertical axis)

April–October mean temperature variable as a temperature variable and a logarithm function, which made it easy to calculate elasticity for Eq. (2).

The yield elasticity of temperature variables was calculated based on temperature-variable parameters obtained from the aforementioned estimated formula and the April–October mean temperature from 1995 to 2009. Figure 2 presents the changes in rice yield using this elasticity for every 0.5 °C increase in the 1995–2009 mean temperature. Figure 2 also points out that while yield growth slows down in Hokkaido as temperature increases, growth does not turn negative even if the temperature increases by 4 °C. However, in Tohoku, growth turns negative when the temperature increases by approximately 2.0 °C, and the yield decreases when the temperature increase exceeds 4 °C. In the other regions, the yield decreases when the temperature increases by 0.5 °C from the 1995 to 2009 mean temperature and decreases exponentially when the temperature increases even further.

3.2 *Prediction of Future Temperature and the Regional Rice Yield*

Next, we estimate the maximum, mean, and minimum values of the April–October mean temperature for the future climate of nine regions (2076–2095 average) based on the present climate (1980–1999 average). We also estimate the future climate (2076–2095 average) predicted by the JMA (2013) and the regional changes in mean

Table 2 Regional future temperature increase rate and prediction of the rice-yield growth rate

Region%	(a) Current (1990–2009) average temperature during April–October	(b) Future (2076–2095) average temperature during April– October			(c) Changes in average temperature during April–October from 2005 to 2076–2095			(d) Changes by a rise in temperature from 2005 to 2076–2095 Rice production per land		
		Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
Hokkaido	14.0	17.5	16.8	16.1	27.0	21.8	16.5	10.98	9.76	8.09
Tohoku	17.2	20.5	19.8	19.0	19.5	15.3	11.1	1.08	1.63	1.76
Hokuriku	19.2	22.4	21.7	20.9	16.3	12.5	8.6	–4.38	–2.58	–1.26
Kanto–Tosan	19.6	22.7	22.1	21.4	15.9	12.5	9.1	–5.19	–3.39	–1.97
Tokai	20.9	23.8	23.2	22.6	12.7	9.7	6.8	–7.33	–5.12	–3.22
Kinki	20.5	23.5	22.9	22.2	12.9	9.9	6.9	–6.69	–4.59	–2.82
Chugoku	20.4	23.1	22.6	22.1	11.6	9.0	6.5	–5.49	–3.87	–2.48
Shikoku	22.0	25.1	24.5	24.0	15.6	13.1	10.5	–11.95	–9.32	–6.94
Kyushu	21.5	24.3	23.8	23.3	10.9	8.6	6.3	–7.87	–5.80	–3.95

Note: Calculation formula is as follows:

$$\frac{\Delta\left(\frac{Y_{it}}{\mathrm{Land}_{it}}\right)}{\frac{Y_{it}}{\mathrm{Land}_{it}}} = \frac{1}{1-\beta_1}\left(\beta_2\frac{\Delta\left(\frac{K_{it}}{\mathrm{Land}_{it}}\right)}{\frac{K_{it}}{\mathrm{Land}_{it}}} + \beta_3\cdot \mathrm{tems}_{i0}\frac{\Delta \mathrm{tems}_{it}}{\mathrm{tems}_{i0}} + \beta_4\cdot(\mathrm{tems}_{i0})^2\frac{\Delta(\mathrm{tems}_{it})^2}{(\mathrm{tems}_{i0})^2}\right)$$

where tems_{i0} is the numerical value of average temperature during Apr.–Oct. of 2005

temperature and standard deviation. The results are shown in column (b) of Table 2. Future temperatures in Hokkaido increase up to the level slightly below Tohoku's 1990–2009 mean temperature, while future temperatures in Tohoku will increase up to the level on par with the 1990–2009 mean temperature of Kanto–Tosan. While future temperatures in Tokai and the region west of Tokai will increase to 23–24 °C in terms of the April–October mean temperature, it will not reach Okinawa's 1990–2009 mean temperature (26.7 °C for April–October). The column (d) of Table 2 presents the results of the estimation of the regional rice-yield growth rate calculated from the regional future temperature increase rate shown in column (c) of Table 2, using the coefficients of explanatory variables shown in Eq. (2) of Table 1b. The following points were reviewed based on this table. Rice yield in Hokkaido and Tohoku will not turn negative even if future temperatures increase to the maximum value. In the other regions, rice yield is negatively affected even if the future climate remains at the minimum value. Especially, rice yield will decrease by 3.95 % in Kyushu and 6.94 % in Shikoku. Looking at the regional differences in the yield growth rate, unlike Hokkaido, which will be most positively affected by temperature increases, Shikoku, which will be most negatively affected, will see a 22.9 % point difference in the case of the maximum value and a 15.03 % point difference in the case of the minimum value.

4 Structure of the Six Spatial Computable General Equilibrium (6SCGE) Model

Here, we explain the framework of analysis in order to simulate the effects of global warming on regional economies through rice production. First, the database used for the 6SCGE model is the six interregional SAM, which encompasses the interregional input-output table of competitive imports for the six regions of Hokkaido, Tohoku, and Kanto (the seven prefectures of the Kanto area plus the four prefectures of Niigata, Nagano, Yamanashi, and Shizuoka), Chubu/Kinki/Chugoku/Shikoku, Kyushu, and Okinawa. The data sources for this SAM include the 2005 Ministry of Internal Affairs and Communications' input-output tables for Japan; the 2005 Ministry of Economy, Trade, and Industry's nine interregional input-output table and its nine intraregional input-output table of competitive imports; and the Cabinet Office's fiscal 2005 Prefectural Accounts for 47 prefectures.[3]

Next, we construct the 6SCGE model, which comprises 20 agents (one household, 16 industries, one company, one regional government, and one investment bank) in the six regions.[4] To this, we add the two agents, i.e., the central government and overseas sector. In addition, the marker consists of 16 commodity markets; three production factor markets of agricultural land, labor, and capital in the five agriculture sectors (rice, wheat and potatoes, vegetables, fruits, and livestock); and two factor markets of labor and capital in the nonagriculture sectors.[5] Then, each endowment of agricultural land, labor, and capital is exogenously fixed, and we assume no transfers outside the region, although agricultural land can move between agriculture sectors and both labor and capital can move between industries within the region.

Next, we explain the main structure of domestic production and households in the 6SCGE model.

[3]We used the Ministry of Economy, Trade, and Industry's nine-region database for the five regions of Hokkaido, Tohoku, Kanto, Kyushu, and Okinawa, whereas we constructed the data for Chubu/Kinki/Chugoku/Shikoku by deducting both the SAM for the above five regions and the export/import sector between the above five regions from the national SAM.

[4]For the static spatial CGE model, see Tokunaga et al. (2003), Hosoe et al. (2010), EcoMod Modeling School (2012), and Okiyama et al. (2014).

[5]"Agriculture land" means "the total amount of rent." We calculate land rent and owned land rent per cultivated land and owned land rent per farmer based on the "Statistics on Production Cost," the "Report of Statistics Survey on Farm Management and Economy," and the "Statistics on Crops" by the Ministry of Agriculture, Forestry, and Fisheries. The total amount of rent can be found by multiplying the rent per cultivated land or farmer by the total cultivated land or total farmers. Therefore, we can obtain the capital in agriculture sectors by deducting the total amount of rent from the sum of operation surplus and compensation of capital stock in the SAM. In addition, the households in the SAM can provide the total amount of rent as household income.

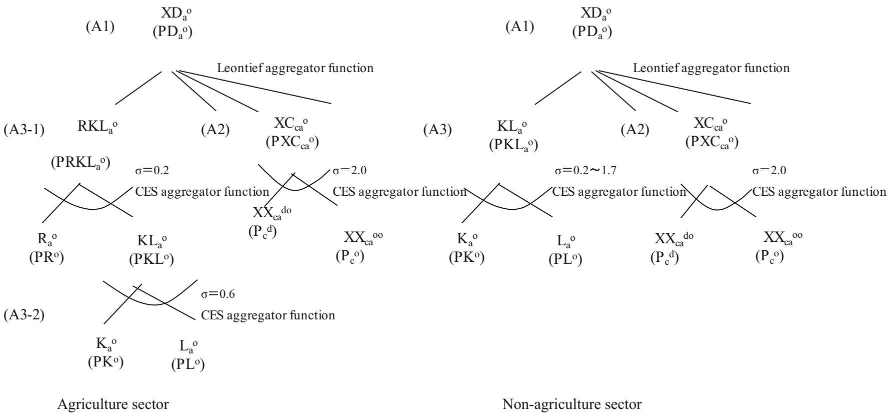

Fig. 3a Structure of the production sector in the 6SCGE model

1. Domestic production sector

The domestic production sector includes the nested production structure shown in Fig. 3a. Each production sector $\alpha(\alpha \epsilon A)$ in region $o(o \epsilon S)$ is assumed to produce XD_a^o of 1one commodity $c(c \epsilon C)$, maximize their profits, and face a multilevel production function. First, we explain the structure of agricultural production on the left. In Level 1 (A1), an industry in sector α constrained by Leontief technology takes the production function using each intermediate input good XC_{ca}^o aggregated from the 16 commodities and the added value LKN_a^o as demand of an agricultural land–capital–labor bundle by the firms. Since the producer price PD_a^o of sector α in region o holds true for the "zero-profit condition," it follows that income = production costs. In Level 2 (A2) on the right, we arrive at the intermediate goods aggregated for the 16 commodities from the composite commodity according to Armington assumption XX_{ca}^{do} input from origin $d \epsilon R$ to region o under the constraint of constant returns-to-scale CES technology and the o intraregional composite commodity according to Armington assumption XX_{ca}^{oo}. In addition, we arrive at PXC_{ca}^o, the price of the intermediate goods aggregated from sector α of region o, by the income definition, considering the zero-profit condition for intermediate goods. On the other hand, in Level 2, the added-value portion consists of two levels. In A3-1, we derive LKN_a^o from agricultural land L_a^o and the capital–labor bundle by the firms (KN_a^o) from sector α of the destination region o under the constraint of constant returns-to-scale CES technology. Furthermore, in A3-2, we derive KN_a^o from capital K_a^o and the labor N_a^o under the constraint of constant returns-to-scale CES technology. Then, each price level of $PLKN_a^o$ and PKN_a^o holds true for the zero-profit condition. Since the use of agricultural land can change, the rent PL^o is identical for agriculture sectors, and the return to capital PK^o and wage rate PN^o are identical for all industries in region o because they can move between industries within region o.

Next, we explain the structure of nonagricultural production on the right. In Level 1 (A1), an industry in sector α constrained by Leontief technology takes the production function using each intermediate input good XC_{ca}^{o} aggregated from the 16 commodities and the added value KN_{a}^{o}. In Level 2 (A2) on the right, we arrive at the intermediate goods aggregated for the 16 commodities from the composite commodity according to Armington assumption XX_{ca}^{do} input from origin $d \epsilon R$ to region o under the constraint of constant returns-to-scale CES technology and the o intraregional composite commodity according to Armington assumption XX_{ca}^{oo}. In addition, even the added-value portion (A3) is derived from capital K_{a}^{o} and labor N_{a}^{o} from sector α of destination region o under the constraint of constant returns-to-scale CES technology in the same manner as the intermediate-goods sector. Since producer price PD_{a}^{o} of sector α in region o holds true for the zero-profit condition, it follows that income = production costs. Finally, we arrive at PXC_{a}^{o}, the price of the intermediate goods aggregated from sector α in region o (by the income definition), taking into account the zero-profit condition for intermediate goods.

2. Household sector

In the household sector, we formulate the behavior maximizing the level of household utility UH^{o} as shown in Fig. 3b. At Level 1 (B1), households in destination region o maximize the linear-homogeneous Cobb–Douglas utility function for goods HC_{c}^{o} aggregated under budgetary constraint $CBUD^{o}$. In addition, at Level (B2), we derive the aggregated goods from the composite commodity according to Armington assumption XH_{c}^{do} imported from origin $d \epsilon R$ to region o under the constant returns-to-scale CES technology constraint and the intraregional o composite commodity according to Armington assumption XH_{c}^{oo}. Furthermore, we arrive at price PHC_{c}^{o} of aggregated goods c (by the income definition), taking into account the zero-profit condition for such goods. Household income comprises employment income, capital income, social security benefits, property income, and receipts from other current transfers. Household budget $CBUD^{o}$ comprises payments of income tax from household income, household savings, social contributions, and payments from property income as well as other current transfers. Household savings is calculated from household income, assuming the fixed propensity to save.

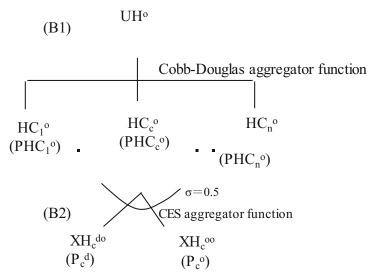

Fig. 3b Structure of the household sector in the 6SCGE model

3. Other sectors

The savings and investment sector includes the same structure as the household sector. The 6SCGE model is closed to prior savings, and in terms of investment, an agent called a "bank" allots savings S^o to investment demand IC_c^o from 16 goods in accordance with the linear-homogeneous Cobb–Douglas utility function. The savings here include the savings of household SH^o, company SN^o, regional government SLG^o, and central government SCG^o, in addition to income transfers SDB^o and overseas savings SF^o to offset interregional current account balances. Hayashiyama et al. (2011), Okiyama et al. (2014), and others used a static interregional CGE model to indicate that income transfers are positive for savings in each region. In the structure of the trade sector, although the trade sector includes exports and imports between each region and the foreign sector, trade also occurs through imports and exports between regions. Finally, we explain the relationship between regional and central governments, which coexist. The central government itself does not engage in spending. Instead, its function is to reallocate the taxes it collects to the regional governments of the six regions and to create savings by taking a fixed proportion of the tax revenue and allocating it to the savings sector of the six regions. Meanwhile, the regional governments in the six regions have budgets that contain the differences between the revenues generated from tax receipts and regional allocation tax grants, and so on, and the subsidies disbursed to each production sector. These budgets are then multiplied by a fixed ratio to create savings, and the expenditures comprise social security benefits to the household sector and transfers to other institutional sectors.

4. Setting the elasticity of substitution and other parameters

We estimated the function parameters for each sector with a calibration method that used the six interregional SAM data with 2005 as the benchmark year. However, estimating these function parameters requires that one of the parameters must depend on an external database. Thus, when describing the setting of these parameters, we referenced the values used in GTAP7.1 for the elasticity of substitution for labor and capital in the production sector and the elasticity of substitution for the CES-type (Armington) function of the trade sector. Then, referencing previous studies by Ban (2007), Hayashiyama et al. (2011), and Tanaka and Hosoe (2009), we set the interregional elasticity of substitution for the production sector, the interregional elasticity of substitution for the household and investment sectors, the elasticity of substitution of the CET-type function for the trade sector, and the elasticity of agricultural land and the capital–labor bundle. These are summarized in Table 3.

Table 3 List of the elasticity of substitution setup in the 6SCGE model

Production activities	Elasticity of substitution between land and capital-labor bundle in the CES function	Elasticity of substitution between capital-labor in the CES function	Elasticity of transformation in CET function	Elasticity of substitution of ARMINGTON function	Elasticity of substitution between intermediate goods of different orgin in the CES function
Rice	0.2	0.6	2.0	5.0	2.0
Wheat and potatoes	0.2	0.6	2.0	3.0	2.0
Vegetables	0.2	0.6	2.0	2.0	2.0
Fruits	0.2	0.6	2.0	2.0	2.0
Livestock	0.2	0.6	2.0	2.0	2.0
Fisheries	–	0.6	2.0	1.2	2.0
Slaughtering and dairy products	–	1.2	2.0	4.0	2.0
Processed seafood	–	1.2	2.0	2.0	2.0
Grain milling and agricultural food stuffs	–	1.2	2.0	3.0	2.0
Other foods, beverage and tobacco	–	1.2	2.0	2.0	2.0
Mining and manufacturing products	–	1.3	2.0	3.2	2.0
Construction	–	1.4	2.0	1.9	2.0
Electricity, gas,and water supply	–	1.3	2.0	2.8	2.0
Commerce	–	1.3	2.0	1.9	2.0
Transport	–	1.7	2.0	1.9	2.0
Services	–	1.3	2.0	1.9	2.0

5 Results of the Simulation Analysis

5.1 Setting Simulation Data

This section illustrates the setting of simulation data related to the changes in rice production caused by global warming-induced climate change. Prior to setting the simulation data for this section, we explain how the results obtained from the rice-yield-production function (estimated in Sect. 3) were reflected in the 6SCGE model. As shown in Fig. 3a, the production function for the production block in the 6SCGE model cannot be used to directly reflect the impact of global warming-induced temperature increases on regional rice production. Therefore, this chapter adopts a method to reflect the results of the rice-yield growth rate obtained from the production function, which reflects the temperature variables shown in Sect. 3. While these two models have clear differences, we interpreted the change in the rice yield calculated by the rise of the temperature shown in column (d) of Table 2 as the impacts of global warming on regional rice production. In addition, the regional rice-yield growth rate was matched with the rice-yield growth rate, which was obtained from the change rate of rice production, and agricultural land as the initial value of the impact of global warming on rice (not affected by rice in other regions) in regions corresponding to the 6SCGE model. Even if the results obtained in Sect. 3 are used to obtain the initial value, it is necessary to devise ways to eliminate any doubts regarding the credibility of the simulation results caused by the process of combining the results of one model with another model's simulation premises. Thus, we address this point by using the JMA's future temperature prediction ranges (maximum and minimum values).

Next, specific steps to obtain parameters for simulation conditions are explained as follows. We use efficiency parameter aF_a^o obtained from a calibration with regard to the rice production function, as shown in Eq. (3):

$$XD_a^o = \frac{1}{b} \cdot \left(\alpha_a^o \cdot aF_a^o\right) \left(\gamma F_a^o \cdot R_a^{o\,\frac{-(1-\sigma F_a)}{\sigma F_a}} + \left(1 - \gamma F_a^o\right) KL_a^{o\,\frac{-(1-\sigma F_a)}{\sigma F_a}}\right)^{\frac{-\sigma F_a}{1-\sigma F_a}} \tag{3}$$

where α_a^o represents the parameter (global warming parameter) that changes the productivity of rice production in each region due to climate change, b represents the efficiency parameter for the agricultural land–capital–labor bundle, σF_α represents the elasticity of substitution between agricultural land and the capital–labor bundle in the CES function, and γF_a^o represents the CES distribution parameter for the capital–labor bundle in sector α's production function of region o (see Okiyama and Tokunaga 2016).

However, since the efficiency parameter cannot be directly changed using information discussed in Sect. 3, another approach is used to change this efficiency parameter. This approach determines a global warming parameter, which changes the efficiency parameter (this parameter's default gives "1.0" to the rice production activities in the six regions) from the 6SCGE model simulations. Under this approach, simulations were performed to determine a global warming parameter, which can reproduce the yield growth rate obtained in Sect. 3 in the 6SCGE model, for 15 cases (rice in five regions, except Okinawa, for the maximum, mean, and minimum values). In order to reproduce the yield growth rate in the 6SCGE model, in addition to the rice production in regions that are to be changed, all endogenous variables in all regions will be changed. In line with the changes in rice production, agricultural land, labor, and capital variables, which are rice production factors, will also be changed. Therefore, the changed agricultural land and capital variables were inserted into the yield production function in Eq. 2 to recalculate the said rice-yield growth rate and reproduce it in the 6SCGE model. Through the repetition of these processes, a global warming parameter was obtained in which the results of Eq. 2's production function almost match those of the 6SCGE model. The results are shown in Tables 4 and 5. By inserting the five regions' global warming parameters in Table 5 into the 6SCGE model, "global warming simulations without adaptation technologies" were performed using three scenarios: (1) when future temperature becomes the maximum value, (2) when future temperature becomes

Table 4 Comparison of the result of the yield production function with the result of the 6SCGE model

	Changes by a rise in temperature from 2005 to 2076–2095								
	Rice production per land			Land			Rice production		
Region%	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
Hokkaido	10.96	9.73	8.07	–1.99	–1.78	–1.46	8.97	7.96	6.61
Tohoku	1.06	1.61	1.73	–0.08	–0.12	–0.13	0.98	1.49	1.60
Kanto	–4.77	–3.00	–1.63	0.97	0.61	0.34	–3.80	–2.39	–1.30
Chubu, Kinki, Chugoku, and Shikoku	–7.03	–5.01	–3.27	1.82	1.35	0.88	–5.22	–3.66	–2.39
Kyushu	–7.76	–5.72	–3.89	2.75	2.04	1.40	–5.00	–3.68	–2.49

Table 5 Setting of the five regions' global warming parameters with/without adaption technologies

	Adaptation technologies do not exist			Adaptation technologies exist
Warming parameter(α)	A maximum rise in temperature	A mean rise in temperature	A minimum rise in temperature	A mean rise in temperature
Hokkaido	1.115	1.103	1.085	1.103
Tohoku	1.013	1.019	1.021	1.019
Kanto	0.940	0.962	0.979	0.973
Chubu, Kinki, Chugoku, and Shikoku	0.913	0.937	0.959	0.955
Kyushu	0.910	0.933	0.954	0.952
Okinawa	1.000	1.000	1.000	1.000

the mean value, and (3) when future temperature becomes the minimum value. This was employed to measure the impact of each scenario on regional economies and the economic welfare for each region as well as the economic spillover effects on the agriculture, forestry, fishery, and food and beverage industries. Next, an assumption was made that the "development of high-temperature-tolerant rice varieties has resulted in curbing global warming-induced productivity decline" (with adaptation technologies, mean value) for regions whose global warming parameter is 1 or below when future temperature has a mean value. The global warming parameter was calculated based on the results obtained from the "assessment model for the impact of high temperature on rice" by Akune et al. (2015), which showed that productivity decline will improve by 29 %. Using this parameter, we conducted "global warming simulations with adaptation technologies" by the 6SCGE model and measured the extent to which the negative economic impact can be mitigated by comparing the results of the former.

5.2 Simulation Results

The simulations in Table 6 revealed the following five points. First, in the simulations assuming changes in regional rice production due to Japan's temperature increase over the next 60–80 years (global warming simulations without adaptation technologies), the national equivalent variation (economic welfare, EV) will decrease by 19.48 billion yen when the impact of global warming is the minimum value and by 68.34 billion yen when the impact is the maximum value (compared to the 2005 standards). When this is converted into per capita value, a decline will be in the range of 152 yen–535 yen. By region, the residents in Hokkaido and Tohoku will be positively affected by global warming, while those in Kanto and the region west of Kanto will be negatively affected. When Kyushu receives the maximum impact of global warming, the decline will be up to 875 yen per person, creating a gap of 1199 yen with Hokkaido, which will see a 324 yen increase. Similarly, looking at the impact of global warming on regional economies, while the real GRP will increase by 0.029–0.041 % in Hokkaido, a decline in the real GRP will be the largest in Kyushu at 0.015–0.031 %. Meanwhile, the real GRP in Kanto and the region west of Kanto will be negatively affected by global warming.

Second, while global warming will increase rice production in Hokkaido and Tohoku, production will decrease in Kanto and the region west of Kanto, with a 0.29–1.04 % national decline. Meanwhile, production in Hokkaido will see a double-digit increase of 13.99 % in the case of the maximum value and an 8.16 % increase in the case of the minimum value. In addition, production in Tohoku, the largest producer of rice, will increase by 2.46–3.25 %. By comparing this rate of increase with the simulation results (Table 4), assuming that only Tohoku receives the impact of global warming, the mean value will increase from 1.48 % to 2.93 %. In the case of the maximum value, the rate of increase in production will grow more than three times from +1.01 %. This is because the outflow from Tohoku

Table 6 Simulation results using the 6SCGE model

Changes in output of base value (2005)			Economic welfare		Main index (unit: %)			Direct and indirect effects by global warming (unit: %)					Spillover effect to nonagriculture output (unit:%)					
Region	Adaptation technologies exist or not	Degree of a rise in temperature	Equivalent variation unit: billion yen	E.V. per capita unit: yen	Real GRP	Total output	Farmer household's sales	Total crops	Rice	Wheat and potatoes	Vegetables	Fruits	Livestock	Slaughtering and dairy products	Grain milling and agricultural food stuffs	Other foods, beverage, and tobacco	Mining and manufacturing products	Services
Whole country	Adaptation technologies do not exist	Max	–683.4	–535	–0.011	–0.014	1.148	–0.746	–1.041	–1.442	–0.271	–0.797	–0.156	–0.139	–1.070	–0.075	0.011	0.004
		Mean	–404.4	–317	–0.006	–0.008	0.671	–0.438	–0.609	–0.844	–0.156	–0.484	–0.086	–0.075	–0.640	–0.043	0.007	0.002
		Min	–194.8	–152	–0.003	–0.004	0.315	–0.208	–0.287	–0.397	–0.072	–0.245	–0.034	–0.028	–0.316	–0.020	0.003	0.001
	Adaptation technologies exist (mean)		–238.0	–186	–0.004	–0.005	0.390	–0.253	–0.350	–0.483	–0.089	–0.292	–0.041	–0.034	–0.385	–0.024	0.004	0.001
Hokkaido	Adaptation technologies do not exist	Max	18.2	324	0.041	0.035	1.901	3.204	13.994	–0.259	–0.162	–0.117	–0.094	–0.052	0.564	–0.002	–0.020	0.016
		Mean	20.4	362	0.036	0.034	1.324	2.624	11.047	–0.044	–0.046	0.014	–0.015	0.000	0.651	0.018	–0.015	0.011
		Min	19.8	352	0.029	0.030	0.848	2.009	8.159	0.088	0.027	0.088	0.034	0.031	0.638	0.028	–0.010	0.007
	Adaptation technologies exist (Mean)		22.5	400	0.036	0.036	1.045	2.444	9.967	0.089	0.025	0.093	0.039	0.035	0.736	0.032	–0.011	0.009
Tohoku	Adaptation technologies do not exist	Max	18.4	191	0.013	–0.003	2.455	1.633	3.245	–2.528	–0.211	–0.552	–0.108	–0.112	–0.722	–0.040	–0.005	0.025
		Mean	17.7	184	0.019	0.010	1.588	1.558	2.933	–1.282	–0.100	–0.284	–0.039	–0.045	–0.189	–0.011	–0.005	0.018
		Min	15.9	165	0.021	0.017	0.907	1.359	2.456	–0.394	–0.023	–0.094	0.006	0.000	0.153	0.007	–0.005	0.011
	Adaptation technologies exist (mean)		14.8	154	0.019	0.014	1.029	1.319	2.417	–0.621	–0.044	–0.139	–0.011	–0.013	0.034	0.002	–0.004	0.012
Kanto	Adaptation technologies do not exist	Max	–244.5	–481	–0.010	–0.012	0.627	–1.476	–3.286	–2.214	–0.277	–0.371	–0.074	–0.092	–0.886	–0.053	0.008	0.002
		Mean	–133.6	–263	–0.006	–0.007	0.275	–0.969	–2.254	–1.241	–0.150	–0.184	–0.036	–0.042	–0.499	–0.028	0.004	0.000
		Min	–55.1	–108	–0.004	–0.004	0.031	–0.583	–1.451	–0.534	–0.059	–0.056	–0.010	–0.008	–0.222	–0.011	0.002	0.000
	Adaptation technologies exist (mean)		–77.2	–152	–0.005	–0.005	0.070	–0.739	–1.815	–0.730	–0.083	–0.091	–0.019	–0.015	–0.301	–0.015	0.002	0.000

(continued)

Table 6 (continued)

Changes in output of base value (2005)			Economic welfare		Main index (unit: %)			Direct and indirect effects by global warming (unit: %)					Spillover effect to nonagriculture output (unit:%)					
Region	Adaptation technologies exist or not	Degree of a rise in temperature	Equivalent variation unit: billion yen	E.V. per capita unit: yen	Real GRP	Total output	Farmer household's sales	Total crops	Rice	Wheat and potatoes	Vegetables	Fruits	Livestock	Slaughtering and dairy products	Grain milling and agricultural food stuffs	Other foods, beverage, and tobacco	Mining and manufacturing products	Services
Chubu, Kinki, Chugoku, and Shikoku	Adaptation technologies does not exist	Max	–350.6	–746	–0.016	–0.017	0.827	–2.422	–4.698	–3.611	–0.331	–1.214	–0.216	–0.189	–1.287	–0.108	0.015	0.002
		Mean	–223.6	–476	–0.011	–0.012	0.399	–1.814	–3.656	–2.326	–0.208	–0.762	–0.133	–0.110	–0.837	–0.067	0.010	0.001
		Min	–122.4	–261	–0.007	–0.007	0.099	–1.243	–2.615	–1.290	–0.111	–0.404	–0.069	–0.050	–0.475	–0.035	0.005	0.000
	Adaptation technologies exist (mean)		–141.5	–301	–0.008	–0.008	0.163	–1.340	–2.782	–1.498	–0.130	–0.474	–0.080	–0.058	–0.544	–0.041	0.006	0.000
Kyushu	Adaptation technologies do not exist	Max	–116.9	–875	–0.031	–0.039	0.825	–1.586	–4.030	–1.531	–0.268	–1.154	–0.276	–0.239	–2.026	–0.111	0.021	0.005
		Mean	–81.0	–607	–0.022	–0.028	0.511	–1.206	–3.170	–1.086	–0.187	–0.799	–0.188	–0.157	–1.425	–0.075	0.014	0.003
		Min	–51.3	–384	–0.015	–0.019	0.268	–0.856	–2.335	–0.709	–0.119	–0.505	–0.116	–0.092	–0.918	–0.045	0.009	0.002
	Adaptation technologies exist (mean)		–54.5	–408	–0.016	–0.020	0.308	–0.880	–2.370	–0.756	–0.127	–0.538	–0.123	–0.097	–0.976	–0.049	0.009	0.002
Okinawa	Adaptation technologies do not exist	Max	–8.0	–588	0.000	–0.005	0.157	0.084	3.959	–0.418	–0.035	–0.030	–0.043	–0.064	–1.014	–0.075	0.026	0.004
		Mean	–4.3	–319	0.000	–0.002	0.082	0.047	2.033	–0.217	–0.017	–0.005	–0.026	–0.033	–0.553	–0.042	0.015	0.002
		Min	–1.7	–125	0.000	0.000	0.030	0.020	0.669	–0.073	–0.005	0.011	–0.014	–0.011	–0.219	–0.018	0.007	0.000
	Adaptation technologies exist (mean)		–2.3	–167	0.000	–0.001	0.041	0.025	0.969	–0.106	–0.008	0.007	–0.018	–0.016	–0.290	–0.023	0.009	0.000

will increase due to the differences in rice prices with western Japan, where rice production will decrease. In addition, the region will see a production increase beyond the positive impact of global warming. A similar situation is pointed out in Hokkaido.

Third, through changes in regional rice production, we find that the production of other agricultural products will be affected negatively. Global warming will have a negative impact on the production of other agricultural products even in regions such as Hokkaido and Tohoku, where rice production will increase because, as mentioned above, as rice production increases beyond the impact of global warming in Hokkaido and Tohoku, the three production factors of agricultural land, capital, and labor will shift from other agricultural products to rice. In Kanto and the region west of Kanto, production factors will also be shifted from other agricultural products to rice in order to mitigate a decline in rice production caused by global warming. Meanwhile, these changes in the production volume of agricultural products will also change producer prices for rice and other agricultural products. By considering the production value of agricultural products in each region as farmers' sales and focusing on the change, while the production volume of agricultural products will decrease in regions other than Hokkaido, Tohoku, and Okinawa due to global warming, producer prices will increase in these regions. While the regional production of agricultural products throughout the nation will decrease by 0.21–0.75 %, farmers' sales will increase by 0.32–1.15 %. Moreover, when the impact of global warming is the maximum value, farmers' sales in Chubu, Kinki, Chugoku/Shikoku, and Kyushu will increase by 0.8 %. This level will be almost on par with farmers' sales in Hokkaido and Tohoku when the impact of global warming is the minimum value. As shown above, while the production volume of agricultural products will decrease in Kanto and the region west of Kanto due to global warming, an increase in producer prices for agricultural products will ensure the level of farmers' sales.

Fourth, we examine the spillover effects of global warming on other industries through the impact on production of agricultural products. Livestock production will be negatively affected in almost all regions except for certain cases in Hokkaido and Tohoku. This is due to reasons similar to agricultural products other than rice. In the case of the food and beverage industries, the production of livestock/livestock food products, agricultural food products, and other food-related products, beverages, and tobacco will be positively affected by global warming in Hokkaido and Tohoku, except for certain cases when the impact of global warming is the minimum value. However, it will have a negative impact on other cases and in any case in Kanto and the region west of Kanto. Looking at the production in the mining and manufacturing industries as well as the service industry, the mining and manufacturing industries will be negatively affected, while the service industry will be positively affected in Hokkaido and Tohoku. Meanwhile, in Kanto, Chubu, Kinki, Chugoku/Shikoku, and Kyushu, the mining manufacturing, and service industries will be positively affected.

Fifth, assuming that "a range of global warming-induced decline in productivity has increased by 29 %," due to the development of adaptation technologies for rice in regions affected by global warming (Akune et al. 2015), the negative impact on the production of rice in Kanto and the region west of Kanto will be slightly higher than the range of decline "when the impact of global warming without adaptation technologies is the minimum value." In comparison with the case when the impact of global warming is the mean value, the rate of decline in national rice production improves by approximately 0.26–0.35 %. In addition, the regional production of agricultural products improves by 0.19 %, and the impact will be reduced to −0.25 %. Furthermore, a decline in the national equivalent variation will be reduced by 16.64 billion yen to −23.80 billion yen. However, it does not fall below 19.48 billion yen when "the impact of global warming without adaptation technologies is the minimum value." Looking at the differences between Hokkaido, which is most positively affected by global warming, and Kyushu, which is most negatively affected, a regional gap in the real GRP will slightly narrow from 0.058 % to 0.052 %. Our study also found that both regions' equivalent variation gaps will narrow from 10.14 billion yen to 7.70 billion yen and from 969 yen to 808 yen per person, respectively. In terms of farmers' sales, the national mean value with adaptation technologies will increase by 0.39 %, a 0.28 % decline from the mean value without adaptation technologies, which will increase by 0.67 %. By region, while the development of adaptation technologies will lower production in Kanto and the region west of Kanto, since the growth rate of producers' prices will be lowered, the range of the increase will actually decrease by approximately 0.2 %. Finally, a decline in the range of increase in farmers' sales in Hokkaido and Tohoku will be larger than that of Kanto and the region west of Kanto. In Tohoku, the range of increase will decrease by 0.56 %.

Based on the results of above measurements, the future development of adaptation technologies for rice in regions affected by global warming is expected to have a positive impact on farmers and regional residents in the regions. Actually, the high-temperature-tolerant rice, such as "Tsuyahime" (Yamagata), "Nikomaru" (Kyushu), and "Kinumusume" (Kinki), have been widely cultivated. Thus, it is necessary to develop the new high-temperature-tolerant rice and other agricultural products in order to improve the income on farmers and regional residents in the regions.

6 Conclusion and Policy Implications

The agriculture industry would be most affected by global warming-induced climate change. Based on the assumption that only rice is affected by global warming, this chapter presented the impact of global warming on regional economies through spillover effects from other agricultural products and the industrial section having an input–output relationship with agriculture. As a result, our study found that global warming-induced climate change causes different impacts in each region and creates regional economic disparities. For example, global warming has a positive impact on regional economies in Hokkaido and Tohoku. In addition to increasing rice production, gaps in rice prices in Kanto and the region west of Kanto will increase outflow, which in turn further increases such production. Meanwhile, global warming will reduce production in Kanto and the region west of Kanto, which will have a negative impact on regional economies. Moreover, other agricultural products will be negatively affected in all regions due to changes in rice production, while production in the food and beverage industries will be negatively affected in Kanto and the region west of Kanto. However, when the impact of global warming becomes greater, production in the food and beverage industries will increase in Hokkaido and Tohoku. While production in the mining and manufacturing industries will be negatively affected in Hokkaido and Tohoku, production will increase in other regions. The service industry will be positively affected in all regions.

Finally, we found that there is the good impact of adaptation technologies on the production of rice in Kanto and the region west of Kanto from simulation results of the development of adaptation technologies such as high-temperature-tolerant rice varieties in regions affected by global warming. Thus, the promotional policy of adaptation technologies such as high-temperature-tolerant rice varieties and public support for industrial clusters based on rice are necessary in order to eliminate the disparities in regional economic welfare caused by global warming.

References

Akune Y, Okiyama M, Tokunaga S (2015) Economic evaluation of dissemination of high temperature-tolerant rice in Japan using a dynamic computable general equilibrium model. JARQ 49(2):127–134

Arellano M, Bond S (1991) Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Rev Econ Stud 58:277–297

Baltagi BH (2013) Econometric analysis of panel data. Palgrave Macmillan, New York

Ban K (2007) Development of a multiregional dynamic applied general equilibrium model for the Japanese economy; regional economic analysis based on a forward-looking perspective. RIETI Discussion paper series (in Japanese)

EcoMod Modeling School (2012) Advanced techniques in CGE modeling with GAMS. Global Economic Modeling Network, Northampton MA-USA

Egaitsu F, Shigeno R (1983) Rice production function and equilibrium level of wage and land rent in postwar Japan. J Rural Econ 54(4):167–174 (in Japanese)

Godo Y (1991) The effect of variation in family-farm Laborers' self-estimated wage rates, by farm-size, on land accumulation by large-size farms in the Japanese rice sector. J Rural Econ 63(2):100–117 (in Japanese)

Hayashiyama Y, Abe M, Muto S (2011) Evaluation of GHG discharge reduction policy by 47 prefectures multi-regional CGE. J Appl Reg Sci 16:67–91

Hosoe N, Gasawa K, Hashimoto H (2010) Textbook of computable general equilibrium modeling: programming and simulations. Palgrave Macmillan, New York

Japan Meteorological Agency (2013) Global warming projection, vol 8, Tokyo

Kako T (1984) Efficiency and economies of scale in rice production: the case of Ishikari area in Hokkaido. J Rural Econ 56(3):151–162 (in Japanese)

Kunimitsu Y (2015) Regional impacts of long-term climate change on rice production and agricultural income: evidence from computable general equilibrium analysis. JARQ 49(2): 173–186

Kunimitsu Y, Iizumi Y, Yokozawa M (2013) Is long-term climate change beneficial or harmful for rice total factor productivity in Japan: evidence from a panel data analysis. Paddy Water Environ. doi:10.1007/s10333-013-0368-0(onlinefirst)

Kuroda Y (1979) A study of the farm-firm's production behavior in the mid-1960's Japan–a profit function approach-. Econ Stud Quarterly 30:107–122

Kuroda Y (2013) Production structure and productivity of Japanese agriculture volume1: quantitative investigations on production structure. Palgrave Macmillan, Basingstoke

Kusakari H (1985) Technical progress and variability in yield of rice. In: Sakiura S (ed) Economic growth and agriculture development. Nourintoukeikyoukai, Tokyo, pp 193–213 (in Japanese)

Ministry of Education, Culture, Sports, Science, Technology, Japan Meteorological Agency and Ministry of the Environment (2009) Climate change and its impacts in Japan. Consolidated report on observation, projections and impact assessments of climate change, Tokyo

Nishimori M, Yokozawa M (2001) Regional change of variability in rice unit yield in Japan by climate change and abnormal weather. Glob Environ Res 6(2):149–158 (in Japanese)

Okiyama M, Tokunaga S (2016) Impact of global warming on a regional economy through fluctuation in agricultural production: utilizing the multi-regional CGE model. J Rural Econ 87(4):341–346 (in Japanese)

Okiyama M, Ikegawa M, Tokunaga S (2013) Analysis of the effects of Japanese agricultural production induced by a climate change: utilizing the panel data being composed of 8 regions. Rural Econ Sociol Ins Agric Univ Tsukuba 29:1–17 (in Japanese)

Okiyama M, Tokunaga S, Akune Y (2014) Analysis of the effective source of revenue to reconstruct the disaster-affected region of the great east japan earthquake: utilizing the two-regional CGE model. J Appl Reg Sci 18:1–16 (in Japanese)

Shimono H (2008) Modelling, information and environment impact of global warming on yield fluctuation in rice in the northern part of Japan (in Japanese). Nippon Sakumotsu Gakkai Kiji (Jpn J Crop Sci) 77:489–497

Tanaka T, Hosoe N (2009) Productivity shocks and national food security for Japan. RIETI discussion paper series (in Japanese)

Tokunaga S, Resosudarmo BP, Wuryanto LE, Dung NT (2003) An inter-regional cge model to assess the impacts of tariff reduction and fiscal decentralization on regional economy. Stud Reg Sci 33(2):1–25

Tokunaga S, Okiyama M, Ikegawa M (2015) Dynamic panel data analysis of the impacts of climate change on agricultural production in Japan. JARQ 49(2):149–158

Yokozawa M, Iizumi T, Okada M (2009) Large scale projection of climate change impacts on variability in rice yield in Japan. Glob Environ Res 14(2):199–206 (in Japanese)

Risk Evaluation of Social Decision Process: A Two-Stage Auction Game Model for Japanese Urban Redevelopment Procedure

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Abstract Under the scheme of Japanese City Renewal Law (JCRL), the cost of urban redevelopment project has been financed by the revenue from selling the reserved floor secured beforehand in the redeveloped building. Since the outcome of whether or not the reserved floor can be sold is unforeseeable, entities for redevelopment are faced with the risk for project financing. Traditional risk evaluation has just focused on the risk inherent in the project that is carried out by a single entity and whose future returns are uncertain. On the contrary, we focus on the risk of urban redevelopment project in which plural decision-makers are involved and whose future outcome becomes uncertain since it depends on the decisions made by other decision-makers involved. Defining the risk for the entities as the probability that the entities suffer a loss and formalizing urban redevelopment procedure as a two-stage auction game, we have demonstrated that we can evaluate numerically the actual amount of risk the entities are going to bear in the project by using hypothetical examples. To give more reality, we also show an application of our model to the actual instance of urban redevelopment project that was broken down to produce a huge amount of loss and see whether our model can infer its amount of loss.

Keywords Risk evaluation • Urban redevelopment procedure • Game theory • Auction model • Bankruptcy • Japanese City Renewal Law • Social decision process

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1 Introduction

Under the scheme of Japanese City Renewal Law (JCRL), the cost of urban redevelopment project has been financed by the revenue from selling the reserved floor secured beforehand in the redevelopment building. Since the outcome of whether or not the reserved floor can be sold is unforeseeable, entities for redevelopment are faced with the risk for project financing.

As seen in financial engineering studies such as DDCF (dynamic discounted cash flow) and real options (See, e.g., Kariya et al. (2003), Kawaguchi (2003), and Trigeorgis (1996)), researches on risk evaluation traditionally have been focusing on the risk entailed by the project that is carried out by a single entity and whose future returns are uncertain. On the contrary, in this study we focus on the risk of urban redevelopment project in which plural decision-makers are involved and whose future outcome becomes uncertain since it depends on the decisions made by other decision-makers involved.

Conceptualizing the process of the conventional urban redevelopment project, we formalize the urban redevelopment procedure as a two-stage auction game. Based on this model, we define the risk for the entities as the probability that the entities suffer a loss. With this setup, we have demonstrated that we can evaluate numerically the actual amount of risk the entities are going to bear in the project by showing hypothetical examples.

The game theoretic model for urban redevelopment procedure was first constructed by Imanishi et al. (2006). They have addressed the problem to evaluate what amount of risk would be transferred from UR (Urban Renaissance Agency), a government entity for redevelopment authorized by JCRL, to the private sector if UR employs a new contract scheme under which UR can delegate the disposition of the reserved floor to the constructor who makes a contract with UR to construct the redevelopment building.

Following their model, our model also is formalized as a two-stage auction game in which the first auction is performed to choose a constructor for the redevelopment building as a sealed bid first lowest price auction and the second one to choose a buyer for the reserved floor as a sealed bid first highest price auction.

In Imanishi et al. (2006), they theoretically derived the risk born by the entities for the redevelopment under a hypothetical case where true preferences of buyers and constructors are distributed according to uniform distributions. While their derivation is an innovative one, they have derived the result for just one case out of all four possible cases. In Imanishi and Saito (2010) and Saito and Imanishi (2010), they have shown derivations for all these four cases. This paper is a revised version of Saito and Imanishi (2010) to add new results.

The remaining parts of this paper are composed as follows. In Sect. 2, we introduce our model. Theoretical derivations of the risk under uniform distribution are shown in Sect. 3. Section 4 gives applications. We conclude in Sect. 5.

2 A Two-Stage Auction Game Model for Urban Redevelopment Procedure

We consider a traditional urban redevelopment project that plans to build a high-rise redevelopment building that includes the reserved floor to be sold for compensating the project cost. In this usual urban redevelopment project, three kinds of players are involved: (1) the entity that carries out the project taking the risk of project financing (hereafter the redevelopment entity), (2) a building constructor who constructs the redevelopment building, and (3) a buyer who buys the reserved floor.

The process of a typical urban redevelopment project proceeds as follows:

1. The redevelopment entity performs the first-stage auction to choose among the bidders a constructor to build the redevelopment building in the form of the sealed bid first lowest price auction.
2. The bidder who set the lowest price is chosen as the constructor.
3. The redevelopment entity performs the second-stage auction to choose among the bidders a buyer to buy the reserved floor in the form of the sealed bid first highest price auction.
4. The bidder who set the highest price is chosen as the buyer of the reserved floor.
5. The payoffs are determined for all three players: the redevelopment entity implementing the project, the constructor, and the reserved floor buyer.

We formulate this procedure as a two-stage auction game.

Let $M = \{1, 2, \ldots, m\}$ and $N = \{1, 2, \ldots, n\}$ be, respectively, the set of bidders in the auction for the reserved floor and the set of bidders in the auction for the redevelopment building construction. They are indexed as $i \in M$ and $j \in N$. We denote the payoff for the redevelopment entity by u_0 and the payoffs for $i \in M$ and $j \in N$ by u_i and u_j, respectively. Let $e_i(>0)$ and $c_i(>0)$ denote the true values of the reserved floor and the redevelopment building construction cost for i and j, respectively.

We make the following assumptions. First, every player is assumed risk neutral. Next, every bidder for each auction is symmetric. In other words, the true value of the reserved floor e_i for every i is distributed according to the same distribution F and the true value of construction cost c_j for every j according to the same distribution G. Third, for the bidding process of the reserved floor auctions, all bidders are assumed to know their own true value e_i, but do not know the true values for all other bidders. Hence, each bidder i regards all bidding prices $e_{i'}$ charged by all other bidders i' as though they were independently drawn from distribution F. We assume that F has a differentiable density f with the support of $[\underline{e}, \overline{e}]$.

In the same way, for the bidding process of construction auction, all bidders are assumed to know their own true value c_j, but do not know the true values for other bidders. Hence, each bidder j regards all bidding prices $c_{j'}$ charged by all other bidders j' as though they were independently drawn from distribution G. We also assume that G has a differentiable density g with the support of $[\underline{c}, \overline{c}]$. These assumptions are typical for the discussion of Bayesian Nash equilibrium. Finally, we assume that two auctions are carried out independently.

From these, the urban redevelopment process can be described as follows. First we draw at random c_j $(j \in N)$ for all bidders of constructors from G. Next, they decide their own bidding prices b_j $(j \in N)$. Then, the successful bidder j^* and his bidding price b_{j^*} are determined. Similarly, we draw at random e_i $(j \in N)$ for all bidders of reserved floor buyers from F. Next, they decide their own bidding prices $t_i(\mathrm{i} \in M)$. Then the successful bidder i^* and his bidding price t_{i^*} are determined.

At the final step, the payoffs for all three players are determined. For the constructors, $u_{j*} = b_{j*} - c_{j*}$ if j is the successful bidder, i.e., $j = j^*$ and $u_j = 0$, otherwise, i.e., for $j \neq j*, j \in N$. For the reserved floor buyers, $u_{i*} = e_{i*} - t_{i*}$ if i is the successful bidder, i.e., $i = i^*$ and $u_i = 0$, otherwise, i.e., for $i \neq i^*$, $i \in M$. The payoff for the redevelopment entity becomes $u_0 = t_{i*} - b_{j*}$. Their payoffs are summarized as follows.

$$u_0 = t_{i*} - b_{j*}$$

$$u_i = \begin{cases} e_{i*} - t_{i*} & \text{for } i = i* \\ 0 & \text{otherwise} \end{cases}, \quad i \in M$$

$$u_j = \begin{cases} b_{j*} - c_{j*} & \text{for } j = j* \\ 0 & \text{otherwise} \end{cases}, \quad j \in N$$

It is well known that for the auction game with incomplete information under Bayesian Nash assumptions, the optimal strategy for each participant is derived as a closed form. Here the optimal strategy for each bidder means that it maximizes the expected utility for the bidder. We state the optimal strategy for each bidder for the above two independent auctions as the following propositions (Cf. Myerson (1991), Miura (2003), and Imanishi et al. (2006). Here we are not concerned with the design of auction. See Milgrom (2004) for auction design theory.

Proposition 1 In the auction for the reserved floor, the optimal strategy t_i of the bidder i with value e_i is

$$t_i = t(e_i) = e_i - \int_{\underline{e}}^{e_i} \left(\frac{F(y)}{F(e_i)} \right)^{m-1} dy. \tag{1}$$

Proposition 2 In the auction for the redevelopment building construction contract, the optimal strategy b_j of the bidder j with value c_j is

$$b_j = b(c_j) = c_j + \int_{c_j}^{\bar{c}} \left(\frac{1 - G(x)}{1 - G(c_j)} \right)^{n-1} dx. \tag{2}$$

For the completeness, we give the proof of these propositions in Appendix.

Since we have the expressions of the optimal bidding prices for participants to the reserved floor and the redevelopment building construction auctions, we can formulate the expected payoff EU_0 for the redevelopment entity.

To do this, we note that the function $t(e_i)$ in Eq. (1) maps the true value e_i of bidder i to the optimal bidding price t_i. Accordingly we see that the function $t(e_i)$ also transforms the distribution of true value e_i to a new distribution of the optimal bidding price t_i. Hence, we assume that the optimal bidding function $t(e_i)$ transforms the probability density function f and the cumulative distribution function F of true value e_i to a probability density function h and a cumulative distribution function H of optimal bidding price t_i. More specifically, the density $f(e_i)$ is assumed to be transformed by $t(e_i)$ to the density $h(t_i)$ on $[\underline{t}, \overline{t}]$ as follows:

$$h\left(t_i\right) = f\left(t^{-1}\left(t_i\right)\right)\left|\frac{\partial t^{-1}}{\partial t_i}\right|$$

The cumulative distribution function $H(t_i)$ of t_i is defined as follows:

$$H\left(t_i\right) = \int_{\underline{t}}^{t_i} h(s)ds$$

In the same way, the density $g(c_j)$ is assumed to be transformed by the optimal bidding function $b(c_j)$ to the density $k(b_j)$ on $\left[\underline{b}, \overline{b}\right]$ in the following way:

$$k\left(b_j\right) = g\left(b^{-1}\left(b_j\right)\right)\left|\frac{\partial b^{-1}}{\partial b_j}\right|$$

The survival function $k(b_j)$ of b_j is defined as below:

$$K\left(b_j\right) = \int_{b_j}^{\overline{b}} k(s)ds$$

Now let $EU_0(i, j)$ denote the expected payoff of the redevelopment entity when constructor j and reserved floor buyer i become successful bidders. The expected payoff $EU_0(i, j)$ is formulated as follows:

$$EU_0\left(i,j\right) = \int_{\underline{b}}^{\overline{b}}\int_{\underline{t}}^{\overline{t}}\left(t_i - b_j\right)h\left(t_i\right)k\left(b_j\right)H(t_i)^{m-1}K\left(b_j\right)^{n-1}dt_i db_j \tag{3}$$

Here h and H denote, respectively, density and distribution functions of t_i on $[\underline{t}, \overline{t}]$. The functions k and K are, respectively, the density and survival function (i.e., = 1 – distribution function) of b_j on $\left[\underline{b}, \overline{b}\right]$.

The integral (3) expresses the expected payoff for the redevelopment entity when the buyer-constructor pair (i, j) offers bidding prices (t_i, b_j) and becomes successful bidders. The reason why this is so is explained by the following interpretation of Eq. (3).

First we fix i and j. The constructor j sets the bidding price b_j by drawing it at random from the density $k(b_j)$. In order for the bidding price b_j to become a successful bid, all other constructors j' must bid higher prices $b_{j'}$ than b_j. Note that the probability that a constructor j' bids the higher price $b_{j'}$ than b_j equals $K(b_j)$. Assuming all other constructors independently draw their bidding prices at random from the identical distribution, the probability that all other constructors offer higher bidding prices than b_j becomes $K^{n-1}(b_i)$. Thus, the term $b_j k\left(b_j\right) K\left(b_j\right)^{n-1}$ in the integrand of integral (3) can be said the expected cost of the redevelopment building construction from the viewpoint of the redevelopment entity since it is the product of bidding price b_j and the probability that the price b_j becomes a successful construction contract price.

In the same way, the term $t_i h\left(t_i\right) H(t_i)^{m-1}$ in the integrand of integral (3) is said the expected revenue for selling the reserved floor from the viewpoint of redevelopment entity since it is the product of bidding price t_i and the probability that the price t_i becomes successful reserved floor selling contract price.

The integral (3) integrates the payoff $(t_i - b_j)$ over the area $\left(t_i, b_j\right) \in \times [\underline{t}, \bar{t}] \times \left[\underline{b}, \bar{b}\right]$ with weighting by the probability that prices $(t_i,\ b_j)$ become successful bidding prices. Thus, the integral (3) is interpreted as the expected payoff for the redevelopment entity obtained from a particular pair $(i,\ j)$ by calculating the expectation with respect to the probability that the pair $(i,\ j)$ becomes successful bidders when they bid the bidding prices $(t_i,\ b_j)$.

Note that from the symmetric assumption, the event that each pair (i, j) becomes a successful pair is symmetric and exclusive. Therefore, its probability becomes $1/(mn)$. We can check this by setting to 1 the term $(t_i - b_j)$ in the integrand at the right-hand side of integral (3) to calculate the probability that the pair (i, j) becomes a successful pair. In fact, the integral (3) in this case becomes equal to $1/(mn)$.

$$\int_{\underline{b}}^{\bar{b}} \int_{\underline{t}}^{\bar{t}} h\left(t_i\right) k\left(b_j\right) H(t_i)^{m-1} K\left(b_j\right)^{n-1} dt_i db_j = \frac{1}{mn} \tag{4}$$

Noting that $EU_0(i, j)$ is the expected payoff obtained from the particular pair (i, j) and that each pair is assumed symmetric, the total expected payoff EU_0 for the redevelopment entity is known to be the sum of $EU_0(i, j)$ over all pairs (i, j) in $M \times N$. Thus, EU_0 is expressed as follows:

$$\begin{aligned} EU_0 &= \sum_{i=1}^{m} \sum_{j=1}^{n} \int_{\underline{b}}^{\bar{b}} \int_{\underline{t}}^{\bar{t}} \left(t_i - b_j\right) h\left(t_i\right) k\left(b_j\right) H(t_i)^{m-1} K\left(b_j\right)^{n-1} dt_i db_j \\ &= m \sum_{i=1}^{m} \int_{\underline{t}}^{\bar{t}} t_i h\left(t_i\right) H(t_i)^{m-1} dt_i - n \sum_{i=1}^{m} \int_{\underline{b}}^{\bar{b}} b_j k\left(b_j\right) K\left(b_j\right)^{n-1} db_j \end{aligned} \tag{5}$$

Here the second equality is derived from a similar calculation to derive Eq. (4).

3 Risk Evaluation of Urban Redevelopment Project

3.1 Evaluating the Risk Under Uniform Distribution Assumption

We define the risk of urban redevelopment procedure as the probability that the redevelopment entity suffers the negative profit from the redevelopment implementation process.

Based on this definition, we wish to calculate the risk of urban redevelopment procedure under the specific distributional assumption. We assume that F and G are distributed as uniform distributions on $[\underline{e}, \overline{e}]$ and $[\underline{c}, \overline{c}]$, respectively.

Under these assumptions, optimal bidding strategy functions $t(e_i)$ and $b(c_j)$ expressed in Eqs. 1 and 2 are formulated as below by a simple calculation.

$$b_j = b\left(c_j\right) = \frac{(n-1)\,c_j + \overline{c}}{n}, \quad t_i = t\left(e_i\right) = \frac{(m-1)\,e_i + \underline{e}}{m} \tag{6}$$

$$\underline{b} = \frac{(n-1)\,\underline{c} + \overline{c}}{n}, \quad \overline{b} = \overline{c}, \quad \underline{t} = \underline{e}, \quad \overline{t} = \frac{(m-1)\,\overline{e} + \underline{e}}{m} \tag{7}$$

From these equations, we see that optimal bidding strategy functions $t(e_i)$ and $b(c_j)$ transform uniform distributions F and G into uniform distributions again. More specifically, uniform distributions of c_j on $[\underline{c}, \overline{c}]$ and e_i on $[\underline{e}, \overline{e}]$ are transformed, respectively, into uniform distributions of b_j on $\left[\underline{b}, \overline{b}\right]$ and t_i on $[\underline{t}, \overline{t}]$. Let K denote the survival function for b_j and H the distribution function for t_i. We obtain

$$K(x) = \frac{\overline{b} - x}{\overline{b} - \underline{b}}, \quad \left(x \in \left[\underline{b}, \overline{b}\right] \subset R_+\right), \quad H(y) = \frac{y - \underline{t}}{\overline{t} - \underline{t}}, \quad \left(y \in [\underline{t}, \overline{t}] \subset R_+\right) \tag{8}$$

Let k and h denote the densities of $1 - K$ and H. We obtain

$$k(x) = \frac{1}{\overline{b} - \underline{b}}, \quad \left(x \in \left[\underline{b}, \overline{b}\right] \subset R_+\right), \quad h(y) = \frac{1}{\overline{t} - \underline{t}}, \quad \left(y \in [\underline{t}, \overline{t}] \subset R_+\right) \tag{9}$$

Now let $p(m, n)$ denote the probability that the payoff of the redevelopment entity becomes negative. As known from the above discussion, each pair is assumed to be symmetric and exclusive so that the probability that a particular pair becomes a successful pair equals $1/(mn)$. Hence, to solve for $p(m, n)$, it suffices to focus on a particular pair and to calculate the probability that this particular pair becomes successful and produces a negative payoff at the same time because $p(m, n)$ is obtained by multiplying this probability by mn. The particular pair can be any pair (i, j) in $M \times N$ so that without loss of generality, we can omit the index (i, j) indicating a particular pair.

With these considerations, we denote by I the probability that a successful pair produces a negative payoff. This probability can be formulated as follows:

$$I = \iint_S k(x)h(y)K(x)^{n-1}H(y)^{m-1}dxdy = A\iint_S \left(\overline{b}-x\right)^{n-1}(y-\underline{t})^{m-1}dxdy, \quad (10)$$

where $S = \left\{(x, y) \in \left[\underline{b}, \overline{b}\right] \times [\underline{t}, \overline{t}] \;\middle|\; x \geq y\right\} \subset R_+ \times R_+$ and $A = \left(\frac{1}{\left(\overline{b}-\underline{b}\right)^n\left(\overline{t}-\underline{t}\right)^m}\right)$.

The integrand of the right-hand side of the first equation in Eq. (10) is interpreted in a similar way to the previous discussion. The term $K(x)^{n-1}H(y)^{m-1}$ equals the conditional probability that given (x, y), the pair (x, y) of bidding prices becomes successful. The term $k(x)h(y)$ is the probability that the pair (x, y) is drawn. Thus, the integrand is equal to the probability that the pair (x, y) of bidding prices becomes successful bids. Note that the area S means that the cost x of redevelopment building construction is equal to or greater than the price y of reserved floor. Thus, the integral in Eq. (10) is identical to the probability that a successful pair produces a negative payoff.

As we defined the risk of urban redevelopment procedure as the probability $p(m, n)$ that the redevelopment entity suffers the negative profit, we can formulate the risk of urban redevelopment procedure as follows:

$$p\,(m, n) = mnI \quad (11)$$

With these setups, we wish to calculate the risk of urban redevelopment procedure. For the purpose, we calculate the integral in Eq. (10). To do this, it is convenient to classify the area S into four cases depending on the values of $\underline{t}$, $\overline{t}$, $\underline{b}$, and $\overline{b}$ as displayed in Fig. 1.

We provide the results for these four cases below. The derivation of these formulae is given in Appendix.

Case 1 ($\underline{b} \leq \underline{t} \leq \overline{b} \leq \overline{t}$) Figure 1a shows the area where the entity's payoff becomes negative in $\underline{b} \leq \underline{t} \leq \overline{b} \leq \overline{t}$. In this case, the risk is

$$I = \frac{A}{mn} \cdot \frac{1}{{}_{n+m}C_m} \left(\overline{b}-\underline{t}\right)^{n+m} \quad (12)$$

Case 2 ($\underline{b} \leq \underline{t} \leq \overline{t} \leq \overline{b}$) Figure 1b shows the area where the entity's payoff becomes negative in $\underline{b} \leq \underline{t} \leq \overline{t} \leq \overline{b}$. In this case, the risk is

$$I = \frac{A}{nm} \cdot \frac{1}{{}_{n+m}C_m} \left(\left(\overline{b}-\underline{t}\right)^{n+m} - \left(\overline{b}-\overline{t}\right)^{n+m}\right) - \frac{A}{mn}\sum_{k=1}^{m-1} \frac{n!m!}{(m-k)!\,(n+k)!} S_1(k),$$
$$\textit{where } S_1(k) = \left(\overline{b}-\overline{t}\right)^{n+k}\left(\overline{t}-\underline{t}\right)^{m-k} \quad (13)$$

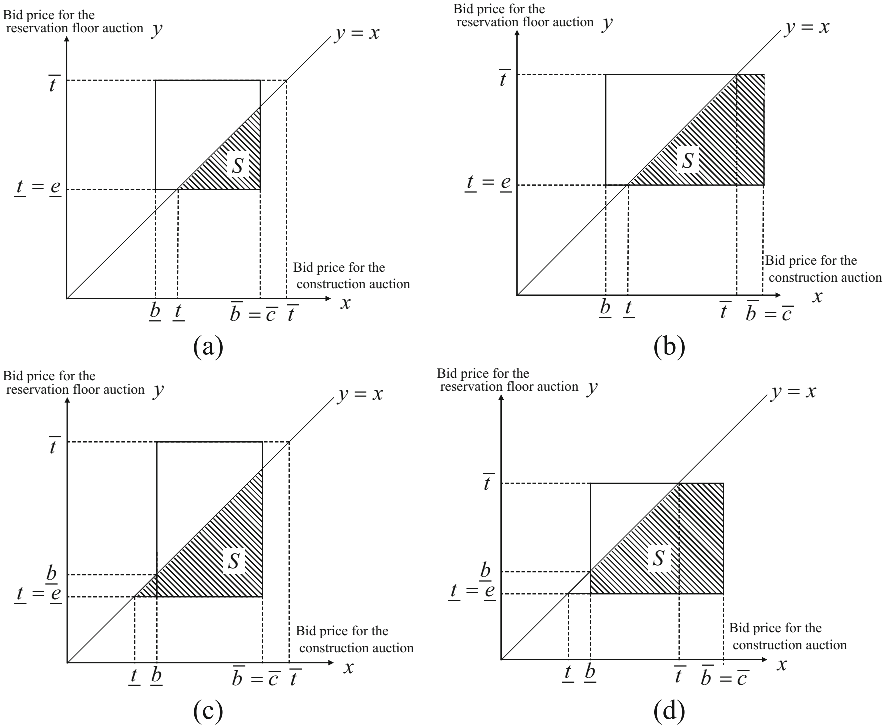

Fig. 1 Four cases. (**a**) Case 1 (**b**) Case 2 (**c**) Case 3 (**d**) Case 4

Case 3 ($\underline{b} \geq \underline{t}$, $\overline{b} \leq \overline{t}$) Figure 1c shows the area where the entity's payoff becomes negative in $\underline{b} \geq \underline{t}$, $\overline{b} \leq \overline{t}$. In this case, the risk is

$$I = \frac{A}{nm}\left(\left(\overline{b}-\underline{b}\right)^n\left(\underline{b}-\underline{t}\right)^m + \frac{1}{{}_{n+m}C_m}\left(\overline{b}-\underline{b}\right)^{n+m}\right) + \frac{A}{mn}\sum_{k=1}^{m-1}\frac{n!m!}{(m-k)!\,(n+k)!}S_2(k),$$
$$where\ S_2(k) = \left(\overline{b}-\underline{b}\right)^{n+k}\left(\underline{b}-\underline{t}\right)^{m-k} \tag{14}$$

Case 4 ($\underline{b} \geq \underline{t}$, $\overline{b} \geq \overline{t}$) Figure 1d shows the area where the entity's payoff becomes negative in $\underline{b} \geq \underline{t}$, $\overline{b} \geq \overline{t}$. In this case, the risk is

$$I = \frac{A}{nm}\left(\overline{b}-\underline{b}\right)^n\left(\underline{b}-\underline{t}\right)^m - \frac{A}{mn}\sum_{k=1}^{m-1}\frac{n!m!}{(m-k)!\,(n+k)!}\left(S_1(k)-S_2(k)\right) \tag{15}$$

3.2 The Number of Auction Repetitions as an Index of the Risk

Suppose that when the redevelopment entity encounters a negative payoff, the redevelopment entity would repeat auctions until the entity's payoff becomes positive. Then, we can use the number of auction repetitions required to get a positive profit as an index of the redevelopment risk.

Remember that $p(m, n)$ denotes the probability that the payoff for the redevelopment entity becomes negative. Define the random variable $X(m, n)$ as the number of auction repetitions required for the redevelopment entity to reach a positive payoff for the first time. The probability that entity's payoff becomes positive for the first time at the kth repetition is equal to $p(m,n)^{k-1}\,(1-p\,(m,n))$. Thus, $X(m, n)$ is distributed as geometric distribution. Hence, the expected number of minimum auction repetitions required to reach positive payoff for the first time becomes as follows (Cf. Nishimura et al. 2002):

$$\frac{1}{1-p\,(m,n)} \tag{16}$$

3.3 Expected Payoff and the Number of Auction Repetitions

Under the uniform distribution assumption, we can get a simple formula for EU_0. Some integral calculations of Eq. (5) lead to the following:

$$\begin{aligned} EU_0 &= \frac{m}{m+1}\bar{t} + \frac{1}{m+1}\underline{t} - \frac{1}{n+1}\bar{b} - \frac{n}{n+1}\underline{b} \\ &= \frac{(m-1)\,\bar{e} + 2\underline{e}}{m+1} - \frac{(n-1)\,\underline{c} + 2\bar{c}}{n+1} \end{aligned} \tag{17}$$

From this, we see that EU_0 approaches $\bar{t} - \underline{b}$ as m, $n\rightarrow\infty$. But as $\bar{t}$ and $\underline{b}$ also converge, respectively, to $\bar{e}$ and $\underline{c}$ as m, $n\rightarrow\infty$, EU_0 consequently converges to $\bar{e}-\underline{c}$.

From its definition EU_0 sums over both negative and positive expected payoffs. As we will see in the numerical example, the risks would be quite different even if the total expected payoffs are the same. To be precise for this, define U_{ij} as $U_{ij} = t_i - b_j$ and introduce the dummy variables such that $D_{ij} = 1$ if $t_i - b\mathrm{j} \geq 0$ and $D_{ij} = 0$ otherwise. Note that $U_{ij} = U_{ij}D_{ij} + U_{ij}\left(1 - D_{ij}\right)$. Then, we can decompose EU_0 into a positive part EU_{0+} and a negative part EU_{0-}.

$$\begin{aligned} EU_0 &= \mathrm{E}\left[\sum_{i=1}^{m}\sum_{j=1}^{n} U_{ij}\right] \\ &= \mathrm{E}\left[\sum_{i=1}^{m}\sum_{j=1}^{n} U_{ij}D_{ij}\right] + \mathrm{E}\left[\sum_{i=1}^{m}\sum_{j=1}^{n} U_{ij}\left(1-D_{ij}\right)\right] \\ &= EU_{0+} + EU_{0-} \end{aligned}$$

If we introduce the conditional expectation, omitting the indices (i, j) from the symmetric assumption, EU_{0+} is reformulated as follows:

$$\begin{aligned} EU_{0+} &= \mathrm{E}\left[\sum_{i=1}^{m}\sum_{j=1}^{n} U_{ij} D_{ij}\right] \\ &= \sum_{i=1}^{m}\sum_{j=1}^{n} \mathrm{E}\left[U_{ij}\middle| D_{ij} = 1\right] \mathrm{P}\left(D_{ij} = 1\right) \\ &= \sum_{i=1}^{m}\sum_{j=1}^{n} \mathrm{E}\left[U_{ij}\middle| D = 1\right] \mathrm{P}\left(D = 1\right) \\ &= \mathrm{E}\left[\sum_{i=1}^{m}\sum_{j=1}^{n} U_{ij}\middle| D = 1\right] P\left(D = 1\right) \\ &= \mathrm{E}\left[U_0\middle| D = 1\right] \mathrm{P}\left(D = 1\right) \end{aligned}$$

Thus, the conditional expected payoff for the redevelopment entity given that the profit is positive is obtained as

$$\mathrm{E}\left[U_0\middle| D = 1\right] = \frac{EU_{0+}}{\mathrm{P}\left(D = 1\right)} = \frac{EU_{0+}}{\left(1 - p\left(m, n\right)\right)}$$

Hence, the conditional expected payoff equals the quotient of EU_{0+} divided by the number of auction repetitions. This expression suggests a method to transform the risk index as the number of auction repetitions into money terms. If we replace EU_{0+} with the cost C incurred by auction repetitions, we can compare the positive conditional expected payoff with the risk in money terms.

4 Applications

4.1 Numerical Examples

In Table 1 we provide numerical examples corresponding to the above four cases. Look at Table 1d, for instance. The caption above this table tells that the true distribution of building construction cost is uniform distribution on $[\underline{c}, \overline{c}] = [1, 3]$ and that of reserved floor value is uniform distribution on $[\underline{e}, \overline{e}] = [1, 3.2]$. Each of 16, 4 by 4, cells corresponds to different combinations with different numbers of m and n, where m is the number of participants for reserved floor auction and n is the number of participants for the redevelopment building construction auction. The

Table 1 The expected number of auction repetitions required for the redevelopment entity to get the positive payoff

(a) Case 1

$\underline{c}=1, \bar{c}=3, \underline{e}=2, \bar{e}=4$

		$\bar{t}$	3	3.3	3.5	3.6
		$\underline{t}=\underline{e}$	2	2	2	2
$\underline{b}$	$\bar{b}=3$	n \ m	2	3	4	5
2	3	2	1.20	1.04	1.01	1.00
1.67	3	3	1.04	1.01	1.00	1.00
1.5	3	4	1.01	1.00	1.00	1.00
1.4	3	5	1.00	1.00	1.00	1.00

(b) Case 2

$\underline{c}=1, \bar{c}=3, \underline{e}=2, \bar{e}=2.2$

		$\bar{t}$	2.1	2.13	2.15	2.16
		$\underline{t}=\underline{e}$	2	2	2	2
$\underline{b}$	$\bar{b}=3$	n \ m	2	3	4	5
2	3	2	7.79	5.28	4.44	4.03
1.67	3	3	1.52	1.45	1.40	1.38
1.54	3	4	1.18	1.15	1.14	1.13
1.4	3	5	1.07	1.06	1.05	1.05

(c) Case 3

$\underline{c}=1, \bar{c}=3, \underline{e}=0.5, \bar{e}=5.5$

		$\bar{t}$	3	3.38	4.25	4.5
		$\underline{t}=\underline{e}$	0.5	0.5	0.5	0.5
$\underline{b}$	$\bar{b}=3$	n \ m	2	3	4	5
2	3	2	2.21	1.21	1.07	1.02
1.67	3	3	1.59	1.11	1.03	1.01
1.54	3	4	1.39	1.07	1.02	1.01
1.4	3	5	1.29	1.05	1.01	1.00

(d) Case 4

$\underline{c}=1, \bar{c}=3, \underline{e}=1, \bar{e}=3.2$

		$\bar{t}$	2.1	2.47	2.65	2.76
		$\underline{t}=\underline{e}$	1	1	1	1
$\underline{b}$	$\bar{b}=3$	n \ m	2	3	4	5
2	3	2	15.53	3.03	1.86	1.47
1.67	3	3	2.56	1.49	1.22	1.12
1.54	3	4	1.70	1.22	1.09	1.05
1.4	3	5	1.41	1.12	1.05	1.02

figure in each cell shows the expected minimum number of auction repetitions to reach the positive payoff, i.e., $E(X(m,n))$, which is equal to $1/(1-p(m,n))$.

Each row of the additional two columns attached to the left side of the table contains the numbers of $[\underline{b}, \bar{b}]$, the minimum and the maximum of construction bidding prices calculated from n, $\underline{c}$, and $\bar{c}$. Similarly each column of the additional two rows above the table contains the numbers of $[\underline{t}, \bar{t}]$, the minimum and the maximum of the reserved floor bidding prices calculated from m, $\underline{e}$, and $\bar{e}$. From these, we see that all 16 cells fall into Case 4 because they all satisfy the condition, $\underline{b} \geq \underline{t}$ and $\bar{b} \geq \bar{t}$.

From these four tables, we see the expected values of true evaluation of construction costs for bidders are two for all four cases. On the other hand, the expected values of true evaluation of the reservation floor for bidders are 3, 2.1, 3, and 2.1 for Case 1 to Case 4, respectively. Therefore, if true evaluations were tendered by bidders, the expected payoff for the redevelopment entity should be 1.0, 0.1, 1.0, and 0.1 for Case 1 to Case 4, respectively. However, while Case 1 (Case 2) and Case 3 (Case 4) have the same expected profit, the risk represented by the number of auction repetitions turns out to be quite different.

In fact, for the case of $n=2$ and $m=2$, the expected numbers of auction repetitions vary from 1.20 (7.79) to 2.21 (15.53) from Case 1 (Case 2) to Case 3 (Case 4). These facts imply that the risks born by the redevelopment entity are quite different even though the expected profits are the same.

Thus, we have demonstrated that expressing the risk by the expected minimum number of the auction repetitions required to arrive at the positive profit should be very effective for the redevelopment entity to understand the risk of urban redevelopment process it plans to organize.

4.2 Application to the Actual Instance of Bankrupted Redevelopment Project

Our risk index by the number of auction repetitions can be transformed into money terms. We will show this possibility with providing an example based on the actual instance. We take up the urban redevelopment project carried out in a city center area of Fukuoka City, Japan, 10 years ago (Cf. URAJA 2000). The project planned to construct the high-rise redevelopment buildings on the site secured by removing low-rise small shops and houses densely located there. The project enforcement entity is the cooperative formed by land owners. The developer, Fukuoka City Futures (FCF) Inc., a third sector subsidiary of Fukuoka City Government, participated in this project as an agent for the redevelopment enforcement cooperative.

The planned redevelopment buildings contained the large size of reserved floors, a hotel, a fine art museum, a shopping mall, and so on. The total cost of the project was 97.8 billion yen. The reserved floors were sold at the price of 90.0 billion yen. Among them, Hotel Okura Fukuoka bought the hotel floor at the price of 22.9 billion yen, and SBC Inc., a subsidiary of FCF, bought the floor for the shopping mall at the price of 56.7 billion yen, which was financed by borrowing from local banks. The project also got the government subsidy of 8.0 billion yen. However, SBC went into bankruptcy in 2002 and SBC has been liquidated after local banks gave debt forgiveness of 45.0 billion yen. Also Hotel Okura went into trouble but was rehabilitated by obtaining from local banks the debt forgiveness of 10.0 billion yen.

Now let us apply our model to this case to see whether our model can infer the loss of this project. According to the manual of UR, contractors who made a contract with UR must pay one tenth of total amount of contract price if they cancel the contract (Cf. UR 2010). Thus, we assume that the cost of one repetition of auction is one tenth of the total cost of the project. Suppose that true evaluation of building construction cost for the constructors is distributed uniformly on the interval between 80.0 and 100.0 billion yen. Suppose also that true evaluation of the reservation floor for the buyers is distributed uniformly on the interval between 90.0 and 92.0 billion yen. Assume $m = 2$ and $n = 2$. In short, we have assumed that $[\underline{c}, \overline{c}] = [80.0, 100.0]$, $[\underline{e}, \overline{e}] = [90.0, 92.0]$ for $m = n = 2$.

In the case of uniform distribution assumption, note that the results of previous numerical examples are the same under any scale transformation such as $X = ax + b$, $Y = ay + b$, $b > 0$. From this, we see that this case corresponds to the above Case 2. From Table 1b, the number of auction repetitions is 7.79 so that the additional cost incurred by auction repetitions becomes 67.9 % of the total cost. Hence, in this case we see that our model infers the risk of this project as 66.4(=97.8*0.679) billion yen. This amount becomes almost the same as the actual loss of this project, 63.0 billion yen, that is, the debt waiver of 55.0 billion yen from local banks plus 8.0 billion yen of government subsidy.

5 Conclusion

We have formulated the urban redevelopment procedure as a two-stage auction game in which three agents are involved to transact each other: the redevelopment entity that performs auctions, constructors participating in the construction auction, and buyers participating in the reservation floor auction. By defining the risk of the urban redevelopment procedure by the probability that the redevelopment entity suffers a negative profit, we have shown that the risk can theoretically be derived in a closed form and can be calculated numerically under the assumption that preferences of bidders for both auctions are distributed as uniform distributions with giving numerical examples.

In contrast to the traditional researches on risk evaluation such as DDCF, real options, and financial engineering in which a single agent is involved facing with uncertainty inherent in the project, the most significant contribution of this study, we believe, is that we have formulated for the first time a model that can be used to evaluate quantitatively the risk of the urban redevelopment procedure where plural decision-makers are involved. In other words, in a social decision process such as urban redevelopment project, the risk of the project not only depends on the uncertainty inherent in the project but also critically depends on how the decision-making processes are organized, how many participants are involved, what kinds of behaviors participants would take, what decisions they would make, and so on. We need such models that can be utilized for assessing these phenomena. Our model tries to be a first step toward such a direction.

Appendix

Proof of Proposition 1

Under the same assumptions, we prove Eq. 1. We assume that any bidder is a risk-neutral expected payoff maximizer. First we must formulate the expected payoff for bidder i. His payoff is $e_i - t_i$ if he becomes a successful bidder, and 0 otherwise. Thus, his expected payoff equals the product of $e_i - t_i$ and the probability that he becomes a successful bidder. In order for bidding price t_i to be successful, it must be the highest among all other bidders. Assume that the optimal strategy function $t(e_i)$ is an increasing function with respect to e_i. Note that for $j \neq i$

$$\Pr\left(t_j \le t_i\right) = \Pr\left(t\left(e_j\right) \le t_i\right) = \Pr\left(e_j \le t^{-1}\left(t_i\right)\right) = F\left(t^{-1}\left(t_i\right)\right).$$

As there are $m-1$ bidders other than i, the probability that the bidding price t_i becomes the highest is equal to $F\left(t^{-1}\left(t_i\right)\right)^{m-1}$. For simplicity, we set $Z\left(t_i\right) = F(t_i)^{m-1}$. From these, the expected payoff EU_i is expressed as $EU_i = \left(e_i - t_i\right) \mathrm{Z}\left(t^{-1}\left(t_i\right)\right)$. The optimal bidding price to maximize EU_i is obtained from the following first-order condition:

$$\frac{\partial EU_i}{\partial t_i} = -\mathrm{Z}\left(t^{-1}\left(t_i\right)\right) + \left(e_i - t_i\right) Z'\left(t^{-1}\left(t_i\right)\right) \frac{\partial t^{-1}\left(t_i\right)}{\partial t_i} = 0$$

Notice that $\partial t^{-1}\left(t_i\right)/\partial t_i = 1/t'\left(e_i\right)$ from the formula for the derivative of inverse function. Since $t^{-1}\left(t_i\right) = t^{-1}\left(t\left(e_i\right)\right) = e_i$, we obtain the following:

$$Z\left(e_i\right) t'\left(e_i\right) + t\left(e_i\right) Z'\left(e_i\right) = e_i Z'\left(e_i\right)$$

To integrate both hands of the equation, we obtain

$$\left[Z\left(e_i\right) t\left(e_i\right)\right]_{\underline{e}}^{e_i} = \int_{\underline{e}}^{e_i} sZ'(s)ds$$

To simplify the above equation, using $Z\left(\underline{e}\right) = 0$ we get the following desired result:

$$t\left(e_i\right) = e_i - \int_{\underline{e}}^{e_i} \left(\frac{F(y)}{F\left(e_i\right)}\right)^{m-1} dy.$$

QED

Derivation of Eq. (12)

For Case 1, Eq. (10) is rewritten as follows:

$$I = A\int_{\underline{t}}^{\overline{b}} \left(\overline{b} - x\right)^{n-1} \left(\int_{\underline{t}}^{x} (y - \underline{t})^{m-1} dy\right) dx \tag{18}$$

Let I_1 be the second integration of the right side, and we have

$$I_1 = \frac{1}{m}(x - \underline{t})^m \tag{19}$$

Hence, we have

$$I = \frac{A}{m}\int_{\underline{t}}^{\bar{b}} \left(\bar{b} - x\right)^{n-1} (x - \underline{t})^m dx \tag{20}$$

Putting the integration of the right-hand side of Eq. (20) as $I_2\left(n-1, m\right)$ and applying the integration by parts, we get the following recursive formula:

$$I_2\left(n-1, m\right) = \frac{m}{n}\int_{\underline{t}}^{\bar{b}} \left(\bar{b} - x\right)^{n} (x - \underline{t})^{m-1} dx = \frac{m}{n} I_2\left(n, m-1\right) \tag{21}$$

Using Eq. (21) recursively, we get

$$\begin{aligned} I_2\left(n-1, m\right) &= \frac{m}{n} I_2\left(n, m-1\right) = \frac{m\left(m-1\right)}{n\left(n+1\right)} I_2\left(n+1, m-2\right) \\ &= \frac{m!\left(n-1\right)!}{\left(n+m-1\right)!} I_2\left(n+m-1, 0\right) \end{aligned} \tag{22}$$

Since $I_2\left(n+m-1, 0\right) = \int_{\underline{t}}^{\bar{b}} \left(\bar{b} - x\right)^{n+m-1} dx = \frac{1}{n+m}\left(\bar{b} - \underline{t}\right)^{n+m}$

we have $I_2\left(n-1, m\right) = \frac{m!\left(n-1\right)!}{\left(n+m\right)!}\left(\bar{b} - \underline{t}\right)^{n+m}$. Equation 12 follows by substitution.

Derivation of Eq. (13)

For Case 2, Eq. (10) is rewritten as follows:

$$I = A\int_{\underline{t}}^{\bar{t}} \left(\bar{b} - x\right)^{n-1} \left(\int_{\underline{t}}^{x} (y - \underline{t})^{m-1} dy\right) dx + A\int_{\bar{t}}^{\bar{b}} \left(\bar{b} - x\right)^{n-1} \left(\int_{\underline{t}}^{\bar{t}} (y - \underline{t})^{m-1} dy\right) dx \tag{23}$$

Let I_3 be the first integration term of equation of the right-hand side. We have

$$I_3 = A\int_{\underline{t}}^{\bar{t}} \left(\bar{b} - x\right)^{n-1} I_1 dx = \frac{A}{m}\int_{\underline{t}}^{\bar{t}} \left(\bar{b} - x\right)^{n-1} (x - \underline{t})^m dx \tag{24}$$

Applying the integration by parts, we get

$$I_3 = -\frac{A}{mn}\left(\bar{b} - \bar{t}\right)^n (\bar{t} - \underline{t})^m + \frac{A}{n}\int_{\underline{t}}^{\bar{t}} \left(\bar{b} - x\right)^{n} (x - \underline{t})^{m-1} dx \tag{25}$$

Denote by I_4 the second integration term of the right-hand side of Eq. (23). Set $I_5 = \int_{\underline{t}}^{\bar{t}} (y-\underline{t})^{m-1} dy$. Since $I_5 = \frac{1}{m}(\bar{t}-\underline{t})^m$, we have $I_4 = \frac{A}{mn}\left(\bar{b}-\bar{t}\right)^n(\bar{t}-\underline{t})^m$. Thus, Eq. (23) can be expressed as

$$I = \frac{A}{n}\int_{\underline{t}}^{\bar{t}} \left(\bar{b}-x\right)^n (x-\underline{t})^{m-1} dx \tag{26}$$

Set $I_6\,(n, m-1) = \int_{\underline{t}}^{\bar{t}} \left(\bar{b}-x\right)^n (x-\underline{t})^{m-1} dx$. Then

$$I_6\,(n, m-1) = \frac{m-1}{n+1}\int_{\underline{t}}^{\bar{t}} \left(\bar{b}-x\right)^{n+1} (x-\underline{t})^{m-2} dx - \frac{1}{n+1}\left(\bar{b}-\bar{t}\right)^{n+1}(\bar{t}-\underline{t})^{m-1} \tag{27}$$

Put $S_1(k) = \left(\bar{b}-\bar{t}\right)^{n+k}(\bar{t}-\underline{t})^{m-k}$. Using the above recursion repeatedly, we have

$$\begin{aligned} 0_6\,(n, m-1) &= \frac{m-1}{n+1} I_6\,(n+1, m-2) - \frac{1}{n+1} S_1(1) \\ &= \frac{(m-1)\,(m-2)}{(n+1)\,(n+2)} I_6\,(n+2, m-3) - \frac{(m-1)\cdot 1}{(n+1)\,(n+2)} S_1(2) - \tfrac{1}{n+1} S_1(1) \end{aligned} \tag{28}$$

$$I_6\,(n, m-1) = \frac{(m-1)!n!}{(n+m-1)!} I_6\,(n+m-1, 0) - \sum_{k=1}^{m-1} \frac{n!\,(m-1)!}{(m-k)!\,(n+k)!} S_1(k) \tag{29}$$

Noting that $I_6\,(n+m-1, 0) = \frac{1}{n+m}\left(\left(\bar{b}-\underline{t}\right)^{n+m} - \left(\bar{b}-\bar{t}\right)^{n+m}\right)$, it follows that

$$I_6\,(n, m-1) = \frac{(m-1)!n!}{(n+m)!}\left(\left(\bar{b}-\underline{t}\right)^{n+m} - \left(\bar{b}-\bar{t}\right)^{n+m}\right) - \sum_{k=1}^{m-1} \frac{n!\,(m-1)!}{(m-k)!\,(n+k)!} S_1(k) \tag{30}$$

Substituting Eq. (30) into Eq. (26) derives Eq. (13).

Derivation of Eq. (14)

For Case 3, Eq. (10) is rewritten as

$$I = A\int_{\underline{t}}^{\bar{b}} \left(\bar{b}-x\right)^{n-1} \left(\int_{\underline{t}}^{x} (y-\underline{t})^{m-1} dy\right) dx - A\int_{\underline{t}}^{\underline{b}} \left(\bar{b}-x\right)^{n-1} \left(\int_{\underline{t}}^{x} (y-\underline{t})^{m-1} dy\right) dx \tag{31}$$

Note that the first term of the right-hand side of Eq. (31) is identical to Eq. (18) in Case 1. Denote this term by I_7. Denote by I_8 the second term of the right-hand side of the above equation.

$$I_8 = -\frac{A}{m}\int_{\underline{t}}^{\underline{b}} \left(\overline{b}-x\right)^{n-1} (x-\underline{t})^m dx \tag{32}$$

$$I_8 = \frac{A}{mn}\left(\overline{b}-\underline{b}\right)^n \left(\underline{b}-\underline{t}\right)^m - \frac{A}{n}\int_{\underline{t}}^{\underline{b}} \left(\overline{b}-x\right)^{n} (x-\underline{t})^{m-1} dx \tag{33}$$

Put $I_9\,(n, m-1) = \int_{\underline{t}}^{\underline{b}} \left(\overline{b}-x\right)^{n} (x-\underline{t})^{m-1} dx$. By integrating by parts, we obtain

$$I_9\,(n, m-1) = \frac{m-1}{n+1}\int_{\underline{t}}^{\underline{b}} \left(\overline{b}-x\right)^{n+1} (x-\underline{t})^{m-2} dx - \frac{1}{n+1}\left(\overline{b}-\underline{b}\right)^{n+1} \left(\underline{b}-\underline{t}\right)^{m-1} \tag{34}$$

By almost the same calculation in I_6, we obtain the following:

$$I_9\,(n, m-1) = \frac{m!n!}{m\,(n+m)!}\left(\left(\overline{b}-\underline{t}\right)^{n+m} - \left(\overline{b}-\underline{b}\right)^{n+m} - \sum_{k=1}^{m-1} \frac{n!\,(m-1)!}{(m-k)!\,(n+k)!} S_2(k)\right. \tag{35}$$

Substituting (35) into (33) and adding (12) to (33) derives Eq. (14).

Derivation of Eq. (15)

For Case 4, Eq. (10) is rewritten as follows:

$$\begin{aligned} I = {} & A\int_{\underline{t}}^{\overline{t}} \left(\overline{b}-x\right)^{n-1} \left(\int_{\underline{t}}^{x} (y-\underline{t})^{m-1} dy\right) dx + A\int_{\underline{t}}^{\overline{b}} \left(\overline{b}-x\right)^{n-1} \left(\int_{\underline{t}}^{x} (y-\underline{t})^{m-1} dy\right) dx \\ & - \frac{A}{mn}\left(\overline{b}-\underline{b}\right)^n \left(\underline{b}-\underline{t}\right)^m - \frac{A}{n}\int_{\underline{t}}^{\underline{b}} \left(\overline{b}-x\right)^{n} (x-\underline{t})^{m-1} dx \end{aligned} \tag{36}$$

Since the first term of Eq. (36) is the same as Eq. (23) for Case 2, and the second term is the same as I_8, we obtain (15) by similar calculation.

References

Imanishi M, Saito S (2010) A risk evaluation of urban redevelopment procedures. Stud Reg Sci 40(3):617–632 (in Japanese)

Imanishi M, Saito S, Tanaka K (2006) A theoretical analysis of a new contract scheme for urban redevelopment project with risk. Jpn J Real Estate Sci 14(4):97–107 (in Japanese)

Kariya T, Ohara H, Honkawa T (2003) A dynamic discounted cash flow method for valuation of an office building. Discussion paper, Kyoto Institute of Economic Research, Kyoto University No. 547. http://www.kier.kyoto-u.ac.jp/fe-tokyo/~kariya/articles/TK-article_en076.pdf. Accessed 18 Dec 2015

Kawaguchi Y (2003) Dynamic DCF and the real option valuation of real estate investment projects. In: Kariya T, Fujita M (eds) Real estate financial engineering and activation of the real estate market (J Jpn Assoc Real Estate Financ Eng). Toyo Keizai, pp 183–207 (in Japanese)

Milgrom P (2004) Putting auction theory to work. Cambridge University Press, Cambridge

Miura K (2003) The economic theory of public contracts. Kyushu University Press, Fukuoka (in Japanese)

Myerson RB (1991) Game theory: analysis of conflict. Harvard University Press, Cambridge

Nishimura K, Asami Y, Shimizu C (2002) A Loss incurred from incomplete information: a measurement for housing trade market in Tokyo. In: Nishimura K (ed) Economic analysis of real estate market. Chap. 6, pp 151–194 (in Japanese)

Saito S, Imanishi M (2010) Evaluating the risk of urban redevelopment viewed as a social decision process. Operations research and its applications: international symposium on operations research and its applications, vol. 12, World Publishing, Beijing, pp 21–30

Trigeorgis L (1996) Real options: managerial flexibility and strategy in resource allocation. MIT Press, Cambridge, MA

UR (Urban Renaissance Agency) (2010) Standard formats of contracts for auctions. http://www.ur-net.go.jp/order/nyusatuyosiki.html. Accessed 20 Mar 2010

URAJA (Urban Renewal Association of Japan) (ed) (2000) Urban redevelopment in Japan: archive for urban redevelopment projects in Japan, vol. 5, pp 693–718 (in Japanese)

Preference Elicitation in Generalized Data Envelopment Analysis: In Search of a New Energy Balance in Japan

Soushi Suzuki and Peter Nijkamp

Abstract The recent dramatic change in energy supply in Japan has prompted a search for a new energy-environment-economic (EEE) efficiency policy, in which the right balance has to be found between a sufficient supply of energy resources, the development of low carbon emission technology, and a continuation of economic growth. The prefectures in Japan – 47 in total – are regarded as the institutional agents or decision-making units (DMUs) which are responsible for the design of a new sustainable energy balance in these regions. The main challenge now is to design an efficient EEE system. The present chapter aims to develop a balanced decision-support tool for achieving an efficient energy supply in all Japanese prefectures. To that end, a new variant of data envelopment analysis (DEA) is presented, which is characterized by two integrated features: (i) the use of a general distance friction minimization (DFM) model to achieve the most appropriate movement toward the efficiency frontier surface (in contrast to the standard radial movement, leading to a uniform proportional input reduction – or a uniform proportional output increase), and (ii) the incorporation of preference-based (PB) adjustments in efficiency policy strategies regarding the input reduction allocation, or the output increase allocation, of DMUs in order to reconcile rigorous efficiency decisions with political priorities at the regional level. This chapter illustrates this new methodology by means of an application to prefectural energy efficiency strategies in Japan.

Keywords Data envelopment analysis (DEA) • Distance friction minimization (DFM) • Preference ased (PB) • Energy-environment-economic (EEE) efficiency

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1 In Search of a New Energy Balance in Japan

After the Fukushima nuclear catastrophe in Japan, the country was faced with an unprecedented challenge in its energy policy, namely, to seek a new energy supply balance after the abandonment of nuclear power technology and supply. This sudden transformation in energy supply policy called for an intensive search for energy alternatives that could meet the requirements of both supply efficiency and sustainable energy supply, while avoiding a situation of electrical power shortage. Thus, the new energy policy of Japan has to find the right balance in the triangular relationship energy-environment-economy, governed by the policy objectives of electrical power savings, low carbon emissions, and the continuation of economic growth. To meet these goals, a strategic foresight analysis of energy supply in the country is necessary.

Although the national government in Japan is responsible for the overall strategic design of future energy policy, the actual implementation of energy policy takes place at the decentralized level of 47 prefectures. These prefectures may be seen as decision agents which may have to find a new balance in the supply of energy resources that would be efficient and environmentally sustainable. These conflicting objectives call for an operational assessment framework for a balanced energy supply at the prefectural level. The main aim of the present chapter is to identify the most efficient and sustainable prefectural strategies in Japan, so that other – lower-performing – prefectures can improve their performance through a comparative benchmarking exercise. The analytical tool used in the present chapter is based on data envelopment analysis (DEA), while the prefectures are regarded here as agents or decision-making units (DMUs). We present a new type of DEA in which two new elements are included, viz., an adjusted distance measure for the most appropriate movement toward the efficiency frontier and a preference elicitation approach for the incorporation of a decision maker's value judgment of input and/or output goals. These integrated elements will be used in a new DEA context, with a view to the identification of the most efficient DMUs (i.e., the Japanese prefectures).

This chapter is organized as follows. Section 2 provides a brief standard introduction to efficiency improvement projection in DEA, including a short overview of DEA developments. This is followed by an exposition of (i) a distance friction minimization (DFM) approach (in Sect. 3) and (ii) a preference-based (PB) approach (in Sect. 4). Next, Sect. 5 contains an empirical application of the above methodology to energy policy at the prefectural level in Japan, including the presentation of various research findings. Finally, Sect. 6 makes some concluding remarks.

2 Efficiency Improvement Projection in DEA

A popular tool to judge efficiency in organizations is data envelopment analysis (DEA). Seiford (2005) mentions that more than 2500 articles have appeared on DEA. Over recent years, comparative efficiency analysis has become a well-established field as part of a benchmarking exercise. DEA was originally developed to analyze the relative efficiency of a DMU, by constructing a piecewise linear production frontier and then projecting the performance of each DMU onto the frontier concerned. A DMU located on the frontier is efficient, whereas a DMU that is not on the frontier is inefficient. An inefficient DMU may then become (more) efficient by reducing its inputs or by increasing its outputs. In the standard DEA approach, this is achieved by a uniform reduction in all inputs (or a uniform rise in all outputs). DEA already has a long history. The standard DEA model was developed by Charnes et al. (1978) (hereafter abbreviated as the CCR input model) for assessing the performance of a given DMU_j $(j = 1, \ldots, J)$ and can be represented as the following fractional programming problem:

$$\begin{aligned} &\max_{v,u} \theta = \frac{\sum_s u_s y_{so}}{\sum_m v_m x_{mo}} \\ &\text{s.t.} \quad \frac{\sum_s u_s y_{sj}}{\sum_m v_m x_{mj}} \leq 1 \quad (j = 1, \ldots, J) \\ &v_m \geq 0, \quad u_s \geq 0, \end{aligned} \tag{1}$$

where θ represents an objective function (efficiency score), x_{mj} is the volume of input m $(m = 1, \ldots, M)$ for DMU_j $(j = 1, \ldots, j)$, y_{sj} is the output s $(s = 1, \ldots, s)$ of DMU_j, and v_m and u_s are the weights given to input m and output s, respectively. Model (1) is usually called an input-oriented CCR model (CCR-I), while its reciprocal (i.e., an interchange of the numerator and denominator in the objective function (1), with a specification as a minimization problem under an appropriate adjustment of the constraints) is known as an output-oriented CCR model. Model (1) is clearly a fractional programming model, which may be solved stepwise by means of standard software (see Cooper et al. 2008). We first provide a standard description of DEA.

The improvement projections $(\widehat{x}_o, \widehat{y}_o)$ are usually defined in (2) and (3) as follows:

$$\widehat{x}_o = \theta^* x_m - s^{-*}; \tag{2}$$

$$\widehat{y}_o = y_o + s^{+*}. \tag{3}$$

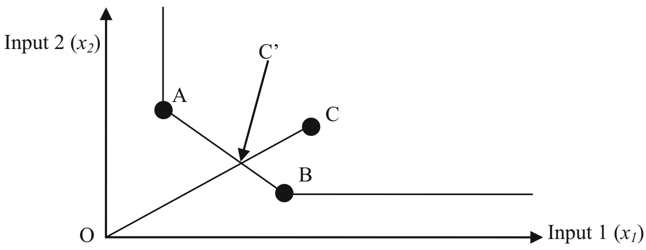


Fig. 1 Illustration of original DEA projection in input space

These projections indicate that the efficiency of (x_o, y_o) for DMU_o can be improved if the input values are reduced radially by the ratio θ*, and the input excesses s^{-*} are eliminated (see Fig. 1). The original DEA models presented in the literature have focused on a uniform input reduction or a uniform output increase in the efficiency improvement projections, as shown in Fig. 1 (θ*=OC'/OC). In principle, an infinite number of improvements are required to reach the efficiency frontier, and hence there is a multiplicity of solutions for any DMU to enhance its efficiency.

The existence of many possible efficiency improvement solutions has led to a rich literature on the methodological integration of the multiple objective linear programming (MOLP) and the DEA models. The first contribution was made by Golany (1988), who proposed an interactive MOLP procedure, which aimed to generate a set of efficient points for a DMU. This model allows a decision maker to select the preferred set of output levels, given the input levels. Thanassoulis and Dyson (1992), Joro et al. (1998), Halme et al. (1999), Korhonen and Siljamäki (2002), Korhonen et al. (2003), Lins et al. (2004), Washio et al. (2012), and Yang and Morita (2013) have also proposed efficiency improvement solutions.

3 The Distance Friction Minimization (DFM) Approach

We now present the principles of a recently developed and more appropriate approach. Detailed descriptions and empirical applications can be found, inter alia, in Suzuki et al. (2010, 2015). As mentioned above, the original efficiency improvement solution in the original CCR input model requires that the input values are reduced radially by a uniform ratio θ* (=OC'/OC in Fig. 1). The (v*, u*) values obtained as an optimal solution for formula (1) result in a set of optimal weights for DMU_o. Hence, (v*, u*) is the set of the most favorable weights for DMU_o, in the sense of maximizing the ratio scale. v_m* is the optimal weight for the input item m, and its magnitude expresses how much in relative terms the item is contributing to efficiency. Similarly, u_s* does the same for the output item s. These values show not only which items contribute to the performance of DMU_o but also to what extent they do so. In other words, it is possible to express the distances (or alternatively, the potential increases) in improvement projections.

Suzuki et al. (2010) proposed a distance friction minimization (DFM) model that is based on a generalized distance function and serves to improve the performance of a DMU by identifying the most appropriate movement toward the efficiency frontier surface. This approach may address both an input reduction and an output increase as a strategy for a DMU. A major advantage of this model is that there is no need to incorporate the value judgment of a decision maker. Nevertheless, it may also be attractive to develop it further to incorporate policy-maker value judgments on political priorities.

We will use the optimal weights u_s* and v_m* from (1) and then describe the efficiency improvement projection model. A visual presentation of this approach (DFM projection) is given in Figs. 4 and 5. In this approach, a generalized distance function is employed to assist a DMU to improve its efficiency by a movement toward the efficiency frontier surface. The direction of efficiency improvement depends, of course, on the input/output data characteristics of the DMU. It is now appropriate to define projection functions for the minimization of distance in weighted spaces. As mentioned, a suitable form of multidimensional projection functions that serves to improve efficiency is given by a multiple objective quadratic programming (MOQP) model which aims to minimize the aggregated input reductions, as well as the aggregated output increases. Thus, the DFM approach can generate a new contribution to efficiency enhancement problems in decision analysis by employing a weighted Euclidean projection function, and, at the same time, it may address both input reduction and output increase. We briefly describe the various steps, based on Suzuki et al. (2010, 2015).

First, the distance functions Fr^x and Fr^y are specified by means of (4) and (5), which are defined by the distances shown in Figs. 4 and 5. Next, the following MOQP is solved by using a reduction of distance for x_{mo} and an increase of distance for y_{so} as variables:

$$\min \quad Fr^x = \sqrt{\sum_m \left(v_m^* x_{mo} - v_m^* d_{mo}^x\right)^2} \tag{4}$$

$$\min \quad Fr^y = \sqrt{\sum_s \left(u_s^* y_{so} - u_s^* d_{so}^y\right)^2} \tag{5}$$

$$\text{s.t.} \quad \sum_m v_m^* \left(x_{mo} - d_{mo}^x\right) = \frac{2\theta^*}{1+\theta^*} \tag{6}$$

$$\sum_s u_s^* \left(y_{so} + d_{so}^y\right) = \frac{2\theta^*}{1+\theta^*} \tag{7}$$

$$x_{mo} - d_{mo}^x \geq 0 \tag{8}$$

$$d_{mo}^{x} \geq 0 \tag{9}$$

$$d_{so}^{y} \geq 0, \tag{10}$$

where x_{mo} is the amount of input item m for any arbitrary inefficient DMU_o and y_{so} is the amount of output item s for any arbitrary inefficient DMU_o. The constraint functions (6) and (7) refer to the target values of input reduction and output augmentation. The proportional distribution of the input and output contributions in achieving efficiency is established as follows. The total efficiency gap to be covered by inputs and outputs is $(1-\theta*)$. The input and the output side contribute according to their initial levels 1 and $\theta*$, implying shares $\theta*/(1+\theta*)$ and $1/(1+\theta*)$ in the improvement contribution. Clearly, the contributions from both sides equal $(1-\theta*)\,[\theta*/(1+\theta*)]$, and $(1-\theta*)\,[1/(1+\theta*)]$.

Hence, we derive for the input reduction target and the output augmentation targets the following expressions:

Input reduction target:

$$\sum_{m} v_m^* \left(x_{mo} - d_{mo}^{x}\right) = 1 - \left(1 - \theta^*\right) \times \frac{1}{(1 + \theta^*)} = \frac{2\theta^*}{1 + \theta^*}; \tag{11}$$

output augmentation target:

$$\sum_{s} u_s^* \left(y_{so} + d_{so}^{y}\right) = \theta^* + \left(1 - \theta^*\right) \times \frac{\theta^*}{(1 + \theta^*)} = \frac{2\theta^*}{1 + \theta^*}. \tag{12}$$

It is now possible to determine each optimal distance ${d_{mo}}^{x*}$ and ${d_{so}}^{y*}$ by using the MOQP model (4, 5, 6, 7, 8, 9, and 10). The distance minimization solution for an inefficient DMU_o can be expressed by means of formulas (13) and (14):

$$x_{mo}^* = x_{mo} - d_{mo}^{x*}; \tag{13}$$

$$y_{so}^* = y_{so} + d_{so}^{y*}. \tag{14}$$

By means of the DFM model, it is possible to present a new efficiency improvement solution based on the standard CCR projection. This means an increase in new options for efficiency improvement solutions in DEA. The main advantage of the DFM model is that it yields an outcome on the efficient frontier that is as close as possible to the DMU's input and output profile (see Fig. 2). For more details, we refer to Suzuki et al. (2010, 2015).

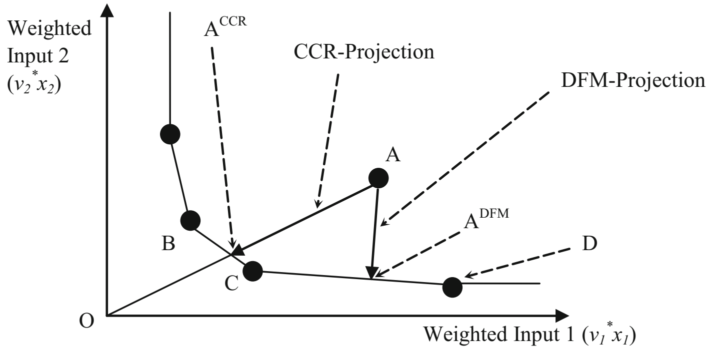


Fig. 2 Degree of improvement of the DFM and the CCR projection in weighted input space

4 A Preference-Based (PB) DFM Model

In this section, we propose a preference-based (hereafter PB) approach to the DFM model. The rationale of this approach is the following. A DMU may have specific priorities on the cost side and on the benefit side of its operation. For example, in various cases, the goal of minimizing all cost items may affect the profit condition. Similarly, extreme output maximization may jeopardize cost efficiency. Therefore, in many decision-making situations, a balance between input and output targets has to be found. Our PB approach specifies an output augmentation parameter (OAP) of the total efficiency gap ($1-\theta^*$) in the DFM model. The value of the OAP ranges from 0 to 1. For example, if the OAP is specified to be 1.0, then the PB model can compute an efficiency-improving projection so that the total efficiency gap ($1-\theta^*$) is fully allocated to output augmentation. If, for instance, the OAP is specified to be 0.7, then the PB model can compute an efficiency-improving projection, so that 70 % of the total efficiency gap ($1-\theta^*$) is allocated to output augmentation, and 30 % of the total efficiency gap ($1-\theta^*$) is allocated to input reduction. And, if the OAP is specified to be 0.0, then the PB model can compute an efficiency-improving projection so that the total efficiency gap ($1-\theta^*$) is fully closed by the input reduction.

Instead of the constraint functions (6) and (7) in the DFM model, the PB model uses the constraint functions (15) and (16):

$$\text{s.t.} \quad \sum_m v_m^* \left(x_{mo} - d_{mo}^x\right) = \theta^* + OAP\left(1 - \theta^*\right) \tag{15}$$

$$\sum_s u_s^* \left(y_{so} + d_{so}^y\right) = \theta^* + OAP\left(1 - \theta^*\right). \tag{16}$$

A visual presentation of constraint functions (15) and (16) is given in Fig. 3.

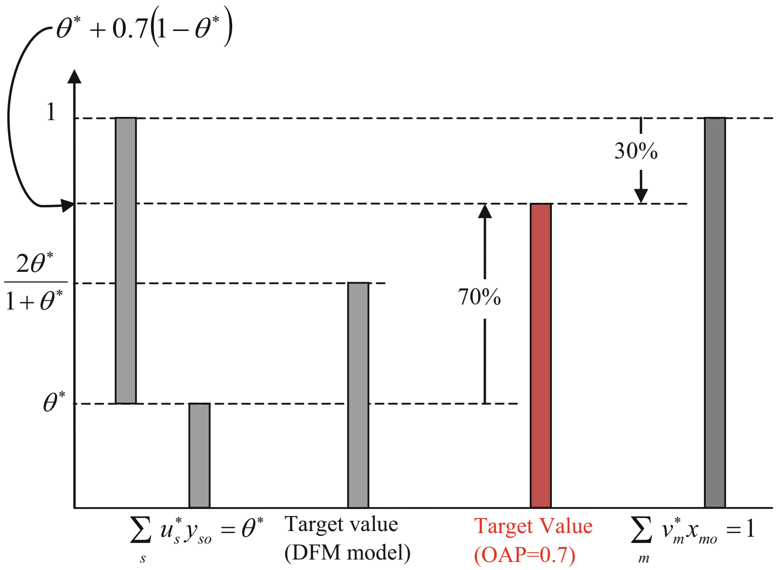


Fig. 3 Illustration of the PB-DFM model with a value 0.7 for the OAP parameter

First, the PB model starts with an initial specification of a value for the OAP. This is just a decision maker's value judgment for the allocation percentage of an output augmentation in the total efficiency gap ($1-\theta^*$). Next, the target values, which are allocated between input efforts and output efforts based on the OAP, are computed in Fig. 3 using constraint functions (15) and (16). Finally, we are able to compute an input reduction value and an output increase value based on the DFM model. A visual presentation of this new PB-DFM projection is given in Figs. 4 and 5. This model will be called a preference-based DFM (PB-DFM) model. We now illustrate the feasibility of the PB-DFM model by means of an application to current Japanese energy policy, as sketched in Sect. 1.

5 An Application of PB-DFM Model for Energy-Environment-Economic (EEE) Efficiency in Japan

5.1 Database and Analysis Framework

In our empirical work, we use the following input and output data on the EEE key variables for a set of 47 prefectures in Japan, as shown in Fig. 6. Figure 6 presents the inputs and outputs considered in this analysis of regional EEE efficiency in Japan.

In our analysis, we consider four inputs (I):

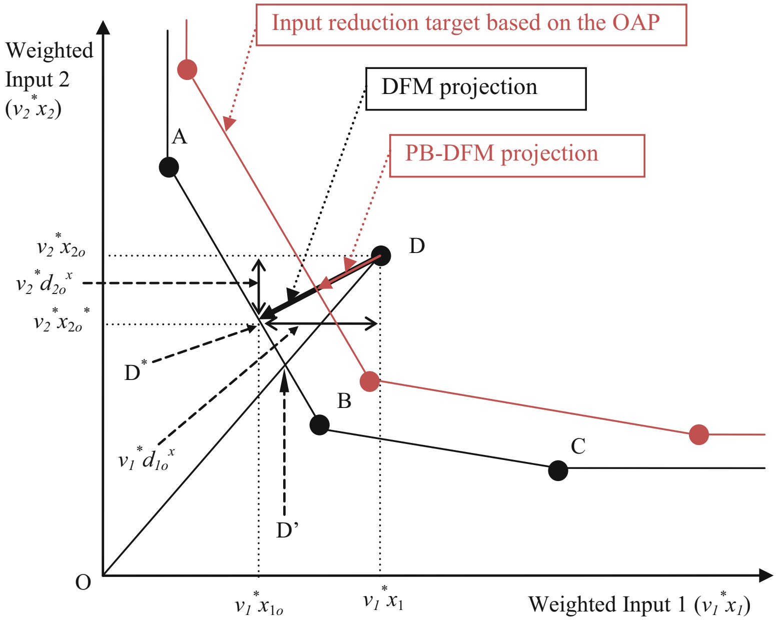


Fig. 4 Illustration of the DFM and PB-DFM approach (input – v_i*x_i space)

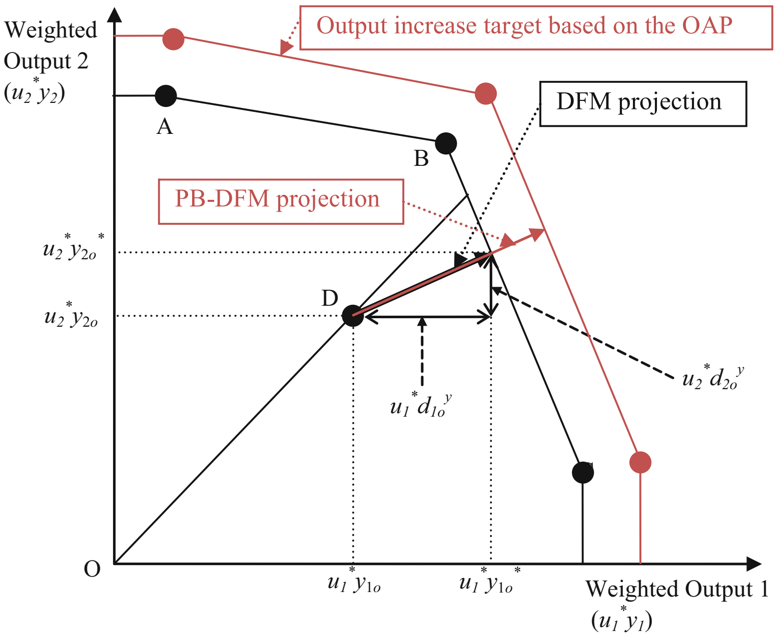


Fig. 5 Illustration of the DFM and PB-DFM approach (output – u_r*y_r space)

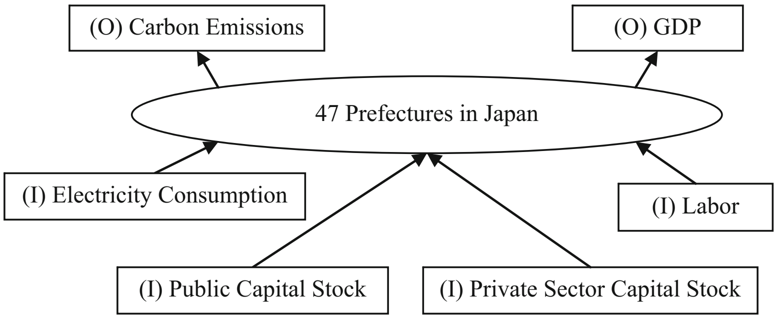


Fig. 6 Inputs and outputs of energy-environment-economic efficiency

(I1) Electricity consumption in each prefecture (gigawatt hours/year) (2010)
(I2) Public capital stock in each prefecture (million yen) (2010)
(I3) Private sector capital stock in each prefecture (million yen) (2010)
(I4) Labor in each prefecture (employed persons) (2010)

Furthermore, two outputs (O) are incorporated:

(O1) GDP in each prefecture (million yen/year) (2010)
(O2) Carbon emission in each prefecture (inverse number) (gigatons/year) (2010)

An explanation of the various inputs and outputs is as follows:

(*I1*) *Electricity consumption* (*EC*) *in each prefecture* (*gigawatt hours/year*) (*2010*)

This data set was obtained from statistical reports on energy consumption and the inter-industry relations table. It was estimated from the energy consumption basic unit for each industry and sector. The sectors included are the industrial sector, the consumer and service sector, the consumer and residential sector, and the household car sector. We excluded the primary energy supply sector, the energy conversion sector, and the traffic and cargo sector, because they supply services beyond the prefecture boundaries.

This data set also accounts for consequential (implicit) energy consumption when one prefecture is supplied from other prefectures, in order to appreciate "pseudo-energy saving" [data source: "statistical report on energy consumption for each prefecture, and statistics report on comprehensive strategy for energy consumption and environment (2010)," Agency for Natural Resources and Energy, Ministry of the Economy, Trade and Industry in Japan].

(*I2*) *Public capital stock* (*PCS*) *in each prefecture* (*million yen*) (*2010*)

This dataset presents the public capital stock in sectors such as transport, national conservation, health care, and education [data source: Economic and Fiscal model for Prefectures (2010), Cabinet Office, Government of Japan].

(*I3*) *Private sector capital stock in prefecture* (*million yen*) (*2010*) (*PSCS*)

This data set presents the private sector capital stock in sectors such as agriculture, forestry and fisheries, mining, construction, manufacturing, wholesale and retail trade, finance and insurance, real estate, transportation and communication, utilities, and services [data source: Economic and Fiscal model for Prefectures (2010), Cabinet Office, Government of Japan].

(*I4*) *Labor in each prefecture* (*employed persons*) (*2010*)

This data set is based on the "National Accounts of Japan" [data source: Economic and Fiscal model for the Prefectures (2010), Cabinet Office, Government of Japan].

(*O1*) *GDP in each prefecture* (*million yen/year*) (*2010*)

This data set is also based on the "National Accounts of Japan" [Data source: Economic and Fiscal model for the Prefectures (2010), Cabinet Office, Government of Japan].

(*O2*) *Carbon emissions* (*CE*) *in each prefecture* (*inverse number*) (*gigatons/year*) (*2010*)

This data set is based on statistical reports on energy consumption and the inter-industry relations table. It was estimated from the carbon emission basic unit for each industry and sector. The sectors included are the same as those used in electricity consumption above.

The data set even accounts for consequential (implicit) carbon emissions, when one prefecture is supplied from the other prefectures, in order to appreciate "pseudo-emissions reduction" [data source: "Statistical report on energy consumption for each prefecture, and statistics report on comprehensive strategy for energy consumption and environment (2010)," Agency for Natural Resources and Energy, Ministry of the Economy, Trade and Industry].

In our application, we first applied the CCR-I model, after which its results were used to determine the CCR-I and DFM projections. Additionally, we applied the PB-DFM model. Finally, these results were compared with each other. We now present the various findings stepwise.

5.2 *Efficiency Evaluation Based on the CCR-I Model*

The efficiency evaluation results for each of the 47 prefectures based on the CCR-I model are given in Fig. 7. The figure shows that eight prefectures (Okinawa, Kochi, Tokushima, Tottori, Nara, Shiga, Yamanashi, and Tokyo) are efficient DMUs. The remaining 39 prefectures are inefficient. In particular, Niigata (0.696), Miyagi (0.696), Ehime (0.689), Gifu (0.686), and Aichi (0.678) have low efficiency.

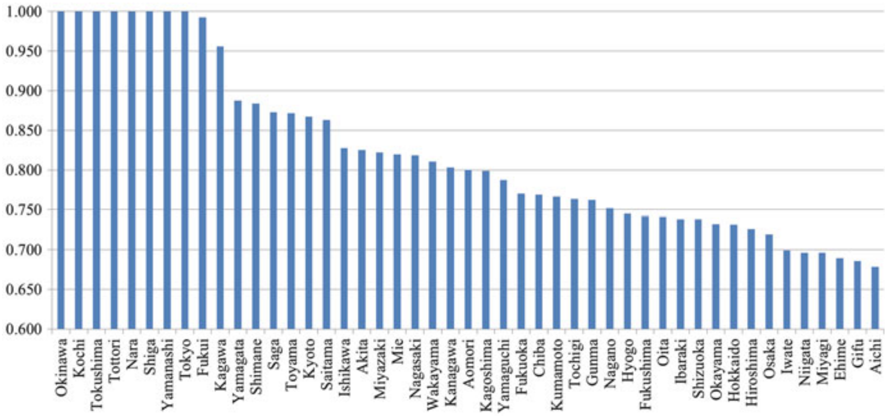


Fig. 7 Efficiency score based on the CCR model

Given the above findings, it seems necessary to make an effort to improve the efficiency of the energy-environment-economic (EEE) efficiency for inefficient prefectures.

5.3 Efficiency Improvement Projection Based on the CCR, DFM, and PB-DFM Models

The efficiency improvement projection results based on the CCR, DFM, and PB-DFM models for the 39 inefficient prefectures are presented in Table 1. In the case of the PB-DFM model, we apply an OAP parameter with an initially neutral value of 0.7 as in Fig. 3. Next, in Sect. 5.4, we show that the outcomes change when the decision maker changes his/her preference parameter OAP.

From Table 1, it appears that the empirical ratios of change in the DFM projection are smaller than those in the CCR projection, as may be expected. In Table 1, this particularly applies to Hokkaido, Miyagi, Akita, Yamagata, Fukushima, Tochigi, Gunma, Toyama, Ishikawa, Nagano, Gifu, Shimane, Ehime, Nagasaki, and Kumamoto which are apparently non-slack-type prefectures. The DFM projection involves both input reduction and output increase, and, clearly, the DFM projection does not involve a uniform ratio, because this model looks for the optimal input reduction (i.e., the shortest distance to the frontier or distance friction minimization).

For instance, the CCR projection shows that Hokkaido should reduce its public capital stock (PCS) by 76.1 %, private sector capital stock (PSCS) and labor by 26.9 %, and electricity consumption (EC) by 56.5 % in order to become efficient.

On the other hand, the DFM results show that a reduction in private sector capital stock (PSCS) of 16.0 % and an increase in GDP of 15.6 % are required for Hokkaido to become efficient. Furthermore, the PB-DFM results show that a reduction in the

Table 1 Efficiency improvement projection results of the CCR, DFM, and PB-DFM models

		CCR	Normal DFM	PB-DFM (OPA = 0.7)
DMU	Score	Score(θ**)	Score(θ**)	Score(θ**)
Input/output	Data	%	%	%
Hokkaido	0.731	1.000	1.000	1.000
(I) PCS	59,252,111.0	−76.1 %	0.0 %	0.0 %
(I) PSCS	44,889,593.7	−26.9 %	−16.0 %	−8.3 %
(I) Labor	2,374,750.0	−26.9 %	0.0 %	0.0 %
(I) EC	43,267.4	−56.5 %	0.0 %	0.0 %
(O)GDP	19,846,756.0	0.0 %	15.6 %	25.9 %
(O) CE	90.3	0.0 %	0.0 %	0.0 %
Miyagi	0.696	1.000	1.000	1.000
(I) PCS	14,343,319.0	−49.6 %	0.0 %	−17.1 %
(I) PSCS	20,031,378.7	−30.4 %	−18.5 %	−9.4 %
(I) Labor	1,077,902.0	−30.4 %	0.0 %	0.0 %
(I) EC	20,018.9	−54.0 %	0.0 %	−37.4 %
(O) GDP	8,164,598.0	0.0 %	18.6 %	31.8 %
(O) CE	239.2	0.0 %	0.0 %	0.0 %
Akita	0.825	1.000	1.000	1.000
(I) PCS	10,761,226.0	−39.7 %	0.0 %	0.0 %
(I) PSCS	9,409,577.9	−17.5 %	−17.3 %	−9.5 %
(I) Labor	527,396.0	−17.5 %	0.0 %	0.0 %
(I) EC	8568.6	−20.6 %	0.0 %	0.0 %
(O) GDP	3,931,020.0	0.0 %	12.0 %	18.5 %
(O)CE	563.3	0.0 %	0.0 %	0.0 %
Yamagata	0.887	1.000	1.000	1.000
(I) PCS	10,515,916.0	−31.4 %	0.0 %	0.0 %
(I) PSCS	9,952,882.1	−11.3 %	−7.4 %	−4.2 %
(I) Labor	576,009.0	−15.0 %	0.0 %	0.0 %
(I) EC	8101.6	−11.3 %	0.0 %	0.0 %
(O) GDP	4,539,434.0	0.0 %	7.5 %	11.2 %
(O) CE	584.1	0.0 %	0.0 %	0.0 %
Fukushima	0.742	1.000	1.000	1.000
(I) PCS	14,886,234.0	−48.9 %	0.0 %	0.0 %
(I) PSCS	24,138,593.0	−31.6 %	0.0 %	0.0 %
(I) Labor	925,459.0	−25.8 %	−15.1 %	−7.9 %
(I)EC	17,822.9	−25.8 %	0.0 %	0.0 %
(O) GDP	7,651,487.0	0.0 %	15.8 %	26.0 %
(O) CE	288.1	0.0 %	0.0 %	0.0 %
Tochigi	0.764	1.000	1.000	1.000
(I) PCS	10,153,835.0	−23.6 %	0.0 %	0.0 %
(I) PSCS	23,221,258.3	−30.3 %	0.0 %	0.0 %
(I) Labor	979,347.0	−23.6 %	−14.0 %	−7.4 %
(I) EC	21,042.1	−43.7 %	0.0 %	0.0 %

(continued)

Table 1 (continued)

		CCR	Normal DFM	PB-DFM (OPA = 0.7)
DMU	Score	Score(θ**)	Score(θ**)	Score(θ**)
Input/output	Data	%	%	%
(O) GDP	8,312,019.0	0.0 %	14.4 %	23.4 %
(O) CE	310.5	0.0 %	0.0 %	0.0 %
Gunma	0.762	1.000	1.000	1.000
(I) PCS	10,868,867.0	−28.3 %	0.0 %	−12.6 %
(I) PSCS	20,700,298.3	−23.8 %	0.0 %	0.0 %
(I) Labor	984,232.0	−23.8 %	−13.8 %	−7.3 %
(I) EC	19,829.8	−42.7 %	0.0 %	−21.3 %
(O) GDP	8,284,852.0	0.0 %	14.5 %	23.4 %
(O) CE	337.4	0.0 %	0.0 %	0.0 %
Toyama	0.871	1.000	1.000	1.000
(I) PCS	9,510,845.0	−20.9 %	0.0 %	0.0 %
(I) PSCS	13,833,473.8	−12.9 %	0.0 %	0.0 %
(I) Labor	555,660.0	−12.9 %	−7.1 %	−4.0 %
(I) EC	13,759.8	−14.8 %	0.0 %	0.0 %
(O) GDP	4,771,179.0	0.0 %	8.3 %	12.5 %
(O) CE	553.1	0.0 %	0.0 %	0.0 %
Ishikawa	0.827	1.000	1.000	1.000
(I) PCS	9,387,676.0	−20.7 %	0.0 %	0.0 %
(I) PSCS	11,277,881.2	−17.3 %	0.0 %	0.0 %
(I) Labor	609,218.0	−17.3 %	−17.0 %	−9.3 %
(I) EC	9923.9	−24.2 %	0.0 %	0.0 %
(O) GDP	4,590,722.0	0.0 %	12.0 %	18.6 %
(O) CE	687.3	0.0 %	0.0 %	0.0 %
Nagano	0.752	1.000	1.000	1.000
(I) PCS	17,175,783.0	−56.3 %	0.0 %	0.0 %
(I) PSCS	20,837,555.5	−24.8 %	0.0 %	0.0 %
(I) Labor	1,076,825.0	−24.8 %	−17.1 %	−9.0 %
(I) EC	18,144.6	−47.5 %	0.0 %	0.0 %
(O) GDP	9,004,613.0	0.0 %	15.1 %	24.6 %
(O) CE	302.4	0.0 %	0.0 %	0.0 %
Gifu	0.686	1.000	1.000	1.000
(I) PCS	14,563,077.0	−53.4 %	0.0 %	−38.4 %
(I) PSCS	20,113,232.7	−31.4 %	0.0 %	0.0 %
(I) Labor	968,187.0	−31.4 %	−19.1 %	−9.7 %
(I) EC	18,298.3	−46.7 %	0.0 %	−17.2 %
(O) GDP	7,353,771.0	0.0 %	19.9 %	34.3 %
(O) CE	286.6	0.0 %	0.0 %	0.0 %
Shimane	0.884	1.000	1.000	1.000
(I) PCS	9,128,071.0	−40.8 %	0.0 %	0.0 %
(I) PSCS	6,590,792.5	−12.8 %	0.0 %	0.0 %

(continued)

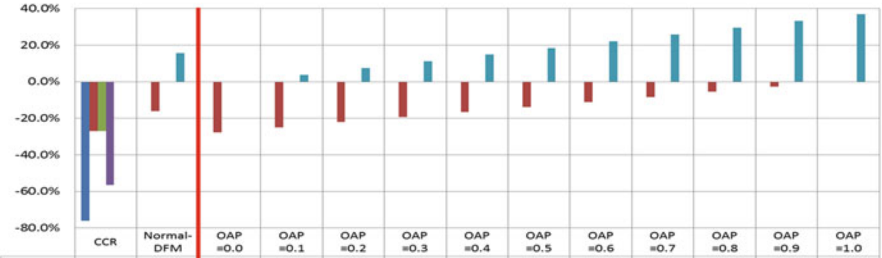
Table 1 (continued)

		CCR	Normal DFM	PB-DFM (OPA = 0.7)
DMU	Score	Score(θ**)	Score(θ**)	Score(θ**)
Input/output	Data	%	%	%
(I) Labor	355,500.0	−14.0 %	0.0 %	0.0 %
(I) EC	5726.6	−11.6 %	−6.2 %	−3.5 %
(O) GDP	2,460,017.0	0.0 %	0.0 %	0.0 %
(O) CE	611.1	0.0 %	10.9 %	16.3 %
Ehime	0.689	1.000	1.000	1.000
(I) PCS	11,213,303.0	−52.5 %	0.0 %	−38.1 %
(I)PSCS	15,027,200.9	−31.1 %	0.0 %	0.0 %
(I) Labor	703,828.0	−31.1 %	−18.9 %	−9.6 %
(I) EC	17,363.1	−55.1 %	0.0 %	−31.8 %
(O) GDP	5,282,850.0	0.0 %	20.0 %	34.4 %
(O) CE	260.3	0.0 %	0.0 %	0.0 %
Nagasaki	0.818	1.000	1.000	1.000
(I) PCS	11,424,311.0	−31.6 %	0.0 %	0.0 %
(I) PSCS	11,272,370.3	−18.2 %	−12.3 %	−6.7 %
(I) Labor	670,352.0	−23.4 %	0.0 %	0.0 %
(I) EC	8924.3	−18.2 %	0.0 %	0.0 %
(O) GDP	4,877,933.0	0.0 %	12.2 %	19.0 %
(O) CE	527.4	0.0 %	0.0 %	0.0 %
Kumamoto	0.767	1.000	1.000	1.000
(I) PCS	12,256,488.0	−30.7 %	0.0 %	−5.0 %
(I) PSCS	14,091,948.1	−23.4 %	−13.7 %	−7.2 %
(I) Labor	855,097.0	−23.4 %	0.0 %	0.0 %
(I) EC	14,261.9	−37.9 %	0.0 %	−23.8 %
(O) GDP	6,088,558.0	0.0 %	14.3 %	23.1 %
(O) CE	380.1	0.0 %	0.0 %	0.0 %

private sector capital stock (PSCS) of 8.3 % and an increase in the GDP of 25.9 % are required to become efficient. Apart from the practicality of such a solution, the models show clearly that a different – and perhaps more efficient – solution is available than the standard CCR projection to reach the efficiency frontier.

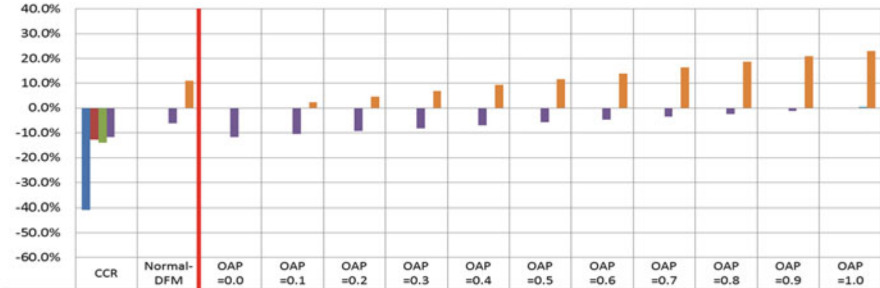
5.4 *Illustration of the Results of the PB-DFM Model for a Given Prefecture*

In this subsection, we use Hokkaido and Shimane as an example of an inefficient reference prefecture and present an efficiency improvement projection result based on the PB-DFM model. We assume that the OAP uses steps from 0.0 to 1.0 at



	CCR	Normal-DFM	OAP =0.0	OAP =0.1	OAP =0.2	OAP =0.3	OAP =0.4	OAP =0.5	OAP =0.6	OAP =0.7	OAP =0.8	OAP =0.9	OAP =1.0
(I)PCS	-76.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
(I)PSCS	-26.9%	-16.0%	-27.6%	-24.9%	-22.1%	-19.4%	-16.6%	-13.8%	-11.1%	-8.3%	-5.5%	-2.8%	0.0%
(I)Labour	-26.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
(I)EC	-56.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
(O)GDP	0.0%	15.6%	0.0%	3.7%	7.4%	11.1%	14.8%	18.5%	22.2%	25.9%	29.6%	33.3%	37.0%
(O)CE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Fig. 8 Efficiency improvement projection results based on the PB-DFM model for Hokkaido Prefecture



	CCR	Normal-DFM	OAP =0.0	OAP =0.1	OAP =0.2	OAP =0.3	OAP =0.4	OAP =0.5	OAP =0.6	OAP =0.7	OAP =0.8	OAP =0.9	OAP =1.0
(I)PCS	-40.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
(I)PSCS	-12.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
(I)Labour	-14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
(I)EC	-11.6%	-6.2%	-11.6%	-10.4%	-9.3%	-8.1%	-7.0%	-5.8%	-4.6%	-3.5%	-2.3%	-1.2%	0.0%
(O)GDP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
(O)CE	0.0%	10.9%	0.0%	2.3%	4.7%	7.0%	9.3%	11.7%	14.0%	16.3%	18.6%	21.0%	22.9%

Fig. 9 Efficiency improvement projection results based on the PB-DFM model for Shimane Prefecture

intervals of 0.1. Next, the input reduction values and the output increase values based on the PB-DFM model are calculated in Figs. 8 and 9.

From Fig. 8, it can be seen that, if Hokkaido Prefecture implements an efficiency improvement plan with an OAP amounting to 0.3 (i.e., 30 % of the total efficiency gap is allocated for output, and 70 % of the total efficiency gap is allocated for input), then a reduction in private sector capital stock (PSCS) of 19.4 % and an increase in GDP of 11.1 % are required to raise efficiency score to 1.000. Furthermore, if such a plan has an OAP of 0.0 (i.e., 100 % of the total efficiency gap is allocated for input), then a reduction in PSCS of 27.6 % is required to raise the efficiency score to 1.000.

From Fig. 9, it can also be seen that if Shimane Prefecture implements an efficiency improvement plan with an OAP amounting to 0.4 (i.e., 40 % of the total efficiency gap is allocated for output, and 60 % of the total efficiency gap is allocated for input), then a reduction in electricity consumption (EC) of 7.0 % and an increase in carbon emission (CE) (inverse number) of 9.3 % are required to raise the efficiency score to reach 1.000. Furthermore, from the results of a plan with an OAP of 0.0 (i.e., 100 % of the total efficiency gap is allocated for input), a reduction in EC of 11.6 % is required to raise the efficiency score to 1.000.

6 Conclusion

In this chapter, we have presented a new methodology, the PB-DFM model. This model is characterized by two integrated features: (i) the use of a general distance friction minimization (DFM) model to achieve the most appropriate movement toward the efficiency frontier surface and (ii) the incorporation of preference-based (PB) adjustments in efficiency strategies regarding the input reduction allocation – or the output increase allocation – of DMUs in order to balance rigorous efficiency decisions with political priorities.

The results of this methodology may offer a meaningful contribution for the decision making and planning for the improvement of the energy-environment-economic (EEE) efficiency for each prefecture in Japan. This new model may act as a policy navigation instrument (a "dashboard") that may have great added value for decision making and planning. For example, this approach – based on interactive preference elicitation – may be useful for EEE strategy, a nationwide agreement on policy where all inefficient prefectures would have to improve their efficiency (to reach the score 1.000), but where the balance of input-output improvement can be freely set, in a decentralized way based on the specific preferences of each prefecture. This framework might form a basis of a new concept like a "Kyoto Protocol" for each prefecture in Japan.

References

Agency for Natural Resources and Energy, Ministry of the Economy, Trade and Industry in Japan (2010) Statistical report on energy consumption for each prefecture, and statistics report on comprehensive strategy for energy consumption and environment. http://www.enecho.meti.go.jp/statistics/energy_consumption/ec002/. Accessed 2 Jun 2011

Cabinet Office, Government of Japan (2010) Economic and fiscal model for prefectures. http://www5.cao.go.jp/keizai3/database.html. Accessed 26 March 2012

Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2:429–444

Cooper WW, Seiford LM, Tesse K (2008) Introduction to data envelopment analysis and its uses. Springer, Berlin

Golany B (1988) An interactive MOLP procedure for the extension of DEA to effectiveness analysis. J Oper Res Soc 39:725–734

Halme M, Joro T, Korhonen P, Salo S, Wallenius J (1999) A value efficiency approach to incorporating preference information in data envelopment analysis. Manag Sci 45:103–115

Joro T, Korhonen P, Wallenius J (1998) Structural comparison of data envelopment analysis and multiple objective linear programming. Manag Sci 44(7):962–970

Korhonen P, Siljamäki A (2002) On the use of value efficiency analysis and some further developments. J Prod Anal 17(1–2):49–64
Korhonen P, Stenfors S, Syrjänen M (2003) Multiple objective approach as an alternative to radial projection in DEA. J Prod Anal 20(20):305–321
Lins MPE, Angulo-Meza L, Moreira da Silva AC (2004) A multi-objective approach to determine alternative targets in data envelopment analysis. J Oper Res Soc 55:1090–1101
Seiford L (2005) A cyber-bibliography for data envelopment analysis (1978–2005). CD-ROM in Introduction to Data Envelopment Analysis and its Uses. Springer Science, Buisness Media, New York
Suzuki S, Nijkamp P, Rietveld P, Pels E (2010) A distance friction minimization approach in data envelopment analysis: a comparative study on airport efficiency. Eur J Oper Res 207:1104–1115
Suzuki S, Nijkamp P, Rietveld P (2015) A target-oriented data envelopment analysis for energy-environment efficiency improvement in Japan. Energy Effic 8(3):433–446
Thanassoulis E, Dyson RG (1992) Estimating preferred target input-output levels using data envelopment analysis. Eur J Oper Res 56:80–97
Washio S, Yamada S, Tanaka T, Tanino T (2012) Improvements by analyzing the efficient frontier in DEA. Eur J Oper Res 217:173–184
Yang X, Morita H (2013) Efficiency improvement from multiple perspectives: an application to Japanese banking industry. Omega 41(3):501–509

Note on the Framework for Disaster Impact Analysis with Environmental Consideration

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Abstract Disaster, as the consequences of a natural hazard, poses a wide range of impacts in the human society and economy. Ever-increasing severity and intensity of natural hazards also threaten the environment where the human society and economy rely on the natural resources and the ecosystem where we live in. The current emphasis of disaster impact analysis has been on the socioeconomic aspects; however, the social and economic activities are certainly interlinked with and are influenced from the changes in the surrounding environment. In this chapter, the framework for extending disaster impact analysis to include the impacts on and from the natural environment is examined. The potential uses of the ECLAC methodology for the input data and of the environmentally extended social accounting matrix for the estimation methodology are reviewed and discussed, and the future directions are suggested.

Keywords Disaster • Impact analysis • Environmental impact • Social accounting matrix

1 Disaster and Natural Environment

Natural hazards, such as earthquakes, hurricanes, tornados, flooding, etc., oftentimes bring severe damages on the built environment and lead to a disaster situation to human societies. At the same time, such sever natural hazards can cause degradation of the natural environment and/or of the ecosystem in the region, through landslides, flooding, or volcanic eruptions.[1] In addition, the damages and destructions of the built environment from natural hazards also create degradation of the natural

[1]Srinivas and Nakagawa (2008) have an excellent summary of the interrelationships of disasters and environment as shown in their Table 1 (page 6).

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environment by means of the debris and wastes, which can potentially spread over a wide range of areas through tsunamis and tidal currents, as observed in the 2011 East Japan Great Earthquake and Tsunami. Meanwhile, environmental degradation caused by mismanagement of the natural environment or by agricultural practices, for example, deforestation or coastal development, can result in intensifying the impact of natural hazards and in increasing the vulnerability of human society in many ways (UN ISDR 2002; Tran et al. 2009).

The natural environment is closely linked with both society and economy or vice versa. And, the interrelationships between natural environment and economy through natural resources, quality of life, pollutions, and regulations, among other things, have been studied in numerous ways, especially in the context of climate change. By the same token, disaster is tightly interwoven with natural environment and economy in the disaster management context. And, the impacts of disaster on an economy have been studied on many different aspects,[2] ranging from microeconomic issue of supply chain management to macroeconomic concern of financing reconstruction projects. In contrast, little attention has been paid to the integrative analysis among these three constituents, "particularly at the local levels" (Tran and Shaw 2007).

The linkages among these three constituents, disaster, economy, and environment, are evident. For example, a natural hazard brings damages to the ecosystem in a particular region; then, the degraded ecosystem decreases the stock level of natural resources, such as the amount of forest, fishes, and water reservoir, among other things; in turn, the production level of primary industries, for example, agriculture, forestry, fishery, and secondary industries, that requires a large amount of natural resources for production would be forced to decrease the production level. In a different direction, the degraded natural environment due to the lack of appropriate management, for example, deforestation, leads to the increase in vulnerability against natural hazards, such as strong storms and severe rain, resulting to landslides, flooding, and water contamination, and consequently causes economic disruptions. These impact propagations are the repercussion process of an initial shock through the intertwined system among economy, environment, and disaster. At the same time, difficulties exist to investigate the impact paths, because disaster and natural environment are both natural phenomena, of which changes in natural environment can be measured using physical unit, while economic activities are usually quantified with monetary term. In addition, the repercussions of and the recovery from the impact would last for a relatively short time to the economy, often a few to several years, whereas the natural environment would respond to the impact with quite a long period, sometimes lasting a few to several decades. Analyzing them together creates challenges to formulate the consistent analytical framework. In addition, for the disaster management practice, "incorporating environmental

[2]An admirable and comprehensive compilation of discussions about disaster impact on the economy can be found in World Bank (2010).

concerns within disaster management has been an elusive objective" (page 5), because of administrative obstacles, lack of awareness, and misplaced priorities (Srinivas and Nakagawa 2008).

In this chapter, the framework to assess disaster impacts on an economy and the natural environment together is discussed in order to analyze the integrative impacts and influences among these three constituents. Section 2 reviews and discusses the practice of disaster impact analysis, mostly economic impact analysis, and the overview of environmental damages from a disaster is presented. Then, the methodologies that can be used for the integrated economic-environmental analysis of disaster impact are discussed and evaluated in Sect. 3. Section 4 concludes this chapter with some remarks on how the integrated analysis can be progressed toward the more practical use and/or more detailed investigation.

2 Economic Impact and Environmental Damage from Disasters

The impact of a disaster has been often evaluated from an economic perspective. The reason for this economic analysis of disaster impacts is mainly to be utilized in the following two cases: (1) the post-event estimation of economic impact for determining the priorities in the recovery and reconstruction budget and (2) the pre-event evaluation of the countermeasures and disaster management policy for the future disaster occurrences in terms of cost-effectiveness and efficiency (Okuyama and Santos 2014). The impact estimation is usually performed based on the input data, such as damages and losses[3] in monetary term, and the higher-order effects[4] are calculated using some economic model, such as input-output (IO) model, social accounting matrix (SAM), or computable general equilibrium (CGE) model, deriving the system-wide impacts of a particular disaster (Okuyama 2007).

While the empirical studies of disaster impact analysis have been done in various cases and with a wide range of methods, this type of quantification studies on disaster impact was criticized with respect to the inaccuracy of input data and the limited features of models used (Albala-Bertrand 2013). To some extent, the Albala-Bertrand's criticisms are apposite, since there have been no standardized frameworks for the definitions and the extent of input data as well as for the features and details of economic model used. Hence, even with the same disaster case, the results of the economic impact estimation have differed from one study to another (Hallegatte and Przyluski 2010).

[3]Damage is the degree of physical or human capital destructions, implying the changes in stock, while loss is a flow measure indicating the decrease in production level of a particular industry during some certain period (Okuyama 2007).

[4]Higher-order effect is a flow measure generated from the (first-order) losses and is the ripple effects through inter-industry linkages in an economic system (Rose 2004).

Meanwhile, the ECLAC methodology (UN ECLAC[5] 2003) has been proposed and employed as the standardized framework for disaster data collection. The ECLAC methodology aims to assess the disaster impact on the social well-being and economic performance of the affected region. It intends to "not entail the utmost quantitative precision, but it must be comprehensive in that it covers the complete range of effects and their cross-implications (page vii)" for economic, social, and environmental constituents. This methodology has been employed for the post-disaster needs assessments (PDNA) of the recent disasters in developing countries for their recovery planning.[6] The PDNA reports have been utilized by the affected government and international organizations, such as the United Nations and the World Bank, to determine the recovery and reconstruction plans and their financing schemes.

For example, the PDNA report of the 2011 Thailand Flood (World Bank 2012) summarized the damages and losses from the event as shown in Table 1. The ECLAC methodology compiles the collected damage and loss data in the similar framework that the social accounting matrix (SAM) does, but with the aggregated sub-sectors. In a typical impact studies using input-output (IO) model, the industrial sectors, especially manufacturing sectors, are rather disaggregated to investigate the detailed ripple effects toward different types of manufacturing activities through inter-industry linkages. On the other hand, the SAM framework has an advantage to include an array of other activities than production ones, such as housing and cultural heritage. In fact, the ECLAC methodology does collect the damage and loss data for environment as a crosscutting sector. This feature of the ECLAC methodology appears particularly advantageous in order for the integrative analysis of disaster impact on economy and environment.

In the ECLAC methodology, the environmental data is categorized into stock and flow, as for the economic data. Environmental stock is environmental capital and assets in the ecosystem, such as forests, water, air, soil, and so forth. Environmental flows are environmental goods and services that the ecosystem produces, for example, timber, flesh water, natural resources like food crops, etc. Once a severe natural hazard hits an ecosystem, environmental stock can be damaged due to landslides, floods, and so on; it changes not only the quantity of environmental stock but also the quality of ecosystem. Then, the changes in environmental stock lead to the changes in the flows of environmental goods and services. In the ECLAC methodology, these environmental damages (decrease in environmental stock) and losses (decline in environmental goods and services) are assessed through the following six steps:

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[5]Economic Commission for Latin America and the Caribbean.

[6]More details about and samples of PDNA can be found at https://www.gfdrr.org/sites/gfdrr/files/urban-floods/PDNA.html

Table 1 Summary of disaster impacts in million Thai bahts

Sub-sector	Disaster impacts	
	Damages	Losses
Infrastructure		
Water resources management	8715	–
Transport	23,538	6938
Telecommunication	1290	2558
Electricity	3186	5716
Water supply and sanitation	3497	1984
Production		
Agriculture, livestock, and fishery	5666	34,715
Manufacturing	513,881	493,258
Tourism	5134	89,673
Financing and banking	–	115,276
Social		
Health	1684	2133
Education	13,051	1798
Housing	45,908	37,889
Cultural heritage	4429	3076
Crosscutting		
Environment	375	176
Total	630,354	795,191

Source: World Bank (2012)

(i) *Description of the environmental state before the event*
In order to measure the changes made by the event, the baseline data has to be collected, including the environmental profiles and histories and the records of past disastrous events.

(ii) *Identification of disaster impacts on the environment*
After the event occurred, it is necessary to first capture broadly what happened to the environment. In this step, the impacts should be classified into "on the physical environment," "on the biotic environment," or "on the perceptual environment."

(iii) *Qualitative environmental assessment*
Based on the identified impacts on the environment above, the qualitative assessment of the impact will be carried out utilizing the qualitative scale, ranging from "zero impact" to "total impact."

(iv) *Classification and assessment of the impacts on the environment*
The identified impacts are then classified to the changes in either environmental damages (stock measure) or environmental losses (flow measures). With this classification, the impacts on the environment are quantified and assessed. The quantification process determines the quantitative magnitude of the impacts,

and the assessment process[7] places an economic value on such magnitude of the impacts.

(v) *Economic assessment of environmental impacts*
Oftentimes, environmental capital and environmental goods and services cannot be measured based on their market value, since the market for most of them rarely exists. In such case, indirect procedures to assess the economic value on the environmental impacts, such as restoration costs,[8] change in productivity approach,[9] environmental value transfer procedure,[10] and so forth. This process is necessary for comparing the environmental impact with the economic impacts.

(vi) *Overlap with other sectors*
In this step, the derived economic values of the environmental impacts are examined and are sorted to not have any overlaps with economic damages or losses, which in turn make double counting of the same impact.

As seen above, the ECLAC methodology entangles a great deal of assumptions and complications to convert environmental damages and losses, which are mostly physical in nature, into economic values. As a result, shown in Table 1, the environmental damages and losses of the 2011 Thailand Flood were measured in monetary value and can be added to the economic damages and losses. However, it is challenging and, to some degree, ambiguous to appraise consistently the changes in environmental capital and environmental goods and services using monetary value. As a more general accounting framework, the System of Environmental-Economic Accounting (SEEA) 2012 (UN 2014) compiles the flows between environment and economy in physical term only, while the transactions within economy are recorded in both monetary and physical terms. On the other hand, the environmental asset accounts are reported in both physical and monetary terms, except "revaluation of the stock" that is recorded only in monetary term. The SEEA12 acknowledges "determining an (environmental) value can be difficult (page 28; UN 2014)" and proposes a few methods to estimate the economic value of the environmental assets, such as net present value approach, resource rent approaches, and so on. To this end, on the one hand, the ways to estimate the economic values of environmental assets appear similar between the ECLAC methodology and the SEEA12. On the other hand, the SEEA12 framework can be seen as more reliable and practical for the use in the analysis of environmental changes because it lists environmental assets in both physical and monetary terms; thus, the data in physical term can be employed to make alternative economic valuations when more suitable economic valuation methods become available. In terms of environmental flows (goods and services),

[7]The assessment process in this step fairly overlaps with the next step, but little discussion of the overlap is offered in the ECLAC methodology.

[8]The restoration cost method is described in page 18, at Section 5 of the ECLAC methodology.

[9]The change in productivity approach is illustrated in page 21, *ibid*.

[10]The environmental value transfer procedure is exhibited in pages 22–23, *ibid*.

the SEEA12 lists them only in physical term, while the ECLAC methodology estimates their monetary values. These differences in unit used surely become an issue for estimating the integrated impacts of a disaster.

3 Methodologies for Economic and Environmental Impacts of Disasters

In order to investigate the economic and environmental impacts of disasters, one of the input data sources for estimating the system-wide impacts, such as the data of damages and losses, is the post-disaster needs assessment (PDNA) based on the ECLAC methodology, as discussed in the previous section. An impact analysis of a disaster can be performed with the input data and a model that can calculate the system-wide impacts, such as the higher-order effects, generated based on the initial damages and/or (first-order) losses. In the case of the economic analysis of disaster impact, especially a short-run analysis for a few years, the usual methodologies employed are input-output (IO) model, social accounting matrix (SAM), or computable general equilibrium (CGE) model (Okuyama and Santos 2014).[11] It is natural to examine whether or not these methodologies can accommodate and integrate the changes in environmental stock and environmental goods and services, as depicted in the ECLAC methodology. While IO models have been widely used for the economic analysis of disaster impact, IO model is a flow model dealing only with the economic flows among industries and households.[12] SAM and CGE models can incorporate with the changes in stock to some extent, such as production factors, with production flows. As such, the SAM frameworks are reviewed below, since the ECLAC methodology compiles the data in a SAM format.

Social accounting matrix (SAM)[13] is a flow model defined as the presentation of the System of National Accounts (SNA) and is an extension of IO framework, adding more detailed interactions with labor, households, and social institutions like governments to inter-industry relationships in the IO model. A series of extended SAM to integrate with environmental accounts has been proposed. Recent examples include the National Accounting Matrix including Environmental Accounts (NAMEA), which was introduced based on the works of the Statistics Netherlands (e.g., Keuning (1993) and de Haan and Keuning (1996)). The NAMEA extends the SAM framework with three accounts on the environment: a substance account including ten types of pollutants; an account for global environmental themes, such

[11]Some other methodologies have also been used, such as econometric models (Okuyama 2007).

[12]The derivation of induced effects through wage-consumption relationship requires a closed IO model with respect to households.

[13]Social accounting matrix was developed by Stone (1961) and further formalized by Pyatt and Thorbecke (1976) and Pyatt and Roe (1977) for policy and planning purpose.

as greenhouse effect and ozone layer depletion; and an account for national environmental themes, for instance, acidification, eutrophication, and waste accumulation. These three environmental accounts are expressed in physical units, in order to avoid the complications originated from economic valuation of environmental data. As an accounting framework, the NAMEA not only embrace the emissions of pollutants but also incorporate with the absorption of such pollutants by the environment. This NAMEA framework has been implemented in other countries, for example, Canada (Siddiqi 2011), and has been utilized in empirical climate change analyses (e.g., Pal 2014).

The NAMEA framework was further extended as the System of Economic and Social Accounting Matrices and Extensions (SESAME) to include a broader set of social and environmental indices (Keuning 1994). The SESAME framework consists of the NAMEA framework and adding supplementary tables for stocks underlying economic flows, the breakdown of values into volumes and prices, socioeconomic indicators,[14] and so on. The SESAME framework intends to be "a consistent meso-level information system from which major economic and social macro-indicators can be derived (page 21)". As such, the SESAME framework focuses more on social indicators in a society, while the inclusion of environmental accounts are very similar to the NAMEA framework.

Other variations of extended SAM framework with respect to environmental and/or social accounts include the extended SAM (ESAM) by Alarcón et al. (2000), which is based on the NAMEA framework with some additional social indicators but different from the SESAME structure, deriving meso-level indicators; the Social Accounting Matrix and Environmental Accounts (SAMEA) by Morilla et al. (2007)[15] follows generally the structure of the SEEA03 (the previous version of the SEEA12 discussed above) and integrates physical water flow and emissions of greenhouse gas with the economic flow in the typical SAM; Resosidarmo and Thorbecke (1996) proposed the Social and Environmental (air pollutant) Accounting Matrix (SEAM) not only to combine the traditional SAM and air pollutants but also to add the associated health costs of the air pollutions in order to analyze the effect of environmental policies on different socioeconomic classes in Indonesia; and Xie (2000) constructed the environmentally extended SAM (ESAM)[16] to investigate the relationships among economic activities, pollution emissions, and pollution abatement activities, such as environmental taxes and investment, and the values in this framework are expressed in monetary term.

Because the recent frameworks reviewed above are for the investigation of the relationships between economic activities and environment in the context of climate

[14]The socioeconomic indicators in the SESAME include life expectancy, infant mortality, literacy, nutrient intake, access to health and education facilities, and housing situation by household group (Keuning 1994).

[15]The SAMEA proposed by the Morilla et al. (2007) is for the national economy of Spain, while Duarte et al. (2010) applied the SAMEA framework to a regional economy (Aragon, Spain).

[16]Xie's ESAM was further extended to an environmental CGE model (Xie and Saltzman 2000).

change research, they contain only air and/or water pollution-related environmental flows and both the emissions and the absorptions of them. While these air- and water-related accounts in the extended SAM can be also applicable to a disaster situation, for example, wildfire and flooding, the changes in ecosystem generated by a natural hazard, such as earthquakes and volcanic eruptions, which results in the changes in environmental stocks, are difficult to deal with in the above frameworks. In this regard, in order to correspond to the environmental damage and loss data gathered using the ECLAC methodology, a more comprehensive representation of the environment and the ecosystem is required. If the traditional SAM framework were extended to feature all the SEEA12 accounts, which includes not only environmental resources and goods and services but also the emissions and absorptions of pollutants in the residuals account, it could tally with the ECLAC environmental damage and loss data once they are disaggregated in the matching categories and are converted in respective units as in the SEEA12. This, however, requires a detailed survey and data collection in the aftermath of a disaster, while the ECLAC methodology aims a quick and timely assessment of damage and loss. This has been a dilemma of disaster-related research.

4 (You Make Me Feel Like a) Natural Disaster?

A broad range of damages and losses in the human society and economy as well as in the natural environment resulted from the recent catastrophic disaster cases, such as the 2004 Indian Ocean Earthquake and Tsunami and the 2011 East Japan Great Earthquake and Tsunami, drives the researchers to investigate and understand how and to what extent the impacts of such disasters can affect the economy and the natural environment. While the economic impacts of a disaster and from the subsequent reconstruction activities can not only last in the regional economy for a sizable length but also change the course of the regional growth and the structure of the regional economy in the long run (Okuyama 2015). At the same time, the damages in natural environment and especially in an ecosystem can potentially lead to much longer as well as wider and broader impacts on the regional (and sometimes global) environment than the economic impacts can be. This utters the necessity and intricacy of the integrated economic-environmental analysis of disaster impacts. In order to combine economic and environmental systems in one framework, some of the challenges are that not only the units of measurement are different between monetary and physical terms but also the duration and the extent and range of propagated impacts can widely and wildly vary. Some innovative approaches are required to achieve such a goal.

For the integrated economic-environmental analysis of disaster impacts, the current state of the input data, potentially the ECLAC methodology, and the available modeling frameworks, the variations of environmentally extended SAM, can handle only the climate change related variables (environmental goods and services) and cannot deal well with the changes in environmental assets. The SEEA12 framework includes such accounts for environmental assets, but the ECLAC methodology can derive only the aggregated data about environmental damages and losses. As such, the opportunity to employ the PDNA data based on the ECLAC methodology and the available environmentally extended SAM framework can produce the limited results in terms of environmental impacts. In order to perform a more comprehensive and sophisticated analysis, integrating the CGE model with some environmental simulation model (e.g., Wang et al. (2006) for water system) can potentially yield inclusive and refined outputs. West and Lenze (1994) warned, however, that the more sophisticated the model becomes, the more detailed and accurate data are required. It is always the case that the collection of detailed and accurate data under a disaster situation is the most difficult task, whereas the ECLAC methodology is not intended to gather such detailed data. At least, releasing the raw data collected with the ECLAC methodology (the intermediate data in the six steps described above) is desired to advance the integrated analysis in this direction.

As the title of the World Bank (2010) report, *Natural Hazards*, *Unnatural Disasters*, dictates, disaster has been defined as the consequences of a natural hazard in the human society and economy (Okuyama and Santos 2014). When the impacts of a disaster on the natural environment are taken into account, should what we call disaster be called natural disaster? Because the integrated economic-environmental impact analysis of a disaster is performed from the human (societal and economical) perspective, the environmental impacts in this regard are still the impacts on the human society and economy, not from the environment perspective. No matter whether disaster is called natural or unnatural, as natural hazards have become harsher and severer, the inclusion of environmental impact in disaster research is the key to our future and to our peace of mind.

References

Alarcón J, van Heemst J, de Jong N (2000) Extending the SAM with social and environmental indicators: an application to Bolivia. Econ Syst Res 12(4):473–496

Albala-Bertrand JM (2013) Disasters and the networked economy. Routledge, Oxon

de Haan M, Keuning SJ (1996) Taking the environment into account. Rev Income Wealth 42(2):131–148

Duarte R, Flores M, Sanchez-Choliz J (2010) Environmental impacts of a regional economy: an application to the Argonese economy (Spain). Reg Sect Econ Stud 10(2):69–84

Hallegatte S, Przyluski V (2010) The economics of natural disasters. CESifo Forum 2:14–24

Keuning SJ (1993) An information system for environmental indicators in relation to the national accounts. In: de Vries WFM, den Bakker GP, Gircour MBG, Keuning SJ, Lenson A (eds) The value added of national accounting. Statistics Netherlands, Voorburg, pp 287–305

Keuning SJ (1994) The SAM and beyond: open, SESAME! Econ Syst Res 6(1):21–50

Morilla CR, Díaz-Salazar GL, Cardenete MA (2007) Economic and environmental efficiency using a social accounting matrix. Ecol Econ 60:774–786

Okuyama Y (2007) Economic modeling for disaster impact analysis: past, present, and future. Econ Syst Res 19(2):115–124

Okuyama Y (2015) The rise and fall of the Kobe economy from the 1995 earthquake. J Dis Res 10(4):635–640

Okuyama Y, Santos JR (2014) Disaster impact and input-output analysis. Econ Syst Res 26(1):1–12
Pal BD (2014) Identifying key sectors for green growth in India: an environmental social accounting matrix multiplier analysis, paper presented at the 22nd International Input-Output Conference, Lisbon, Portugal
Pyatt G, Roe AR (1977) Social accounting for development planning. Harvard University Press, Cambridge
Pyatt G, Thorbecke E (1976) Planning techniques for a better future. ILO, Geneva
Resosidarmo BP, Thorbecke E (1996) The impact of environmental policies on household incomes for different socio-economic classes: the case of air pollutants in Indonesia. Ecol Econ 17:83–94
Rose A (2004) Economic principles, issues, and research priorities in hazard loss estimation. In: Okuyama Y, Chang SE (eds) Modeling spatial and economic impacts of disasters. Springer, New York, pp 13–36
Siddiqi Y (2011) The economy and environment: an integrated approach for Canada. Paper presented at the 19th international input-output conference, Alexandria, VA
Srinivas H, Nakagawa Y (2008) Environmental implications of disaster preparedness: lessons learned from the Indian Ocean Tsunami. J Environ Manage 89:4–13
Stone JRN (1961) Input-output and national accounts. OECD, Paris
Tran P, Shaw R (2007) Towards an integrated approach of disaster and environment management: a case study of Thus Thien Hue province, central Viet Nam. Environ Hazards 7:271–282
Tran P, Sonak S, Shaw R (2009) Disaster, environment and development: opportunities for integration in Asia-pacific region. In: Shaw R, Krishnamurthy RR (eds) Disaster management: global challenges and local solutions. University Press, Himayatnagar
United Nations (2014) System of environmental-economic accounting 2012: central framework. United Nations, New York
United Nations Economic Commission for Latin America and the Caribbean (UN ECLAC) (2003) Handbook for estimating the socio-economic and environmental effects of disasters. UN ECLAC, Santiago
United Nations International Strategy for Disaster Reduction (UN ISDR) (2002) Natural disasters and sustainable development: understanding the links between development, environment and natural disasters, background document for the World Summit on Sustainable Development (WSSD) No.5
Wang Q, Gu G, Higano Y (2006) Toward integrated environmental management for challenges in water environmental protection of Lake Taihu basin in China. Environ Manag 37(5):579–588
West CT, Lenze DG (1994) Modeling the regional impact of natural disaster and recovery: a general framework and an application to Hurricane Andrew. Int Reg Sci Rev 17:121–150
World Bank (2010) Natural hazards, unnatural disasters: the economics of effective prevention. The World Bank, Washington, DC
World Bank (2012) Thai flood 2011: overview. The World Bank, Bangkok
Xie J (2000) An environmentally extended social accounting matrix: conceptual framework and application to environmental policy analysis in China. Environ Res Econ 16(4):391–406
Xie J, Saltzman S (2000) Environmental policy analysis: an environmental computable general-equilibrium approach for developing countries. J Policy Model 22(4):453–489

Evaluating the Economic Impacts of Hybrid and Electric Vehicles on Japan's Regional Economy: Input–Output Model Approach

Hiroyuki Shibusawa and Yuzuru Miyata

Abstract In this paper, we estimate the economic impacts of the next-generation vehicles on the national and regional economy in Japan. Recently, the hybrid and electric vehicles gradually become popular. The industrial structure will be affected by the production of new-generation vehicles. A new technology in the automobile industry has an influence on not only own industry but also other industries. The regions where the automobile firms are concentrated will be affected by a new technology. In this study, we explore the economic impacts of shifting the production system in the automobile industry from the conventional automobile technology to an electric and hybrid vehicle technology using the national and multiregional input–output models in Japan.

Keywords Multiregional model • Automotive industry • New technologies • Economic benefit

1 Introduction

Environmental friendly vehicles have economic and environmental benefits. In the past decade, the automotive industry has experienced a technical innovation. As part of the country's economic recovery policies, Japan has subsidized vehicles having a significant positive impact on the environment. Though conventional petrol cars are included in the models entitled to subsidy, hybrid vehicles are the main focus of this policy. Hybrid vehicles are a type of next-generation vehicles, which also include electric vehicles, bioethanol vehicles, and fuel-cell vehicles. Factors underlying the advent of next-generation vehicles include the prevention of global warming accompanied by carbon oxide reduction as well as energy-saving measures. On the one hand, next-generation vehicles have been used as an economic policy tool to encourage recovery following the worldwide recession caused by the collapse

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of Lehman Brothers; however, even after such revival measures, new policies are expected to be developed to promote these vehicles in response to inherent environmental issues.

Next-generation vehicles signify the first full-scale technological innovation in the automotive industry. To date, the internal combustion engine has been central to automotive technology. Japanese automobile manufacturers are world leaders in this technology and have maintained a leading edge; indeed, they have utilized this advantage to invest efforts in hybrid vehicles equipped with internal combustion engines. Electric vehicles, powered solely by an electric motor, and fuel-cell vehicles have become the predominant types of next-generation vehicles. Furthermore, to endure as the key industry in the Japanese economy, the automotive sector will need to adopt a new format different from the traditional one.

The automotive sector is a key industry in Japan and plays a vital role in driving the economy. Examining Japan, we find that in regions that depend on the automotive industry, there is a sense of crisis regarding the environment-related changes in the automotive market. The advent of next-generation vehicles is considered to indicate a shift in Japan's automotive industry from a structure characterized by vertical integration to one with a horizontal division of labor. Vehicles with an internal combustion engine comprise approximately 20,000–30,000 parts. The current automotive industry features a pyramid-like structure that comprises a multitude of parts subcontractors; tertiary, secondary, and primary subcontractors; and, finally, manufacturers of finished vehicles. It seems that the number of components used in electric cars will exhibit a reduction of approximately one-third compared with current requirements, and this is expected to have a major impact on existing vehicle parts manufacturers. There have been various studies— conducted by the industry, the academia, as well as the government—concerning the format that the new automotive industry should adopt.

The socioeconomic and environmental impacts of the advent of next-generation vehicles have been widely discussed in various fields. Granovskii et al. (2006) conducted a comparative study of conventional, hybrid, electric, and fuel-cell vehicles using various, publically available economic and environmental indicators. The study found that hybrid and electric vehicles had an advantage compared with other vehicles and specifically showed that this advantage increased when the power was produced from renewable energy sources. Carlsson and Johansson-Stenman (2003) performed cost–benefit analyses on the increase in electric cars used in Sweden's transport sector. These indicated that hybrid vehicles were socially beneficial and the existence of subsidies lowered private life cycle costs and external costs for electric vehicles compared with conventional vehicles. Samaras and Meisterling (2008) utilized life cycle assessment to analyze the impact of emissions from plug-in hybrid vehicles on greenhouse gases (GHGs). Meanwhile, Nakata (2000) showed a reduction in carbon emissions from hybrid passenger cars compared with conventional passenger cars using input–output tables, and the partial equilibrium model further showed how the introduction of the BTU tax had noticeably enhanced this effect. Scott (1995) analyzed the impact of the electric car industry on regional economic development. Finally, Wells (2010) examined future prospects for the automotive industry in terms of the expansion of global markets and sustainable development of automobiles.

This paper focuses on the economic effects of the shift in the production technology used for next-generation vehicles. Specifically, we use input–output analysis to derive the production inducement coefficients for conventional vehicles and next-generation vehicles. Furthermore, we also identify the impact of increased production in hybrid and electric vehicles at both the national and regional levels. Shibusawa and Sugawara (2011, 2013) conducted effect analyses on the production of next-generation vehicles using the input–output tables for Japan. Shibusawa and Xu (2013) compared the effects of the production of next-generation vehicles in Japan and China. This paper analyzes the impact of the shift in the production from conventional vehicles to hybrid and electric vehicles on the Japanese economy and its individual regions. A key aspect of this study is that it identifies the impact of technological changes in automobile production (i.e., in the production shift from internal combustion engines to electric motors and batteries) on the industry at the national and regional levels by considering these technological changes as changes in the input coefficient of the input–output model.

Section 2 presents an overview of the Ministry of Economy, Trade, and Industry's policy for the automotive industry. Section 3 describes the input–output model. In Sects. 4 and 5, we examine the economic effects of the national and multiregional input–output models. Finally, Sect. 6 provides concluding remarks and describes future challenges.

2 The Automotive Industry and Government Policies

Hybrid vehicles incorporate a prolonged history. Indeed, in 1896, Ferdinand Porsche developed a car that functioned with an electric motor powered by electricity that was generated by the engine. In 1997, the Toyota Prius was the first full-fledged mass production model of hybrid vehicles sold in Japan. Initially, the price of hybrid vehicles was high, and petrol cars were more efficient; however, vehicle tax incentives and eco-car subsidies provided by the government gave a boost to hybrid vehicles and their production volumes.

The history of electric cars—dating back to 1800 when Alessandro Volta first produced the battery—extends further than that of the internal combustion engine. The first electric vehicle was produced in 1839; however, the first practical electric vehicle was developed in 1873 in the United Kingdom. In 1899, Japan began importing electric vehicles. Since then, the advancement of petrol cars has led to a series of peaks and troughs for electric vehicles. Most recently, in the 1990s, electric vehicles again began attracting attention as the issue of global warming was revealed.

Figure 1 displays trends in the production volumes of hybrid vehicles and electric vehicles in Japan in recent years. With the exceptions of 2008 and 2010, hybrid vehicles have exhibited steady increases in production volumes, with figures for

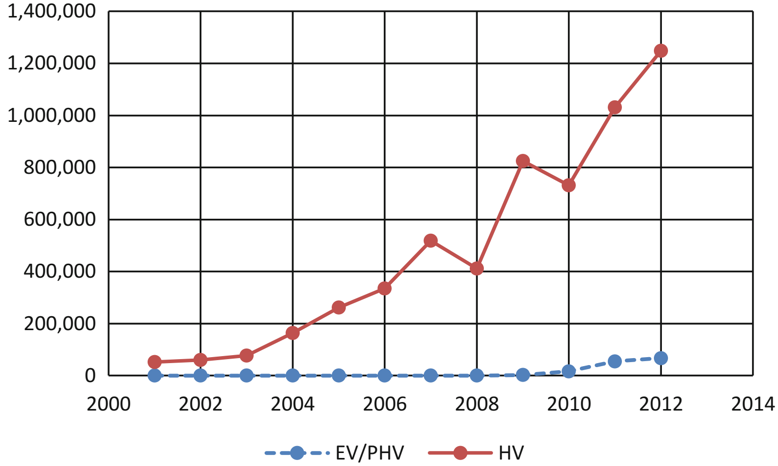

Fig. 1 Hybrid vehicles and electric vehicles: production volume (Source: Next-Generation Vehicle Promotion Center 2014)

2012 being approximately 1,248,000 vehicles. Electric vehicles (EV/PHV) have shown an increase in production volumes since 2010, with around 670,000 vehicles produced in 2012.

A publication by the Ministry of Economy and Industry (2010) summarizes the strategy concerning next-generation vehicles in Japan over the next few decades. In the coming years, Japan is expected to maintain the competitive edge that stems from the country's lead in internal combustion engine technology; further, it is also expected to more actively expand the next generation of vehicles in response to changes in the external environment. For Japan's automotive industry to derive continual future benefits from the achievements of cutting-edge technological development, Japan needs to remain fully informed of and react to changes in the external environment, such as changes in global automotive market trends, increasing energy constraints, and the need for measures to counteract global warming, along with Japan's macroeconomic growth strategies.

Table 1 presents forecasts for the penetration of different categories of passenger cars from 2010 to 2030. These forecasts are based on manufacturers expending the utmost effort to improve fuel efficiency and develop next-generation vehicles to facilitate the penetration of such vehicles. Government targets assume proactive incentive measures by the government, such as investment incentives to boost the scale of production, development/purchase assistance, priority lanes/parking lots, preferential rates on toll roads, and infrastructure development; these targets are higher than the figures incorporating private sector efforts.

Figure 2 shows the distribution of employees in Japan's automotive sector. These figures show the number of employees involved in the "Manufacture of motor vehicles, parts, and accessories" in each of Japan's prefectures in 2009. We can see how the industry is concentrated in Aichi Prefecture in Chubu,

Table 1 Next-generation vehicle plan

	Including private sector efforts	Government targets		
	2020	2030	2020	2030
Conventional vehicles	80 % or more	60–70 %	50–80 %	30–50 %
Next-generation vehicles	Less than 20 %	30–40 %	20–50 %	50–70 %
Hybrid vehicles	10–15 %	20–30 %	20–30 %	30–40 %
Electric vehicle	5–10 %	10–20 %	15–20 %	20–30 %
Plug-in hybrid vehicles				
Fuel-cell vehicles	Minuscule	1 %	0–1 %	0–3 %
Clean diesel vehicles	Miniscule	0–5 %	0–5 %	5–10 %

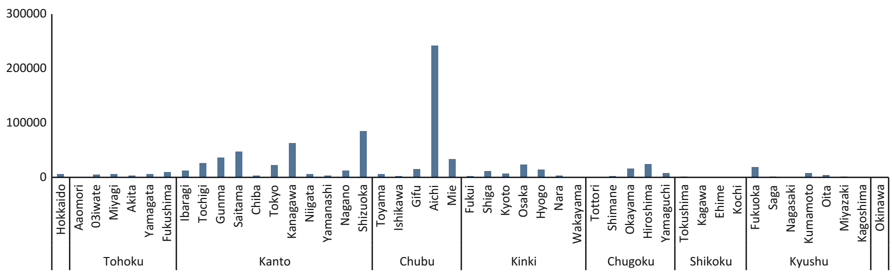

Fig. 2 Manufacturing positions in motor vehicles, parts, and accessories (Source: Labor Force Survey, 2009; Ministry of Internal Affairs and Communications of Japan (2011))

Shizuoka/Kanagawa/Saitama and Gunma Prefectures in Kanto, Osaka and Hyogo Prefectures in Kinki, Hiroshima and Okayama Prefectures in Chugoku, and Fukushima Prefecture in Tohoku. In these areas where the industry is located, we can expect to observe changes in the industrial structure if full-scale production of electric vehicles proceeds. Efforts are underway in such areas to form industrial clusters aimed at new concentrations in the sector.

3 The Method

This paper evaluates the impact of changing automobile production technologies in Japan using both national and multiregional input–output models. The advantage of the former model is its ability to incorporate a more detailed sector classification. Particularly, the influence of a decrease in the number of internal combustion engines and parts due to the production of electric vehicles can be clearly assessed. In contrast, the multiregional input–output model encapsulates changing regional trade patterns within a specific production sector and also facilitates estimation of interregional spillover effects of a new technology. In this study, we focus on the "Motor vehicles" sector and estimate backward linkage effects of a new vehicle technology.

In this study, the appearance of next-generation vehicles is regarded as a change in the production technology in the automotive industry (International Science Foundation 1986). Specifically, the introduction of a new technology into the automobile production process is considered to be a change in the input structure of the automotive industry. Within the input–output framework, this change is represented by a change in the input coefficient matrix, $A \to A_c$. If the automotive industry produces a new type of motor vehicle to satisfy the additional final demand ΔF and exports ΔE, then the economic impact ΔX is calculated using a given competitive import-type model (Leontief 1966) as follows:

$$\Delta X = \left[I - \left(I - \overline{M}\right)\ A_c\right]^{-1}\left[\left(I - \overline{M}\right)\Delta F + \Delta E\right]$$

where X is the vector of output, A is the input coefficient matrix, F is the vector of final demand, E is the vector of exports, $\overline{M}$ is the diagonal import share matrix, and I is an identity matrix.

Here, we extend our analysis to the interregional impacts of next-generation vehicles. The same concept as in the national input–output model is applied; however, the change in the regional technical coefficients for a specific region is considered. For example, we can solve the economic impacts if the automotive sector in the Chubu region produces only hybrid vehicles or if the automotive sector in the Kanto region produces only electric vehicles. We adopt the multiregional input–output model, originally developed by Chenery (1953) and Moses (1955), because this model enables us to parameterize the regional technical coefficients for a specific region. In the multiregional input–output framework, a change in the regional input coefficients for a specific region is represented by $A \to A_c$. Next, if the production of next-generation vehicles extends beyond a particular region, then the interregional trade patterns between regions would be affected. A change in the interregional trade in a certain industry related to automotive production will be simulated by changing the interregional trade coefficients $T \to T_c$. If the automotive industry in a specific region produces a new type of motor vehicle to satisfy the additional final demand ΔF and exports ΔE, then the economic impact ΔX is calculated as follows (Miller and Blair 2009):

$$\Delta X = \left[I - T_c A_c + \overline{M}\left(T_c^{*} A_c\right)\right]^{-1}\left[T_c \Delta F - \overline{M}\left(T_c^{*}\Delta F\right) + \Delta E\right]$$

where X is the vector of the gross output, T is the matrix of the interregional trade coefficients, and A is the diagonal block matrix of the regional technical input coefficients (both derived from a multiregional input–output table). Parameter F is the vector of the final demand, and E is the vector of exports (both are exogenously given). $\overline{M}$ is the diagonal import share coefficient matrix, and the symbol * indicates that the given matrix assumes a diagonal block form.

4 The Impacts of Next-Generation Vehicles at the National Level

Our input–output analysis at the national level in Japan utilizes the national input–output table for 2005 issued by the Ministry of Internal Affairs and Communications of Japan (2009). This basic table comprises 520 rows and 407 columns valued at producer prices. For our analysis, this basic table is aggregated to an input–output table with 111 sectors. Table 2 presents the production sectors related to next-generation automobiles. The "Motor vehicles" sector involves assembling a vehicle using automobile parts. The "Trucks, buses, and other vehicles" and "Two-wheeled vehicles" sectors are distinguished from the "Motor vehicles" sector, which produce passenger cars. The "Motor vehicle body," "Internal combustion engine and parts," and "Automotive parts" sectors produce automotive parts. These sectors are characterized as upstream industries for producing conventional vehicles with an internal combustion engine.

If the "Motor vehicles" sector produces next-generation vehicles such as hybrid or electric cars, the "Motor vehicle body," "Internal combustion engine and parts," and "Automotive parts" sectors would play a significant role in the automobile supply chain. Here, we assume that the "Industrial electrical equipment" and "Other electrical equipments" sectors provide an electric motor and a battery, respectively, to the "Motor vehicles" sector to produce a hybrid electric vehicle (HEV) or an electric vehicle (EV).

Figure 3 shows the input structure of the "Motor vehicles" sector which is depicted based on the input coefficients from the 2005 table. The "Motor vehicles" sector involves assembling a motor vehicle using the inputs from the "Motor vehicle parts" (30.9 %), "Internal combustion engine and parts" (15.1 %), and "Motor vehicle body" (14.3 %) sectors as intermediate inputs. Each percentage represents the input coefficients of the "Motor vehicles" sector. The three values are relatively large, suggesting that the "Motor vehicles" sector strongly depends on these sectors. Further, the input coefficients of the "Industrial electrical equipment" (2.0 %) and "Other electrical equipments" (1.2 %) sectors are small because the "Motor vehicles" sector mostly produces conventional vehicles that utilize petroleum. At

Table 2 List of sectors related to next-generation vehicles in Japan

Sector	Production process
Motor vehicles	Assembling parts
Trucks, buses, and other vehicles	
Two-wheeled vehicles	
Motor vehicle body	Producing automotive parts
Internal combustion engines and parts	
Automotive parts	
Industrial electrical equipment	Producing motors for HEV/EV
Other electrical equipments	Producing batteries for HEV/EV

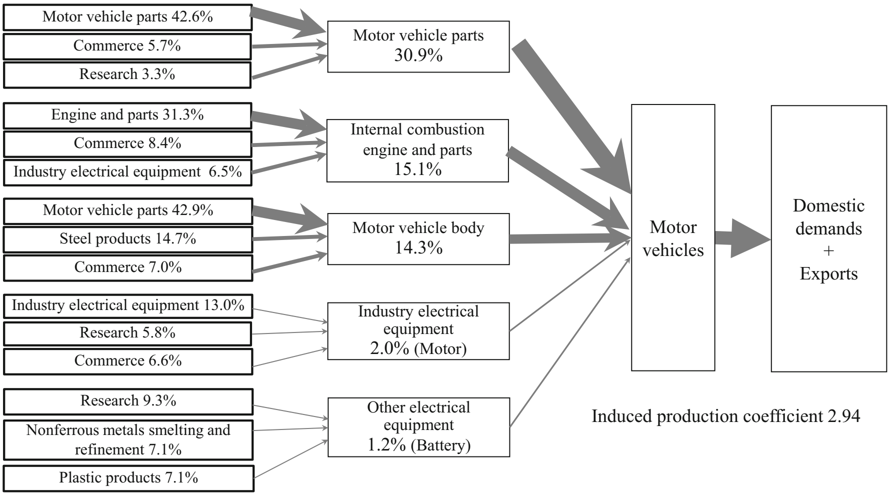

Fig. 3 Input–output structure of "Motor vehicles" sector

the production stage, the "Motor vehicle parts" (42.6 %) sector produces its parts using inputs from within the "Commerce" sector (5.7 %) and "Research" (3.3 %) sector. If the demand of "Motor vehicles" increases, then the economic impacts extend to these upstream sectors.

If an electric vehicle is produced in the "Motor vehicles" sector, then inputs from the "Internal combustion engine and parts" sector would decrease, and the inputs from the "Industrial electrical equipment" and "Other electrical equipments" sectors would increase. It is said that the production of hybrid and electric vehicles shows greater expansion; therefore, the automotive industry would shift from the vertical industrial structure to a horizontal industrial structure.

In our simulation, economic impact is measured in terms of new demand (including final demand and exports) for automotive industry products, represented in one-unit (one trillion yen) increments. Notably, the additional demand of one trillion yen accounted for 6.4 % of the final demand and exports in 2005. We set three cases: Base, Case 1, and Case 2. In Base, the "Motor vehicles" sector produces only conventional vehicles fueled by gasoline. In Case 1, the sector produces only hybrid vehicles fueled by gasoline and electricity. In Case 2, the sector produces only electric vehicles. In Base, the input coefficients from the original input–output table (A_{Base}) are incorporated into the input–output model. In Case 1 and Case 2, the input coefficients of hybrid and electric vehicles (A_{Case1}, A_{Case2}) are estimated on the basis of the previous literature and published data (The Institute of Energy Economics of Japan 2006). Consider, for example, a situation where the "Motor vehicles" sector produces only electric vehicles. In this case, we could increase the input coefficients of the "Industrial electrical equipment" and "Other electrical equipments" sectors that produce batteries and electric motors. Similarly, we could assume that the input coefficients of the conventional automotive parts sectors such

Table 3 Economic impacts of next-generation vehicles in Japan

Case	Inducement coefficient	Ratio
Base conventional vehicle	2.942	100.0 %
Case 1 hybrid electric vehicle (HEV)	2.979	101.3 %
Case 2 electric vehicle (EV)	2.803	95.3 %

as the "Motor vehicle body," "Internal combustion engine and parts," and "Motor vehicle parts" would be reduced.

The economic impacts (specifically, the sum of induced production) are measured according to the details of the three cases. Table 3 shows results of the economic impacts resulting from an increased demand for "Motor vehicles." For an increased demand of 1 (trillion yen) in Base, the sum of induced production is calculated as 2.942 (trillion yen). In Case 1 and Case 2, the corresponding figures are estimated as 2.979 and 2.803 (trillion yen), respectively. When the impact of Base is normalized as 100 %, the impact for Case 1 is 101.3 % and for Case 2 is 95.3 %. Concerning hybrid vehicle production, as both a motor and battery must be installed in a motor vehicle, increased inputs from those sectors would result in impacts across a border spectrum of production sectors. In contrast, in the production of electric vehicles, where internal combustion engines are not installed, there would be a negative impact on all the related production sectors.

Now, we consider the economic impacts on each sector from increased demand for new types of vehicles. We compare the induced production of each sector in Base (conventional vehicles) with those of Case 2 (electric vehicles). The shift in emphasis from gasoline to electric power is expected to impact the broader industrial structure. The question arises regarding which industries will be positively (or negatively) impacted by shifting the production from conventional to electric vehicles. In this analysis, some sectors such as "Internal combustion engine and parts," "Automotive parts," "Motor vehicle body," "Industrial electrical equipment," and "Other electrical equipments" (which have been directly affected in terms of the input coefficients of Table 2) are not considered, because these sectors would obviously be affected by the new technology. Figure 4 reveals the sectors experiencing a positive impact because of electric vehicle production. The horizontal axis represents the difference between Case 2 (EV) and Base, i.e., induced production in Case 2 (electric vehicles) − induced production in Base (conventional vehicles).

Figure 4a revealed that the "Plastic products" and "Nonferrous metals smelting and refinement" sectors are positively affected by electric vehicle production. These sectors produce parts for electric motors and rechargeable batteries. In contrast, Fig. 4b shows the sectors experiencing negative impacts from electric vehicle production such as "Steel materials," "Cast products," and "Pig iron crude steels." These three sectors are involved in the production process of internal combustion engines and related transmission parts.

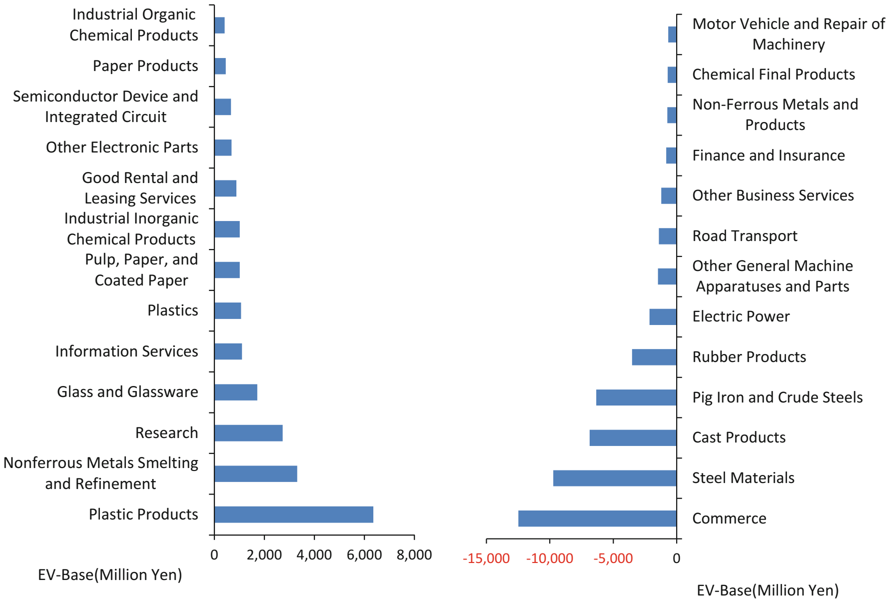

Fig. 4 Impact of the production of electric vehicles on industries. (**a**) Positive impact and (**b**) negative impact

5 The Impacts of Next-Generation Vehicles at the Regional Level

To extend our analysis to the interregional impacts of next-generation vehicles, the interregional input–output table of Japan for 2005 issued by the Ministry of Economy, Trade, and Industry of Japan (2011) is utilized. This table contains trade data spanning 9 regions and 53 production sectors. The interregional input–output table is converted to a multiregional input–output table, which allows us to observe economic impacts from a technical change in a specific region. The interregional trade coefficients are derived from this table. These coefficients reflect trade patterns among nine regions of Japan.

Table 4 shows the production sectors related to next-generation automobiles. The "Motor vehicles" sector manufactures vehicles using automobile parts from the "Automotive parts and accessories" sector. The "Other motor vehicles" sector is separate from the "Motor vehicles" sector. It should be noted that the definition of the "Automotive parts and accessories" in this table differs from that in the input–output table at the national level. The "Automotive body," "Internal combustion engine and parts," and "Automotive parts" sectors are aggregated into one sector labeled "Automotive parts and accessories."

In our analysis, two scenarios are assumed. The first is at the production stage of the next-generation vehicles. Second, as an example of the next stage, we assume the

Table 4 List of sectors for next-generation vehicles at the regional level

Sector	Production process
Motor vehicles	Assembling parts
Other motor vehicles	Assembling and producing parts
Automotive parts and accessories	Producing parts
Industrial electrical equipment	Producing motors for HEV/EV
Other electrical equipments	Producing batteries for HEV/EV

introduction of new services and a change in the interregional trade pattern among industries related to next-generation vehicles. Then, we evaluate the impacts of these changes on the regional economy.

5.1 Scenarios for the Initial Stage of Next-Generation Vehicle Production at the Regional Level

Similar to the national-level analysis, the economic impacts are measured in terms of new demand (including final demand and exports) for automotive industry products, represented in one-unit (one trillion yen) increments. An increased demand is allocated to all regions by initial allocation ratios from the original input–output table for 2005. The automotive sectors manufacture products in each region to satisfy the increased demand. The regional economic impacts are affected by regional technical changes and trade patterns among regions.

In Base, the "Motor vehicles" sectors in all regions produce only conventional vehicles. In Case 1, the "Motor vehicles" sector in a specific region—for example, Chubu region—produces only hybrid electric vehicles (HEVs), whereas other regions produce only conventional vehicles. In this case, only the regional technical coefficients for the specific region (Chubu) are changed. We also consider that the "Motor vehicles" sector in all other regions produces only hybrid vehicles. This situation reflects a diffusion of next-generation vehicle technology from a specific region to the whole of Japan. In Case 2, the "Motor vehicles" sectors in a specific region or in Japan as a whole produce only electric vehicles. The economic impacts are measured in terms of new demand for next-generation vehicles in one-unit increments in a specific region and the whole of Japan. However, the regions of Tohoku, Kanto, Chubu, Kinki, Chugoku, and Kyushu feature a "Motor vehicles" sector, whereas other regions do not feature such sectors. Accordingly, the scenario of a regional technical change is applied to a specific region in Tohoku, Kanto, Chubu, Kinki, Chugoku, and Kyushu.

In Case 1 and Case 2, we could increase the input coefficients of the "Industrial electrical equipment" and "Other electrical equipments" sectors that produce batteries and electric motors; similarly, we could assume that the input coefficients of the conventional parts sector, i.e., the "Automotive parts and accessories," would be reduced.

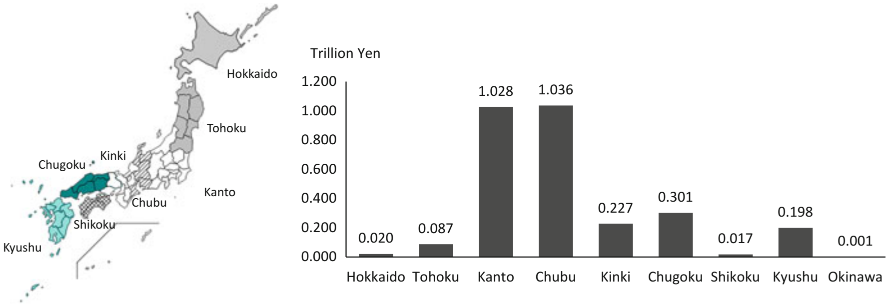

Fig. 5 Induced production of "Motor vehicles"

5.2 Impacts of the Initial Stage of Next-Generation Vehicle Production at Regional Level

5.2.1 Conventional Vehicles

In Base, the "Motor vehicles" sector produces only conventional vehicles in a given region. As shown in Fig. 5, the sum of induced production in all regions is calculated as 2.915 (trillion yen), with 1.036 in Chubu, 1.028 in Kanto, 0.301 in Chugoku, 0.227 in Kinki, 0.198 in Kyushu, 0.087 in Tohoku, 0.020 in Hokkaido, 0.017 in Shikoku, and 0.001 in Okinawa. The estimates of induced production in Chubu and Kanto are larger than those in other regions, reflecting the fact that conventional automotive sectors are concentrated in these regions.

5.2.2 Hybrid Vehicles

Table 5 shows the economic impacts resulting from an increased demand for automobiles in Japan. To measure the impacts of a regional technical change, we assume a specific region (Tohoku, Kanto, Chubu, Kinki, Chugoku, and Kyushu) produces only hybrid vehicles. For example, if Chubu region, where the automotive industry is mostly concentrated, produces only hybrid vehicles, the sum of induced production is calculated as 2.944 (trillion yen) which is larger than that in Base (2.915). In Case 1, the regional shares are 1.049 in Kanto and 1.018 in Chubu, and these shares are larger than those of other regions. The induced production in Kanto increased from 1.028 to 1.049; however, the induced production in Chubu decreased from 1.036 to 1.018. If Chubu produces only hybrid vehicles, this induces a relatively larger production of electric parts, such as motors and batteries, in Kanto. This means that a regional technical change would generate a different regional impact.

Figure 6 shows the economic impacts of the production of hybrid vehicles. The horizontal axis represents regions that produce hybrid vehicles. The vertical axis is the difference between Case 1 and Base, i.e., the induced production in Case

Table 5 Economic impacts of the production of hybrid vehicles on the regional economy

Unit: million yen		Induced production by region									
		Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa	Japan
Region producing HEVs only	Tohoku	2037	8667	102,850	103,473	22,788	30,084	1747	19,856	107	291,608
	Kanto	2058	8890	102,754	103,279	23,389	30,120	1867	19,921	107	292,385
	Chubu	2008	8922	104,855	101,797	23,234	30,133	1823	19,933	107	292,812
	Kinki	2037	8672	102,858	103,449	22,822	30,078	1759	19,863	107	291,644
	Chugoku	2043	8735	103,190	103,393	22,994	29,746	1769	19,883	107	291,859
	Kyushu	2039	8712	103,069	103,268	23,091	30,029	1761	19,770	107	291,846
	Japan	2036	9311	105,744	100,854	24,623	29,734	2026	19,977	108	294,412
Conventional vehicle		2037	8657	102,766	103,561	22,739	30,091	1740	19,850	106	291,549

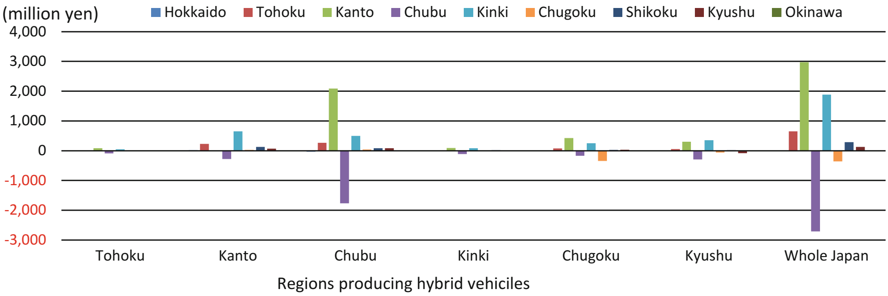

Fig. 6 Economic impacts of the production of hybrid vehicles

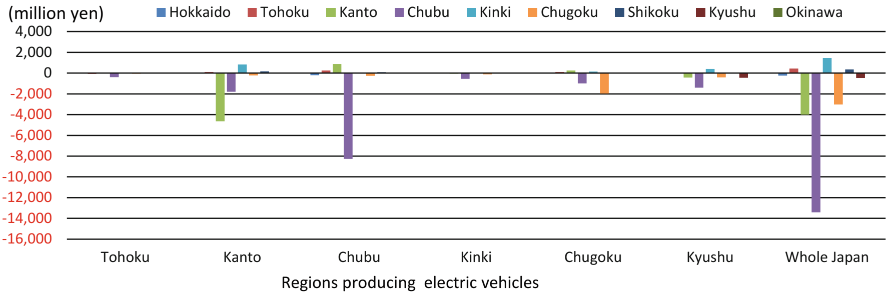

Fig. 7 Economic impacts of the production of electric vehicles

1 − the induced production in Base. The production of hybrid vehicles in each region generates various economic impacts. For example, if the "Motor vehicles" sector in Chubu produces only hybrid vehicles, then the total induced production increases by +0.4 % from 291,549 to 292,812 (million yen). However, from a regional perspective, the induced production within Chubu decreases to −1.7 % from 103,561 to 101,797 (million yen), whereas that in Shikoku, Tohoku, Kinki, and Kanto increases by +4.8 %, +3.1 %, +2.2 %, and +2.0 %, respectively. The production of hybrid vehicles in Chubu causes spillover effects into other regions where the electric industries are relatively concentrated.

5.2.3 Electric Vehicles

The differences in economic impacts of electric vehicles are shown in Fig. 7. The differences for electric vehicles are larger than those for hybrid vehicles. For example, if Chubu produces electric vehicles, the sum of induced production decreases to −2.6 % as compared with Base. From a regional perspective, the induced production in Kanto and Kinki increases by +0.8 % and +0.2 %, respectively. On the other hand, the induced production in Chubu decreases to −8.0 %. In Kanto and Kinki (where the electric industries are concentrated), the economic impacts increase, whereas in Chubu (where the conventional automobile industries are concentrated), the impacts decrease. If all "Motor vehicles" sectors produce electric vehicles, the economic impacts remarkably change relative to Base.

5.3 *Impacts of the Spread Stage of Next-Generation Vehicles*

5.3.1 New Services

We consider a situation where the "Motor vehicles" sector produces electric vehicles that include new services. In Case 3, the sector produces a new vehicle with additional value. Examples of new services include wireless Internet services, driving school services, and car rental services. This case is given by changes in the input coefficients of the "Motor vehicles" sector. The values of coefficients from "Information services," "Goods rental and leasing services," "Other business services," and "Other personal services" change.

The differences of the economic impacts of electric vehicles with additional new services are shown in Fig. 8. In this case, the sum of induced impacts increases. Compared with Case 2, the additional production of the new services has a tendency to partly eliminate the economic differences between regions. It shows that additional new services to next-generation vehicles produce economic benefits in all regions.

5.3.2 Production Shift

In Case 4, we consider the impacts of the production shift from conventional vehicles to next-generation vehicles. We assume that the conventional automotive parts industries shift the system of production for the next-generation vehicles. This means that the conventional automotive parts industries produce motors, batteries, or accessories for new vehicles. Another possible interpretation is that the electric

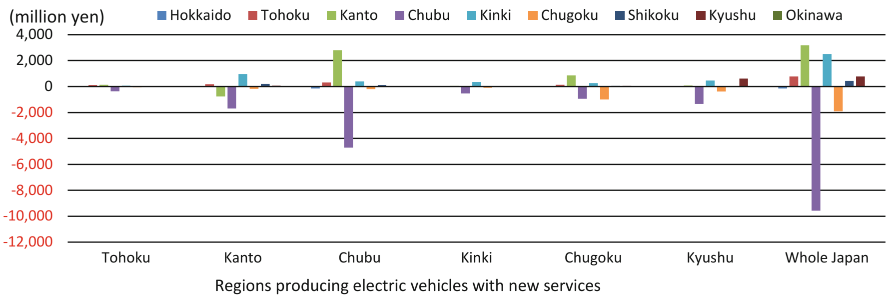

Fig. 8 Economic impacts of the production of electric vehicles with new service

Table 6 Trade coefficients

a "Automotive parts and accessories" sector

	Hokkaido	Tohoku	Kanto	Chubu	Kansai	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	7.1%	0.1%	0.2%	1.3%	0.3%	0.1%	0.0%	0.3%	0.0%
Tohoku	0.1%	29.7%	4.1%	0.5%	1.3%	0.3%	0.1%	2.4%	0.0%
Kanto	7.5%	19.9%	75.7%	17.3%	14.4%	7.3%	13.1%	28.5%	19.1%
Chubu	62.1%	42.7%	14.9%	73.7%	43.7%	19.1%	56.7%	31.7%	50.2%
Kansai	0.7%	1.0%	2.2%	4.6%	30.5%	8.8%	1.2%	4.6%	2.5%
Chugoku	22.4%	5.4%	1.6%	1.2%	8.7%	62.4%	22.2%	10.8%	27.5%
Shikoku	0.0%	0.0%	0.0%	0.0%	0.5%	0.1%	6.3%	0.1%	0.0%
Kyushu	0.1%	1.2%	1.3%	1.4%	0.7%	1.9%	0.4%	21.6%	0.2%
Okinawa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

b "Other electrical equipment" sector

	Hokkaido	Tohoku	Kanto	Chubu	Kansai	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	27.3%	0.0%	0.6%	0.1%	0.1%	0.3%	0.0%	0.3%	0.0%
Tohoku	4.1%	42.8%	7.4%	4.2%	3.1%	3.3%	5.5%	4.3%	4.8%
Kanto	31.0%	36.2%	69.3%	50.4%	26.0%	26.9%	22.9%	35.8%	49.8%
Chubu	1.3%	1.2%	2.9%	31.8%	5.9%	4.6%	1.1%	2.4%	3.6%
Kansai	31.1%	15.1%	14.6%	10.7%	56.5%	18.2%	25.9%	24.3%	33.0%
Chugoku	3.2%	1.0%	1.2%	0.8%	2.5%	43.6%	1.0%	2.4%	1.0%
Shikoku	1.4%	1.7%	2.9%	0.9%	3.9%	1.1%	42.8%	0.7%	0.5%
Kyushu	0.6%	1.9%	1.1%	1.2%	2.0%	2.0%	0.7%	29.8%	0.5%
Okinawa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

parts industries relocate to regions where the conventional vehicle industries are concentrated. In the multiregional input–output model, this case is expressed by changing the trade coefficients of the "Industrial electrical equipment" and "Other electrical equipments" sectors. These sectors are primary input industries for next-generation vehicles. As such, this association is approximated by bringing the trade coefficients of these two electrical sectors close to that of the conventional "Automotive parts and accessories" sector.

Tables 6 shows the interregional trade coefficients of the "Automotive parts and accessories" and "Other electrical equipments" sectors. The intra-trade coefficients for Kanto and Chubu of "Automotive parts and accessories" are 75.7 % and 73.7 %, respectively. These high values imply that this sector is concentrated in Kanto and Chubu and acquires the goods from within the region. On the other hand, the "Other electrical equipments" sector, which produces batteries in Kanto and Chubu, accounts for 69.3 % and 31.3 %, respectively, within these regions. Especially for Chubu, the interregional trade is more significant than the intra-region trade. If the automotive production shifts from conventional vehicles to next-generation vehicles, the automotive parts industries decentralize to other regions. To avoid this decimalization of the automotive parts industries, we assume in Case 4 that either the conventional "Automotive parts and accessories" sector shifts to next-generation vehicle parts or the electrical parts industries relocate to Kanto and Chubu.

Figure 9 shows the economic impacts if the automotive parts industries shift from conventional vehicles to next-generation vehicles. In this case, the sum of induced production is almost the same as that in Base. Compared with Case 2, there is a tendency whereby the production shift partly eliminates the economic differences between regions since the location patterns of the new automotive parts industries are closest to those of the conventional automotive parts industries. If the "Motor

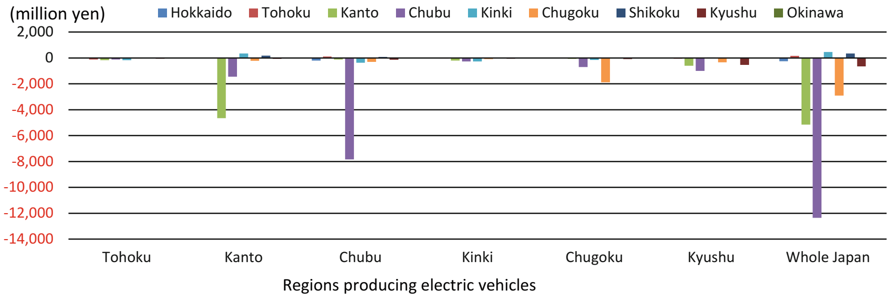

Fig. 9 Economic impacts of the production shift to electric vehicles

vehicles" sectors in all regions produce only electric vehicles, then the induced production of Chubu remarkably decreases to $-12.9\,\%$ in Case 2 compared with $-11.9\,\%$ in Case 4.

6 Concluding Remarks

This paper has analyzed the impact of an increase in the production of next-generation vehicles on the national and regional economies of Japan using national and multiregional input–output models. From a macroeconomic perspective, the production of hybrid passenger cars tends to produce positive effects, whereas the production of electric passenger cars tends to produce negativities at the production stage of next-generation vehicles. There are fewer conventional parts used in electric passenger cars; another influencing factor seems to be that compared with the traditional automotive industry, the electric automotive industry currently has little knock-on effect on other sectors.

Our analysis of regional economic effects showed a tendency for regions with stronger ties to the automobile/mechanical sectors, such as Chubu and Kanto, to suffer greater negative impacts from the production of next-generation vehicles. It is increasingly important for these regions to change the industrial structure focused on mechanical parts to avoid the impact of a production-induced decline in the automotive industry caused by electric vehicles and the shift toward electronics.

Moreover, assuming that additional EV support and new services will be required in the automotive parts industry, there will be an increase in factors that generate new production inducements. Production inducements from IT are likely to be particularly influential. In recent years, smartphones and tablet devices, computers with enhanced mobile capabilities, and high-speed wireless communication have been successively launched. The advent of hybrid and electric vehicles will expedite the "electrification" of vehicles, and incorporation of IT is expected to yield new incentives for production.

An issue for the future is improving the accuracy of analysis results by adopting a comprehensive, time-sequenced approach to the penetration rates of the various categories of next-generation vehicles. In terms of industries related to next-generation vehicles, it is also necessary to analyze the economic effects of new infrastructure, such as the smart grid, and the resultant impact on the energy and power markets. Another important issue is the impact of technological changes related to fuel-cell vehicles.

Following the Great East Japan earthquake, questions have been raised in Japan regarding supply chains and industrial locations during periods of risk, and we would also like to conduct analyses on the location of industry in light of such enormous risks. We suggest extending analytical techniques to include the applied general equilibrium model that can consider the impact of price changes and supply constraints.

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References

Carlsson F, Johansson-Stenman O (2003) Costs and benefits of electric vehicles: a 2010 perspective. J Trans Econ Policy 37(1):1–28

Chenery HB (1953) Regional analysis. In: Chenery HB, Clark PG, Pinna VC (eds) The structure and growth of the Italian economy. US Mutual Security Agency, Rome, pp 97–129

Granovskii M, Dincer I, Rosen MA (2006) Economic and environmental comparison of conventional, hybrid, electric and hydrogen fuel cell vehicles. J Power Sources 159:1186–1193

International Science Foundation (1986) An analysis of the international economic impacts of new technologies (in Japanese)

Leontief W (1966) Input-output economics. Oxford University Press, New York

Miller R, Blair PD (2009) Input-output analysis foundations and extensions, 2nd edn. Cambridge University Press, Cambridge

Ministry of Economy, Trade and Industry (2010) Outline of the next generation vehicle strategy 2010. http://www.meti.go.jp/english/press/data/20100412_02.html

Ministry of Economy, Trade and Industry of Japan (2011) 2005 Inter-regional input-output table

Ministry of Internal Affairs and Communications of Japan (2009) 2005 Input-output tables

Ministry of Internal Affairs and Communications of Japan (2011) 2009 Labor force survey (basic tabulation)

Moses LN (1955) The stability of interregional trading patterns and input-output analysis. Am Econ Rev 45:803–832

Nakata T (2000) Analysis of the impact of hybrid vehicles on energy systems in Japan. Trans Res Part D 5:373–383

Next Generation Vehicle Promotion Center (2014) Homepage. http://www.cev-pc.or.jp/tokei/hanbai2.html

Samaras C, Meisterling K (2008) Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: implications for policy. Environ Sci Technol 42(9):3170–3176

Scott AJ (1995) The electric vehicle industry and local economic development: prospects and policies for Southern California. Environ Plann A 27(6):863–875

Shibusawa H, Sugawara T (2011) Evaluating the economic impacts of the production of new generation automobiles with technological innovations. Stud Reg Sci 31(1):127–146 (in Japanese)

Shibusawa H, Sugawara T (2013) A study on the economic impacts of hybrid and electric vehicles. J Human Environ Symbiosis 22:28–37 (in Japanese)
Shibusawa H, Xu Z (2013) Economic impacts of hybrid and electric vehicles in Japan and China: national and multi-regional input-output applications. Stud Reg Sci 42(2):271–28
The Institute of Energy Economics of Japan (2006) A study on the technology information which contributes the comprehensive economic. Energy Environ Anal: 33–49 (in Japanese)
Wells EP (2010) The automotive industry in an era of eco-austerity–creating an industry as if the planet mattered. Edward Elgar Publishing, Cheltenham

Evaluation of the Water-Environment Policy in the Toyogawa Basin, Japan

Katsuhiro Sakurai, Hiroyuki Shibusawa, Kanta Mitsuhashi, and Shintaro Kobayashi

Abstract This study develops a socioeconomic model to evaluate the water-environment policy for the Toyogawa Basin, Japan. The Toyogawa Basin is located in the East Mikawa area, which lies in the southern part of Aichi Prefecture. The basin has an area of 724 km^2, which spreads from the urban bay area in the south to the rural mountainous area in the north. In particular, the basin's southern area has been developed since the area's water for household, agricultural, and industrial uses is supplied by the Toyogawa River. Currently, this development includes high-value-added agricultural systems in the cities of Toyohashi and Tahara as well as the manufacturing base, which includes the automobile industry, beyond the Mikawa Port. Because the area's water supply also depends on the Toyogawa River, changes in the industrial structure and residents' lifestyles have resulted in a serious problem of water shortage. This has also caused several policy issues to arise, including environmental preservation in the Mikawa Bay, highway construction, consolidation of municipalities, and the aging and depopulation of communities in the northern mountainous area. However, the water-environment problems such as water contamination have become increasingly important. To clarify the relationship between these factors and determine the best approach to solve these pressing issues, we first analyze regional data of the Toyogawa Basin and construct a system model to clarify the interaction between the regional economy and the water environment

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in the basin. This model describes ongoing socioeconomic activities and their impact on the water environment in the area. Next, using this model, we will analyze the relationship between the regional economy and water environment and estimate the impacts of the regional economy on the water environment in the Toyogawa Basin. Finally, we evaluate the water-environment policy in the basin via a simulation analysis using the developed model.

Keywords Simulation analysis • Policy evaluation • Regional economy • Water environment • Toyogawa Basin

1 Introduction

In recent years, water resource management has become an essential feature of both social and economic activities. Water availability is closely related to the spatial characteristics of regional and urban economies. Many firms involved in the automobile industry are concentrated in the Toyogawa Basin, which is the eastern area of Aichi Prefecture, Japan, and they use industrial water as an intermediate input. Figure 1 shows the Toyogawa Basin area that faces several policy issues including environmental preservation in Mikawa Bay, highway construction, consolidation of municipalities, and the aging and depopulation of communities in the northern mountainous area. The problem of water quality is of increasing importance in this area.

A wide-ranging analysis of urban and regional issues facing the Toyogawa Basin, which is in the East Mikawa area, has been undertaken by the Institute of Regional Research of Chubu (1998) and the East Mikawa Development Council (1994). Esaki (1992) and Makino (1997) analyzed the economic impact of the Toyogawa waterway in East Mikawa. Sakatou et al. (1990) investigated the relationship

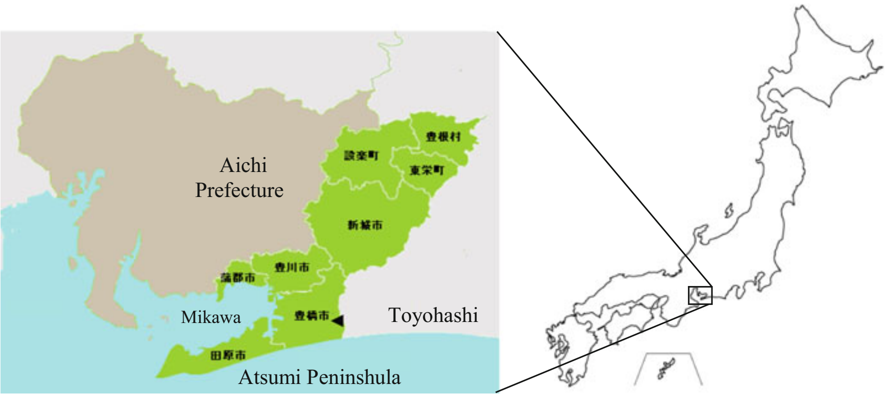

Fig. 1 Toyogawa Basin in Japan

between water demand and land use in the Toyogawa Basin. Matsukura et al. (1998) explored environmental issues such as the quality of water in the Toyogawa River and Mikawa Port. Yamaguchi and Shibusawa (2006) focused on the water resources and regional economy by an econometric model of East Mikawa area (Toyogawa Basin). Shibusawa and Yamaguchi (2014) analyzed the impact of water demand and supply on the social and economic structure in East Mikawa using our multiregional econometric model. Most of these previous studies simply relied on regional statistical data and a questionnaire. There have been few attempts to examine the interaction between the regional economic system and the water environment using the dynamic optimization approach.

2 Research Purpose and Target Area

The purpose of our study is to construct a dynamic model including regional socioeconomic activities and water pollution in the Toyogawa Basin. Moreover, we also try to analyze the impacts of the environmental management policy on the regional economy and water environment.

The population of the Toyogawa Basin is about 770,918 (2009), which is 10.4 % of the population of Aichi Prefecture. The central city in East Mikawa is Toyohashi, whose population is about 375,000. This area is home to the largest share of Aichi Prefecture's primary industry. There is also an advanced agricultural area that has a high-value-added system. Land mainly used for agriculture extends over the Atsumi area in Toyohashi City. Atsumi Peninsula is home to Japan's largest-scale agricultural cooperative association. This area's main agricultural products are vegetables, fruits, flowers, and livestock. The agricultural sector strongly depends on the waterways in the Toyogawa Basin. Three channels, namely, the eastern, western, and Muro/Matsubara channels, go through this area.

The east side of the target area has a superior forest zone in its northeastern mountains. The main industries are involved in the manufacturing, for example, of transport equipment, electrical machinery, and general machinery.

The target area has several regional issues. This area sometimes faces water shortage problems, especially in summer. Balancing water supply and demand is an important regional issue. Aging and depopulation are general problems not only in the Toyogawa area but also in other regions of Japan. The Toyogawa River goes through Mikawa Bay. Mikawa Bay is a closed area of the sea and the water depth is shallow. Water pollution in Mikawa Bay is feared.

Figure 2 shows the main indicators in the Toyogawa Basin and the average growth rate from 1985 to 2005. Most indicators have positive average growth rates. Agricultural output shows 0.7 % growth, whereas manufacturing sales grew by 4.5 %. Agricultural and tap water supplies also have positive average growth rates. We can thus observe that the regional economic growth and water usage are closely related.

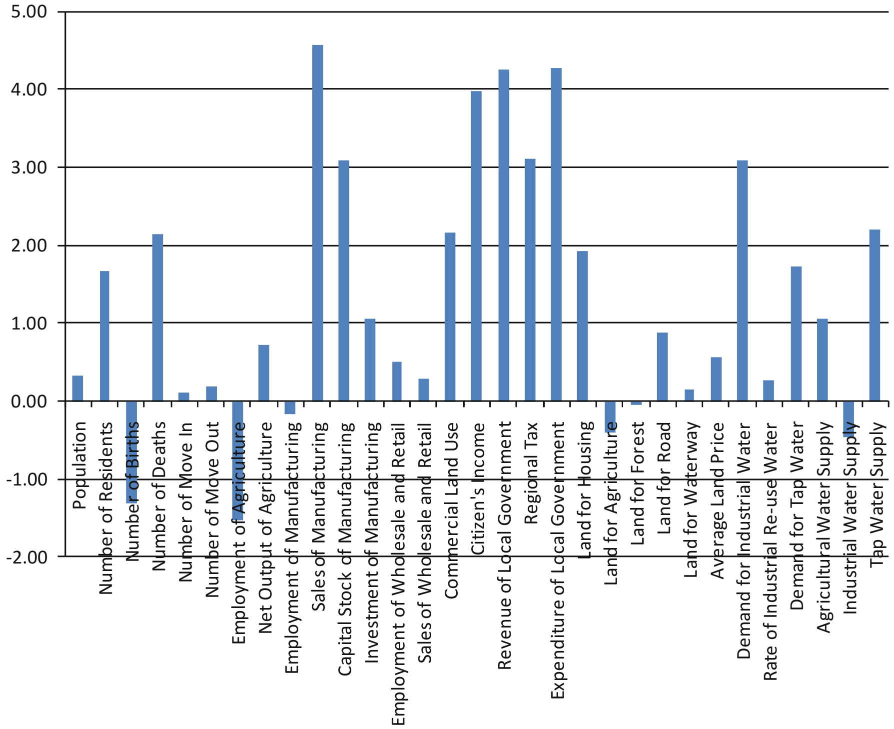

Fig. 2 Average growth rate from 1985 to 2005 (%/year) (Reprinted from Shibusawa and Yamaguchi 2014)

This study explores the relationship between the water quality in Mikawa Bay and the regional economy in the Toyogawa Basin.

3 The Model

In this study, we develop a dynamic socioeconomic model with water pollutant emissions. Our target area is the Toyogawa Basin, including five cities and one town. Planning years run from 2005 to 2050.

In our simulation, one period is assumed to last 5 years. The method is the dynamic optimization approach. The objective function is GRP and constraints are social, economic, and environmental conditions.

3.1 Amount of Water Pollutant Emission from the Target Area

The total amount of water pollutant emissions caused by socioeconomic activities around the Toyogawa Basin flowing into the Mikawa Bay is calculated as follows:

$$Q^i(t) = \sum_j QS_j^i(t) + QR^i(t) \quad (1)$$

where

$Q^i(t)$: Total amount of water pollutant emission i from the Toyogawa Basin at period t
t: Time period of the model simulation
$QS_j^i(t)$: Amount of water pollutant emission i from municipality j in the basin at period t
$QR^i(t)$: Amount of water pollutant by rainfall at period t
$i = 1$ (T-N), 2 (T-P), 3 (COD)

3.2 Amount of Water Pollutant Emissions from Socioeconomic Activities

Water pollutants from socioeconomic activities in the Toyogawa Basin consist of emissions from households, the industry sector, land use, and a sewage treatment plant as follows:

$$QS_j^i(t) = QZ_j^i(t) + QL_j^i(t) + QX_j^i(t) + \sum_d QD_d^i(t) \quad (2)$$

where

$QZ_j^i(t)$: Amount of water pollutant emission from household of the municipality j in the basin at period t (excluding sewage system)
$QL_j^i(t)$: Amount of water pollutant emission from land use area of the municipality j in the basin at period t
$QX_j^i(t)$: Amount of water pollutant emission from industry of the municipality j in the basin at period t
$QD_d^i(t)$: Amount of water pollutant emission from the sewage treatment plant d in the basin at period t

3.3 Amount of Water Pollutant Emissions from Households

The amount of water pollutant emissions from household activities in the Toyogawa Basin is calculated as follows:

$$QZ_j^i(t) = \sum_h E^h \cdot z_j^h(t) \tag{3}$$

where

E^h: Water pollution coefficient by water pollutant treatment facility h
$z_j^h(t)$: Numbers of users of water pollutant treatment facility h of the municipality j in the basin at period t

3.4 Amount of Water Pollutant Emissions from Land Use

The amount of water pollutant emissions from land use in the Toyogawa Basin is calculated as follows:

$$QL_j^i(t) = \sum_l G^l \cdot L_j^l(t) \tag{4}$$

where

G^l: Water pollution coefficient by land use l
$L_j^l(t)$: Area of land use l of the municipality j in the basin at period t

3.5 Amount of Water Pollutant Emissions from Industry

The amount of water pollutant emissions from the industrial sector in the Toyogawa Basin is calculated as follows:

$$QX_j(t) = \sum_m P^m \cdot x_j^m(t) \tag{5}$$

where

P^m: Water pollution coefficient by industry m
$x_j^m(t)$: Production of industry m of municipality j in the basin at period t

3.6 Population in the Basin

The population in the Toyogawa Basin is calculated as follows:

$$z_j(t) = z_j\,(t-1) + \Delta z_j\,(t-1) \tag{6}$$

where

$z_j(t)$: Population of municipality j in the basin at period t
$\Delta z_j(t)$: Population change of municipality j in the basin at period t

3.7 Finance of Municipality in the Basin

The finance of the municipality in the Toyogawa Basin is calculated as follows:

$$R_j(t) = \rho_j \cdot z_j(t) \tag{7}$$

where

$R_j(t)$: Revenue of municipality j in the basin at period t
ρ_j: Local government tax per capita of municipality j in the basin.

3.8 Restriction of Financial Expenses

We introduce a restriction whereby the subsidy expense for the water-environment policy to control water pollutant emissions is less than the total tax revenue:

$$\mathrm{wep}_j(t) \leq \omega_j R_j(t) \tag{8}$$

$\mathrm{wep}_j(t)$: Subsidy for water-environment policy by municipality j at period t
ω_j: Ratio of financial expenses for water-environment policy

3.9 Users of Household Wastewater Treatment Facility

The total number of users of water pollutant treatment facility h is equal to the total population of municipality j in the Toyogawa Basin. Changes in users depend on the construction investment made in the wastewater treatment facility:

$$z_j(t) = \sum_h z_j^h(t) \tag{9}$$

$$z_j^h(t) = z_j^h\,(t-1) + \Delta z_j^h\,(t-1) \tag{10}$$

$$\Delta z_j^h(t) \le \Gamma_j^h \cdot i_j^h(t) \tag{11}$$

where

Γ_j^h: Ratio of investment made in construction for water pollutant treatment facility h and increase of users
$i_j^h(t)$: Investment in construction of water pollutant treatment facility h

3.10 Production Function

The amount of production is dependent on capital accumulation of production, as follows:

$$x_j(t) \le \omega_j k_j^P(t) \tag{12}$$

where

ω_j: Proportion coefficient of production to capital stock
$k_j^P(t)$: Capital accumulation of industrial production

3.11 Capital Accumulation

The accumulation of capital by the water pollutant treatment facility is defined as follows:

$$k_j^{mP}(t) = k_j^{mP}\,(t-1) + i_j^{mP}\,(t-1) - d^m \cdot k_j^{mP}\,(t-1) \tag{13}$$

where

$k_j^{mP}(t)$: Accumulation of capital for the production of industry m of the municipality j in the basin
$i_j^{mP}(t)$: Investment for the production of industry m of the municipality j in the basin
d^m: Discount rate of industry m

3.12 Flow Condition of Production Market

$$x(t) \geq Ax(t) + C(t) + i^P(t) + B^S\left\{i^1(t) + i^2(t)\right\} + B^C \cdot \delta \cdot \Delta Z^3(t) + e(t) \quad (14)$$

where

$x(t)$: Industrial production vector
A: Input coefficient matrix
$C(t)$: Consumption vector
$i^P(t)$: Production investment vector ($P \neq 1, 2$)
B^s: Production inducement coefficient matrix by investment in the sewage system and rural community's sewage system
$i^1(t)$: Investment in the sewage system
$i^2(t)$: Investment in the rural community's sewage system
B^c: Production inducement coefficient matrix by investment in combined treatment septic tanks
$\delta \cdot \Delta z^3(t)$: Total cost of installing a combined treatment septic tank
$e(t)$: Exports

3.13 Restriction of Consumption

Consumption in municipality j is determined by the municipality's population:

$$C_j(t) \leq k_j z_j(t) \quad (15)$$

where

k_j: Consumption coefficient vector

3.14 Regional Economy

GRP in the basin is determined by the rate of added value and amount of production:

$$\text{GRP}(t) = v \cdot x(t) \quad (16)$$

where

GRP(t): Regional GDP
v: Added value rate

3.15 Water-Environment Policy

We try to evaluate the impact and effect of plant factory construction on the regional economy and water environment in the target area as a water-environment policy in the model:

$$\mathrm{PF}_j(t) \leq \mathrm{wep}_j(t) \tag{17}$$

where

$\mathrm{PF}_j(t)$: Subsidy for construction of plant factory in municipality j at period t

3.16 Objective Function

We define the objective function in the model, which maximizes GRP in the simulation terms with a restriction on the amount of water pollutant emissions from the Toyogawa Basin flowing into the Mikawa Bay as follows:

$$\begin{aligned} &\max \sum_{t=1} \frac{1}{(1+\rho)^{(t-1)}} \mathrm{GRP}(t) \\ &\text{subject to } \; Q^i(t) \leq Q^i(t) \end{aligned} \tag{18}$$

where

ρ: Social discount rate (= 0.04)
$\overline{Q^i(t)}$: Restriction on the amount of water pollutant emission i from the Toyogawa Basin at period t

4 Dynamic Simulation

4.1 Study Area and Environmental Index

The study area of our study is the Toyogawa Basin, which contains five cities and one town, as shown in Table 1. We simulate the model using the dynamic optimization approach and maximizing GRP with restrictions on social, economic, and environmental conditions.

The planning years range from 2005 to 2050 (ten periods, one period = 5 years).

The pollution indices analyzed in the simulation are total chemical oxygen demand, total nitrogen, and total phosphorus (Table 2).

Table 1 Target area

Index	Municipality	
1	Toyohashi	City
2	Toyokawa	City
3	Gamagori	City
4	Tahara	City
5	Shinshiro	City
6	Shitara	Town

Table 2 Water pollutant index

Index	Water pollutant	
1	T-COD	(Total chemical oxygen demand)
2	T-N	(Total nitrogen)
3	T-P	(Total phosphorus)

4.2 Classifications and Variables

In our simulation model, the industry is classified into 22 sections, which are shown in Table 3. Table 4 shows the land use in the model, which covers a range of uses such as paddy fields, rice fields, mountain forests, city area, plant factory sites, and others. This model includes the household wastewater disposal system, which is shown in Table 5 and comprises the sewage system, rural community sewage, combined treatment septic tanks, single-treatment septic tank, and night soil septic tank. The amount of water pollutant emissions, which refers to three kinds of pollutants (T-COD, T-N, and T-P), is estimated by our simulation model. The water pollutant emission coefficients are shown in Table 6, and the pollutants are generated from nonpoint sources (land use), production sources (production activities), and household wastewater generation sources.

4.3 Simulation Cases

The base year was set up as 2005, and Aichi Prefecture Statistical Yearbook and other statistics were used as initial data (Aichi Environment Department water ground Environment Division (2006), Aichi Construction Department Sewer Division (2014): Sewer of Aichi HP, Aichi Prefectural life part Statistics Division (2006), and Aichi Prefectural life part Statistics Division (2010)). The following four cases were examined. The simulation was performed for ten units (5 years as a unit) per dynamic:

1. *Case 1*: Maximize GRP not considering environmental measures.
2. *Case 2*: Maximize GRP with setting a 3 % reduction of pollutant load as a constraint. Assume receipt of a grant from the national government, thus prompting changes of land use and economic activity.

Table 3 Water pollutant index

Index	Industry
1	Manufacture of food
2	Manufacture of feed
3	Manufacture of textile mill products
4	Manufacture of apparel
5	Manufacture of lumber and wood products
6	Manufacture of furniture and fixtures
7	Paper products
8	Printing
9	Manufacture of chemical and allied products
10	Manufacture of petroleum and coal products
11	Manufacture of plastic products
12	Manufacture of rubber products
13	Manufacture of leather products
14	Manufacture of ceramic, stone, and clay products
15	Manufacture of iron and steel
16	Manufacture of nonferrous metals and products
17	Manufacture of fabricated metal products
18	Manufacture of general machinery
19	Manufacture of electrical machinery, equipment, and supplies
20	Manufacture of transportation equipment
21	Manufacture of precision instruments and machinery
22	Others

Table 4 Land use

Index	Land use
1	Paddy field
2	Rice field
3	Mountain forest
4	City area
5	Others
6	Plant factory

Table 5 Classification of household wastewater disposal system

Index	Household wastewater disposal system
1	Sewage system
2	Rural community sewage system
3	Combined treatment septic tank
4	Single-treatment septic tank
5	Night soil septic tank

Table 6 Pollutant emission coefficient (g/ha/day)

Index	Emission source	COD	T-N	T-P
1	Paddy field	208.2	28.2	1.9
2	Rice field	304.4	94.4	8.5
3	Mountain forest	58.9	9.9	0.8
4	City area	386.3	54	7.4
5	Others	58.9	9.9	0.8
6	Plant factory A	42.6	6.3	0.5
7	Plant factory B	84.1	17.9	1.1

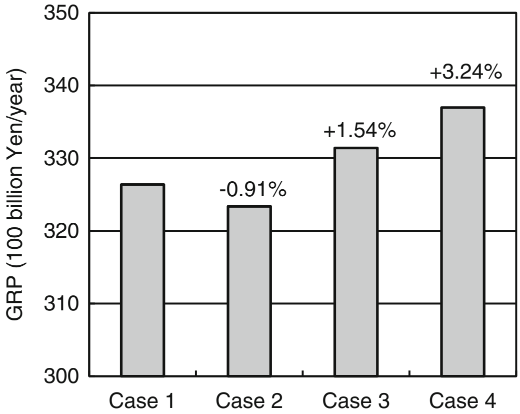

Fig. 3 GRP of each case in 2050 and percentage rates as compared with Case 1

3. *Case 3*: Maximize GRP with setting a 3 % reduction of pollutant load as a constraint as in Case 2. Assume receipt of a grant from the national government, thus prompting change of existing farmland to advanced agricultural facilities (sunlight-use-type plant factory, plant factory A).
4. *Case 4*: Maximize GRP with setting a 3 % reduction of pollutant load as a constraint as in Case 2. Assume receipt of a grant from the national government, thus prompting change of existing farmland to advanced agricultural facilities (full-control-type plant factory, plant factory B).

5 Simulation Result

Figure 3 shows GRP of each case in 2050, and the percentage rates as compared with Case 1 needed to maintain the status quo. In Case 2, which takes measures to protect the environment, GRP decreased by 1.28 % compared with Case 1. Meanwhile, in Cases 3 and 4, which aggregate subsidy uses from countryside to advanced agricultural facility development, GRP increased 1.54 % and 3.24 %, respectively, compared with Case 1 despite the environmental measures being in place. In these cases, percentages of advanced agricultural facilities in 2050 were 1.75 % and

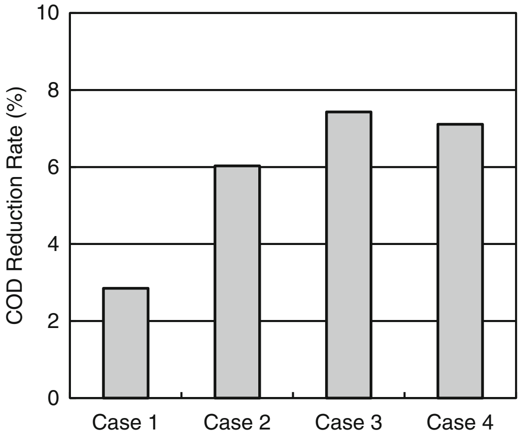

Fig. 4 Reduction rates of COD load of each case in 2050 compared with base year (2005)

0.94 %, respectively; from these changes, agricultural production values increased 3.3 % and 8.4 %, respectively. Agricultural water usage decreased 0.8 % and 0.6 %, respectively, compared with initial values. In turn, GRP increased by approximately 1.5 and 3 times compared with the amount of subsidies received. From these results, Cases 3 and 4 were considered effective policies to achieve both environmental and economic benefits. In all cases, though GRP decreased in 2050 compared with the base year, the main reason is population decline. Furthermore, despite the decreased overall GRP, per capita GRP increased in all cases other than the base year. From this, we can conclude that stemming population decline will bring about increases in total GRP.

Figure 4 shows reduction rates of COD load for each case in 2050 compared with the base year in order to demonstrate the success of the proposed environmental measures. COD load decreased approximately 3 % even in Case 1, which did not impose intentional environmental measures. This is also because of population decline, and per capita COD was the same as the initial value. On the other hand, the reduction rate of COD load increased 6–7.5 % from Case 2 to Case 4. These cases were estimated as offering effective environmental protection policies. However, it is difficult to bring about such improvements solely through human actions. Thus, more drastic measures are necessary to significantly improve the target area's water quality.

6 Concluding Remarks

In this study, we constructed a dynamic environment-economic model to evaluate regional economy and water-environment policies for the Toyogawa Basin in consideration of regional characteristics. Specifically, we analyzed regional economic and environmental data for the Toyogawa Basin and constructed a whole-system model to elucidate the interaction between the regional economy and the water environment in the basin, as the devised model describes the area's socioeconomic activities and their impact on the area's water environment. The analysis encompassed the option of vegetable cultivation factory systems, a high-value-added agricultural system, as a choice of environmental improvement technology. Then using this model, we analyzed the relationship between the regional economy and water environment and estimated the impacts of the regional economic activities on the water environment in the Toyogawa Basin. Finally, we evaluated the regional economic and water-environment policies in the basin via a simulation analysis using the developed model.

The analysis results show that the introduction of advanced agricultural facilities is more effective than other policies, as they are projected to decrease pollution load by approximately 7 % compared with initial values and further increase GRP by 1.5–3 % compared with current policies. However, the effects will not be significant in everyday terms. Moreover, from the viewpoint of water resource management, these policies will be able to reduce agricultural water needs by only 0.6–0.8 %. Therefore, we have to conclude that benefits cannot be expected for the flow management of rivers or the habitat improvement of freshwater aquatic organisms.

We considered the effectiveness of advanced agricultural facilities foremost as a preliminary specific positioning. However, radical improvements are not expected to stem from only adding a single change in isolation, regardless of whether that technique meets local characteristics or not. Thus, it is important to clarify the real-life impact of proposed policies as well as determine what policies are effective in practice in order to combine many elements organically a unique combined solution that can best meet local characteristics and challenges.

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References

Aichi Construction Department Sewer Division: Sewer of Aichi HP, website, (URL:www.pref.aichi.jp/gesuido/). Final accessed date 20 June 2014

Aichi Environment Department water ground Environment Division (2006) 2005 fiscal year water quality survey of public waters and groundwater result, digital data

Aichi Prefectural life part Statistics Division (2006) 2006 fiscal published Aichi Statistical Yearbook, digital data

Aichi Prefectural life part Statistics Division (2010) 2005 Aichi industry input-output tables, digital data

East Mikawa Development Council (1994) Regional and urban plan for East Mikawa area (in Japanese)

Esaki K (1992) On the impact given by the water supply of toyogawa irrigation canal for local farm households income and agriculture management. Bull Fac Agric Meiji Univ 95:37–60

Institute of Regional Research of Chubu (1998) Economy and Society of East Mikawa 6, Aichi University

Makino Y (ed) (1997) Toyokawa water and Atsumi Village, Iwata Sho-in (in Japanese)
Matsukura G, Kokugo O, Higuchi Y and Tanaka Y (1998) Environmental issues of east Mikawa, Okumikawa Shobo (in Japanese)
Sakatou K, Yamasaki S, Konno A (1990) A study of the water demand and land use of toyogawa waterway. Pap City Plan 25:133–138 (in Japanese)
Shibusawa H, Yamaguchi M (2014) Evaluating the social and economic impacts of the water resources in the toyogawa basin. The Lark Hill, Toyohashi Univ Technol 36:45–60
Yamaguchi M, Shibusawa H (2006) A comparative analysis of water resources and regional economic structures in East Mikawa. Stud Reg Sci 35(4):1007–1020

A Management Policy of Demand-Driven Service for Agricultural Water Use in Japan

Katsuhiro Sakurai

Abstract To this day in Japan, the water supply service for agricultural use has been formed as the supply-driven system. In fact, the farmers can use the utilization volume of agricultural water, and they have to pay the price of agricultural water fee decided by water supplier side. The purpose of this study is to clarify the present condition and consciousness of rice farmers about water use by interview survey in case of Aichi-Yosui irrigation area and to analyze the agricultural water management system from an economic viewpoint. Second, we propose the evaluation concept and simulation method for construct of the desirable water service system as a regional policy. In this study, the model analysis suggests that demand-driven irrigation facilities can fit appropriately with the needs of each farmer and simultaneously increase the productivity of the entire region.

Keywords Management policy • Agricultural water use • Demand-driven service

1 Introduction

Water usage by humans is classified into three main categories: agricultural, residential, and industrial water. Agricultural water use is the highest among the three categories, accounting for about two-thirds of the water resources used in Japan and the rest of the world (Ministry of Land, Infrastructure, Transport and Tourism 2011; Ishii 2007). Figure 1 also shows the usage of the water, especially the importance of agricultural water use in Japan and the world. Current agricultural water usage in Japan has been geared mainly toward agriculture-related public works projects involving rice cultivation since World War II. As of 2009, two-thirds of the entire agricultural land in Japan was irrigated, and there were approximately 400,000 km of waterways and 7000 dams and other primary facilities managing water for the agricultural sector (Ministry of Agriculture, Forestry and Fisheries 2010).

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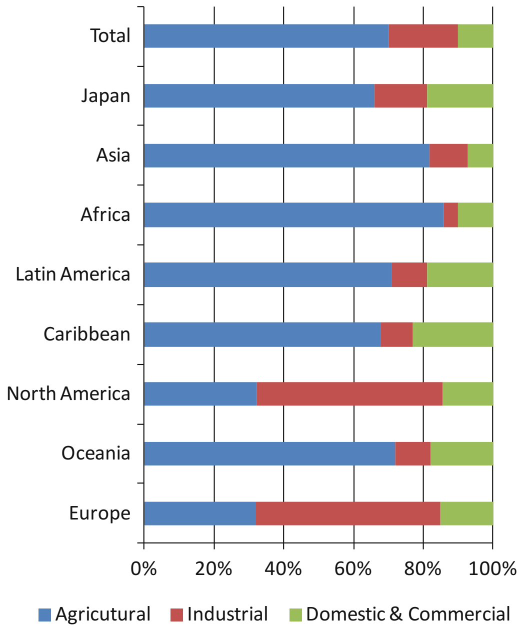
Fig. 1 The water use of the world



To date, such infrastructure for managing and using agricultural water (in this report, referred to as "irrigation facilities") has been based on a supply-driven system, i.e., farmers have been passive users based on the volume, price, and form of supply as set by a supplier (Shirai 1998). However, in recent years, increased international interest in water resources problems and the development of a service-science approach have led to the creation of a demand-driven system that aims to reflect the diverse needs of farmers and the efficient use of agricultural water (Dinar and Tiwari 2003). Furthermore, many other aspects of water resources, in addition to their use in agricultural production, are seen as important; these include the provision of a water-friendly environment and the role of water as a habitat for wildlife (Faurès et al. 2002).

The current situation, however, is at a stage of theoretical consideration and proposals (Berck et al. 1991; Sylvie et al. 2005), and to the best of our knowledge, there are virtually no reports or case studies on specific research and analysis concerning the actual application of irrigation water. Therefore, gaining an understanding of actual water usage and current and potential demands through an investigation of farmers' actual use of irrigation facilities is of urgent importance.

In this study, we aim to quantitatively clarify rice farmers' current status and awareness with regard to water usage from an economic perspective, and based on this, we aim to consider a more desirable form of agricultural water service. To this end, we conducted a field survey, which then formed the basis for creating a model and running a simulation.

2 Research Methodology

2.1 *Survey*

2.1.1 Target Area

Aichi-Yosui provides water for agricultural, industrial, and residential uses in Aichi Prefecture throughout an area that extends from the Owari Hills to the Chita Peninsula. The Aichi-Yosui waterworks system was selected as the target area for studying agricultural water use for two reasons: (1) the desire to efficiently resolve the chronic shortage in the volume of water available relative to the demand and (2) the consideration being given to the replacement of aging facilities.

Aichi-Yosui is a waterway that was constructed to eliminate water shortages in the Chita Peninsula, where the precipitation is low and there are no major rivers. The Ministry of Agriculture and Forestry (as it was known at that time) started surveying the area in 1949, began construction in 1957, and oversaw the waterway's completion in 1961. Three dams, i.e., Makio Dam, Misogawa Dam, and Agigawa Dam, draw water from the Kisogawa River system. The Kaneyama intake conveys the river's water to the irrigation canals. At that time, the construction costs amounted to ¥42.2 billion. Following subsequent developments, including the second phase of the Aichi-Yosui project from 1981 to 2004 and the construction of water resource infrastructure, the system is now managed by the Japan Water Agency (an Incorporated Administrative Agency). The Aichi-Yosui service area covers approximately 13,584 ha of agricultural land of which rice paddies account for 8536 ha, dry fields account for 4113 ha, and land under permanent crops account for 935 ha. The area comprises a 112 km main canal with 1012 km of subcanals that break off from the main canal to service agriculture (Ohsawa and Tatematsu 2004). Figure 2 shows the Aichi-Yosui waterway service area in Japan. The waterway is located in the central area of Japan, and the water intake point of the waterway, which joins the Kiso River, is located in the north of its service area. For the survey, this study targets an area within this region that typifies a supply-driven system which plans and implements public works projects, including agricultural land development and improvement.

2.1.2 Survey Methodology

The survey was conducted via interviews because the limited number of farmers within the target area led to the assumption that the researchers in this study would be able to ask uniform questions and elicit uniform responses.

The interview questions fell into three broad categories: (1) basic attributes, (2) the scale of a farmer's business in terms of farm production costs and revenues, and (3) the current state and awareness of irrigation usage. The researchers adjusted their method of posing the questions to correspond with the survey form presented to respondents.

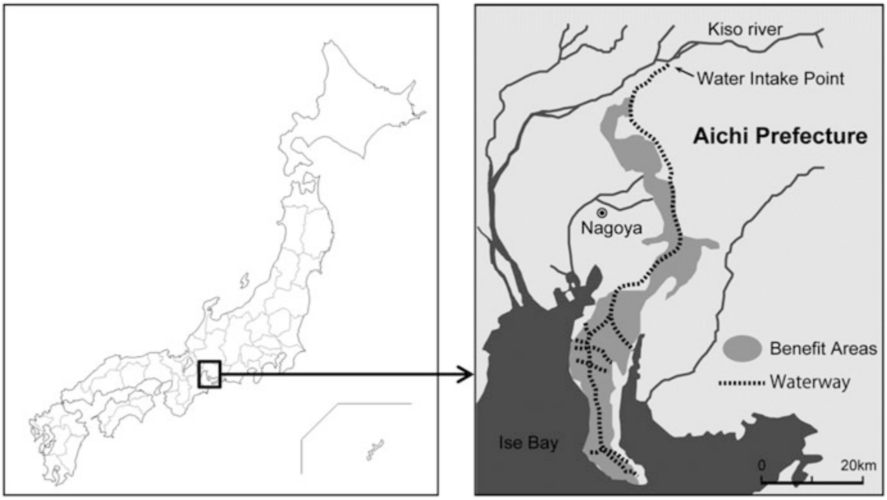


Fig. 2 Aichi-Yosui waterways and irrigation canals and the area serviced

2.1.3 Interviews and Data Analysis

Interviews were conducted on March 29, 2012, with a total of six farmers who specialized in rice cultivation within the target area. The total area of land cultivated by those interviewed was 1660 ha, which equates to 66.4 % of the target area (approximately 2500 ha).

The interview results were converted, revised, supplemented, and quantified, and the analysis was then conducted based on statistical data from central and local government authorities (Ministry of Agriculture, Forestry and Fisheries 2012; Aichi Prefecture 2012), information provided by the local agricultural cooperatives (JA), and materials from the Aichi-Yosui Land Improvement District.

2.2 Model Analysis

2.2.1 Model Assumptions

In the model, the researchers took the current status of Japanese rice farms as elicited by those surveyed in the Aichi-Yosui service area and assumed a virtual target area with the agricultural water and service area shown in Fig. 3. The service area comprises three zones referred to as A, B, and C from upstream to downstream. Farmers located in each zone are shown in Table 1. The model equations, indicated in the next section, show each farmer's benefit-maximizing behavior based on the size of his/her cultivated area and his/her value system. In addition, the conditions

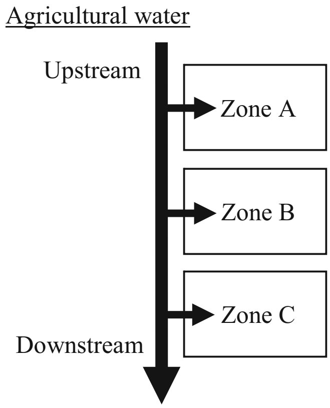


Fig. 3 Conceptual diagram of the virtual target area

Table 1 Profile of the farmers in the virtual target area

Area	Farmer	Cultivated area (10a)	Value system*
A	A1	5	Type (3)
	A2	10	Type (3)
	A3	15	Type (3)
	A4	20	Type (3)
	A5	25	Type (3)
	A6	30	Type (3)
	A7	35	Type (3)
	A8	50	Type (3)
	A9	100	Type (3)
	A10	150	Type (2)
B	B1	50	Type (3)
	B2	60	Type (3)
	B3	100	Type (2)
	B4	150	Type (2)
	B5	200	Type (3)
C	C1	50	Type (2)
	C2	100	Type (1)
	C3	500	Type (2)

*See Sect. 2.2.2 (f) about type (1), (2), and (3)

for cultivating agricultural land are not uniform because time and spatial variations exist. Specifically, there are two trends: (1) the earlier the rice-planting period, the higher the market price of rice and (2) the further downstream the area of cultivation, the greater the yield per unit of cultivated land. Furthermore, the area for one paddy field is set at 10 ha per farm, which is the minimum area of cultivation. Moreover, the exogenous factors for this model have been set based on the interviews and existing documentation and assigned the symbols as follows:

(a) Based on the interviews.
(b) See Ministry of Land, Infrastructure, Transport, and Tourism and Water and Disaster Management Bureau (2011).
(c) See Rural Development Bureau of the Ministry of Agriculture, Forestry, and Fisheries 2010).

2.2.2 Overview of Model Equations

(a) Profit
Farm profit is derived by deducting total farm production costs from total crop revenues.

$$\pi = R - TC, \tag{1}$$

$$TC = WC + OC, \tag{2}$$

where π represents profit, R represents crop revenue, TC represents the total farm production cost, WC represents water costs, and OC is farm production costs other than water costs.

(b) Farm production costs
Farm production costs other than water costs relative to the cultivated area are given as

$$OC = \varnothing \cdot L, \tag{3}$$

where $\varnothing$ represents the farm production cost coefficient (exogenous[a)]) and L represents the cultivated area (exogenous[a)]).

Water costs are determined by multiplying irrigation cost per unit area by the total number of units in the cultivated area. Here, irrigation cost per unit area depends on the rice-planting period. However, in the scenarios I and II, irrigation cost per unit area is taken to be uniform, regardless of the planting time.

$$WC = \gamma(t) \cdot L, \tag{4}$$

where $\gamma(t)$ represents irrigation cost per unit area for each planting period (exogenous[a), b)]).

(c) Crop revenue
Crop revenue is derived by multiplying the crop's sales price for each period and the yield per unit area by the cultivated area for each period. Here, the sales price and yield per unit area depend on the rice-planting period.

$$R = p(t) \cdot Y(t) \cdot L,$$

where $p(t)$ represents the sales price for each period (exogenous[c]) and $Y(t)$ represents the yield per unit area for each period (exogenous[a), c)]).

(d) Maintenance of irrigation water
A management association maintains an irrigation system with irrigation costs paid by each farmer, and these irrigation costs are set at a fixed amount.

$$\sum WC = TB, \tag{6}$$

where TB is the management association's total maintenance cost (exogenous[a)]).

(e) Volume of irrigation water supplied
The volume of water supplied in each period must be within the water volume limits. However, a large volume of agricultural water is required during rice planting in the target area, whereas the water required at other stages of production is limited and stable. Therefore, in this study, the water volume is limited to the irrigation water used during the rice-planting period.

$$WA(t) \leq LWA(t),$$

where $WA(t)$ represents the volume of water supply for each period and $LWA(t)$ represents the water volume limit for each period (exogenous[a)]).

(f) Farmer behavior
Each farmer behaves so as to maximize his/her own benefit. Farmers' value systems are categorized into three types: profit seeking, balanced, and production-cost containment. However, regardless of the value system, cultivation does not occur unless a farmer expects to generate a profit. In addition, where there are multiple optimal solutions, farmer type (1) selects the earliest period for planting, whereas farmer types (2) and (3) select what they hope will entail the lowest farm production costs.

Type (1): Profit seeking
This type of farmer seeks to maximize profit.

$$\max \quad \pi$$
$$\text{s.t.}(1) - (7), \pi > 0.$$

Type (2): Balanced
This type of farmer sets a limit on farm production costs and seeks to maximize profit within that framework.

$$\max \quad \pi$$
$$\text{s.t.}(1) - (7), TC \leq, LTC, \pi > 0,$$

where LTC is the upper limit for farm production costs (exogenous[a)]).

Type (3): Production-cost containment

This type of farmer seeks to minimize farm production costs.

$$\min \ TC$$
$$\text{s.t.}(1) - (7), \pi > 0.$$

2.2.3 Scenarios

The three scenarios that were set are as follows:

I. *Upstream priority system*
Upstream farms draw water preferentially and independently. Therefore, zones further downstream can only draw water if the upstream farms have not used up the limit for that period; thus they can draw water only up to the amount that is available (this is the current policy in the area where interviews were conducted).

II. *Equal allocation system*
The irrigation water management association allocates irrigation usage rights equally, relative to the area under cultivation by each farm. Therefore, the volume of water that can be drawn per unit of cultivated area in a particular period is the same for each farm.

III. *Variable price system*
Demand and supply are balanced by varying the irrigation costs in accordance with the level of demand. Specifically, as shown in Fig. 4, the unit price of the irrigation water increases when demand exceeds the water volume limit and decreases during periods when demand falls below a certain level. Ultimately, the total demand for water from farms in each period is kept within the available supply limit, while the aggregate irrigation costs for the entire period are adjusted to be the same as for scenarios I and II. The aforementioned process is endogenous because the behavior of each farmer is based on his/her particular value system.

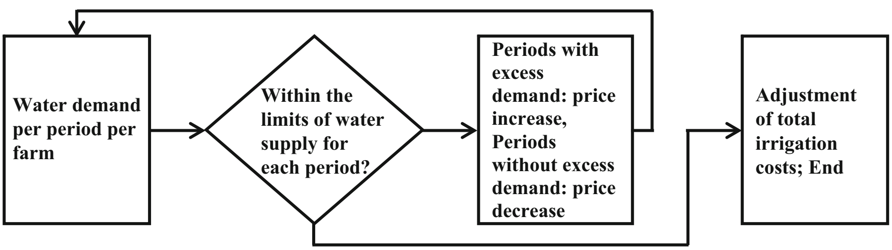


Fig. 4 Balanced flow under the variable price system

3 Results

3.1 Results of Interviews

Table 2 provides an overview of the interview results. In addition, Fig. 4 shows the relation between the size of the farm and farm production costs based on those results, whereas Fig. 5 shows the relation between the size of the farm and farm revenues. Farm revenues are a linear equation or linear approximation (Fig. 5, $R^2 = 0.9675$), whereas farm production costs approximate a third-order polynomial relative to the size of the farm (Fig. 6, $R^2 = 0.9859$). Although farm revenues in this zone increase in direct proportion to the size of the cultivated area and farm production costs increase logarithmically relative to the increase in the initial amount of production, there is a tendency for this increase in costs to flatten for cultivated areas from 500 to 1500 ha in size, followed by an exponential increase for sizes above 1500 ha.

Next, Fig. 7 shows the relation between the size of cultivated area and irrigation costs. Although the difference among the farms in the size of their cultivated areas was about 22 times between the largest and smallest, the irrigation costs of the largest farms exceeded those of the smallest by only about threefold. This means that there was an exponential decline in the cost of irrigation per unit area as the size of the cultivated area increased.

A list of responses is provided below to illustrate the farmers' qualitative awareness with regard to irrigation and farming.

Farmer A: "I want to maximize revenue even if I have to increase production costs and risk."

Farmer D: "Since I am cultivating the land in my spare time apart from my principal occupation, I only need to generate a certain level of harvest."

Farmer E: "I'm thinking about closing the business because staff and capital needs are increasing."

3.2 Results of Model Analysis

Figure 8 illustrates farmers' crop revenues, farm production costs, and profits under each scenario and for each type of value system. For both crop revenue and profit, the value for the total area was highest under the variable price system scenario, followed by the equal allocation system and then the upstream priority system. In addition, observing each type of value system, for all farms, the variable price system scenario is found to generate a higher profit than the upstream priority system or the equal allocation system. The profit from the variable price system scenario is 6.9–24.7 % higher than that from the upstream priority system. However, for the farmers who take a balanced or production-cost containment approach, this

Table 2 Overview of interview results

Category	Item	Farmer A	Farmer B	Farmer C	Farmer D	Farmer E	Farmer F	Unit
Basic attributes	Full time or part time	Full time	Full time	Full time	Part time	Full time	Full time	–
	Farming income ratio	80.0	53.7	88.9	50.0	100.0	100.0	%
	Area of cultivated land	2200.0	320.0	400.0	350.0	100.0	1800.0	a
Scale of farm business	Farm production costs	21,319.0	7958.4	6656.7	6055.1	3580.5	11,373.3	Thousand yen
	Irrigation costs	624.2	257.7	328.4	360.6	219.1	328.4	Thousand yen
	Other expenses	21,319.0	7958.4	6656.7	6055.1	3580.5	11,373.3	Thousand yen
	Farm revenue	50,000.0	10,808.0	8167.5	6352.5	1815.0	32,670.0	Thousand yen
	Revenue from crops	40,000.0	5808.0	7260.0	6352.5	1815.0	32,670.0	Thousand yen
	Other revenues	10,000.0	5,000.0	907.5	0.0	0.0	0.0	Thousand yen

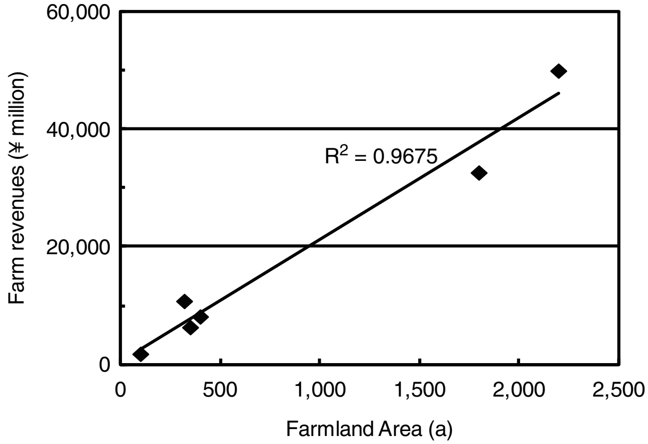


Fig. 5 Relation between the size of cultivated area and farm revenues

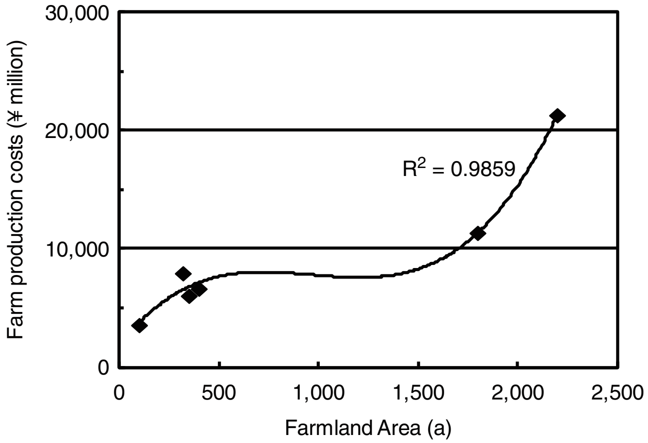


Fig. 6 Relation between the size of cultivated area and farm production costs

scenario reduces farm production costs the most, with production costs lower than those under the upstream priority system by 5.2 % and 7.3 %, respectively.

In addition, the relation between the cultivated area and irrigation costs (Fig. 9) indicates that under the upstream priority system and equal allocation system, the smaller the cultivated area, the higher the proportion of costs attributed to irrigation costs, whereas under the variable price system, there is a tendency for the irrigation costs per unit area of cultivated land to increase.

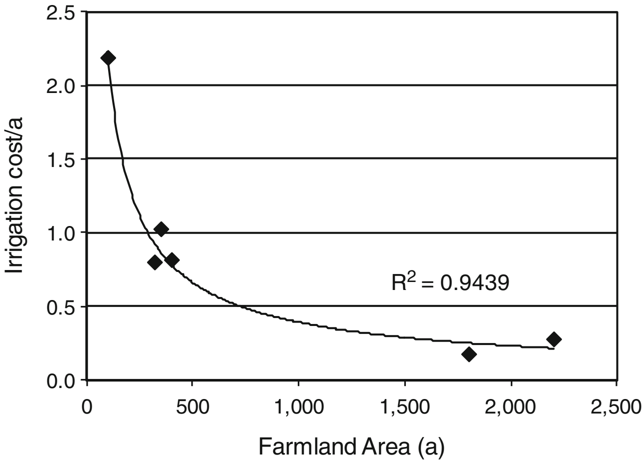


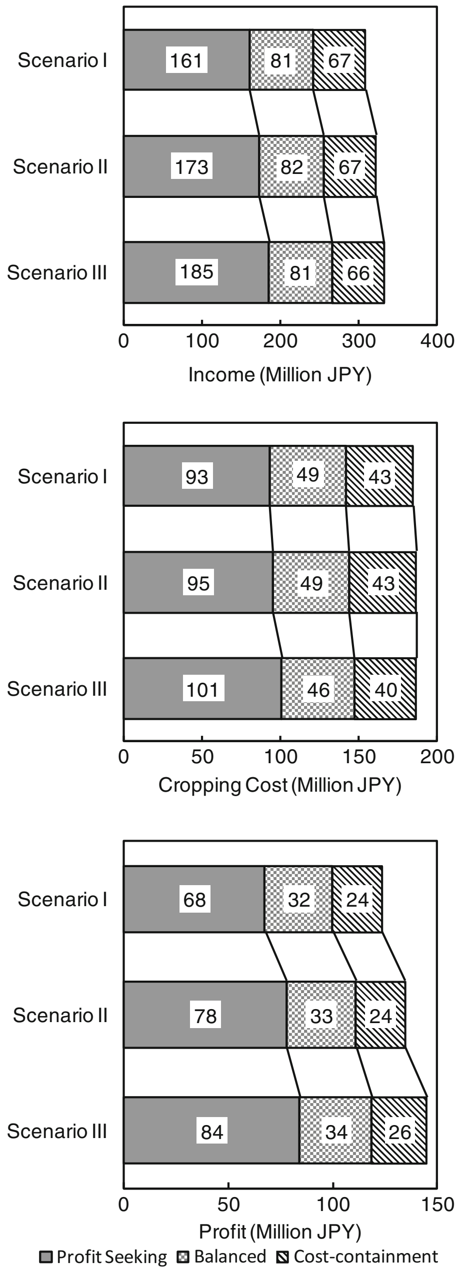
Fig. 7 Spending on irrigation per unit of cultivated area

4 Discussion

The results of the interviews indicate three points concerning the characteristics of the target area: (1) there were large differences in the scale of cultivated area even within the same zone; (2) the smaller the cultivated area, the higher the proportion of costs attributed to irrigation costs under the system; and (3) farmers also had differing value systems (management policies and needs); thus while large-scale farmers, in particular, tended to pursue profits, many small-scale farmers wanted to reduce their farm production costs and associated risks. While this is just one case study of an area, these results point to theoretical considerations and proposals for dealing with the issues that farmers face under the current system that supplies uniform irrigation facilities.

In addition, the results of the model analysis, which consider the above points, indicate that the implementation of a variable price system would satisfy the respective needs of farmers with different value systems, i.e., the variable price system scenario would simultaneously lead to increased profits for profit-seeking farmers and reduced farm production costs for farmers taking a balanced approach or a production-cost containment approach, thereby ultimately increasing profits for the latter. Furthermore, it was noted that in addition to its direct benefits, such a demand-driven system would decrease farm production costs and increase profits for the entire region. Consequently, compared to the current system, the variable price system is a market-principle-based policy that promotes the most efficient choice of a planting period for both the land and farmers. In addition, the interviews clearly demonstrated that many small-scale farmers are considering exiting the business because of staff and capital constraints and a variable price system will probably help small-scale farmers to maintain their viability.

Fig. 8 Crop revenue, farm production costs, and profits by type of farmer for each scenario



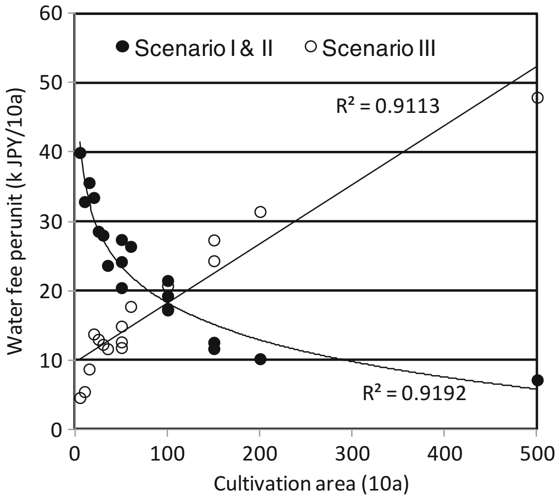


Fig. 9 Irrigation cost per unit of cultivated area for each scenario

5 Conclusion

The interviews in this study confirmed the diversity of management approaches and value systems of Japanese rice farmers. The model analysis suggests that demand-driven irrigation facilities can fit appropriately with the needs of each farmer and simultaneously increase the productivity of the entire region.

Going forward, it will be essential to consider specific policies and their effectiveness in this area of study by conducting more field surveys that further clarify the current status of and issues for agricultural water irrigation facilities and by performing additional simulation analyses that give more in-depth information on current circumstances, such as those conducted under multi-agent systems.

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References

Aichi Prefectural Government Department of Agriculture, Forestry, and Fisheries (2012) Trend Survey No. 151, Agricultural Trends 2012. digital data

Berck P, Robinson S, Goldman G (1991) The use of computable general equilibrium models to assess water policies. In: The economics and management of water and drainage in agriculture. pp 489–509

Dinar A, Tiwari D (2003) Prospects for irrigated agriculture: whether irrigated area and irrigation water must increase to meet food needs in the future. Agriculture and Rural Development Department, World Bank, 111p

Faurès J, Hoogeveen M, Bruinsma J (2002) The FAO irrigated area forecast for 2030. Food and Agriculture Organization

Ishii M (2007) Sekai no suidogen to nosui kanri ni tsuite [Global water resources and management of agricultural water]. J Econ Policy Stud, Kagawa University 3:53–80

Ministry of Agriculture, Forestry and Fisheries Minister's Secretariat (2012) Report of statistical survey on farm management and economy 2010. digital data

Ministry of Agriculture, Forestry and Fisheries Rural Development Bureau (2010) Nogyo kiban joho kiso chosa [Basic survey on fundamental information for agriculture]. digital data

Ministry of Land, Infrastructure, Transport and Tourism Water and Disaster Management Bureau (2011) FY2011 White paper on water resources. Mitsuba Total Printing 307p

Ohsawa K, Tatematsu I (2004) History and features of Aichi Canal. J Jpn Soc Irrig Drain Reclam Eng 73(2):87–90

Shirai Y (1998) Historical study of the consumption-based allocation of irrigation costs in modern Japan. J Aichi Gakuin Univ Humanit Sci 46(2):3–33

Sylvie M, Douglas M, Jetrick S, Hilmy S (2005) Improving irrigation project planning and implementation process: diagnosis and recommendations. International Water Management Institute, H038124

An Analysis on Social Benefit Derived by Introducing New Technology and Optimal Environmental Policy: Case Study in Lake Kasumigaura

Takeshi Mizunoya

Abstract In this study, we evaluate social benefit derived by introducing new technologies and analyze a dynamic optimal policy to improve the water quality of Lake Kasumigaura, considering both – the total ecological system in and around the lake and the situational changes over a certain period of time. We specify three sub-models (socio-economic model, material flow balance model and water cycle model) and one objective function in order to analyze the optimal policy to improve the water quality of Lake Kasumigaura. The pollutants measured in this study are nitrogen (T-N), phosphorus (T-P) and COD. These have been strongly affecting the deterioration of water quality. We found the social benefit of new technology is 1.4 trillion yen when the water pollutants reduction rate is 33 % and the social benefit rate is around 33. This means efficiency of the new technologies adopted is very high. The simulation shows that the present technology has an inadequate abatement capability for T-N as compared with other pollutants. Also it shows that we should consider the reduction of T-N as the most important subject when we formulate an environmental policy or develop new technology to improve the water quality. Excessively accumulated nitrogen gives load in environment in a circulation process. The environmental policy should be drafted associated with food self-sufficiency problem.

Keywords New technology • Social benefit • Environmental policy • Environmental quality • Simulation

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1 Introduction of Lake Kasumigaura and Advantage of Social Benefit Analysis

The quality of water in Lake Kasumigaura (Fig. 1) has been deteriorating since the 1970s by pollution discharged from socio-economic activities of the catchment area. Even in recent years, sometimes we can see the abnormal emergence of plankton such as green algae in the lake. To prevent emergence of green algae many engineering experts are working to develop technologies. For example, Inamori et al. (1998) and Yoshida et al. (1979) developed new technologies to prevent eutrophication. In addition, The Science and Technology Promotion Foundation of Ibaraki (2005) developed a biomass energy plant that utilizes livestock manure discharged from Kasumigaura basin. On the other hand, there are many research initiatives which analyse environmental policy and integrated watershed management. For example, Baumol and Oates (1988) and Oka (1997) analyzed the political aspects of the environmental problems. Higano and Yoneta (1998) and Takagi (1999) conducted simple simulation analyses to evaluate water purification policies. Hirose and Higano (2000), Mizunoya et al. (2007), and Hataya et al. (2010) analysed the comprehensive watershed management of sustainable development and environmental remediation in the region.

The objectives of this research are to find out the social benefit, necessary budgets and its allocation, and environmental changes when adopting new technologies in Kasumigara basin. In this research, the social benefit of environmental remediation new technology is calculated as an increase in the GRP (Gross Regional Product).

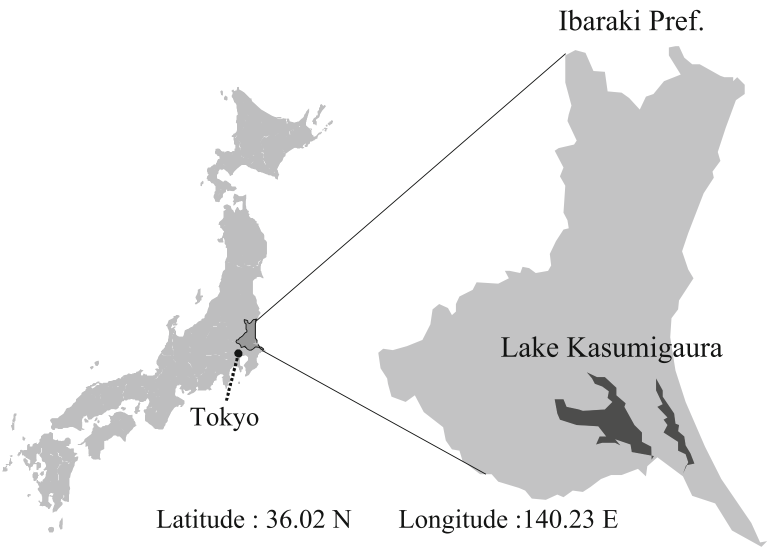

Fig. 1 Location of Lake Kasumigaura

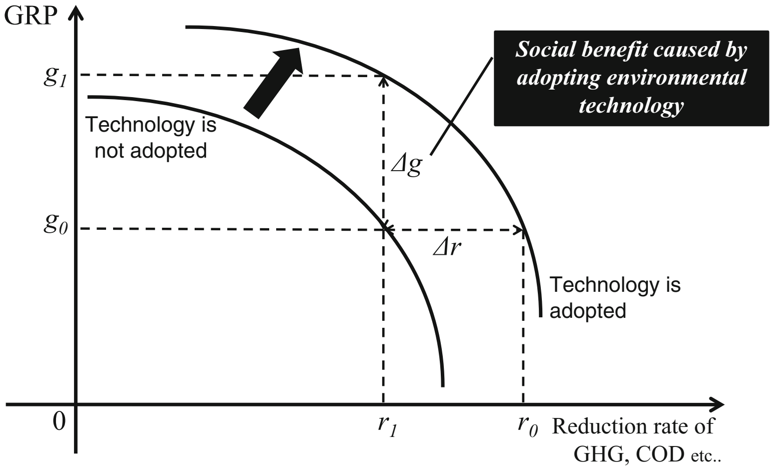

Fig. 2 Trade-off and shift of Gross Regional Product (GRP) by adopting new technology

For example, we assume an advanced remediation technology is now developed. It has an advantage as it treats wastewater as well as it utilizes potential energy of the wastewater. Usually, the economy and the environment have a trade-off relation. However, the trade-off can be shifted by introduction of new technology. Figure 2 shows such a trade-off and a shift by new technology. The lower line means the trade-off before the technology is adopted. The upper line means after that. So, we can judge the increase in the social benefit that can be attributable to the new technology is Δg when the same level of the environment is kept. Or, when we keep the same level of GRP, we can more improve the environment. And, the improvement is due to the new technology, of course.

2 Outline of Simulation Model

2.1 Model Abstract

In this study, three sub-models (material flow balance model, socio-economic model and water cycle model) and one objective function (Regional GDP) are specified in order to clarify the social benefit of environmental remediation new technology and predict the optimal policy to improve the water quality of Lake Kasumigaura. The socio-economic model describes the social and economic activities in the catchment areas and the relationship between the activities and the emission of pollutants. The water cycle model describes how much water is generated and the flow of water in the catchment areas. All the policy measures to improve water quality directly, indirectly and potentially are built in the mode as alternatives that provide an optimal hybrid of the policy measures. The model simulates the socio-economic activities when the load of total water pollutants is restricted gradually and clarifies *endogenously* an optimal hybrid of environmental and economic policies, namely how to control the timing and regions of economic activities and how to spend the environmental budget for the implementation of the policies. The simulation running period was from 1999 to 2003 (total 5 years) and the pollutants measured in this study are total nitrogen (T-N), total phosphorus (T-P) and chemical oxygen demand (COD). The simulation analysis was conducted by maximizing the GRP in the basin. The environmental quality is controlled by restricting the amount of water pollutants flowing into the lake in the final period of the horizon. We set some simulations so that the amount of water pollutants flowing into Kasumigaura were reduced by *n*% by the year 2003 as compared to the actual data of 1999. For example, when the reduction rate was 20 %, we set the name as Case 20. The restricted amounts of water pollutants inflow in each simulation are shown in Table 1.

Table 1 Simulation cases

Case name	Reduction rate in 2003 (compares to the real data in 1999) (%)	Upper constraints on the amount of T-N flowing 2003 (t)	Upper constraints on the amount of T-P flowing 2003 (t)	Upper constraints on the amount of COD flowing in 2003 (t)
Case-0	0	4427	278	10,532
Case-5	5	4205	264	10,005
Case-10	10	3984	251	9478
Case-15	15	3763	237	8952
Case-20	20	3541	223	8425
Case-25	25	3320	209	7899
Case-26	26	3276	206	7793
Case-27	27	3231	203	7688
Case-28	28	3187	200	7583
Case-29	29	3143	198	7477
Case-30	30	3099	195	7372
Case-31	31	3054	192	7267
Case-32	32	3010	189	7162
Case-33	33	2966	186	7056
Case-34	34	2922	184	6951
Case-35	35	2877	181	6846
Case-36	36	2833	178	6740
Case-37	37	2789	175	6635
Case-38	38	2744	173	6530
Case 39	39	2700	170	6424

2.2 Classification of Water Pollutant Sources and Types of New Technology to Improve Water Quality

We classified water pollutant generation source into three categories, namely household, non-point and industrial wastewater. The household wastewater disposal system was divided into eight categories of household wastewater generation sources, land use into five categories of non-point generation sources and industry into seven categories of industrial activity generation sources (See Tables 2, 3, and 4). "Other Land Use" in Table 3 and "Other Industry" in Table 4 emits no water pollutants. It is assumed that the population that uses septic tanks and night soil septic tank do not grow as the trade of septic tank has voluntarily restrained provision of the service and facility since 1999. Recently, research on developing water pollutant removal equipment and inventing discharge control technology to improve water quality are being carried out. We classified the new technologies into three categories as follows (See Tables 5). Examples of numerical data of new technologies are shown in the Appendix. These new technologies were improved in the Project for Water Environment Renovation of Lake Kasumigaura.

2.3 Sub-basin of the Major River and Municipality in the Kasumigaura Basin

The area of the municipality and sub-basin does not necessarily coincide. When the area of a municipality belongs to several sub-basins, we estimated the ratios of rainfall in the area that flows into the rivers of the sub-basins. The estimation is based

Table 2 Classification of household wastewater disposal

Index	Facility
1	Sewage system
2	Rural community sewage system
3	Combined treatment septic tank
4	Treatment septic tank
5	Night soil septic tank
6	Untreated domestic wastewater
7	New type of septic tank A
8	New type of septic tank B

Table 3 Classification of land use

Index	Land use
1	Upland field
2	Rice filed
3	Mountain forest
4	City area
5	Other land use

Table 4 Classification of industry

Index	Industry
1	Upland cropping
2	Rice cropping
3	Dairy farming
4	Pig farming
5	Fisheries
6	Manufacturing industry
7	Other industries

Table 5 Classification of new technology

Category no.	Category name
1	New type of septic tank
2	New type of technology installed in the existing septic tank
3	Direct removal equipment

on the official data published by The Science and Technology Promotion Foundation of Ibaraki (2001) (Table 6). The 15 major rivers in the basin are structured into the model assuming the other small rivers in the sub-basins flow into one of the major rivers. Indices of municipalities in Table 6 are made so that those having smaller number are located upper the major rivers than those having large.

2.4 Policy Measures to Reduce Water Pollutants Emission

The policy measures, assumed in the simulation and listed in Table 7, should be adopted by the Ibaraki prefectural government to make a hybrid policy for the most efficient improvement in the water quality of the Lake Kasumigaura. Most of these measures are currently adopted and several new technologies are added to the list. It is also assumed that the annual budget that the government spends directly and indirectly for improvement is limited to 20 billion Japanese yen based on Hirose and Higano (2000).

3 Formulation of Simulation Model

This simulation model consists of more than 90 equations. Because of restrictions on the number of pages, only the most important model equations are presented in this paper.

Table 6 Classification of taget area

Water areas		Rivers		Cities, towns and villages		Notes
No.	Name	No.	Name	No.	Name	(Proportion of the area include in the catchment) (%)
1	Coast of Tsuchiura	1	Sakura River	1	Iwase Town	100
				2	Yamato Village	100
				3	Makabe Town	100
				4	Akeno Town	45
				5	Kyowa Town	84
				6	Shimodate City	2
				7	Shimotsuma City	1
				8	Tsukuba City	45
				9	Niihari Village	100
				10	Tsuchiura City	100
		2	Seimei River	11	Miho Village	100
2	Coast of Takasaki	3	Koise River	12	Chiyoda Town	100
		4	Sonobe River	13	Yasato Town	100
				14	Ishioka City	100
				15	Tamari Village	100
3	Center of the Lake	5	Kashinashi River	16	Tamatsukuri Town	100
		6	Ono River	17	Kukizaki Town	2
				18	Ushiku City	84
				19	Ryugasaki City	87
				20	Ami Town	100
				21	Edosaki Town	100
				22	Sakuragawa Village	100
		7	Ichinose River	23	Kasumigaura Town	100
4	Asou	8	Shin-Tone River	24	Tone Town	100
				25	Kawachi Town	75
				26	Shin-Tone Town	100
				27	Azuma Town	100
5	Kitaura (1)	9	Hokota River	28	Asahi Village	21
		10	Tomoe River	29	Iwama Town	20
				30	Minori Town	100
				31	Ibaraki Town	7.6
				32	Ogawa Town	100
				33	Hokota Town	93
		11	Yamada River	34	Kitaura Town	100
		12	(Direct Discharge)	35	Taiyo Village	55
6	Kitaura (2)	13	Gantsu River	36	Asou Town	100
		14	(Direct Discharge)	37	Kashima City	52
7	Sotona Sakaura	15	Yogoshi River	38	Ushibori Town	100.0
		16	Maekawa River	39	Itako Town	100.0
		17	Hitachi Tone River	40	Hasaki Town	100.0

Table 7 Measures for treatment of water pollutants

Source of water pollutants	Name of policy	Treatment measurements
Household	High-grade treatment and direct reduction	I. Subsidization for the Municipalities to install a sewage system and rural community sewage system
		II. Subsidization for the Municipalities to promote installation of a combined treatment septic tank
		III. Subsidization for the Municipalities to promote installation of a facility of new technology that substitutes a septic tank
		IV. Subsidization for the Municipalities to promote installation of a supplementary facility of new technology for the existing septic tank
		V. Installation of a new plant that further reduces water pollutants from the treated water discharged from the existing sewage treatment plant
Non-point	Agriculture that preserves the environment and fallow field	VI. Subsidization for purchase of a machine to plant rice seedlings with a function of precise fertilization (Subsidizing rate is 5.6 % to the purchase price[a])
		VII. Subsidy for rice farmer who uses less-elution type of fertilizer (subsidization rate is 15 % of the price[b])
		VIII. Subsidy to promote leaving field fallow (conversion of paddy field and rice field into fallow field)
Production	End of pipe policy and reduction of the capital employed	IX. Installation of a new technology for direct reduction of water pollutants at the end of pipe at the factory
		X. Subsidy for industries to reduce working capital so as to adjust production
Sediments at the bottom and dissolution	Direct reduction	XI. Installation of facility that directly reduces water pollutants discharged to Lake and rivers

[a] Actual subsidizing rate of Ibaraki Prefecture
[b] 15 % assumed based on difference in the prices

3.1 Objective Function

The market mechanism and driving force of the economy is simulated by the non-linear maximization of the Gross Regional Products (GRP) in the basin being subject to the structural constraints of socio-economic activities, the emission and the transportation of water pollutants, the water demand and supply and its recycling in the basin, the upper and lower constraints of the water level in the lake, etc.:

$$\max \sum_{t=1} \frac{1}{(1+\rho)^{(t-1)}} GRP(t) \tag{1}$$

in which,

$t = 1{:}1999, \ldots..,$

$t = 5$:2003,
ρ: social discount rate(=0.05)

3.2 The Material Flow Balance Model

The *net* water pollutants in the lake are defined as the sum of those that flow through the rivers, are directly discharged by the sewage plants, fisheries and rainfall on the surface of the lake *minus* direct removal from the lake by the new technology plants. In this model, we assume no removal for water utilization from the lake.

3.2.1 Water Pollutant Load of Lake Kasumigaura

$$Q^{hp}(t) = \sum_i RQ_i^{hp}(t) + QF^{hp}(t) + \sum_d QD_d^{hp}(t) + QR^{hp}(t) - QAL_a^{hp}(t) \quad (2)$$

$Q^{hp}(t)$: the total net load of pollutant p in block h of the lake at time t (*en.*);
RQ_i^{hp}: load of pollutant p in block h of the river i at time t (*en.*);
$QF^{hp}(t)$: load of pollutant p by fisheries in block h at time t (*en.*);
$QD_d^{hp}(t)$: load of pollutant p in block h by sewage plant d at time t (*en.*);
$QR^{hp}(t)$: load of pollutant p by rainfall in block h at time t (*ex.*);
$QAL_a^{hp}(t)$: direct removal of pollutant p by the plant of new technology A installed in block h at time t (*en.*).
*(*en.*) indicates endogenous variable and (*ex.*) indicates exogenous variable in the above and following equations

3.2.2 Pollutant Load in Each Municipality in the Sub-basin of Each River

Water pollutants are assumed to be generated by socio-economic activities and flow into the lake through the rivers:

$$RQM_{ij+1}^{hp}(t) = RQM_{ij}^{hp}(t) + \gamma_{ij}^{hp}(t) + QR_{ij}^{hp}(t) + QD_d^{ijp}(t) - QAR_{ija}^{hp}(t) \quad \left(1 \le j \le E^i - 1\right) \quad (3)$$

E^i: index of municipality in which the mouth of river i is located;
$RQM_{ij}^{hp}(t)$: pollutant p transported to municipality j from the upstream of river i that flows into block h of the lake at time t (*en.*);
$\gamma_{ij}^{hp}(t)$: pollutant p emitted by socio-economic activities in municipality j in the sub-basin of river i that flows in block h (*en.*);

$QR_{ij}^{hp}(t)$: pollutant p of the rainfall in municipality j in the sub-basin of river i that flows into block h (*ex.*);

$QD_{d}^{ijp}(t)$: pollutant p discharged by the sewage plant d in municipality j of the sub-basin of river i (*en.*);

$QAR_{ija}^{hp}(t)$: pollutant p removed by the plant of new technology A installed in municipality j the river i that flows into block h (*en.*).

3.2.3 Pollutants Emitted by Socio-economic Activities

The total pollutants emitted by socio-economic activities in the sub-basin are composed of pollutants from households, non-point sources and point sources. Pollutants caused by fisheries (mainly cultivation of carp and eel) are specified in other equations because they are directly loaded into the lake. Also, pollutants discharged through sewage are specified in other equations.

$$r_{ij}^{hp}(t) = QZ_{ij}^{hp}(t) + QL_{ij}^{hp}(t) + QX_{ij}^{hp}(t) \qquad \left(1 \le j \le E^{i}\right) \tag{4}$$

$QZ_{ij}^{hp}(t)$: pollutant p (excluding those through sewage) loaded by households in municipality j of river i that flows into block h at time t (*en.*);

$QL_{ij}^{hp}(t)$: pollutant p emitted by non-point sources in municipality j of river i that flows into block h (*en.*);

$QX_{ij}^{hp}(t)$: pollutant p emitted by socio-economic activities (excluding those by fisheries) in municipality j of river i that flows into block h (*en.*).

3.2.4 Pollutants from Household Wastewater in Each Municipality

$$QZ_{ij}^{hp}(t) = \sum_{k \neq 1} E^{pk} \cdot Z_{ij}^{k}(t) - \sum_{b} SA_{b}^{p} \cdot ZZ_{ijb}(t) - QAZ_{ija}^{p6} \tag{5}$$

E^{pk}: emission coefficient of pollutant p from household wastewater treatment facility k ($k \neq 1$) (*ex.*);

$Z_{ij}^{k}(t)$: population that used household wastewater treatment facility k in municipality j and discharged pollutants into river i (*en.*);

SA_{b}^{p}: removal coefficient of pollutant p by new technology b installed in household wastewater treatment facility; (*ex.*)

$ZZ_{ijb}(t)$: population in municipality j that used household wastewater treatment facility in which new technology b was installed and discharged pollutants into river i (*en.*);

QAZ_{ija}^{p6}: direct removal of pollutant p by new technology G from untreated household wastewater that was emitted in municipality j and discharged into river i (*en.*);

3.2.5 Pollutants Discharged from Sewage Plant

Wastewater that uses sewage services is treated at a sewage plant. It can be treated by a plant that is with high grade facility of new technology additionally installed as well as by a usual plant, namely a plant that mainly focuses on removal of organic materials such as in terms of COD/BOD. The treated wastewater is discharged into rivers in the basin, directly into the lake or discharged outside the basin (into the Tone River, etc.).

$$QD_d^{hp}(t) = D_d^{hp} \sum_j Z_{dj}^{h1} - \sum_a QAD_{ad}^{hp}(t) \tag{6}$$

D_d^{hp}: coefficient of pollutant p in the treated water of sewage plant d directly discharged into block h (*ex.*);
Z_{dj}^{h1}: population in municipality j that used sewage service (superscript index = *1*) of plant d which discharged the treated water into block h (*en.*);
$QAD_{ad}^{hp}(t)$: removal of pollutant p by additional facilities of new technology A installed in sewage plant d that directly discharged treated wastewater into block h (*en.*);

3.2.6 Direct Removal of Pollutants by New Technology

The direct removal of pollutants is dependent on the number of facilities of new technology (capital stock) and the direct removal coefficient of the facilities.

$$QAD_{ad}^{hp}(t) = A_a^p \cdot KA_{ad}^h \tag{7}$$

A_a^p: removal coefficient of pollutant p by the facility of new technology a (*ex.*);
$KA_a^h(t)$: the number of facilities of new technology a installed in or around block h of the lake (endogenous variable);

3.3 The Socio-economic Model

3.3.1 Treatment Measures for Household Wastewater Generation Sources

The measures for treatment of household wastewater include provision of sewage services, rural community sewage services, installation of combined treatment septic tank, and promotion of the installation of new technologies that can be substituted for existing septic tank. These measures are mainly implemented by local governments.

Budget of Municipality

It is assumed that the budget of a municipality is dependent on the size of the population:

$$R_{ij}(t) = \rho_{ij} z_{ij}(t) \tag{8}$$

$R_{ij}(t)$: the budget of municipality j for the sub-basin of river i (*en.*);
ρ_{ij}: the budget per person of municipality j for the sub-basin of river i (*ex.*).

Equipment for Sewage and Rural Community Sewage Services

An increase in the population that uses a sewage system or a rural community sewage system are dependent on the construction investment:

$$\sum_{i \in I(j)} \Delta z_{ij}^k(t) \leq \Gamma_j^k \cdot i_j^k(t) \tag{9}$$

Γ_j^k: reciprocal of the necessary construction investment per person that uses the sewage and rural community sewage services (*ex.*).
$i_j^k(t)$: construction investment of municipality j for sewage system ($k = 1$) and rural community sewage system ($k = 2$) (*en.*);

Sewage System and Rural Community Sewage System

The investment for construction of a sewage system and rural sewage system is determined by the construction allotment of the municipality and subsidies that are provided by the prefectural and central governments for the allotment:

$$i_j^k(t) = \left(\frac{1}{1 - M_j^k} \right) cc_j^k(t) \tag{10}$$

M_j^k: rate of the subsidization by the prefectural and central governments (*ex.*);
$cc_j^k(t)$: construction allotment of municipality j ($k = 1$: sewage system; $k = 2$: rural community sewage system) (*en.*).

Construction Allotment of Municipality for Sewage System

The construction allotment of municipality is covered by transfer from the general account and local bond:

$$cc_j^k(t) = db_j^k(t) + b_j^k(t) \tag{11}$$

$db_j^k(t)$: amount of the local bonds issued by the municipality j ($k = 1$: sewage system; $k = 2$: rural community sewage system) (*en.*);
$b_j^k(t)$: amount transferred from the general account of municipality j (*en.*).

Maintenance Costs of the Sewage System

The study assumes that maintenance costs of the sewage system and rural community sewage system are covered by the users and the municipality:

$$mc_j^k(t) = \nu_j^k z_{ij}^k(t) = N_j^k z_{ij}^k(t) + g_j^k(t) \tag{12}$$

$mc_j^k(t)$: total maintenance cost of facility k ($k = 1$: sewage system; $k = 2$: rural community sewage system) in municipality k (*en.*);
ν_j^k: maintenance cost per user of k in j (*ex.*);
N_j^k: user charge per person of k in j (*ex.*);
$g_j^k(t)$: transfer from the general account of j to cover maintenance costs of k (*ex.*).

Subsidization for Installation of Combined Treatment Septic Tank

The installation of a combined treatment septic tank ($k = 3$) is subsidized by the municipality, the central government and the prefectural government:

$$\delta \Delta z_{ij}^3(t) = \left(\frac{1}{1 - M^3}\right) b_j^3(t) \tag{13}$$

δ: installation cost of combined treatment septic tank per person (*ex.*);
M^3: rate of subsidization by the central and prefectural governments (*ex.*);
$b_j^3(t)$: amount of transfer from the general account of municipality j for the installation of a combined treatment septic tank (*en.*).

Subsidization for Facility of New Technology Substitutable for Septic Tank

The installation of a facility of new technology that can be substituted for a septic tank is subsidized by the municipality and the prefectural government:

$$\mu^k \Delta z_j^k(t) = \left(\frac{1}{1 - M^k}\right) b_j^k(t) \tag{14}$$

μ^k: installation costs of facility k ($k = 7$: new technology A: $k = 8$: B) per person (*ex.*);
M^k: rate of subsidization by the prefectural government (*ex.*)
$b_j^k(t)$: amount transferred from the general account of municipality j for the installation of k (*en.*).

Budget Constraints

Subsidization by the municipality for construction of a sewage system ($k = 1$) and rural community sewage system ($k = 2$), and installation of a combined treatment septic tank ($k = 3$) and the facility of new technology A ($k = 7$) and B ($k = 8$), is covered by a special account in which a specific portion of the general account of the municipality and the household wastewater treatment subsidy granted by the prefectural government to the municipality for intensive promotion of construction and installation of measures for treatment of household wastewater:

$$b_j^1(t) + b_j^2(t) + b_j^3(t) + b_j^7(t) + b_j^8(t) + g_j^1(t) + g_j^2(t) \leq \omega_j R_j(t) + s_j^1(t) \tag{15}$$

ω_j: transfer of the special account of measures for treatment of household wastewater to the general account of municipality j (*ex.*);
$s_j^1(t)$: subsidy for household wastewater measures (superscript index = 1) in municipality j which is granted by the prefectural government to the special account of the municipality (*en.*);

3.3.2 Treatment Measures for Industrial Activity Generation Sources

Production Function and Curtailment

Production is dependent on the capital accumulated. The prefectural government restricts production paddy of fields ($m = 1$) and rice fields ($m = 2$) by the fallowing policy. The production of other industries ($m = 3, \ldots, 8$) is restricted by leaving capital idle and subsidizing for loss due to the idle capital. The production paddy of fields and rice fields is also dependent on the area of cultivated land.

$$x_j^m(t) \leq \alpha^m \cdot k_j^m(t) \qquad \text{for } m = 1 \text{ and } m = 2 \tag{16}$$

$$x_j^m(t) \leq \alpha^m \left\{k_j^m(t) - s_j^m(t)\right\} \qquad \text{for } m = 3, \ldots, 8 \tag{17}$$

α^m: ratio of capital to output in industry m (*ex.*).

Capital Accumulation

$$k_j^{mP}(t+1) = k_j^{mP}(t) + i_j^{mP}(t) - d^m k_j^{mP}(t) \tag{18}$$

$k_j^{mP}(t)$: capital of industry m available in municipality j at time t (*en.*);

$i_j^{mP}(t)$: investment for industry m in municipality j at time t (*en.*);
d^m: depreciation rate of industry m (*ex.*).

3.3.3 Budget for Installation of New Technology for Direct Removal

Budget for Installation and Maintenance

The prefecture installs plants or facilities in the lake or in the sewage plant that directly remove water pollutants and maintains it:

$$s_h^a(t) \geq i_h^a(t) + mc_h^a(t) \tag{19}$$

$s_h^a(t)$: budget assigned to the plant for direct removal by new technology installed in block h (*en.*);
$i_h^a(t)$: investment to the plant for direct removal by new technology installed in block h (*en.*);
$mc_h^a(t)$: maintenance costs of the plant for direct removal by new technology installed in block h (*ex.*);

Maintenance Costs of New Technology for Direct Removal

The maintenance costs are dependent on the number of the facilities/plants installed:

$$mc_h^a(t) = M^a \cdot KA_h^a(t) \tag{20}$$

M^a: maintenance cost per one million JPY of the facility/plant with new technology (*ex.*).

Accumulation of Facilities/Plants with New Technology

$$KA_h^a(t+1) = KA_h^a(t) + i_h^a(t) - d^a KA_h^a(t) \tag{21}$$

d^a: depreciation rate of facility/plant with new technology (*ex.*);

Budget for New Technology That Supplements Septic Tank

The Prefecture subsidizes municipalities to cover all the necessary costs of installation and maintenance of new technology that supplements septic tanks:

$$s_j^b(t) \geq i_j^b(t) + mc_j^b(t) \tag{22}$$

$$i_j^b(t) = \theta^b \cdot \Delta ZZ_j^b(t) \tag{23}$$

$$mc_j^b(t) = M^b \cdot ZZ_j(t) \tag{24}$$

$s_j^b(t)$: budget assigned to municipality j for installation and maintenance of the facility for new technology that supplements a septic tank (*en.*);
$i_j^b(t)$: installation cost of the facility for new technology that supplements a septic tank in municipality j (*en.*);
$mc_j^b(t)$: maintenance cost of the facility for new technology that supplements a septic tank in municipality j (*en.*)
θ^b: installation cost per person of the facility for new technology that supplements a septic tank (*ex.*);
M^b: maintenance costs per person for the facility with new technology that supplements a septic tank (*ex.*);

3.3.4 Total Budget of the Prefecture for the Countermeasures

It is assumed that the prefectural government spends 20 billion JPY for implementing the countermeasures every year. This figure is based on the actual budget that has been directly and indirectly spent to improve the quality of the lake in the past:

$$\begin{aligned} y(t) \geq & \sum_j s_j^1(t) + \sum_j \sum_m s_j^m(t) + \sum_j \sum_l S_j^l(t) + \sum_a \sum_h S_h^a(t) + \sum_a \sum_j S_j^a(t) \\ & + \sum_a \sum_d S_d^a(t) + \sum_b \sum_j S_j^b(t) + \sum_a \sum_j S_j^{6a}(t) + \sum_j SS_j(t) + \sum_j SU_j(t) \end{aligned} \tag{25}$$

$y(t)$: the total budget spent by the prefectural government for implementing the countermeasures (*ex.*).

3.3.5 Flow Balance in the Commodity Market

Total products of each industry are decided by balances between supply and demand.

$$\begin{aligned}\mathbf{x}(t) \geq \mathbf{A}\mathbf{x}(t) + \mathbf{C}(t) + \mathbf{i}^P(t) + \mathbf{B}^S\left(i^1(t) + i^2(t)\right) \\ + \mathbf{B}^C\left(\delta\Delta Z^3(t)\right) + \sum_k \mathbf{B}^k\left(\delta^k\Delta Z^k(t)\right) \\ + \sum_a \mathbf{B}^a \cdot i^a(t) + \sum_b B^b\left(\theta^b\Delta ZZ^b(t)\right) + \mathbf{e}(t)\end{aligned} \tag{26}$$

$\mathbf{x}(t) = \sum_j \mathbf{x}_j(t)$: column vector of the *mth* element is the total product of industry *m* in the basin (*en.*);

$\mathbf{i}^P(t) = \sum_j \mathbf{i}_j^P(t)$: column vector of the *mth* element is the total investment in industry *m* (*en.*);

$i^h(t) = \sum_i i_i^h(t)$: total investment for construction of sewage system ($k = 1$) and rural community sewage ($k = 2$) (*en.*);

$\delta\Delta z^3(t) = \delta\sum_i \Delta z_i^3(t)$: total investment for installation of a combined treatment septic tank (superscript index = *3*) (*en.*);

$\delta^k\Delta z^k(t) = \delta^k\sum_i \Delta z_i^k(t)$: total investment for the installation of new technology that is substitutable for a septic tank ($k = 7, 8$) (*en.*);

A: input-output coefficient matrix (*ex.*);

C(*t*): column vector of consumption (*en.*);

$\mathbf{B}^S$: column vector of the *i*th coefficient is induced production in industry *i* by construction of sewage and rural community sewage systems (*ex.*);

$\mathbf{B}^C$: column vector of the *i*th coefficient is induced production in industry *i* by construction of a combined treatment septic tank (*ex.*);

$\mathbf{B}^k$: column vector of the *i*th coefficient is induced production in industry *i* by construction of a facility that is substitutable for septic tank ($k = 7,8$) (*ex.*);

$\mathbf{B}^a$: column vector of the *i*th coefficient is induced production in industry *i* by construction of a facility/plant for direct removal of pollutants (*ex.*);

$i^a(t) = \sum_h i_h^a(t) + \sum_j i_j^a(t) + \sum_d i_d^a(t)$: total investment for construction of a facility/plant for direct removal of pollutants (*en.*);

e(*t*): column vector of net export (*en.*).

3.3.6 Gross Regional Product

We consider the gross regional product of the basin as an index that reflects the level of all socio-economic activities. It is also a potential function in which maximization of the function simulates the driving force of the economy and market mechanism.

$$GRP(t) = \mathbf{v}\mathbf{x}(t) \tag{27}$$

v: row vector of *i*th element is rate of added value in the *i*th industry (*ex.*).

3.3.7 The Water Cycle Model

The water cycle model of the basin was largely created on the basis of the studies by Aramaki and Matsuo (1998a, b).

Water in the lake and rivers are utilized for agriculture, manufacturing and tap water. An optimal amount of water taken from the rivers, lake and drainage are controlled so that running water from the rivers and the water level of the lake are stable within a specific range of the simulation. The River flow in the municipality is described with the following equation:

$$\begin{aligned} R_{j+1}^{hi}(t) = R_j^{hi}(t) &+ \left\{SF_j^i(t) - UDS_j^i(t) - UIS_j^i(t) - UAS_j^i(t)\right\} \\ &+ \left\{UD_j^s(t) - LUD_j \cdot UD_j^s(t) - \sum_d SPUD_{jd}^i(t)\right\} \\ &+ \left\{UI_j^s(t) - LUI_j \cdot UI_j^s(t) - \sum_d SPUI_{jd}^i(t)\right\} \\ &+ \left(1 - LUA_j\right) \cdot UA_j^s(t) \\ &+ \sum_d \left\{SPW_{jd}^i \cdot SP_d(t)\right\} \end{aligned} \tag{28}$$

$R_j^{hi}(t)$: river flow in municipality j along river i that flows into block h at time t(*en.*)
$SF_j^i(t)$: spontaneous generation flow rate in municipality j along river i(*en.*)
$UDS_j^i(t)$: amount of city water taken by residents in municipality j from river i (*en.*)
$UIS_j^i(t)$: amount of industrial water taken from river i for usage in municipality (*en.*)
$UAS_j^i(t)$: amount of agricultural water taken from river i of municipality j(*en.*)
$UD_j^s(t)$: total supply of city water for municipality i (*en.*)
LUD_j: loss of water used for household activity in municipality i(*ex.*)
$SPUD_{jd}^i(t)$: household wastewater flow from municipality j to sewage plant d(*en.*)
$UI_j^s(t)$: total supply of industrial water for municipality j(*en.*)
LUI_j: loss of water used for industrial activity in municipality i(*ex.*)
$SPUI_{jd}^i(t)$: industrial waste water flow from municipality j to sewage plant d(*en.*)
LUA_j: loss of water used for agricultural activity in municipality i (*ex.*)
$UA_j^s(t)$: total supply of agricultural water in municipality j (*en.*)
SPW_{jd}^i: coefficient that shows the release of treated water from the sewage plant into river i from municipality j (released = 1, not released = 0) (*ex.*)
$SP_d(t)$: total amount of wastewater treated in sewage plant d(*en.*)

3.4 Constraints on Each Pollutant

We set constraints on the amount of T-N, T-P and COD flow into Lake Kasumigaura for each year.

$$Q^{p*}(t) \geq \sum_h Q^{hp}(t) \tag{29}$$

$Q^{p*}(t)$: restrictions on flow of each water pollutant into Lake Kasumigaura (*ex.*)

3.5 Water Quality

In this model, the water quality of each flowing river was determined by the following equation.

$$WQ_{ij}^{hp}(t) = \frac{RQM_{ij}^{hp}(t)}{R_j^{hi}(t)} \tag{30}$$

$WQ_{ij}^{hp}(t)$: water quality of river i flowing along municipality j (*en.*)

4 Result of the Simulation

4.1 The Change in the Objective Value and Social Benefit Attributable to New Technology

The changes in the objective values (total GRP) of two different cases: "Adopted new technologies" and "Not adopted new technologies" are shown in Fig. 3. In this simulation, a feasible solution was achieved from Case 0 to Case 39, when we adopted introduction of the new technologies policy. On the other hand, when we did not adopt the policy, a feasible solution was reached from Case 0 to Case 33.

In Fig. 3, the lower line shows the trade-off between environment and economy, and the trade-off is shifted upward into the upper line by adopting new technology. For example, the environment level is kept with 33 % reduction of water pollutants, GRP could be increased by around 1.4 trillion yen by adopting new technology. Therefore, we can see the social benefit of new technology is 1.4 trillion yen when the reduction rate is 33 %.

4.2 Budget Allotment by Local Government and Social Benefit Rate

Sectoral change in the budget allotment for each policy in Case 30, Case 35, and Case 37 are shown in Figs. 4, 5, and 6. In this simulation, it was derived that the prefectural government should spend 20 billion yen every year, totally

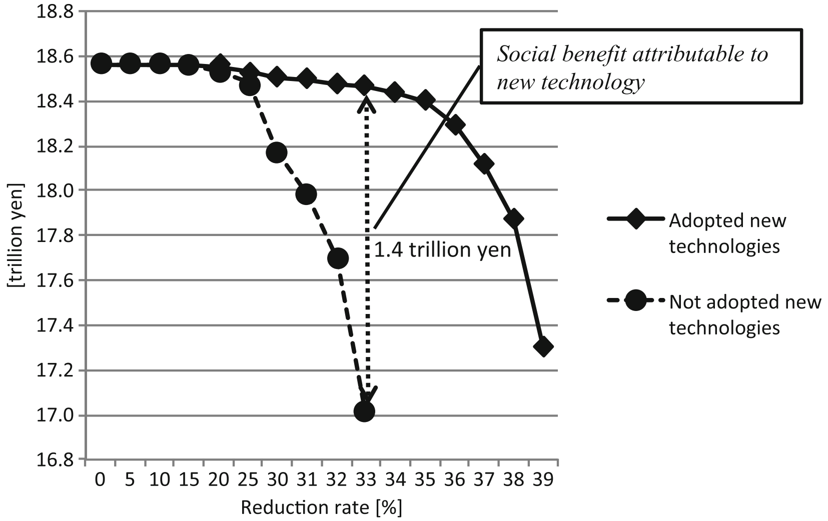

Fig. 3 The change in the objective value

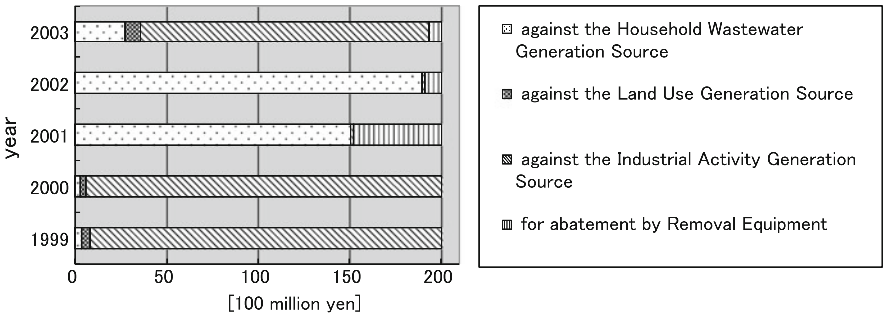

Fig. 4 Sectoral change in budget allotment of Case 30

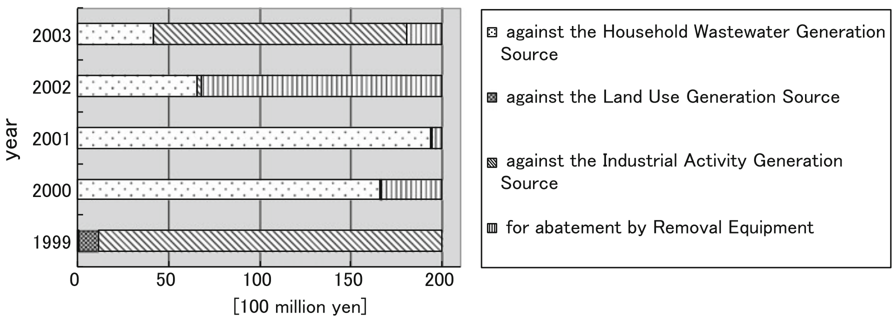

Fig. 5 Sectoral change in budget allotment of Case 35

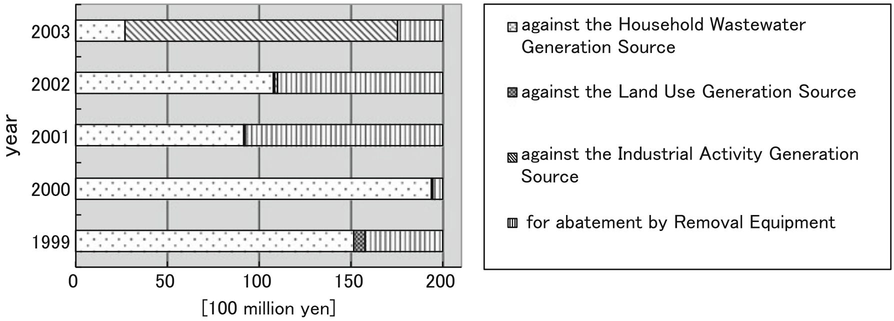

Fig. 6 Sectoral change in budget allotment of Case 37

100 billion yen in whole simulation period, for implementing the countermeasures in all cases. This 20 billion yen meets the budget restriction. It is interesting that the higher the reduction rate becomes, the larger the peak of the budget expenditure to the measure for the household wastewater generation source that was seen to be realized 1 year earlier for each simulation and the amount disbursed became larger and larger. This result indicates that the countermeasure against the household wastewater generation source is the key factor to improve the water environment of this lake. These three graphs show that most efficient reduction program for each target reduction rate differ from rate to rate. For the inhabitant's agreement of the policy enforcement, disclosure of the information such as an effect of the policy, the necessary budget and optimal timing of the budget spending is essential. Those informations are provided only by ex-ante evaluation using this kind of simulation.

Figure 7 shows the accumulated amount of budget allocation by the local government in Case 37. The total budget for implementation of environmental policies is 100 billion Yen, among which, 43 billion yen is spent for adoption of new technology. So the social benefit rate is calculated as around 33 (See Eq. 31). This value is extremely high. This means efficiency of the new technologies adopted is very high.

$$\frac{\text{Social benefit caused by adopting new technology}}{\text{New technology-related expenditure}} = \frac{1.4 \text{ trillion yen}}{0.043 \text{ trillion yen}} = 32.6 \tag{31}$$

4.3 The Water Quality of Rivers Flowing into Lake Kasumigaura

Figure 8 shows the average water quality in T-N at river mouths in the final period. As expected, the water quality decreases as the reduction rate increases. However, the water quality does not necessarily monotonically decrease. This is because the

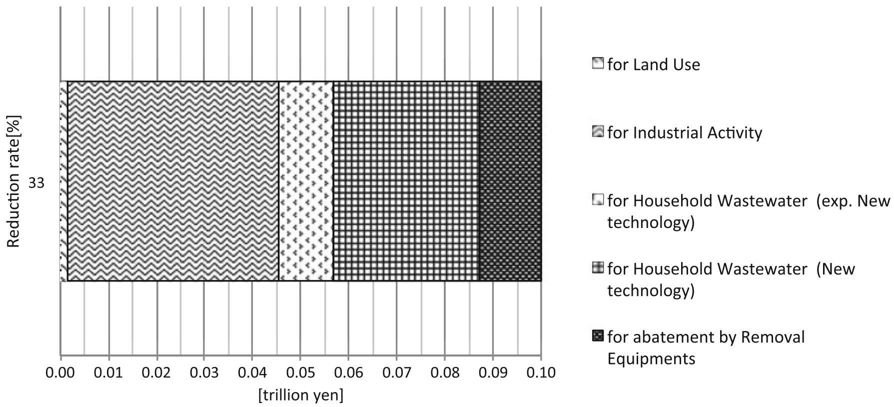

Fig. 7 Sectoral change in budget allotment of Case 37

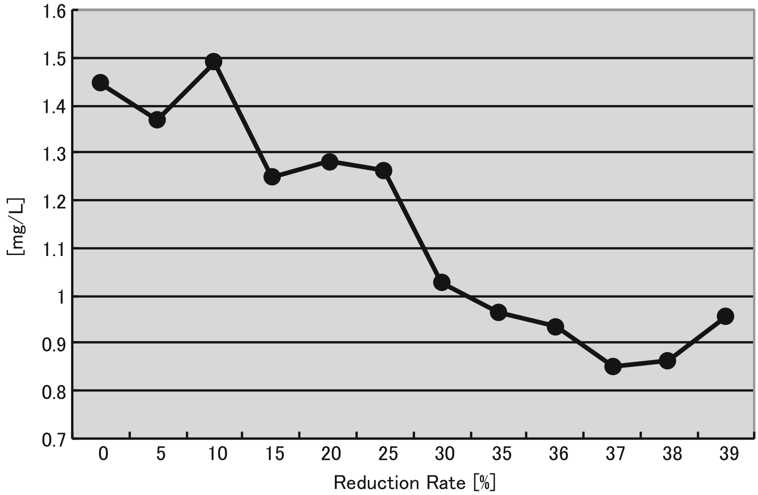

Fig. 8 Average T-N concentration at the river mouth in 2003

water cycle becomes blunt with stagnation of economic activity in the catchment area and the amount of water flowing decreases as compared to the amount of water pollutants flowing from each river as the reduction rate tightens more than 38 %. This is because that, as the result of pumping amount of groundwater and agricultural water use from outside of basin is greatly decreased with the big decline in economic activities, amount of drainage to rivers is greatly decreased. This result shows that the water quality of rivers is affected by the economic activity of catchments area, and large stagnation of economic activity worsens the water quality of rivers.

Municipalities in the Kasumigaura basin are drawing water from rivers in the basin and use it for their social economic activities. Deterioration of river quality

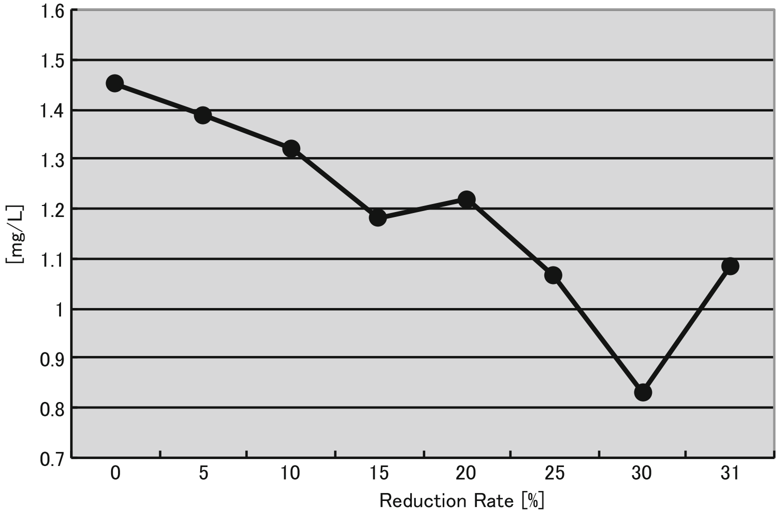

Fig. 9 Average T-N concentration at the river mouth in 2003 (in the case of introducing only new technologies while canceling introduction of sewage system and rural community sewage system)

leads to a rise in water purification cost. Therefore, considering socio-economic efficiency in the basin, the local government has to take into account not only water quality in Lake Kasumigaura but also water quality of rivers in the basin when introducing watershed management policy.

Figure 9 shows the average water quality in T-N at river mouths in the final period in the case of introducing only new technologies while canceling introduction of sewage system and rural community sewage system. In this case, the concentration of T-N is minimized at 30 % reduction rate and getting bigger at 31 %. The concentration in the conversion point is unchanged compare to the case that allows introduction of sewage system and rural community sewage system. However, 7 % of differences occur to the reduction rate of water pollutants. This result shows even if developed new technologies were available in the basin, sewage system and rural community sewage system still has usefulness for effective water pollutants reduction.

4.4 The Amount of Water Pollutants Flowing into Lake Kasumigaura: Suggestion from Policy and Technological Aspects

The differences in the amount of water pollutants flowing into Lake Kasumigaura derived in the simulation and the constraint amount are shown in Table 8. In this table, we can see the amount of inflow of T-N is equivalent to the restrictions. On the

Table 8 Comparing amounts of pollutants with constraints (with new technologies)

	COD		T-N		T-P	
Case name	Constraint (t)	Amount of pollutant derived in simulation (2003) (t)	Constraint (t)	Amount of pollutant derived in simulation (2003) (t)	Constraint (t)	Amount of pollutant derived in simulation (2003) (t)
Case-0	10,532	10,214	4427	4427	278	226
Case-5	10,005	9676	4205	4205	264	202
Case-10	9478	8369	3984	3984	251	164
Case-15	8952	7247	3763	3763	237	151
Case-20	8425	7083	3541	3541	223	148
Case-25	7899	6792	3320	3320	209	117
Case-30	7372	6291	3099	3099	195	98
Case-35	6846	5800	2877	2877	181	86
Case-36	6740	5689	2833	2833	178	84
Case-37	6635	5686	2789	2789	175	84
Case-38	6530	5609	2744	2744	173	84
Case-39	6424	5411	2700	2700	170	83

other hand, the amount of T-P and COD are much less than the constraint amount. This result shows that the present technology has an inadequate abatement capability for T-N as compared with other pollutants. Also it shows that we should consider the reduction of T-N as the most important subject when we formulate an environmental policy or develop new technology to improve the water quality. Food self-sufficiency ratio in Japan is approximately 40 %, and approximately 1.2 million tons of nitrogen per year included in imported feed and food has accumulated in recent years in this country (Oda 2006). The nitrogen adds load in environment in a circulation process in the country. The environmental policy should be drafted associated with food self-sufficiency problem.

5 Conclusion

When we adopted a policy that introduces new technology to improve the water quality, the policy was selected as a very effective tool to reduce environmental pollutants in all simulations. The introduction of the new technology raised the rate of pollutant reduction by 6 % as compared to non-adoption. Moreover, when introduction of the new technology reduced the rate by 33 %, the objective value had a difference of about 1.4 trillion yen as compared to when not introduced. Therefore, we can consider the social benefit of new technology is 1.4 trillion yen when the reduction rate is 33 %. In addition to that, we could find the social benefit rate derived from introducing new technology was calculated as around 33. This value is extremely high. This means efficiency of the new technologies adopted is very high.

In this study, it was found that the efficiency of new technologies is still not sufficient to treat wastewater with high concentrations of pollutants, and that the most important factor for the development of new technology in the future is how to enable treatment of wastewater with higher concentrations, especially of total nitrogen.

Appendix

Table A.1 Numerical data of a new type of septic tank

Name	Principle	Construction cost (million yen/person)	BOD emission coefficient (interms of COD) (kg/person year)	COD emission coefficient (kg/person year)	T-N emission coefficient (kg/person year)	T-P emission coefficient (kg/person year)
New type of septic tank A	Biological processing	0.40	0.67	1.06	0.65	0.42
New type of septic tank B	Biological processing	0.29	0.82	0.82	0.88	0.09

Table A.2 Numerical data of a new type of technology installed in existing septic tanks

Name	Principle	Construction cost (million yen/person)	Maintenance cost (million yen/person year)	Energy charge (million yen/person year)	COD abatement coefficient (kg/person year)	T-N abatement coefficient (kg/person year)	T-P abatement coefficient (kg/person year)
New technology installed in existing septic tank A	Phosphorous removal	0.08	0.038	0.007	0	0	0.038
New technology installed in existing septic tank B	Phosphorous removal denitrification	0.035	0	0	0	0.219	0.029

Table A.3 Numerical data of direct removal equipment (setting on the lakeside)

Name	Principle	Scale (10,000 L/year)	Construction cost (million yen/unit)	Maintenance (million yen/construction cost million yen year)	Energy charge (million yen/construction cost million yen year)	BOD abatement coefficient (in terms of COD) (kg/construction cost million yen year)	COD abatement coefficient (kg/construction cost million yen. year)	T-N abatement coefficient (kg/construction cost million yen. year)	T-P abatement coefficient (kg/construction cost million yen. year)
Direct removal	Biological processing	10,950	3	–	–	–	28.1	8.2	0.4
Direct removal system D	Biological + Chemical procession	18,250	20	0.027	0.025	0	9.125	9.125	0
Direct removal system E	Biological processing	167.96 (BOD abatement kg/year)	1	0.018	0	167.97	0	0	0
Direct removal system F	Electrochemical processing	1022	16.7	0.77	0.022	–	26.9	1.39	0.2
Direct removal system G	Electrochemical processing	263	25	0.036	0.018	6.766	3.311	2.541	0.468

References

Aramaki S, Matsuo T (1998a) Relative probability evaluation of amount of water and water quality management measure by Water and a corruption substance income-and-outgo simulation. J Jpn Soc Civ Eng 601(VII-8):45–57 (in Japanese)

Aramaki S, Matsuo T (1998b) A study on the creation technique of the flux used for a simulation of watershed management. J Jpn Soc Civ Eng 601(VII-8):23–33 (in Japanese)

Baumol WJ, Oates WE (1988) The theory of environmental policy. Cambridge University Press, Cambridge

Hataya Y, Mizunoya T, Uchida S, Sugiura S, Higano Y (2010) An evaluation of biomass utilization technology and regional environmental policy in a river basin. J Hum Environ Symbiosis 17:48–58

Higano Y, Yoneta A (1998) Economical policies to relieve contamination of Lake Kaimigaura. Stud Reg Sci 29(3):205–218

Hirose F, Higano Y (2000) A simulation analysis to reduce pollutants from the catchment area of Lake Kasumigaura. Stud Reg Sci 30(1):47–63 (in Japanese)

Inamori Y, Sankai T, Sudou R (1998) Development and popularization of the Nitrogen and Phosphorus removal advanced technologies for treating black and gray water simultaneously. J Environ Pollut Control 34(10):923–934 (in Japanese)

Mizunoya T, Sakurai K, Kobayashi S, Higano Y (2007) Simulation analysis for an optimal environmental policy including the introduction of new technologies. Stud Reg Sci 37(1): 199–227

Oda K (2006) Trends in nitrogen flow since the 1980s in the food and feed system in Japan. J J Soil Sci Plant Nutr 77(5):517–524 (in Japanese)

Oka T (1997) Welfare economics and environmental policy. Iwanami Press, Tokyo (in Japanese)

Takagi A (1999) Economic evaluation of the water quality improvement policy in the closed water area. Stud Environ Syst 27:9–16 (in Japanese)

The Science and Technology Promotion Foundation of Ibaraki (2005) City Area Program Development of Integrated Processing/Recycling System for Food- and Livestock-Related Biomass. The Science and Technology Promotion Foundation of Ibaraki, Ibaraki, Japan (in Japanese)

Yoshida T, Aizaki M, Asami T, Makishima N (1979) Biological nitrogen fixation and denitrification in Lake Kasumiga-ura. Jpn J Limnol 40(1):1–9 (in Japanese)

Promotion Policies for Sustainable Energy Technologies: Case Studies in Japan

Susumu Uchida

Abstract Sustainable energy technologies continue to be in the nascent stage for the most part. These characteristics should be considered when drafting promotion policies for such technologies. Using a socioeconomic model, this chapter simulates the effects of specific promotion policies for two particular sustainable energy technologies in Japan. An estimated input coefficient is used in the socioeconomic model analyzing thermal recovery from biomass, as actual market data are not available. The flows of energy and waste are also considered in the model. Restrictions on total greenhouse gas (GHG) emissions and subsidies for the thermal recovery industry funded by the emission tax were revealed to be effective toward promoting the industry. If actual market data, including those on pricing and products, are available for a certain time period (as they are for the residential photovoltaic market), a more detailed analysis is possible. In such cases, the socioeconomic and environmental simulation model may be combined with the growth model, which focuses on the cycle of cost decline created by the learning effect and environmental evaluation by consumers. The results of these simulations reveal the effectiveness of specific promotion policies, namely, a combination of GHG emission tax and subsidy, for sustainable energy industries.

Keywords Renewable energy • Sustainable energy • Model simulation • Environmental evaluation • Learning effect • Emission tax

1 Introduction

Japan's outlook and situation pertaining to environmental issues have changed drastically after the Great East Japan earthquake. In particular, the nuclear accident at TEPCO's Fukushima Daiichi power plant led to a national discussion about the pros and cons of specific power sources. The Japanese people are thus

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facing the "trilemma" of the need for a safe power source, the compulsion to reduce carbon dioxide (CO_2) emissions, and the requirement of a reliable power supply. Unfortunately, no single power source, be it nuclear energy, fossil fuels, or renewable/sustainable energy, meets all these requirements.

Nonetheless, we must accord the highest priority to examining how we may promote and diffuse sustainable energy technologies, since energy resources are limited, and therefore, the development of a society reliant on sustainable energy is necessary for the long term.

The length of the time horizon to be considered for such a study depends on the circumstances of the external environment. Moreover, it is always prudent to consider events that are liable to occur with high certainty. Scholars have already predicted that we will likely suffer a new ice age in the far-off future. Some have even suggested that our planet may be hit by an object from outer space. Although these are serious threats against the continued existence of human beings, the information on which these predictions are based is so insufficient that it is not possible to consider reasonable measures against them; in concrete terms, the adequate time horizon to be considered in our case would be several hundred years, but it is quite unlikely that the planet would experience the impending ice age within that time period.

When we consider which energy system is likely to last for several hundred years, solar energy immediately comes to mind. Notably, while we term certain energies as "sustainable," in reality, energy does not have such characteristics. The major qualification for sustainability in the case of some materials is the fact that they can be recycled; however, it makes no sense to recycle energy since recycling itself consumes energy, and therefore, the whole exercise would be counterproductive. Thus, what we refer to as "sustainable energy" is just a consumption pattern in which we continuously reuse solar-derived energy.

The definition of sustainable energy is also relative. It depends on the relationship between the speed of generation and consumption of the energy source. For example, fossil fuels would be termed as "sustainable" if they could be generated from plants faster than we consume them. Thus, our current definition of sustainable energies rests on the availability of a stable energy source within the targeted time horizon, such that its speed of energy generation surpasses our speed of its consumption.

In this chapter, we use model simulations to discuss economical approaches for promoting sustainable energies. Since most sustainable energies are in their nascent stage, their cost structures and prices are uncertain. In such cases, we use estimated values in the simulation. However, if the actual market data in terms of pricing and products are available for a certain time period, we could employ a growth model as well. In the first case (i.e., where detailed data are unavailable), we employ an extended input–output (I/O) model to examine the effects of restrictions on greenhouse gas (GHG) emissions and a subsidy funded by environmental tax on thermal recovery from biomass waste. Details of the model and the results of the simulation are described in the next section. Next, we construct a new growth model of the cycle that consists of cost decline resulting from the learning effect and the demand increase for environmental value in sustainable energy in the third section.

2 Extended Input–Output Simulation for Promoting Thermal Recovery from Biomass Waste

Waste is one of the most serious problems affecting the development of a sustainable society. In addition to its ever-increasing requirement for landfill capacity, the improper treatment of waste causes serious environmental burdens such as air and water pollution as well as global warming. For example, methane (CH_4) and nitrous oxide (N_2O), which have much higher global warming potential than CO_2, are discharged during incomplete combustion. Methane can be converted into an energy source via proper treatment. Utilizing the potential energy of waste can not only resolve energy-specific problems but also mitigate or slow down climate change.

The actual amount of waste biomass utilized toward energy generation is very small because of the high technology cost. Therefore, positive, especially positive economic, measures such as environmental taxes and subsidies are desirable to promote the utilization of waste biomass as energy sources. However, it is difficult to estimate the effectiveness of these measures.

Model simulation is commonly used method for prior forecast and estimation of the effects of a planned policy, without incurring the huge costs associated with actually implementing policy changes through the trial and error process. Many models including MARKAL (Loulou et al. 2004) and GREEN (Burniaux et al. 1992) have been used for energy policy evaluation with satisfactory results. However, these global models are quite wide-ranging for an analysis specific to sustainable energy technologies. Thus, additional attention must be paid to the particularities of these new energy technologies while evaluating promotion policies for them.

The analysis of the promotion policy for sustainable energy technologies in this section is based on Uchida and Higano (2006) and Uchida et al. (2008). The simulation model in these studies examines the flows of waste and energy resulting from the utilization of biomass waste for energy generation. We examine the dynamic changes in the correlation between economic activity and GHG emissions and clarify the extent and effect of a suitable environmental tax rate to promote biomass waste utilization and maximize economic activity.

2.1 Simulation Model

The fundamental structure of the model is shown in Fig. 1. The flow balances of materials as goods, waste and GHGs, services, energy, and monetary values are considered in this model. Eighteen industries are included within the classification "normal goods and services." The energy and waste treatment industries are classified separately in Tables 1 and 2, respectively. In Table 1, the horizontal rows indicate the categories of energy and the items in the same row indicate the competition.

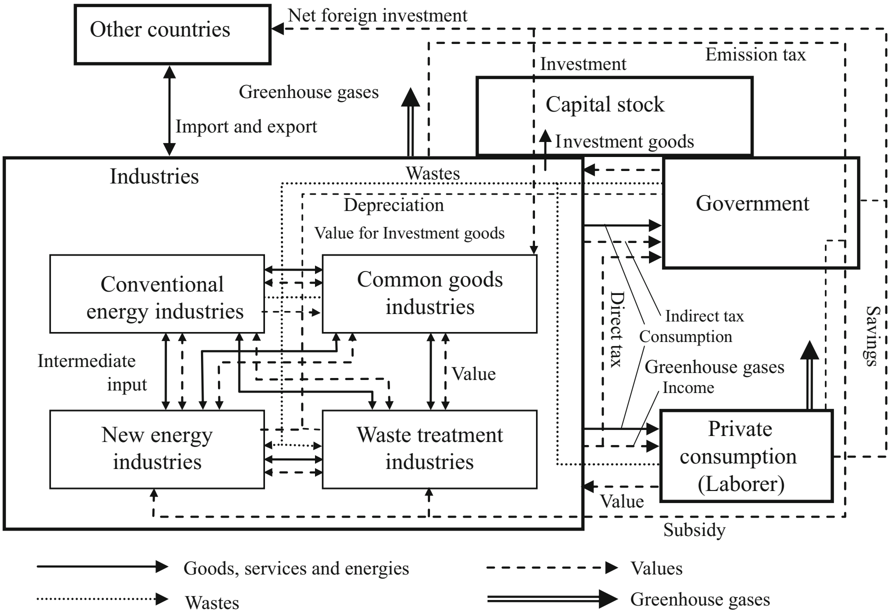


Fig. 1 Outline of the simulation model (*Source*: Uchida et al. (2008))

The objective function is the total real gross domestic product (GDP) throughout the simulated period. By maximizing the GDP under various restrictions of GHG emission, the trade-off between the economy and the environment can be clarified, and each solution can be analyzed in detail from both viewpoints.

In this simulation, CO_2, CH_4, and N_2O are considered as GHGs because of their high contribution to the greenhouse effect. The emission coefficients of GHGs are first converted to CO_2 equivalents using Nansai et al. (2002) and then converted again to carbon equivalents. The model is as described in Uchida et al. (2008).

2.2 Simulation Result

2.2.1 Promotion of Sustainable Energy Technologies Under GHG Emission Restrictions

First, optimized values of the gross domestic product (GDP) are compared for two scenarios, each considering different restrictions in GHG emissions. The scenarios consider the presence and absence of sustainable/new energy industries in Japan's economy. The emission restrictions are capped to three levels: Japan's actual emissions in 2000, Japan's Kyoto Protocol target, and 80 % of Japan's actual emissions in 2000. The simulation results are shown in Fig. 2. In the absence of

Table 1 Classification of energy and corresponding industries

No.	Energy classes	No.	Fossil fuels	No.	New energy
1	Raw material (solid fuels)	1	Coal	–	–
2	Raw material (liquid fuels)	2	Crude petroleum	–	–
3	Raw material (gaseous fuels)	3	Natural gas	1	Methane fermentation
4	Raw material for dimethyl ether production	–	–	2	Synthetic gas
5	Fuel for home heating equipment	4	Kerosene	3	Wood pellets
6	Fuel for gasoline-powered vehicles	5	Gasoline	4	Ethyl alcohol
7	Fuel for diesel-powered vehicles	6	Diesel oil	5	Dimethyl ether, biodiesel
				6	
8	Other liquid fuels	7	Other petroleum refinery products	–	–
9	Solid fuels	8	Coal products	–	–
10	Electricity	9	Nuclear power, thermal power, hydroelectric power, etc.	7	Waste power generation, compound waste power generation, fuel cell
		10		8	
		11		9	
11	Private power generation	12	Private power generation	–	–
12	Gaseous fuels	13	Gas supply	–	–
13	Heat supply	14	Steam and hot water supply	–	–

Source: Uchida et al. (2008)

Table 2 Classification of waste treatment industries

No.	Wastes	No.	Wastes	No.	Wastes
1	Food waste	6	Animal and vegetable residue	11	Waste oil
2	Waste paper and waste textiles	7	Dust, incinerator ash, and slag	12	Animal waste
3	Waste plastic	8	Wood waste	13	Carcass
4	Metals and glass	9	Organic sludge	14	Bulky waste
5	Waste rubber	10	Inorganic sludge		

Source: Uchida et al. (2008)

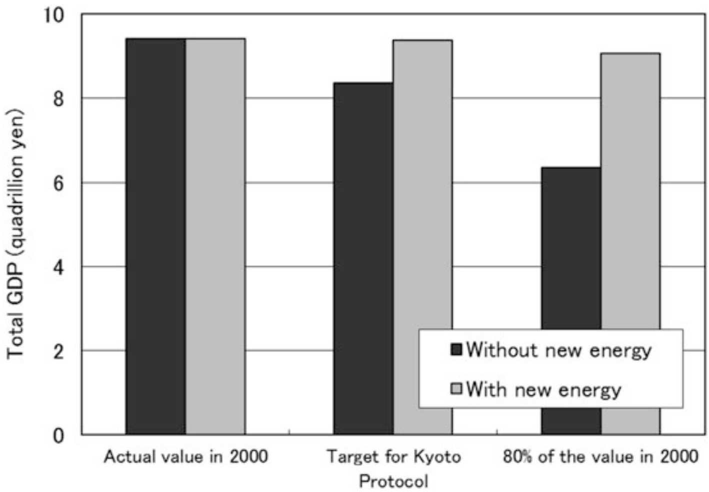


Fig. 2 Total GDP corresponding to various restrictions on GHG emissions (*Source*: Uchida et al. 2008)

new energy, GDP decreases as the emission restrictions become tighter. However, in the presence of new energy technologies, the GDP under the tightest restriction is almost similar to that under the lax restriction. These results suggest that new energies that do not emit GHGs can replace conventional energies and still maintain the previous GDP and prevent the decrease in GDP. Figure 3 shows the production achieved by new energy industries under the first restriction, namely, that the emissions remain the same as in 2000.

Among the new energy industries, production via methane fermentation, wood pelletization, and compound waste power generation appear to be optimal solutions according to the simulations. In other words, these industries alone achieve production for all the simulations in this study. Thus, these industries can be said to possess some economic or environmental advantage compared to the other new energy technologies. Furthermore, Fig. 4 shows the substitution of these three energy technologies for their conventional counterparts. Methane fermentation and compound waste power generation show apparent substitution abilities for natural gas and electricity, respectively. Although energy production from wood pellets is

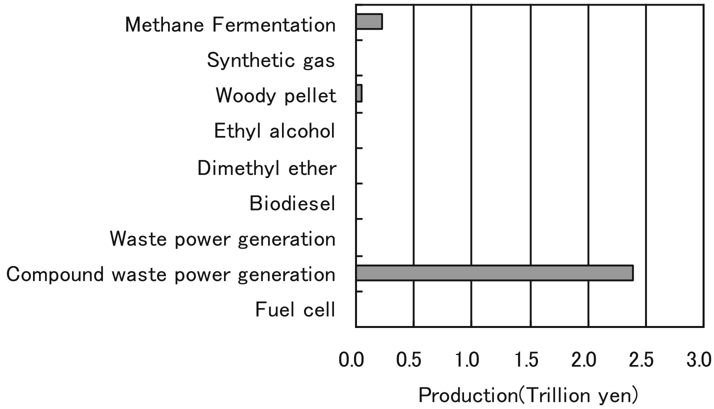


Fig. 3 Production by new energy industries when GHG emissions are restricted to the actual value in the year 2000 (*Source*: Uchida et al. 2008)

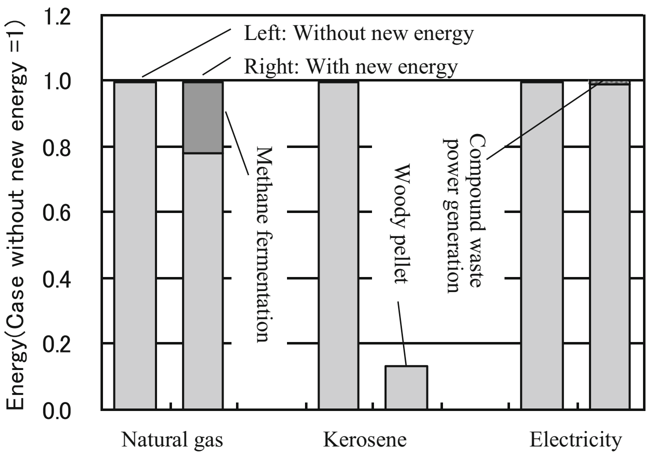


Fig. 4 Substitution with new energy technologies when GHG emissions are restricted to the actual value in the year 2000 (*Source*: Uchida et al. 2008)

so low (0.0002 in Fig. 4) that it can hardly be considered as a possible substitute to kerosene, the production of kerosene decreased remarkably. These results indicate that the industrial structure changes on account of GHG emission restriction in favor of industries that emit less GHGs.

The changes in the amount of discharged waste are shown in Fig. 5. Waste generation decreases by 13 % after introducing new energy industries in the simulation model. The categories of waste that decrease include animal waste, wood waste, animal and vegetable residues, and components of domestic garbage such as food waste, waste paper and waste textiles, waste plastics, and waste rubber. All these components are organic in nature, and their energy generation potential is

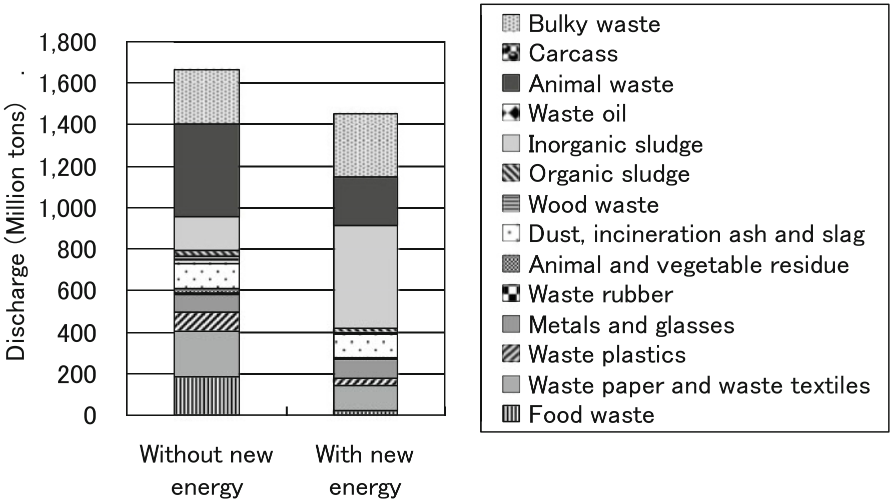


Fig. 5 Changes in total waste discharged depending on the exclusion/inclusion of new energy industries in the simulation model (*Source*: Uchida et al. 2008)

utilized in methane fermentation, wood pelletization, and compound waste power generation. The increase in inorganic waste is attributed to the conversion of other wastes after their utilization by the new energy industries.

2.2.2 Influence of Emission Tax and Subsidy

In practice, mandatory restrictions on GHG emissions are likely to face difficulties in the implementation phase. Thus, tax and subsidy are considered to be more feasible measures. We simulate two cases. In the first, the tax earned by the government is treated as general revenue in the absence of new energies, and in the second, the tax earned is applied as a subsidy to new energies and waste treatment technologies. These economic measures are expected to endogenously control the total GHG emissions without actually imposing compulsory restrictions.

Figure 6 illustrates the results of the abovementioned simulations. Total GHG emissions decrease with an increased tax rate and show apparent effects on new energy industries. When a tax of more than 20,000 yen per ton of carbon is diverted as a subsidy to new energy industries, GHG emissions decrease below the restrictions proposed in the Kyoto Protocol.

The reliance on new energy industries in each case is shown in Fig. 7. There is a positive correlation between the ratio of new energy generation per GDP and tax rate, indicating that the emission tax and subsidy promotes new energy industries.

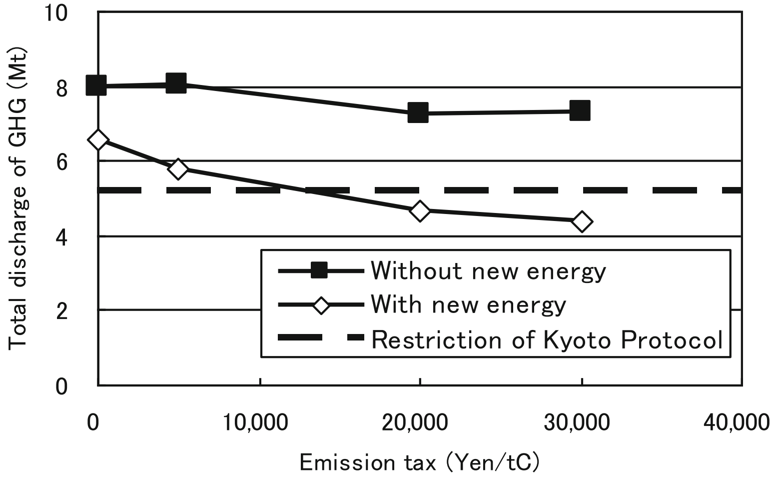
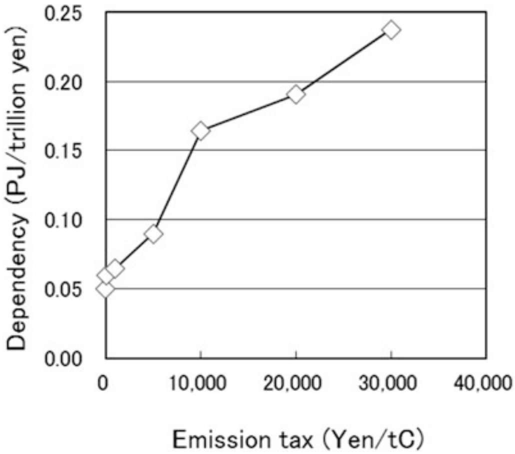


Fig. 6 Changes in GHG emissions with the levy of tax and its diversion to subsidies for new energy technologies (*Source*: Uchida et al. 2008)

Fig. 7 Dependency on new energy industries (*Source*: Uchida et al. 2008)



3 Promotion of the Residential Solar Power Industry, Considering the Cycle of Demand Increase for Environmental Value and Price Decline Through the Learning Effect

3.1 Learning Effect in Sustainable Energy

When considering the promotion of sustainable energy, we must account for the facts that most of these industries are still in their nascent stage and that they possess an environmental value. We can expect to improve the accuracy of the predictions by performing simulations with a model that considers these characteristics.

The most distinctive feature of industries in their early stages is the cost reduction associated with the learning effect. This has long been observed as a phenomenon at manufacturing sites, and while it was likely recognized among workers and supervisors, this subject was first studied systematically by Andress (1954), according to whom

$$Y = a_1 X^{a_2} \ (a_2 < 0) \tag{1}$$

Here, Y is labor input time per product, X is cumulative production volume, a_1 is working hours committed to the first product, and a_2 is an index representing rate of proficiency. In economics, this phenomenon is considered as an entry barrier problem within the oligopoly theory; however, the learning effect itself has been treated as being heuristic (as described above), and until now, its mechanisms have not been taken into consideration. First, we shall attempt to examine the mechanisms of cost reduction resulting from learning.

There are various levels of learning. Taking the manufacturing industry as an example, the simplest type of learning entails the improvement of skills in individual tasks, while higher levels include improvements in operational procedures and use of specialized tools. Still higher learning involves optimal staffing and implementation of machinery. A state of inexperience and unfamiliarity results in loss, and while there are several elements, such as erroneous operation and failure to address aberrance, all of these can be explained as incorrect outputs (decisions and operations) for the given inputs (external information).

Excluding cases where action is dictated by manuals/established operating procedures, it is assumed that as decisions on input involve uncertainties, they are assessed based on workers' subjective probabilities. In situations where there are several choices of output, the worker first selects one by random. If this proves incorrect, it results in excess cost. Next, when given the same input, the worker will select an alternative option. If excess cost is avoided as a result, the output is deemed to have been correct, and the worker will subsequently provide the proper output when given that particular input. Moreover, even in situations where excess costs are not immediately clear, the worker can make another selection from the remaining options and determine the one that results in the least cost through trial and error.

In the example above, the result for each output is uniform, but this is not always the case. For example, let us assume a situation where a worker is confronted with a nonstandard phenomenon during operations. While it may not directly impact operations, there is the possibility that it may lead to an abnormality. Because an unskilled worker has limited knowledge on which to base his or her decision, the worker is pressed to decide for several inputs that a skilled worker would simply be able to ignore. Workers do not merely specialize in appropriate outputs; they increase their proficiency through the process of narrowing input candidates to those generating the required output.

Let us consider a sign with probability p_1 of causing a breakdown. c_1 represents the cost of countermeasures needed in order to prevent the breakdown upon recognition of the sign, and c_2 represents the cost when a breakdown has occurred ($c_1 < c_2$). Workers are given information regarding cost. Countermeasures should be taken in situations where the cost for countermeasures c_1 is less than the expected cost if left neglected, p_1c_2. However, as p_1 is unknown to the workers, they decide whether to take countermeasures using subjective probability p_0, which is dependent on the worker's experience until that point. Assuming a distribution represented by the cumulative distribution function, $F(x)$, as workers take countermeasures when $c_1 < p_0c_2$, and do not act when$c_1 \geq p_0c_2$, the expected cost for the sign is expressed as

$$\left\{1 - F\left(\frac{c_1}{c_2}\right)\right\} c_1 + F\left(\frac{c_1}{c_2}\right) p_1c_2 = F\left(\frac{c_1}{c_2}\right)(p_1c_2 - c_1) + c_1 \tag{2}$$

When $p_1c_2 - c_1 > 0$, in other words, when $p_1 > \frac{c_1}{c_2}$, this value takes the minimum value of c_1, where $F = 0$, and when $p_1c_2 - c_1 < 0$ (in other words, when $p_1 < \frac{c_1}{c_2}$), this value takes the minimum value p_1c_2, where $F = 1$. Here, if we assume p_0 to be asymptotic to p_1 on account of workers' proficiency, F(x) has an average distribution of p_1 and approaches zero dispersion. In this situation, as $F\left(\frac{c_1}{c_2}\right)$ approaches 0 when $p_1 > \frac{c_1}{c_2}$, and $F\left(\frac{c_1}{c_2}\right)$ approaches 1 when $p_1 < \frac{c_1}{c_2}$, the worker's skill is shown to reduce costs in both cases. In this manner, workers select only the sign that requires countermeasures from among myriad information, and by responding ex post facto to abnormalities with low probabilities, they are able to reduce overall costs. This process applies similarly to higher-level actions, and the overall costs are reduced by cutting costs at each level. Although, in practice, it is difficult to determine these parameters in all individual cases, we may hypothesize that their accumulation may exhibit a form similar to Eq. (1).

3.2 Evaluation of the Environmental Value of Sustainable Energy

Similar to appearance and performance, environmental value included in general goods is typically treated as a single characteristic of the said good and is rarely presented independently. However, in the case of conventional energy, the function is assumed to be singular. Because the demand for sustainable energy exists in spite of its higher costs in comparison to conventional energy, we must explicitly treat environmental value as the explanation for the price difference.

Here, we refer to a model that considers the price difference between conventional and sustainable energy as compensation for environmental value. By purchasing both conventional and sustainable energy, consumers consume two services: energy and environmental value. However, both services are provided by sustainable energy. As such, consumers initially purchase the amount of sustainable energy that satisfies their demand for environmental value and then supplement their remaining energy demand (i.e., the amount unfulfilled by sustainable energy alone) with conventional energy. In other words, consumers' willingness to pay for environmental value provided by sustainable energy is reflected in the price difference between it and conventional energy. Thus, using the price difference and consumption data from the past to the present, we estimate the parameters and forecast demand in response to future price changes. Then, if prices were to decrease because of the learning effect, demand would expand, giving rise to further proficiency, thus allowing us to construct an independent sustainable energy growth model based on this cycle.

In this chapter, in order to construct such a growth model, we select the residential solar power industry for which there is sufficient market data. Our purpose is to estimate the functional form for demand and the associated parameters. In doing so, we aim to clarify the effects of promotional policies needed to spur industry growth (such as GHG emission taxes, subsidies, and regulation of total GHG emissions) and its impacts on GHG emissions and the economy.

3.3 Growth Theory of Sustainable Energy

In the case of distributed sustainable energy such as solar power generation, energy demands are met according to the amount of operational installed stock in the market. Deterioration of equipment is considered depreciation, and assuming continuity of goods, the change in the amount of installed stock from point t_1 to point t_2, X' is expressed by subtracting the integrated depreciation amount during time t from production x during the period.

$$\Delta X'_{t_1 \to t_2} = m\Delta(DS)_{t_1 \to t_2} = x_{t_1 \to t_2} - k\int_{t_1}^{t_2} X' dt = x_{t_1 \to t_2} - mk\int_{t_1}^{t_2} DSdt \quad (3)$$

Here, k is the depreciation rate, m is the installed stock required to meet unit energy demand, D is the total energy demand, and S is the demand share of sustainable energy against total demand. S is considered a function of the price of sustainable energy,[1] and if we consider price to be a function of the cumulative production volume X, x from Eq. 1 is represented by the function pertaining to market data m,D,k as well as its cumulative production volume X. Thus, we can determine the change in production over time using market data.

In some cases, subsidies are paid as part of promotional policies for sustainable energy. In those instances, the demand curve must be adjusted, as the demand share S shifts exactly by the amount of price difference. However, in cases where

[1]The price of sustainable energy is* total cost, which includes the cost of the equipment divided by energy generated over the lifetime of the equipment.

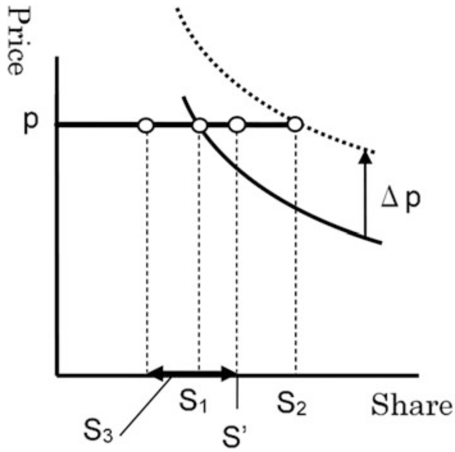


Fig. 8 Relationship between subsidy and energy demand in the case of limited subsidy payments (*Source*: Uchida and Higano 2008)

there is a predetermined and limited amount of total subsidy payment to be issued, the share cannot be determined simply from the demand function, as two prices exist due to either approval or denial of payment issuance. In Fig. 8, when the subsidy is expressed in terms of the energy price difference Δp, the demand curve (represented by a solid line) shifts upward by Δp to the dotted line. Here, the price of conventional energy and sustainable energy are p_0 and p, respectively. The demand share S_1 of consumers who are not paid subsidies is expressed as

$$S_1 \equiv f\,(p_0, p) \tag{4}$$

while the demand share S_2 of consumers who are paid subsidies is expressed as follows:

$$S_2 = f\,(p_0, p - \Delta p) \tag{5}$$

If C represents the total monetary value of subsidies for a given year, dividing it by Δp yields the amount of power covered by the subsidy. However, in order to examine consumption on an annual basis (as it covers the lifetime of the solar panels), it is necessary to multiply this term by k. Expressing this in terms of share S_3, we get

$$S_3 = kC/D\Delta p \tag{6}$$

Of the subsidy applicants S_2, if S_3 represents consumers who receive the subsidy, among the consumers S_1 and S_2–S_1, only S_3/S_2 of each group will receive the subsidy. If information regarding approval or denial of subsidy issuance was at the consumers' disposal when they were deciding on their purchase, consumer group S_1 would purchase sustainable energy regardless of subsidy approval, whereas consumer group S_2–S_1 would not purchase if not for the subsidy. As such, the final demand S' is expressed by the following equation:

$$S' = S_1 + \frac{(S_2 - S_1)\, S_3}{S_2} = \frac{S_1 S_2 + S_2 S_3 - S_1 S_3}{S_2} \tag{7}$$

In cases where there is a limited amount of subsidy payment to be issued, we are left with a model in which S from Eq. (3) is replaced with S'.

3.4 Estimating the Functional Form and Parameters

It is necessary to estimate the functional form of demand share S, which is a function of the price of sustainable energy p. We present residential solar power generation as a case study. Based on the price and sales volume data from 1993 to 2006, we estimate the best approximation function and its parameters. We select four basic types of functional forms: (i) that obtained by dividing sustainable energy services into energy and environmental value, to seek a balance between environmental value and other synthetic goods under a constant elasticity of substitution (CES) utility function, (ii) that obtained by a probit model from among the demands derived from random utility theory, (iii) that obtained using a logit model with the same random utility theory, and (iv) the demand obtained using a Weibull distribution function in survival analysis. Furthermore, we modify each function using the information transfer model, and after adding cases where the parameters themselves exhibit a dependence on the share, we eventually compare a total 12 function types. We assume that the share-dependent parameters are parameters in the demand function that reflect consumers' attitudes toward the environment and social awareness of the specific sustainable energy technology and that such factors will change as the share increases. As we were unable to find any examples from the previous literature regarding this dependency, we assume a linear change on the linear function.

The results of curve fitting for our case study (Fig. 9) indicate that the model accounting for the share dependency of the parameters using the Weibull distribution function best replicates the actual data. The functional form used is as follows:

$$S = \exp\left\{ \frac{-(p - p_0 + a_3 S + a_4)^{a_5 S + a_6}}{a_7 S + a_8} \right\} \tag{8}$$

Here, $a_3, \ldots, a_8$ are the parameters, and the three parameters of the original Weibull function are each replaced by $a_3 S + a_4$, $a_5 S + a_6$, and $a_7 S + a_8$. The estimation results of these parameters are shown in Table 3.

Next, we estimate the parameters of the learning effect exhibited as a decrease in price in response to the cumulative production volume. The learning effect, expressed in price, is represented by Eq. (9), after replacing the left-hand side of Eq. (1) with price:

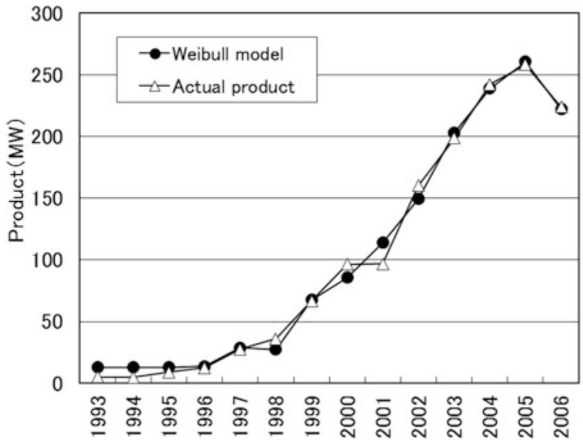


Fig. 9 Economic impacts of production shift to electric vehicles (*Source*: Uchida and Higano 2010a)

Table 3 Parameters in the demand share function

Parameter	Value	Parameter	Value
a_3	0	a_6	0.0374
a_4	59.1	a_7	33.7
a_5	17.0	a_8	0.154

Source: Uchida and Higano (2010a)

$$p = a_1 X^{a_2} \ (a_2 < 0) \tag{9}$$

Based on this equation and the residential solar power generation price data from 1993 to 2004, we conduct curve fitting using the logarithmic least-squares method and spreadsheet software and arrive at the following results: $a_1 = 909$, $a_2 = -0.224$, and X_0(the initial value of X) = 0.251. The results of the curve fitting are shown in Fig. 10. In addition, the rate of progress, represented by 2^{a2}, yields a result of 0.86. This means that as the cumulative production volume in the photovoltaic panel industry doubles, the cost rises by 0.86 times. The details of the models used, including subsequent simulations, are illustrated in previous literature (Uchida and Higano 2008, 2010a, b).

3.5 Forecast of Production Volume

Once we estimate the function by parameter fitting, we can forecast the future demand function of the environmental value and cost decline due to learning effects for solar power generation. Based on the data from 2006, we estimate the number of solar panels (represented by power capacity) introduced in the market from 2006 to 2030, assuming that the price of conventional power remains constant. The predictions pertaining to the production volume appear in Fig. 11, while those pertaining to the price of solar power are shown in Fig. 12. According to the

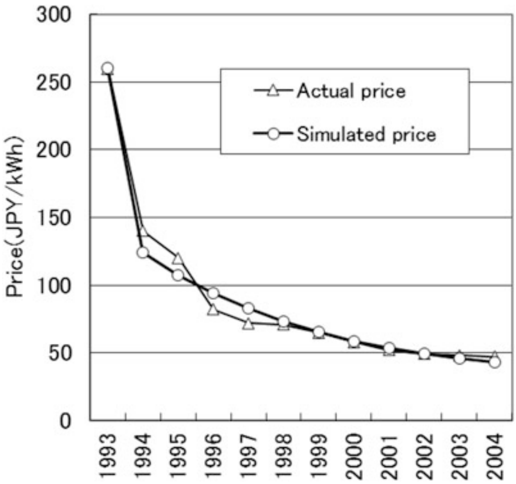


Fig. 10 Estimating the energy price from the learning function (*Source*: Uchida and Higano 2008)

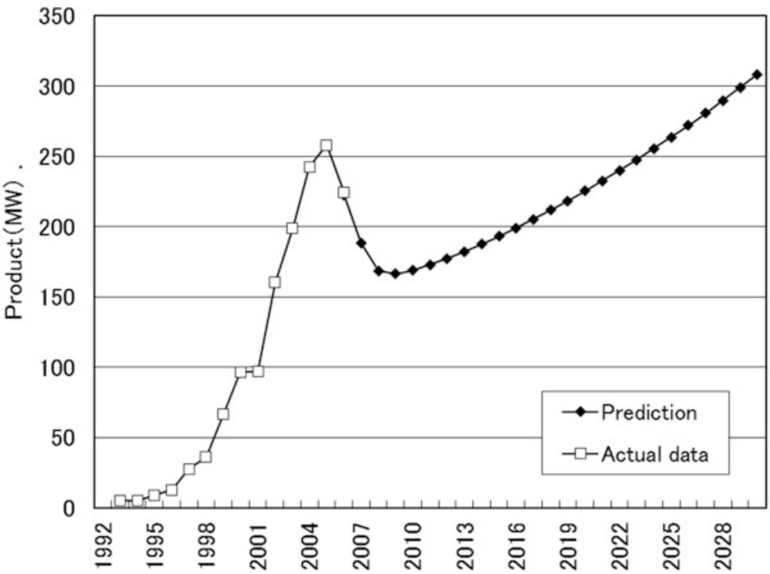


Fig. 11 Forecast of solar power generation output according to the growth model (*Source*: Uchida and Higano 2010a)

forecasts, production decreases until 2008 and then increases again, exceeding 300 MW by 2030. On the other hand, while the price gradually decreases, falling to 31 yen per kWh in 2030, a price discrepancy remains between photovoltaic power generation and conventional power (roughly 22 yen).

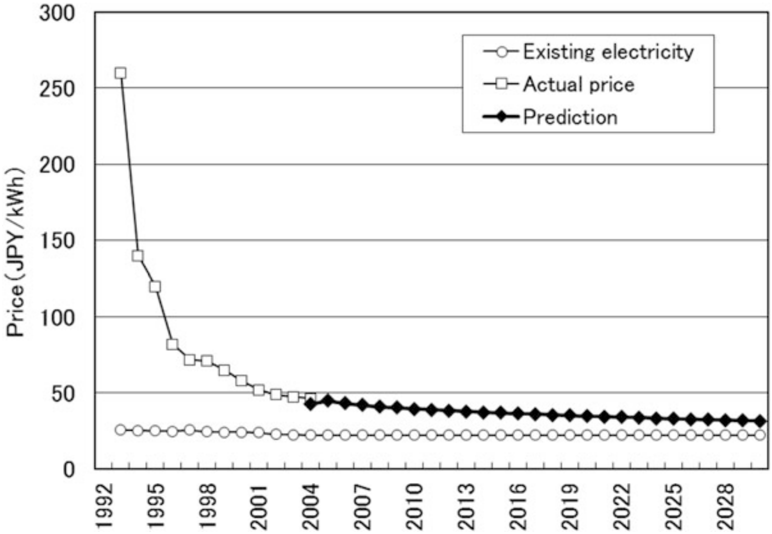


Fig. 12 Forecast of solar power generation price according to the growth model

3.6 Estimating the Effects of Subsidies

After incorporating the growth model into general economic models, where the activities of other industries, including conventional power, are endogenously derived, the growth model for solar power generation takes on the traits of a true endogenous growth model. In order to prevent the model from becoming too unwieldy to usefully produce solutions, we conduct separate simulations with the growth model and general model and input the results from one into the other to successively derive their solutions. The optimal result is indicated by the point where the solutions converge. Using this method, we conduct a dynamic optimization simulation on the 11 periods from base year 2005–2015, using the GDP over the entire period as the objective function. This case assumes a promotional policy that imposes a tax on GHG emissions for all industrial and consumption sectors from the third period (2007). Moreover, we assume that all the revenue from this tax is directed to the solar power generation industry in the form of subsidies. It is assumed that the subsidy payment method is such that the price stated in terms of electric power at the time of solar power generation equipment purchase is equal to that of traditional electricity. For the simulation, we establish three tax rates of carbon equivalent of CO_2 per ton, namely, 500 yen, 1000 yen, and 2000 yen. In addition to these, we designate a fourth pattern, the business-as-usual (BAU) case. We then find the optimal solution for these four patterns and examine the overall effects of promotional policies on the Japanese economy.

Figure 13 shows the gross production results of the solar power generation industry for the entire period. The tax and subsidy implementation resulted in

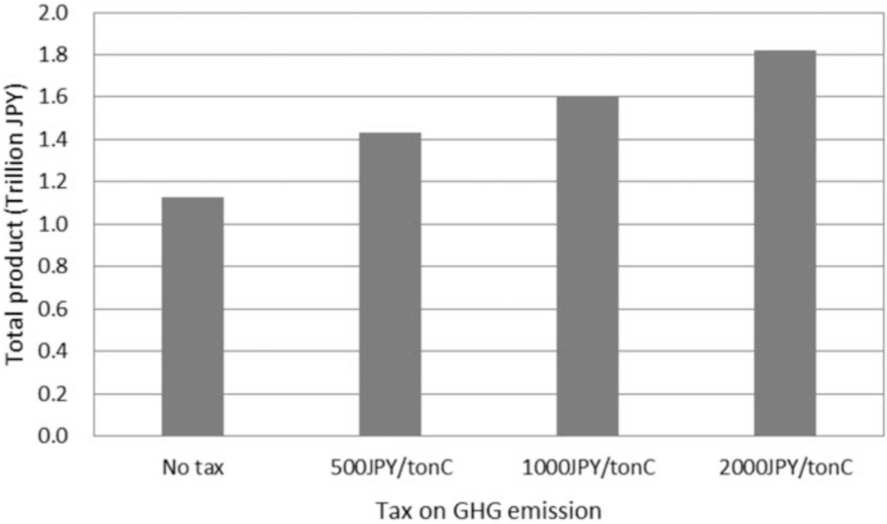


Fig. 13 Predicted uptake of the solar power generation industry depending on emission tax and subsidies

increasing gross production as the tax rate increased. The highest tax rate predicts an average annual effect of approximately 70 billion yen compared with the BAU scenario. In addition, the calculated GHG emissions over the entire period are 4.785 billion tons for the BAU case and 4.755 billion tons for the tax rate of 2000 yen/ton of carbon, a forecast reduction of roughly 30 million tons. Imposing the tax suppresses the production of all other industries (i.e., excluding the solar power generation industry), shrinking the economy as a whole. To verify this finding, we compare the total GDP over the whole period. The BAU case yields a total of 5696 trillion yen, and GDP is seen to decrease as the tax rate increases. A tax rate of 2000 yen/ton of carbon corresponds to a total GDP of 5680 trillion yen, a decrease of 16 trillion yen. However, calculating the GHG emissions per million yen of GDP over the entire period indicates an improvement (0.840 ton of carbon per million yen for the BAU case and 0.837 ton of carbon per million yen when we consider the tax rate of 2000 yen).

4 Concluding Remarks

In this chapter, we introduced analytical methods using model simulation to assess the potential effects of promotional policies for sustainable energy. Even for new energy technologies lacking cost information, it is possible to use the conventional I/O model by estimating the input coefficients. However, we explained the growth of the solar power industry, which has a track record in the new energy technology market, using a model based on the cycle of demand for environmental values and learning effects. Integrating this model with conventional economic models allowed us to focus our analysis on the industry. Promotional sustainable energy policies that employ taxes and subsidies do not necessarily result in an optimistic future, as consumers' perceptions of environmental value are likely to change over time. However, the effects of such promotional policies may become more pronounced in the future. Thus, the economic model simulations presented here are useful to analyze scenarios for a sustainable energy society, as they can account for changes in external factors.

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References

Andress FJ (1954) The learning curve as a production tool. Harv Bus Rev 32:87

Burniaux JM, Nicoletti G, Oliveira Martins J (1992) GREEN: a global model for quantifying the costs of policies to curb CO_2 emissions. OECD Econ Stud 19:49–92

Loulou R, Goldstein G, Noble K (2004) Documentation for the MARKAL family of models, Energy Technology Systems Analysis Programme

Nansai K, Moriguchi Y, Tohno S (2002) Embodied energy and emission intensity data for Japan using input-output tables: inventory data for LCA. National Institute for Environmental Studies, Tsukuba

Uchida S, Higano Y (2006) An evaluation of the policy promoting energy recovery from wastes. Stud Reg Sci 36(1):21–35 (in Japanese)

Uchida S, Higano Y (2008) Diffusion model of renewable energies considering the learning effect and environmental value. J Jpn Soc Energy Res 29(3):15–21

Uchida S, Higano Y (2010a) Evaluation of subsidy for residential photovoltaic by the learning and environmental evaluation model. Stud Appl Econ 3:46–58

Uchida S, Higano Y (2010b) Comprehensive evaluation of a promotion policy for residential photovoltaic considering the cycle of learning and environmental evaluation. Stud Reg Sci 40(2):277–292

Uchida S, Mizunoya T, Higano Y (2008) A dynamic evaluation of policies to promote the use of the potential energy in wastes. Stud Reg Sci 38(2):339–350