

Suminori Tokunaga  
Budy P. Resosudarmo *Editors*

# Spatial Economic Modelling of Megathrust Earthquake in Japan

Impacts, Reconstruction, and Regional  
Revitalization

# **New Frontiers in Regional Science: Asian Perspectives**

Volume 11

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Suminori Tokunaga • Budy P. Resosudarmo  
Editors

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Impacts, Reconstruction, and Regional  
Revitalization



Springer

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# Preface

The Great East Japan Earthquake of March 11, 2011, had a massive economic impact, primarily on the affected areas in Japan. The research projects that this book is based on started in July 2011 after the Great Earthquake. The Research Institute of Economy, Trade and Industry (RIETI) took initiative in the following projects: (1) “Studies on the Structure of Japanese Economic Space and Japanese Supply Chains Sustaining Growth Under Globalization and Disaster Risks [July 2011–June 2013, Project Leader: [Nobuaki Hamaguchi](#) (Faculty Fellow)]” and (2) “Sustainable Regional Development: New Industrial Clusters and Division of Functions [July 2013–June 2015, Project Leader: Ryohei Nakamura (Faculty Fellow)].” In addition, we organized a special session of the Japan Section of Regional Science Association International (JSRSAI) on “Impacts of Disaster on Regional Economy” with Dr. Okiyama and Dr. Kunimitsu (Tokunaga as organizer) in 2013 and 2014 and a special session of JSRSAI on “Impacts of Regional Recovery Policy on Regional Economy” with Dr. Okiyama and Dr. Kunimitsu (Tokunaga as organizer) in 2015. Moreover, we organized a special session of the 23rd Pacific Conference of the Regional Science Association International (RSAI, PRSCO) on “Macroeconomic Policies, Global Crisis, and Recovery” with Budy Resosudarmo in Bandung, Indonesia, from July 2 to 4, 2013.

Many of the papers contained in this book were presented at the workshops of RIETI and special sessions of JSRSAI and PRSCO. Subsequently, all papers have been thoroughly reviewed and revised. We thank the members of research projects in RIETI including Masahisa Fujita (president for 2007–2016), Masayuki Morikawa (vice president), [Nobuaki Hamaguchi](#), Ryohei Nakamura, and Tatsuaki Kuroda and the members of RSAI such as Kazuhiko Kakamu (Kobe University), Yoshihiro Kameyama (Saga University), Mitsuru Ota (University of Tsukuba), and Kingsley E. Haynes (George Mason University) for their valuable advice and

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Tokyo, Japan  
March 2017

Suminori Tokunaga  
Budy P. Resosudarmo

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# Chapter 1

## A Spatial and Economic Analysis of Megathrust Earthquakes

Suminori Tokunaga

**Abstract** The Great East Japan Earthquake, which struck on March 11, 2011, had a massive economic impact, primarily on the affected areas in Japan. The Indian Ocean Tsunami hit Aceh and Nias, Indonesia, on December 26, 2004 and destroyed life and infrastructure within 10 km of the coastline in north and western Aceh. In this book, we examine the economic and human damage inflicted by megathrust earthquakes and tsunamis and analyze the economic effects of policies for reconstruction and regional renewal after such catastrophes, using a spatial and economic model. The contents of this book are as follows: Part I, Impacts of the Great East Japan Earthquake, is composed of three chapters that form a foundation on which further earthquake research can be based. Part II, Reconstruction and Regional Renewal after the Great East Japan Earthquake, focuses on reconstruction and regional renewal after the Great East Japan Earthquake amid a declining Japanese population, using reconstruction budgets and industrial clusters. Part III analyzes the impact and reconstruction after the Great East Japan Earthquake, in a depopulating society, as summarized in Parts I and II. Part III evaluates regional impacts of megathrust earthquakes and tsunamis, such as the Great East Japan Earthquake, the Nankai Megathrust Earthquake, the Tokai earthquake in Japan, and the Indian Ocean Tsunami in Asia.

**Keywords** Megathrust earthquakes • Tsunami • Depopulating society • Reconstruction • New industry cluster • Regional renewal

### 1.1 Introduction

In the last 200 years, Japan had approximately 20 major tsunamis, such as the Meiji Sanriku Tsunami in 1896, the Showa Sanriku Tsunami in 1933, the Southwestern Hakkaido Coast Tsunami in 1993, and the Great East Japan Earthquake in 2011.

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Japan also had megathrust earthquakes that reoccurred approximately every 100–150 years, such as the Ansei-Tokai Earthquake and the Ansei-Nankai Earthquake in 1854, the 1944 Tonankai Earthquake, the 1946 Nankaido Earthquake, the 1993 Hokkaido Earthquake, and the 1994 offshore Sanriku Earthquake (Karan and Suganuma, eds., 2016). In particular, the Great East Japan Earthquake, on March 11, 2011, had a massive economic impact in the region where the disaster occurred, with damage resulting from the earthquake itself (the largest ever recorded), from the resulting massive tsunami, and from accidents at a nuclear reactor within the region, in addition damage to production sites outside the disaster-affected region. More than 5 years have passed, and it is likely that a disaster similar to the Tokai Earthquake or the Nankai Trough Megathrust Earthquake will recur.

Since about 2010, Japan has seen its overall population decrease, caused by a declining birth rate and aging. These changing demographics, in which the core labor force aged 20–64 is shrinking while the population aged 65 and above is growing, are not uniform across Japan because of inter-regional disparities. Population forecasts can be seen in *Population Projections for Japan* (March, 2013), published by the National Institute of Population and Social Security Research (IPSS) in Japan. According to these projections, Japan's population is expected to decrease by approximately 970,000 per year from 2035 to 2040, when 36% of its total population will be of 65 years and above. While the elderly population will be growing in all regions of Japan, with this trend becoming more pronounced every year, the young will be shrinking in number. This is particularly noticeable in Hokkaido and Tohoku, where the population aged 20–64 is projected to decline by 40% relative to 2010, and the population aged 65 and above is projected to rise, despite regional disparities between 2025 and 2030. For instance, the 20–64 years population in Tohoku is projected to peak in about 2025 (before declining) while the population in Hokkaido aged 65 and above is projected to remain virtually flat.<sup>1</sup> Even as Japan's population goes down, we must strive to rebuild from the Great East Japan Earthquake and to revitalize the region.

## 1.2 Conceptual and Empirical Developments

This book aims to empirically assess (i) the economic impact of megathrust earthquakes, such as the Great East Japan Earthquake and the Nankai Trough Earthquake in a depopulating society, and (ii) the subsequent economic impact of policies regarding regional revitalization and industrial reconstruction, using spatial economic models. (iii) the regional impacts of megathrust earthquakes and tsunamis, such as the Nankai Megathrust Earthquake, the Tokai earthquake in Japan, and the Indian Ocean Tsunami in Asia.

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<sup>1</sup>The IPSS Japanese population forecast (2012, 2013) does not consider population disruptions caused by the Great East Japan Earthquake.

The book also asks five questions. First, what is the status of the massive economic damage resulting from the Great East Japan Earthquake and the industrial and fiscal reconstruction measures executed after this earthquake, in a society with a declining population? To answer this question, an inter-regional social account matrix (SAM), an input–output (I–O) table, a geographically weighted regression (GWR) model and a two-regional computable general equilibrium (2SCGE) model are used to empirically explain the economic impact of the Great East Japan Earthquake in the afflicted and other regions (Chaps. 2 and 3). Chapter 4 examines supply chain disruptions from the Great East Japan Earthquake in the automotive and electronic parts and devices industries.

Prior studies have primarily analyzed the economic impact of earthquakes or the subsequent rebuilding in a growing population as opposed to a declining one. Thus, the second question is whether fiscal reconstruction measures or regional industrial reconstruction policies are possible in a declining population. Using a dynamic two-regional computable general equilibrium model (D2SCGE) for this population, we measure the economic impact of a reconstruction budget (Chap. 5) and new industry cluster policies, based on the New Economic Geography (NEG) model<sup>2</sup> as the effects of regional and industrial reconstruction policies (Chap. 6) on the regional economies in the disaster-affected region amid a declining population. This idea of Chap. 6 is that in addition to agglomeration within a same industry, it is essential to form “new industry clusters” using innovation to promote agglomeration in different industries (co-agglomeration). By using a D2SCGE model that incorporates the Dixit–Stiglitz model, which is characteristic of an NEG, we examine whether reconstruction and regional revitalization after an earthquake are possible by forming new industry clusters, using (1) subsidies and tax reduction policies, (2) a commodity-grade scenario with products (particularly intermediate goods) that have varying levels of inter-regional elasticity of substitution, and (3) a scenario with innovative TFP improvement. A dynamic computable general equilibrium (DCGE) model that assesses production recoveries after the disaster in the fishing and seafood industries (where damage was severe) is analyzed in Chap. 7. Using an I–O table, the process of reconstruction after the disaster, in the construction of a biogas electric power plant, is analyzed in Chap. 8.

The third question examines the impacts of an earthquake and of population migration in a declining population on regional economies. Because the aforementioned D2SCGE model does not incorporate an explicit inter-regional population migration, and therefore the first part of the questions is answered by analyzing the impact of further population declines due to a major earthquake, using an I–O table

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<sup>2</sup>For economics of agglomeration, see Marshall (1890). For the NEG mode and agglomeration, see Krugman (1991), Fujita et al. (1999), and Fujita and Thisse (2013). For the industrial cluster, see Porter (1998, 2000), Tokunaga and Okiyama (eds) (2014); Tokunaga et al. (2014), and Tokunaga and Okiyama (2017). According to Porter (1998), the formation of an industrial cluster depends on the relative strength of three forces of localization: economies, price competition, and transport costs. Fujita and Thisse (2013, p. 350) also point out that firms must be able to serve almost all markets equally to enjoy the local advantages associated with the formation of a cluster.

of 47 prefectures (Chap. 9). The second part of the questions is answered using an NEG model that studies migrations caused by the Great East Japan Earthquake and a Nankai Trough Earthquake (Chap. 10).

The fourth question asks whether, in the event of a major earthquake, advance measures impact the recovery process. This question is answered using a forward-looking, dynamic inter-regional CGE model, which analyzes different post-disaster recoveries for a Tokai Earthquake (Chap. 11).

The Indian Ocean Tsunami that occurred after the Sumatra Earthquake in December 2004 is used as a successful example of reconstruction after a major tsunami. The fifth question asks how central and local governments, NPOs, and the international community should manage a reconstruction after a major natural disaster. This section proposes a set of policies that respond to damages caused by major natural disasters that are likely to occur in Asia in the future (Chap. 12). It also analyzes the Sumatra Earthquake's impact on the Indonesian state of Aceh and its surrounding regions and conducts a time-series analysis of the reconstruction policies implemented after a large natural disaster and for regional revitalization. Figure 1.1 shows the chapters' details and the causal relations between them.

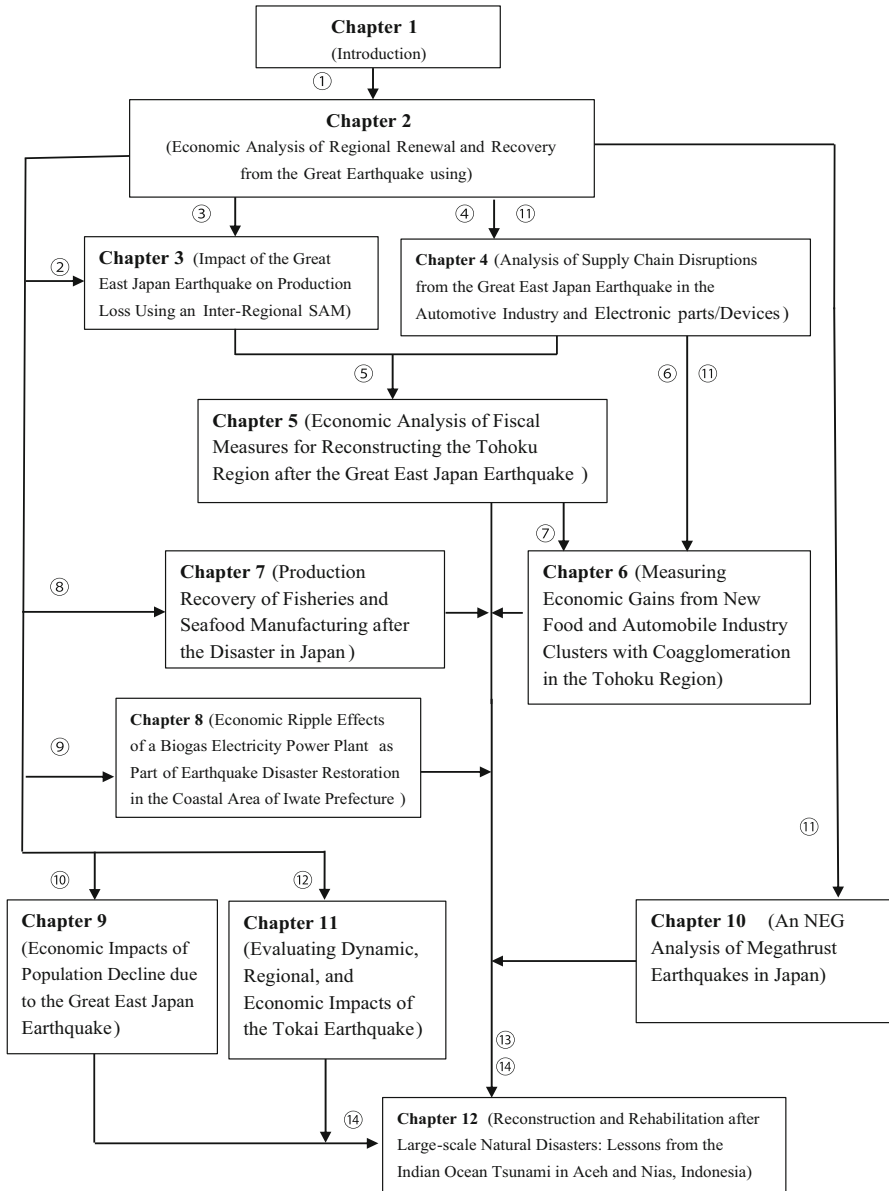
### 1.3 Contributors to the Book

Part I, *Impacts of the Great East Japan Earthquake*, comprises three chapters that form a foundation on which further earthquake research can be based. In Chap. 2, entitled "Economic Analysis of Regional Renewal and Recovery from the Great Earthquake," Suminori Tokunaga, Maria Ikegawa, and Mitsuru Okiyama examined the impacts of the Great East Japan Earthquake on affected areas in Japan, using a simple spatial econometrics (GWR) model. They also evaluated economic policies for regional renewal and recovery from the Great Earthquake using a static regional computable general equilibrium (SCGE) model.

Chapter 3, entitled "Impact of the Great East Japan Earthquake on Production Loss Using an Inter-Regional Social Accounting Matrix," written by Mitsuru Okiyama, estimates the magnitude of production losses in regions of Japan both affected and not affected by this earthquake, primarily damage to agriculture and fisheries' production and loss of capital stock in the manufacturing industry.

Chapter 4, "Analysis of Supply Chain Disruptions from the Great East Japan Earthquake in the Automotive Industry and Electronic Parts/Devices," was written by Suminori Tokunaga and Mitsuru Okiyama. This chapter simulates negative supply shocks for both upper-level sectors between regions and lower-level sectors within the regions, using a two-region computable general equilibrium (2SCGE) model.

Part II, *Reconstruction and Regional Renewal after the Great East Japan Earthquake*, focuses on reconstruction and regional renewal in a declining population after the Great East Japan Earthquake, using reconstruction budgets and industrial clusters. This part comprises four chapters. Chapter 5, entitled "Economic Analysis of Fiscal Measures for Reconstructing the Tohoku Region after the Great East Japan Earthquake," written by Mitsuru Okiyama and Suminori



**Fig. 1.1** Flowchart of the book (Note: ① Economic analysis using GWR and CGE model, ② Economic analysis using an inter-regional SAM, ③ SAM multiplier analysis of production loss, ④ Economic analysis of supply chain disruption using 2SCGE model, ⑤ Economic analysis of fiscal measure using D2SCGE model, ⑥ Economic gain from industry clusters, ⑦ Economic evaluation of industry clusters using D2SCGE model, ⑧ Production recovery of fishers and seafood manufacturing by DCGE model, ⑨ Economic analysis of ripple effects of a biogas power plant using a regional Input-output tables, ⑩ An inter-regional Input-output analysis of population decline, ⑪ Economic analysis of the megathrust earthquakes using an NEG model, ⑫ Economic analysis of the Tokai earthquake using Dynamic spatial CGE model, ⑬ Lessons from the Indian Ocean Tsunami in Indonesia, ⑭ Policy recommendation)

Tokunaga, measures the economic impact of the reconstruction budget and illustrates the regional economies' transition in the disaster-affected region in a declining population, using a recursive dynamic regional CGE model. One of the most fascinating findings in this chapter is that even if the Great East Japan Earthquake had not occurred, the disaster-affected region would have experienced weaker growth in its sub-regional economies simply because of its declining population. It is advisable that the government provide fiscal measures to the disaster-affected region after the reconstruction period by adopting a different form of reconstruction budget; that is, by revising the distribution ratios of local allocation tax grants. However, this measure alone would not allow the regional economy in the disaster-affected region to recover and exceed its level prior to the earthquake.

Chapter 6, entitled "Measuring Economic Gains from New Food and Automobile Industry Clusters with Coagglomeration in the Tohoku Region," written by Suminori Tokunaga and Mitsuru Okiyama, provides, in the context of NEG, a new type of industrial cluster to assist recovery from the Great East Japan Earthquake amid a declining population. Using Porter's (1998, 2000) clusters, they analyze the feasibility of ongoing economic development in disaster regions, utilizing two new industry cluster models. The two clusters are the automobile industry, which targets the entire disaster region and where innovation comes from coagglomeration with different industries in megaregions, and the food industry, which focuses on leveraging local resources and targets individual disaster-struck prefectures. Using a dynamic two-region computable general equilibrium (D2SCGE) model, they conduct a simulation analysis of scenarios for these two new clusters, whose positive and high productivity reveals the two effects: (1) economies of agglomeration from vertical and horizontal coagglomerations boost real gross regional product (GRP) and productivity at the macro level when the two new industry clusters are formed jointly rather than separately and (2) the clusters contribute to long-term, sustained growth in disaster economies, thus reducing the gap between their growth and that of other regional economies.

Chapter 7, entitled "Production Recovery of Fisheries and Seafood Manufacturing after the Disaster in Japan: Economic Evaluation Using a Dynamic CGE Model," written by Yuko Akune, shows the economic effects of recoveries in the fisheries and seafood industries after the disaster in Japan with respect to depopulation, employing a DCGE model. She confirms the clear contrast between the production recovery at seafood manufacturers in Iwate and Miyagi Prefectures after the earthquake. From these five simulations, the author concludes the following: (1) The earthquake accelerated the problem caused by depopulation; (2) prompt capital restoration and production recovery contributed to shortening the period of production loss; (3) the degree of production recovery of the downstream industry was faster than that of the upstream industry; (4) no scenario based on the GEJE evidence was sufficient to reach a base scenario without a disaster; (5) stepwise production recovery contributed to increases not only in specific industries but also in economic welfare in the long term.

Chapter 8, "Economic Ripple Effects of a Biogas Electricity Power Plant as Part of Earthquake Disaster Restoration in the Coastal Area of Iwate Prefecture" was

contributed by Yoji Kunimitsu. This chapter focuses on the coastal area of Iwate Prefecture, which was seriously damaged by the Great East Japan Earthquake. Using the input–output tables of this region from before and after the earthquake, the author shows the impacts of a particular revitalization measure, the construction of a biogas electricity power plant, and finds the following three points: (1) value-added production in 2011 was higher than the previous year because of recovery investments, but both intermediate inputs and total production decreased; (2) while investment demand increased in 2011 and 2012, intermediate inputs and private and public consumption decreased because of the earthquake; (3) if it had been constructed before the earthquake, the multiplier value of induced production for the construction of a biogas electricity power plant would have been 0.64. However, the value after the earthquake was 0.17 because the industrial linkage was damaged.

After analyzing the impacts of the reconstruction after the Great East Japan Earthquake in a depopulating society in the preceding two parts, Part III turns to *evaluating regional impacts of megathrust earthquakes and tsunamis*, such as the Great East Japan Earthquake, the Nankai Megathrust Earthquake, the Tokai earthquake in Japan, and the Indian Ocean Tsunami in Asia.

Yoshifumi Ishikawa contributed Chap. 9, which is titled “Economic Impacts of Population Decline Due to the Great East Japan Earthquake: An Inter-Regional Input–Output Approach.” In the aftermath of the Great 2011 Earthquake, Fukushima Prefecture in particular is still suffering from its impacts, specifically, the nuclear power plant accident and the consequent evacuation of numerous people. Using a 47-region, inter-regional input–output table at the prefecture level, the author analyzes the economic impacts of the population decline for the 5 years after the Great Earthquake and its long-term economic impacts, using population projections that consider the impact of the earthquake.

Chapter 10, entitled “An NEG Analysis of Megathrust Earthquakes in Japan,” was written by Ryusuke Ihara. This contribution focuses on the Great East Japan Earthquake, the Nankai megathrust earthquakes, and the associated tsunami. The author considers how these events changed the regional economies of Japan. Constructing an NEG model composed of the 47 prefectures of Japan, simulation results show that the predicted labor distribution approaches the actual distribution, and as transportation costs decrease, labor distribution changes from dispersion to agglomeration in metropolitan areas and then to re-dispersion in rural areas. In addition, adapting the damage data from megathrust earthquakes to this model, the author predicts the impact of the Great East Japan Earthquake and a Nankai Megathrust Earthquake on regional potential and labor distribution among the prefectures.

Chapter 11, “Evaluating Dynamic, Regional, and Economic Impacts of the Tokai Earthquake,” was contributed by Hiroyuki Shibusawa. This chapter investigates the negative economic impacts of an earthquake, using a dynamic spatial computable general equilibrium model with a decentralized economy, utility-maximizing consumers, and value-maximizing firms in a dynamic context. The author estimates the impacts of a hypothetical earthquake, which is expected to

occur in the near future, on Tokai's regional economy and shows both dynamic and spatial economic impacts before and after such an earthquake.

Finally, Chap. 12, written by Budy P. Resosudarmo, is entitled "Reconstruction and Rehabilitation after Large-scale Natural Disasters: Lessons from the Indian Ocean Tsunami in Aceh and Nias, Indonesia." It observes that the Indian Ocean Tsunami hit Aceh and Nias, Indonesia, on the morning of December 26, 2004 and destroyed life and infrastructure within 10 km of the coastline in north and western Aceh, which were a zone of armed conflict and all islands offshore. The author shows the impact of this huge natural disaster in a conflict zone and analyzes the responses to the Indian Ocean Tsunami of 2004 to estimate the recovery from this mega-disaster and to propose policies for regional renewal. This final contribution emphasizes the regional revitalization theme of this book.

## 1.4 Concluding Remarks

To conclude this introduction, we note the following. Looking back on the March 11, 2011 Great East Japan Earthquake, 5 years later, a number of research organizations calculated almost 18 trillion yen in damages to the social capital stock. Project expenditures in the 5 years (2011–2016), which were devoted to restoration and reconstruction in the areas hit by the disaster, already exceeded the amount of damages to social capital stock (Keynes 1936/1973). While it cannot be denied that businesses and factories have been restored to their previous condition after 5 years, areas outside those impacted by the Fukushima nuclear reactor disaster are entering a new reconstruction stage that will construct new full-scale towns. The purpose of this book is not to recommend a simple restoration to a pre-disaster state but rather to strive for a reconstruction and regional revitalization plan, amid a declining population, and to analyze the impact of policies necessary to achieve it. It is hoped that the various lessons learned from the Great East Japan Earthquake and the Indian Ocean Tsunami and the findings presented in this book, particularly, the new industrial agglomerations discussed in Chap. 6, specifically, policies for "forming new industry clusters" (Porter 1998, 2000) and "innovation" (Schumpeter 1934) should be linked to countermeasures and responses in preparation for megathrust earthquakes such as the Tokai and Nankai Trough Earthquakes, which are predicted to occur in the future.

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**Part I**  
**Impacts of the Great East Japan**  
**Earthquake**

## Chapter 2

# Economic Analysis of Regional Renewal and Recovery from the Great East Japan Earthquake

Suminori Tokunaga, Maria Ikegawa, and Mitsuru Okiyama

**Abstract** The Great East Japan Earthquake, which struck on March 11, 2011, had a massive economic impact, primarily on the affected areas in Japan. In this chapter, we examine the economic and human damage inflicted on Iwate, Miyagi, Fukushima, and Ibaraki Prefectures by the Great East Japan Earthquake, as well as the current situation of industrial recovery, based on several statistical sources and a geographically weighted regression (GWR) model. In the latter part of this chapter, we will show the extent of fiscal transfers to date from the government for reconstruction and renewal of stricken areas and analyze the economic effect of the formation of new industrial clusters for reconstruction and renewal on these areas using a static two-regional computable general equilibrium (2SCGE) model. Our findings are as follows: (1) if production subsidies to support industries form new industry clusters, positive effects on regional economies could appear in the disaster regions; however, these impacts are weak and (2) formation of new industry clusters with productivity improvement has a positive effect on real gross regional product (GRP) and economic welfare in these regions, reducing the economic welfare gap between disaster and non-disaster regions.

**Keywords** Great East Japan Earthquake • Economic and human damage • Geographically weighted regression (GWR) model • Two-regional computable general equilibrium (2SCGE) model • New economic geography (NEG) model • New industry clusters • New industrial agglomeration

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## 2.1 Introduction

Compared with past earthquake disasters in Chap. 1, the Great East Japan Earthquake, which struck on March 11, 2011, had a massive economic impact, primarily on the affected areas. The damage inflicted directly by the earthquake was compounded by damage from the tsunami arising from the earthquake and by the nuclear power plant incident. In the former part of this chapter, we examine the economic and human damage inflicted on Iwate, Miyagi, Fukushima, and Ibaraki Prefectures by the Great East Japan Earthquake, as well as the current situation of industrial recovery. In the latter part, we show the impacts of fiscal measures for reconstruction and industrial cluster in disaster-affected region for reconstruction on regional economy using a simple computable general equilibrium model. Section 2.2 presents the economic and human damage wrought by the earthquake and the current situation of industrial recovery, based on several statistical sources and surveys such as industrial production indices. In particular, we discuss the impact of the nuclear power plant catastrophe in Fukushima Prefecture, distinguishing it from the damage in Iwate, Miyagi, and Ibaraki Prefectures. Section 2.3 then discusses which elements were prioritized in the allocation of government recovery funding measures to deal with the economic damage, the status of implementation, and additional challenges. In Sect. 2.4, we estimate impacts of this earthquake on firms' output, using a spatial econometric model. Section 2.5 moves on to present an economic model for natural disaster assessment and labor migration: a) the regional input-output and two-regional computable general equilibrium (2SCGE) models used in this tract to assess the policies of recent years, to analyze economic and human loss from the quake, and to assess recovery policies; b) a new economic geography (NEG) model that facilitates explicit analysis of population and labor migrations; and c) research about new industrial agglomerations and clusters. Section 2.6 uses the static 2SCGE model to analyze the earthquake's destruction and to describe a simulation analysis of regional renewal based on new industrial agglomerations and clusters. Finally, Section 2.7 presents conclusions for this chapter and discusses future topics.

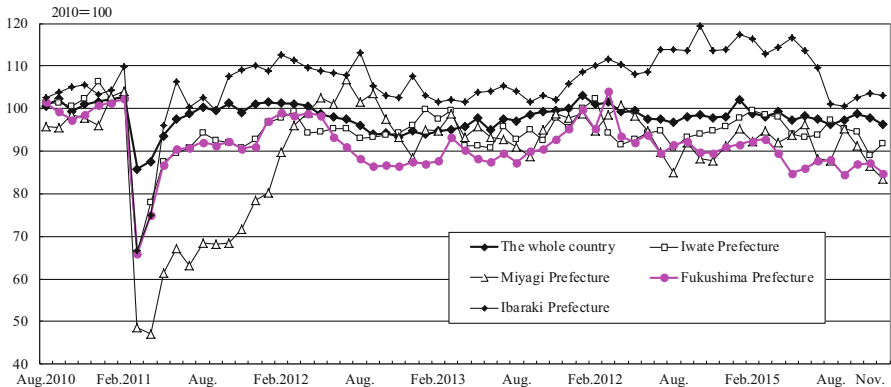
## 2.2 Economic and Human Loss in the Disaster Areas and the Current State of Industrial Recovery

### 2.2.1 *Economic Loss in the Disaster Areas and the Current State of Industrial Recovery*

The Great East Japan Earthquake that struck on March 11, 2011 caused the greatest damage to the Japanese economy since World War II. Production activities in the automotive and electronics industries were hit not only in the affected areas but also throughout the country, as damage to factories in the stricken areas and power

shortages disrupted the supply of products and raw materials. Industrial production plummeted due to this enormous supply shock. In this section, we shall consider supply shocks to major industries in the stricken areas immediately after the quake occurred and the extent to which production activities have subsequently recovered.<sup>1</sup> We begin with indices of industrial production. Fig. 2.1 shows these indices, and we can see that production in each prefecture took a 30%–50% fall immediately after the quake. Subsequently, the speed of the recovery differed among prefectures, with Miyagi Prefecture initially lagging behind but catching up 1 year after the quake. In Fukushima Prefecture, which suffered the largest impact from the nuclear power plant disaster, the impact of the quake was prolonged, with production levels stalling at approximately 90% in 2012 and subsequent years. At present, industrial production in the three affected prefectures, excluding Ibaraki, remains below national industrial production indices.

Table 2.1 shows the drop in manufacturing output by sector and the subsequent recovery. It is obvious that in the 6 months immediately following the disaster, production in all sectors declined in the affected areas, notably in Fukushima Prefecture. Therefore, as in Fig. 2.2, we see that while manufacturing sites damaged by the earthquake were concentrated in the coastal regions of Miyagi and Ibaraki Prefectures (where the automotive and electrical-related industries are concentrated) and in the coastal regions of Iwate and Miyagi Prefectures (where marine processing-related industries are concentrated), damaged factories were dispersed over a broad area, which caused enormous damage to the manufacturing industries of affected regions.



Source: Economic survey of Tohoku Bureau of Economy, Trade and Industry (2012 through 2016).

**Fig. 2.1** Drop and recovery of production in manufacturing by sector in the disaster-affected prefectures (Source: Economic Survey of Tohoku Bureau of Economy, Trade and Industry (2012 through 2016))

<sup>1</sup>This section is an expanded version of Sect. 1.2 from Tokunaga and Okiyama (eds) (2014).

Table 2.1 Change amount of production value from September 2010 through December 2015

Change amount of Average production value from September 2010 through February 2011 (unit: Billion yen, %)	From March 2011 through June 2011 (The three months period after the earthquake)	From July 2011 through September 2011 (From three months through six months period)	Change % from pre-the earthquake level	From October 2011 through January 2012 (From six months through one year period)	Change % from pre-the earthquake level	From February 2012 through January 2013 (From one year through two years period)	Change % from pre-the earthquake level	From January 2013 through December 2015 (after four years period)	Change % from pre-the earthquake level
	Fukushima Prefecture	-1,240 -223 -114 -188 -218 -19 -278 -93 -46 -60	-509 -186 -21 -102 -74 -2 -58 -16 -23 -26	-24.8 -40.5 -42.7 -30.1 -34.7 -4.3 -17.6 -28.6 -14.1 -24.6	-378 -119 -15 -111 -33 -19 -32 0 -29 -19	-7.6 -21.6 -5.6 -17.7 -5.3 -4.2 -2.0 -0.1 -8.8 -7.9	-459 -26 -14 -99 -31 -15 -154 -64 -44 -13	-9.2 -4.7 -5.3 -15.8 -4.9 -3.3 -9.7 -19.6 -13.2 -5.1	-696 -139 -6 -82 -58 22 -239 -105 -60 -30

The Stricken three prefectures		-4,505	-25.7	-1,746	-10.0	-969	-5.5	-44	-0.2	-137	-0.8
	Foods and tobacco	-521	-18.7	-156	-5.6	-18	-0.7	19	0.7	334	12.0
	Non-durable goods	-258	-29.1	-159	-18.0	-120	-13.5	-64	-7.2	-24	-2.7
	Petroleum products and chemicals	-1,870	-46.4	-897	-22.3	-771	-19.1	-199	-4.9	-155	-3.8
	Steel and metals	-938	-25.0	-289	-7.7	-161	-4.3	-141	-3.8	-313	-8.4
	General machinery	-243	-10.7	230	10.2	338	14.9	172	7.6	413	18.2
	Electronic parts and devices	-262	-21.2	-338	-27.3	-276	-22.4	-128	-10.3	-345	-27.9
	Motor vehicle and Motor vehicle parts	-249	-30.5	-26	-3.2	9	1.1	278	34.0	94	11.6
	Other durable goods	-60	-5.6	-65	-6.1	15	1.4	9	0.8	-111	-10.4
	Miscellaneous manufacturing goods	-103	-15.8	-45	-6.9	15	2.3	10	1.5	-31	-4.7

(continued)

Table 2.1 (continued)

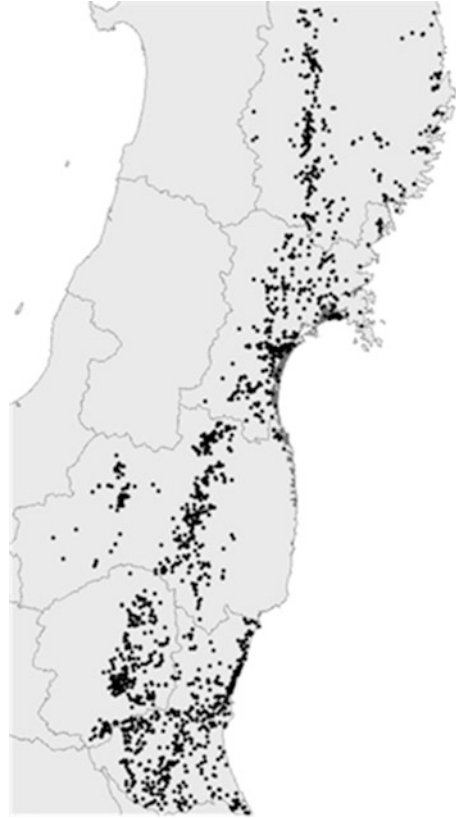
Change amount of Average production value from September 2010 through February 2011 (unit: Billion yen, %)	From March through June 2011 (The three months period after the earthquake)	From July through September 2011 (From three months through six months period)	Change % from pre-the earthquake level	From October through January 2012 (From six months through one year period)	Change % from pre-the earthquake level	From February through January 2013 (From one year through two years period)	Change % from pre-the earthquake level	From January 2013 through December 2015 (after four years period)	Change % from pre-the earthquake level
	Other Region	-16,587	-22	0.0	1,958	0.7	-7,258	-2.7	2,826
Foods and tobacco	80	303	0.9	209	0.6	-172	-0.5	889	2.7
Non-durable goods	-20	-192	-1.5	39	0.3	-446	-3.6	-577	-4.6
Petroleum products and chemicals	257	368	0.8	-196	-0.4	-836	-1.7	-1,057	-2.2
Steel and metals	-1,060	-1,157	-2.7	-964	-2.3	-1,059	-2.5	-2,073	-4.9
General machinery	328	1,913	6.8	1911	6.8	-1,384	-4.9	848	3.0
Electronic parts and devices	-3,554	-3,482	-11.3	-5,550	-18.0	-6,429	-20.9	-5,130	-16.6
Motor vehicle and Motor vehicle parts	-13,803	-472	-1.1	4,177	9.9	1,536	3.6	555	1.3
Other durable goods	1,095	2,794	11.7	2,368	9.9	1,678	7.0	10,052	42.2
Miscellaneous manufacturing goods	90	-97	-0.9	-37	-0.3	-146	-1.3	-681	-6.2

Whole country	-22,332	-7.6	-2,277	-0.8	611	0.2	-7,760	-2.6	1,993	0.7
Foods and tobacco	-664	-1.8	-39	-0.1	72	0.2	-179	-0.5	1,084	2.9
Non-durable goods	-392	-2.9	-373	-2.7	-96	-0.7	-524	-3.9	-606	-4.5
Petroleum products and chemicals	-1,801	-3.4	-630	-1.2	-1,078	-2.0	-1,134	-2.1	-1,293	-2.4
Steel and metals	-2,216	-4.7	-1521	-3.2	-1,158	-2.5	-1,230	-2.6	-2,444	-5.2
General machinery	65	0.2	2141	6.9	2,230	7.2	-1,227	-4.0	1,284	4.1
Electronic parts and devices	-4,094	-12.2	-3878	-11.5	-5,859	-17.4	-6,710	-19.9	-5,714	-17.0
Motor vehicle and Motor vehicle parts	-14,145	-32.6	-515	-1.2	4,186	9.6	1,751	4.0	544	1.3
Other durable goods	989	3.9	2706	10.7	2,354	9.3	1,643	6.5	9,882	39.2
Miscellaneous manufacturing goods	-74	-0.6	-168	-1.4	-41	-0.3	-148	-1.2	-742	-6.2

Source: Tokunaga and Okiyama (eds) (2014, p. 4) and economic survey of Tohoku Bureau of Economy, Trade and Industry (2012 through 2016)

Unit: billion yen

**Fig. 2.2** Sites Damaged by the Great Earthquake (Manufacturing Industry) (Source: Tokunaga and Okiyama (eds) (2014, p. 5). Note: The authors composed this based on the results of the “2011 Investigation of Damage to Firms due to Great East Japan Earthquake” survey conducted by the Economic and Industrial Research Laboratory as well as Figure 2.4 by Hamaguchi (2013))



However, visible differences can be seen in the recoveries for Fukushima Prefecture and the other three affected prefectures. This holds true both for the same industry and among industries. It is difficult to say whether this similarity is due to the nuclear power plant incident, the relative impact of fiscal measures, or non-earthquake factors such as the rise in the yen's value, subsidies that stimulated demand for eco-friendly products, or some combination of these factors. From Table 2.1, we see that in the affected regions, for the 3 month period after the quake, manufacturing production reached 74.5% of pre-quake levels, rising to 90.0% during a 3–6 month period. Between 6 and 12 months after the quake, manufacturing production reached 94.0%, moving up to 97.8% between the first and second years. Four years after the quake, manufacturing production was 96.3%.

Some industries, such as the food and tobacco industry in Fukushima, showed noteworthy production recovery. Nevertheless, its recovery from the drop in production lagged behind other prefectures and other industries in Fukushima. It is conjectured that this was caused by negative rumors about radioactive pollution relating to the nuclear power plant incident. However, fiscal measures are effective against harmful rumors, and 1 year after the disaster, production levels in these

industries had recovered to within 5% of pre-quake levels. Four years after the quake, however, production fell by 25%.

We also see contrasting patterns of recovery in the automotive and electronics equipment industries. Production after the quake dropped sharply in both industries by about the same amount. We can see from Fig. 2.3, which plots the automotive

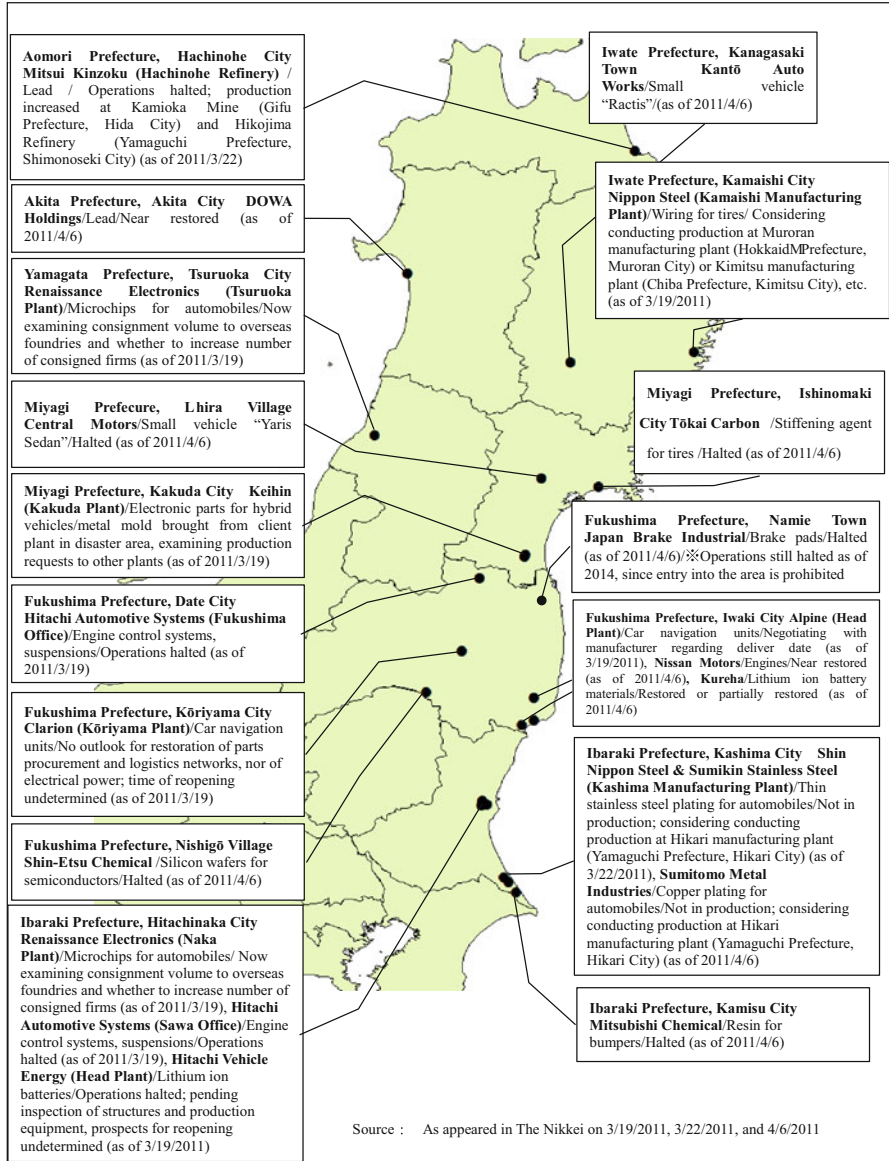


Fig. 2.3 Damaged plants for assembly and parts/components related to automobiles/electrical (Source: As appeared in The Nikkei on 2011/03/19, 2011/3/22, and 2011/4/6)

and electronics industries in the afflicted areas, how damaged factories were concentrated in the coastal area of the four affected prefectures where these industries were clustered. By contrast, damaged manufacturers of raw materials and parts were spread across a broad region, so supply shortages limited production at assembly firms. In particular, damage to the Naka plant of Renesas Electronics, which holds a 40% global share in microcontrollers, halted production of special-order microcontrollers, forcing automotive manufacturers, such as Toyota Motors and Honda, to reduce or stop production.<sup>2</sup> These supply chain interruptions in the affected areas caused automotive production in other geographic areas to fall even more. Three months after the quake, the automotive supply chain interruptions were being resolved, and with the help of eco-car subsidies, production recovered faster than in other industries. In the electronics industry, which suffered from the high value of the yen at that time, production in both affected and other areas was down by double digits, both 6 months and 4 years after the quake.

Let us now consider the earthquake's damage to non-manufacturing industries and how they subsequently recovered. Table 2.2 shows the recovery from the tsunami and the earthquake in the agriculture and fisheries industries. Although a budget of 509 billion yen has been allocated to date to support these two industries, with the exception of Ibaraki Prefecture, a clear disparity in the degree of recovery exists between affected prefectures. The table shows that even 2 years after the earthquake and the tsunami, recovery from damage to farmlands in Fukushima Prefecture was 15.2%, a full 20 percentage points behind the recovery in Iwate Prefecture, the second-worst performer. With regard to fisheries, 1 year after the quake, nearly half of the fishing businesses had reopened. By contrast, in Fukushima Prefecture, virtually no fisheries were open 2 years later. Because radioactive pollution was the principal factor hindering the recovery of farming and fishing production in Fukushima Prefecture, it will probably take time for these industries to recover to pre-quake levels.

The 2014 results of the "State of Agricultural and Fishery Businesses in Regions affected by the Tsunami Disaster from the Great East Japan Earthquake," published regularly by the Ministry of Agriculture, Forestry and Fisheries (MAFF) since the earthquake, show that the number of businesses that had intended to reopen but have not yet done so has shrunk, while the number of reopened businesses with turnover exceeding pre-quake levels has grown. In contrast, 40%–50% of businesses report that even after reopening, their turnover had not reached pre-quake levels.

Looking at Fig. 2.4, which uses public materials from Fukushima Prefecture, we see that production in the forestry and fisheries industries declined by 20.6% year-on-year to a production value of 185.1 billion yen in FY2011. Rice production dropped by 5% in 1 year but declined by 20% over 2 years. Fruits and vegetables also declined by 30% from the previous fiscal year. Agricultural production rose in fiscal 2012 and 2013, growing to the 200 billion-yen level, but with the national

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<sup>2</sup>See Nikkei Shimbun from March 19, 2011 and March 26, 2011.