New Frontiers in Regional Science: Asian Perspectives 52

Yoshiro Higano
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New Frontiers of Policy Evaluation in Regional Science

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New Frontiers in Regional Science: Asian Perspectives

Volume 52

This series is a constellation of works by scholars in the field of regional science and in related disciplines specifically focusing on dynamism in Asia.

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New Frontiers of Policy Evaluation in Regional Science

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Preface

The Japan Section of the Regional Science Association International (JSRSAI) was founded in 1962 and has been active ever since. In 1991, it established a new award system to recognize the outstanding research achievements of its members and has been awarding the Encouragement Prize and the Best Paper Award since 1992.

The awards for encouragement are given to papers published by individuals or groups of researchers under the age of 37, which are budding papers on regional science that are judged to have sufficient potential for future development.

It is stipulated that the Best Paper Award is given to research papers that can be judged to be of great significance and contribution based on outstanding research achievements that have significantly contributed to the development of regional science. The evaluation of research achievements considers a wide range of academic results, such as new concepts in regional science as a basis for knowledge creation, excellent analytical methodologies, development, and improvement of databases, measurement methods, and systems, and new survey methods.

The Encouragement Award and the Best Paper Award are given to papers published in the JSRSAI-related journals *Studies in Regional Science* and *Papers in Regional Science* during the past 3 years before the awarding year. In principle, one Encouragement Award and one Best Paper Award will be given each year.

This book consists of two parts: theoretical research and empirical research in Policy Evaluation. The theoretical research section contains eight papers (Chaps. 1–9) on international trade, development of developing countries, organizational management, land development, disaster mitigation, environmental policy, and policy of the future society. The empirical studies section contains ten papers (Chaps. 10–19) on fiscal policy, real estate policy, food system, agricultural system, road policy, disaster prevention policy, environmental policy, and urban policy for Japan and China.

We hope that this book will contribute to the study of policy evaluation.

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Part I
Theoretical Research in Policy Evaluation

Chapter 1
Trade, Capital Accumulation, and Wage Differentials: A Dynamic Model of the Comparative Advantage Theory

Masaaki Abe

Abstract The decline in local economies has become more serious in recent years, and globalization has resulted in increasing regional disparities. The reason the gap has widened so much lies in the basic principle of a market economy: companies that operate in a market economy seek to maximize profits. There is no doubt that this pursuit of profit will be the engine of economic growth, but it is also true that continuing to increase profits raises various concerns. While it is true that the production structure of global companies is very efficient, social disparities will continue to grow.

In this paper, we construct an economic development model for two regions (south and north) and three sectors (agriculture, industry 1, and industry 2). We show that due to labor constraints in industrialized regions, each region specializes in the production of different goods only by increasing wages, and present a model showing the process that achieves endogenous equal development.

Initially, even if capital accumulation in the two industries is more advanced in the north than in the south, labor supply will be short in the north, and wages will rise in that region. The competitiveness of the north declines, and in industries where capital accumulation has been relatively slow in the north, the south can also develop. As a result, each region will specialize in one industry. However, this results in a wage gap between the north and south.

Keywords International trade · Regional disparities · Capital accumulation · Wage differentials

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1.1 Introduction

The decline in local economies has become more serious in recent years, and globalization has resulted in increasing regional disparities. According to the report "Reword Work, not Wealth" by Oxfam, an international non-governmental organization, "Last year saw the biggest increase in billionaires in history, one more every 2 days. This huge increase could have ended global extreme poverty seven times over. 82% of all wealth created in the last year went to the top 1%, and nothing went to the bottom 50%" (Oxfam 2018).

The reason the gap has widened so much lies in the basic principle of a market economy: companies that operate in a market economy seek to maximize profits. There is no doubt that this pursuit of profit will be the engine of economic growth, but it is also true that continuing to increase profits raises various concerns. If market competition develops on a global scale, a handful of winners will inevitably become huge global companies, and in the growth process, countless companies will go bankrupt or become affiliated companies. While it is true that the production structure of global companies is very efficient, social disparities will continue to grow.

Krugman (1981) presented the mechanism causing the gap to widen as a dynamic model of international trade theory. Krugman describes an economic model consisting of two regions (north and south), each with two segments, agriculture and industry, with the assumption that there is free trade in industrial goods and the sectors of both countries have economies of scale. In a long-term equilibrium, the model shows that the industrial output of one segment tends to expand while the other contracts, demonstrating the unequal development in the north and south.

Several papers based on the Krugman model were published later, illustrating the potential for equal development. Dutt (1986) built a model that introduced an arrow-type learning effect instead of economies of scale where the long-term equilibrium was stable depending on the model's parameter values and the industrial sectors of both countries developed to a certain scale. However, in the main case, as in the Krugman model, the long-term equilibrium is unstable and results in unequal development of the two countries.

Kubo (1993, 1994) uses the Krugman model to show that when the industrial products produced in the two countries are different and are intermediate goods in other countries, equal development is possible. Kawano (1999) did not assume that the north and south would specialize in the production of different goods, but instead started with a concentration of capital in one area and then proceeded with technological progress in the agricultural sector; this specialization is derived endogenously.

In this paper, we construct an economic development model for two regions (south and north) and three sectors (agriculture, industry 1, and industry 2). We show that due to labor constraints in industrialized regions, each region specializes in the production of different goods only by increasing wages, and present a model showing the process that achieves endogenous equal development.

The idea of two industries is easy to understand by considering the computer industry and clothing industry. Initially, even if capital accumulation in the two industries is more advanced in the north than in the south, labor supply will be short in the north, and wages will rise in that region. The competitiveness of the north declines, and in industries where capital accumulation has been relatively slow in the north, the south can also develop. As a result, each region will specialize in one industry. However, this results in a wage gap between the north and south.

1.2 The Dynamic Model

This economic model has two regions, north (N) and south (S). Both regions have three industries, an agricultural sector and two industrial sectors that use the same technology. The agricultural sector uses a technology with constant returns to scale, with labor as the only factor of production.

The industrial sectors include both labor and capital as factors of production, using a technology with increasing returns to scale. It is assumed that the industrial goods (M^1, M^2) and agricultural products (A) are freely traded between the two regions. Therefore, the price of each good is the same in both regions. Since agricultural products are produced using only labor, units can be selected so that one unit of labor produces one unit of agricultural products. The prices of the industrial products are measured in terms of agricultural products, P^1 and P^2.

We assume that the labor force (L_{N}, L_{S}) in each region is equal at $\overline{L}$:

$$L_{\mathrm{N}} = L_{\mathrm{S}} = \overline{L} \tag{1.1}$$

The industrial sector uses labor (L) and capital (K) as production factors, and its production uses a fixed coefficient Leontief-type production function. It is assumed that the production technologies in both countries are the same, but due to economies of scale, the capital coefficient (c) and labor coefficient (v) decrease as the amount of capital increases.

Then, the coefficients given below are for the two industrial products,

$$c^i_j = c\left(K^i_j\right), \quad v^i_j = c\left(K^i_j\right) \quad (i = 1, 2 : j = N, S) \tag{1.2}$$

and satisfy the following properties for economies of scale:

$$c'(K) < 0, \quad v'(K) < 0 \tag{1.3}$$

In the initial state, we assume that the level of capital accumulation is lower than the labor force and that labor is not a constraint on the output of industrial goods.

Assuming that the two industrial products (M^1, M^2) are produced efficiently, then the outputs in both regions are determined as follows:

$$M_j^i = \frac{K_j^i}{c\left(K_j^i\right)} \quad (i = 1, 2 : j = N, S) \tag{1.4}$$

Given the output, the total labor requirement in the two industrial sectors of both regions is given by $v_N^1 M_N^1$, $v_N^2 M_N^2$ and $v_S^1 M_S^1$, $v_S^2 M_S^2$.

In the agricultural sector, one unit of labor produces one unit of agricultural product; therefore, the agricultural outputs (A) are determined as follows:

$$A_j = \overline{L} - v_j^1 M_j^1 - v_j^2 M_j^2 \quad (j = N, S) \tag{1.5}$$

In the economy formulated above, there is an upper limit to expanding production due to labor restrictions in the industrial sector. As the accumulation of capital in the industrial sector progresses, labor is absorbed into the industrial sector, but once all the labor has been absorbed, it is impossible to expand production in the industrial sector. The constraint formula for this labor force is given below:

$$v\left(K_j^1\right) \frac{K_j^1}{c\left(K_j^1\right)} + v\left(K_j^2\right) \frac{K_j^2}{c\left(K_j^2\right)} = \overline{L} \quad (j = N, S) \tag{1.6}$$

Next, the profit rate of industrial goods (ρ) is calculated. If there is no full specialization in the industrial sector, the wage rate measured for agricultural products will be one. Then, assuming that the prices of industrial goods are P^1 and P^2, the profit rate per unit of capital is given by dividing gross profit by the capital amount as follows:

$$\rho_j^i = \frac{P^i - v_j^i}{c_j^i} \quad (i = 1, 2 : j = N, S) \tag{1.7}$$

Here, since the capital coefficient (c) and labor coefficient (v) are functions of capital stock (K), Eq. (1.7) can be rewritten as follows:

$$\rho_j^i = \rho\left(P^i, K_j^i\right) \quad (i = 1, 2 : j = N, S) \tag{1.8}$$

The profit rate property is $\partial\rho/\partial P > 0$, $\partial\rho/\partial K > 0$ according to Eqs. (1.3) and (1.7). The second property is due to economies of scale.

Assume that all wage income is consumed and all profit income is saved and invested in the local area. Therefore, the capital accumulation function is as follows:

$$\frac{\dot{K}_j^i}{K_j^i} = \rho_j^i \quad (i = 1, 2 : j = N, S) \tag{1.9}$$

Since free trade is assumed for industrial goods, the price of industrial goods is determined by the balance between supply and demand. Assuming that a certain percentage of wage income (μ^1, μ^2) is allocated to the purchase of industrial goods 1 and 2 in each region, the supply-demand equation for industrial goods is as follows ($\mu^1 + \mu^2 < 1$):

$$P^i \left(M_{\mathrm{N}}^i + M_{\mathrm{S}}^i \right) = \mu^i \left(L_{\mathrm{N}} + L_{\mathrm{S}} \right) = 2\mu^i \overline{L} \quad (i = 1, 2) \tag{1.10}$$

The supply-demand equilibrium equation (1.10) for industrial goods can then be rewritten as follows:

$$P^i = \frac{2\mu^i \overline{L}}{\frac{K_{\mathrm{N}}^i}{c\left(K_{\mathrm{N}}^i\right)} + \frac{K_{\mathrm{S}}^i}{c\left(K_{\mathrm{S}}^i\right)}} = P^i \left(K_{\mathrm{N}}^i, K_{\mathrm{S}}^i \right) \quad (i = 1, 2) \tag{1.11}$$

Based on the simple differentiation and assumptions so far, the following holds for each of the industrial goods (1 and 2):

$$\frac{\partial P^i}{\partial K_j^i} < 0 \quad (i = 1, 2 : j = N, S) \tag{1.12}$$

That is, the capital accumulation in each industrial sector lowers the price of each industrial product through increased supply.

The dynamic model of two regions and two industrial goods can be summarized in the following formula:

$$\begin{aligned} \frac{\dot{K}_{\mathrm{N}}^i}{K_{\mathrm{N}}^i} &= \rho \left(P^i, K_{\mathrm{N}}^i \right) = g_{\mathrm{N}}^i \left(K_{\mathrm{N}}^i, K_{\mathrm{S}}^i \right) \\ \frac{\dot{K}_{\mathrm{S}}^i}{K_{\mathrm{S}}^i} &= \rho \left(P^i, K_{\mathrm{S}}^i \right) = g_{\mathrm{S}}^i \left(K_{\mathrm{S}}^i, K_{\mathrm{N}}^i \right) \end{aligned} \quad (i = 1, 2) \tag{1.13}$$

The following properties are derived for the functions g_{N} and g_{S}. This property is equal in industrial goods 1 and 2 due to the symmetry of the model:

$$\begin{aligned} \frac{\partial g_{\mathrm{N}}}{\partial K_{\mathrm{S}}} &= \frac{\partial \rho}{\partial P} \cdot \frac{\partial P}{\partial K_{\mathrm{S}}} < 0 \\ \frac{\partial g_{\mathrm{S}}}{\partial K_{\mathrm{N}}} &= \frac{\partial \rho}{\partial P} \cdot \frac{\partial P}{\partial K_{\mathrm{N}}} < 0 \\ \frac{\partial g_{\mathrm{N}}}{\partial K_{\mathrm{N}}} &= \frac{\partial \rho}{\partial P} \cdot \frac{\partial P}{\partial K_{\mathrm{N}}} + \frac{\partial \rho}{\partial K_{\mathrm{N}}} \\ \frac{\partial g_{\mathrm{S}}}{\partial K_{\mathrm{S}}} &= \frac{\partial \rho}{\partial P} \cdot \frac{\partial P}{\partial K_{\mathrm{S}}} + \frac{\partial \rho}{\partial K_{\mathrm{S}}} \end{aligned} \tag{1.14}$$

From these two equations, it can be seen that capital accumulation in one industrial sector lowers the price of industrial goods, thereby lowering the profit rate (capital accumulation rate) of the industrial sector in the other region. However, in the two equations below, it can be seen that capital accumulation in the local industrial sector has a direct positive effect on the rate of return arising from economies of scale, in addition to a negative effect through price. Therefore, the net effect on the profit rate (capital accumulation rate) is unknown. For the sake of simplicity, it is assumed that the absolute value of the effect of price exceeds that of the effect of scale; this assumption has no intrinsic effect on the model conclusion:

$$\frac{\partial g_j}{\partial K_j} < 0 \quad (j = N, S) \tag{1.15}$$

The long-term equilibrium of this model is given by $\dot{K}_j = 0 \ \ (j = N, S)$. This is equivalent to $g_{\mathrm{N}}(K_{\mathrm{N}}, K_{\mathrm{S}}) = 0$, $g_{\mathrm{S}}(K_{\mathrm{S}}, K_{\mathrm{N}}) = 0$. From Eqs. (1.14) and (1.15), the following properties are satisfied on the curve $g_{\mathrm{N}} = 0$:

$$\frac{\mathrm{d}K_{\mathrm{N}}}{\mathrm{d}K_{\mathrm{S}}} = -\frac{\frac{\partial g_{\mathrm{N}}}{\partial K_{\mathrm{S}}}}{\frac{\partial g_{\mathrm{N}}}{\partial K_{\mathrm{N}}}} < 0 \tag{1.16}$$

In other words, on the $K_{\mathrm{S}} \cdot K_{\mathrm{N}}$ plane, the $\dot{K}_{\mathrm{N}} = 0$ curve goes down to the right, with $\dot{K}_{\mathrm{N}} < 0$ on the right side of the curve and $\dot{K}_{\mathrm{N}} > 0$ on the left side of the curve.

On the other hand, the following properties are satisfied on the curve $g_{\mathrm{S}} = 0$. This curve also goes down to the right, with $\dot{K}_{\mathrm{S}} < 0$ on the right side of the curve and $\dot{K}_{\mathrm{S}} > 0$ on the left side of the curve:

$$\frac{\mathrm{d}K_{\mathrm{N}}}{\mathrm{d}K_{\mathrm{S}}} = -\frac{\frac{\partial g_{\mathrm{S}}}{\partial K_{\mathrm{S}}}}{\frac{\partial g_{\mathrm{S}}}{\partial K_{\mathrm{N}}}} < 0 \tag{1.17}$$

Next, the relative slope of the $\dot{K}_{\mathrm{N}} = 0$ curve ($g_{\mathrm{N}} = 0$ curve) and the $\dot{K}_{\mathrm{S}} = 0$ curve ($g_{\mathrm{S}} = 0$ curve) is confirmed.

According to Eqs. (1.14) and (1.15), which show the properties of the functions g_{N} and g_{S}, the capital accumulation in one region reduces the profit rate in both regions, but it can be seen that the rate of decline in the profit rate of its own region is smaller than in other regions because of economies of scale. Therefore, the following equation holds:

$$\left|\frac{\partial g_{\mathrm{N}}}{\partial K_{\mathrm{N}}}\right| < \left|\frac{\partial g_{\mathrm{N}}}{\partial K_{\mathrm{S}}}\right|, \quad \left|\frac{\partial g_{\mathrm{S}}}{\partial K_{\mathrm{S}}}\right| < \left|\frac{\partial g_{\mathrm{S}}}{\partial K_{\mathrm{N}}}\right| \tag{1.18}$$

According to Eqs. (1.16), (1.17), and (1.18), the slope of the $\dot{K}_{\mathrm{N}} = 0$ curve is steeper than the slope of the $\dot{K}_{\mathrm{S}} = 0$ curve. As a result, the phase diagram of this model can be drawn for industrial goods 1 and 2, as shown in Fig. 1.1:

1.3 The Growth Pathway

Using the models assembled in the previous section, we examine the long-term growth paths of industry 1 and industry 2 in both the north and south regions. When analyzing this model's long-term equilibrium, two cases may be considered. The

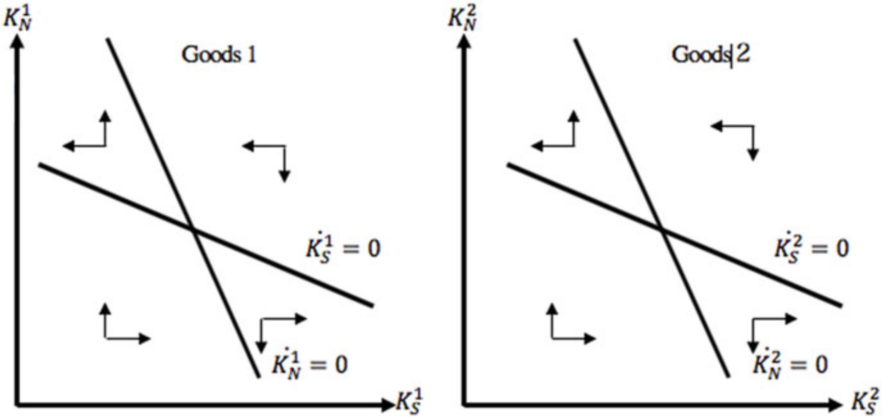

Fig. 1.1 Phase diagrams of industrial goods 1 and 2

first case is that, at the initial stage, each region has a capital stock of one industrial good superior to the other region. The second case is that, at the initial stage, one region is superior to the other region in its capital stock of both industrial goods.

Therefore, in Sect. 1.3.1, we look at Case 1 as the growth path when the north region has an industrial good 1 that is slightly superior to that of the south region, and the south region has an industrial good 2 that is somewhat superior to that in the north region. Then, in Sect. 1.3.2, as Case 2, we analyze the growth path when the capital accumulation in the north at the initial stage is slightly greater compared to that of the south in both industrial goods 1 and 2.

1.3.1 Analysis when each Region Is Superior in One Good

Here, at the initial stage, we examine the growth path when the north has an industrial good 1, which is slightly superior to that of the south, and the south has an industrial good 2, which is somewhat superior to that in the north. First, we look at the process of capital accumulation in industrial good 1 in both the north and south regions.

As shown in the phase diagram of industrial good 1 in Fig. 1.2, at the initial stage, capital accumulation in the north started at a little higher level than in the south. As the capital accumulation progressed in both regions, the difference in the levels of capital accumulation gradually widens, and in the long term, the capital of industrial good 1 will be concentrated in the north.

Next, we look at the process of capital accumulation in industrial good 2 in the north and south. Here, in the phase diagram of industrial good 2 in Fig. 1.2, the process is completely opposite that of industrial good 1, and in the long term, the capital of industrial good 2 will be concentrated in the south.

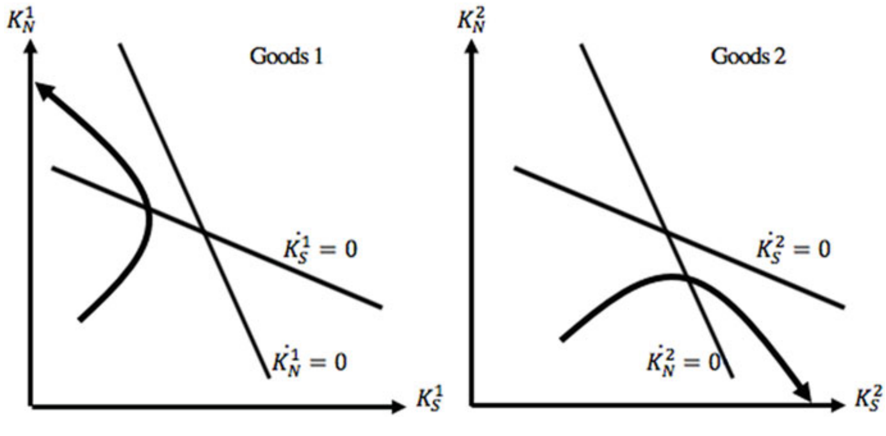

Fig. 1.2 Growth paths of industrial goods 1 and 2 (Case 1)

This case shows that unequal development occurs in each good, consistent with Krugman's analysis. In the long term, each region specializes in its own goods, and both regions develop superior goods.

1.3.2 Analysis when One Region Is Superior in both Goods

In this case, we analyze the growth path when the capital accumulation in the north at the initial stage is slightly greater than the south's in both industrial goods 1 and 2.

At first, the capital accumulation process shown in the phase diagram of good 1 shown in Fig. 1.2 in Sect. 1.3.1 occurs in both goods, and both industries develop in the north. However, when industry 1 and industry 2 continue to grow together in the north, all the labor force existing in the north will eventually be absorbed as a production factor of industrial goods 1 and 2, and no further growth will be possible due to labor constraints (Oxfam 2018).

Figure 1.3 shows this labor constraint using the production volumes of two industrial goods $\left(M_{\mathrm{N}}^1, M_{\mathrm{N}}^2\right)$ in the north.

When the north's economy is on the labor constraint line in Fig. 1.3, both industries have stopped growing because of this constraint, but profits are positive. It is assumed here that this profit cannot be used for capital accumulation and is therefore allocated to higher wages for northern workers. Let $w_{\mathrm{N}}(w_{\mathrm{N}} > 1)$ be the wage rate in the north that begins rising, and the wage rate increase is expressed by the following equation:

$$\frac{\dot{w_{\mathrm{N}}}}{w_{\mathrm{N}}} = \rho_{\mathrm{N}}^1 + \rho_{\mathrm{N}}^2 \quad \text{if} \ \ v_{\mathrm{N}}^1 M_{\mathrm{N}}^1 + v_{\mathrm{N}}^2 M_{\mathrm{N}}^2 = \overline{L} \ \ \text{and} \ \ \rho_{\mathrm{N}}^i \geq 0 \tag{1.19}$$

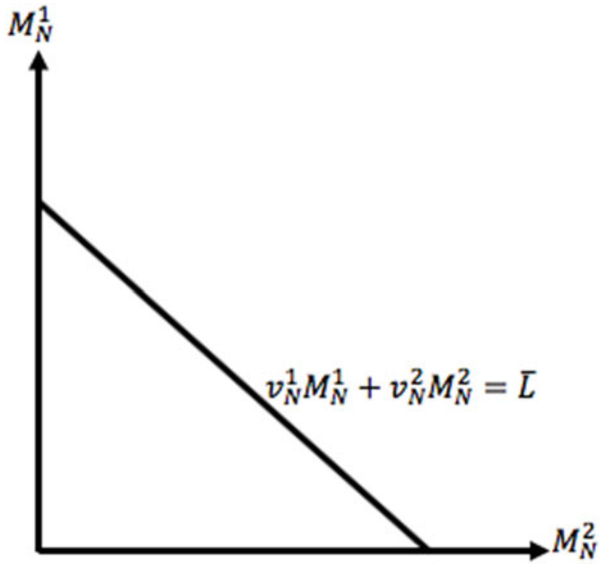

Fig. 1.3 The labor constraint line in the north

As growth is limited by labor shortages, the assumption of increasing wages to acquire workers seems realistic. However, this wage increase only occurs in the north, and the wage rate in the south remains at $w_S = 1$. Here, we do not consider the transfer of labor between regions. Due to the worsening trade terms caused by the continued increase in wages, when the profit rate of either industry becomes negative, labor shifts from industries with negative profits to industries with positive profits, and the wage increases stop.

We find the supply-demand equation and profit function after the start of the wage increase in the north. First, the supply-demand equation is as follows:

$$P^i \left(M_N^i + M_S^i\right) = \mu^i \left(w_N L_N + L_S\right) = \mu^i \left(1 + w_N\right) \overline{L} \quad (1.20)$$

The following equation is obtained by modifying Eq. (1.20):

$$P^i = \frac{\mu^i (1+w_N)\overline{L}}{M_N^i + M_S^i} \quad (1.21)$$

Here, it can be seen from a simple differentiation that an increase in the wage rate in the north will raise the prices of industrial goods 1 and 2:

$$\frac{\partial P^i}{\partial w_N} > 0 \quad (1.22)$$

Then, the north and south profit functions are as follows:

$$\rho_N^i = \frac{P^i - v_N^i w_N}{c_N^i}, \quad \rho_S^i = \frac{P^i - v_S^i}{c_S^i} \tag{1.23}$$

From the above, the profit function for industrial goods 1 and 2 in the north and south can be defined as follows:

$$\begin{aligned} &\rho_N^1 \left(P^1, K_N^1, w_N\right) = h_N^1 \left(K_N^1, K_S^1, w_N\right) \\ &\rho_S^1 \left(P^1, K_S^1\right) = h_S^1 \left(K_N^1, K_S^1, w_N\right) \\ &\rho_N^2 \left(P^2, K_N^2, w_N\right) = h_N^2 \left(K_N^2, K_S^2, w_N\right) \\ &\rho_S^2 \left(P^2, K_S^2\right) = h_S^2 \left(K_N^2, K_S^2, w_N\right) \end{aligned} \tag{1.24}$$

The properties of the functions h_N and h_S are the same as the properties of g_N and g_S shown in Eq. (1.14) for K_N and K_S, but we have the following properties for the new element w_N:

$$\begin{aligned} \frac{\partial h_N}{\partial w_N} &= \frac{\partial \rho}{\partial P}\frac{\partial P}{\partial w_N} + \frac{\partial \rho}{\partial w_N} \\ \frac{\partial h_S}{\partial w_N} &= \frac{\partial \rho}{\partial P}\frac{\partial P}{\partial w_N} > 0 \end{aligned} \tag{1.25}$$

In other words, an increase in wages in the north raises the profit rates of industries 1 and 2 in the south by raising the prices of both industrial goods. On the other hand, the effect of rising wages in the north on the north's industrial profits cannot be determined because the increase has both a positive effect (increase in prices) and a negative effect (increase in wages). However, to make the results of the analysis more certain, it is assumed, as a favorable condition for the north, that increasing wages in the north will increase the profit rate in the north. Under this assumption, we can show that one industry can be developed in the south in the long run:

$$\frac{\partial h_N}{\partial w_N} > 0 \tag{1.26}$$

From the above formulation, the phase diagram shown in Fig. 1.1 in Sect. 1.2 changes as shown in Fig. 1.4, due to the increase in wages in the north. That is, the zero-profit curve ($\dot{K}_N = 0$ curve, $\dot{K}_S = 0$ curve) moves to the upper right. However, as can be seen from Eq. (1.25), since $\partial h_N/\partial w_N < \partial h_S/\partial w_N$, the $\dot{K}_S = 0$ curve moves faster than the $\dot{K}_N = 0$ curve.

As described above, it is possible to see a growth path in the case where capital accumulation in the north at the initial stage is slightly advanced compared to the south in both industrial goods 1 and 2.

First, assuming that the capital accumulation of industrial good 1 in the north is delayed compared to industrial good 2 in the north, then the growth path of industrial good 1 is examined in Fig. 1.5.

In the first phase, the north's gap with the south will gradually increase, accumulating capital for industrial good 1 until it encounters labor constraints. Then,

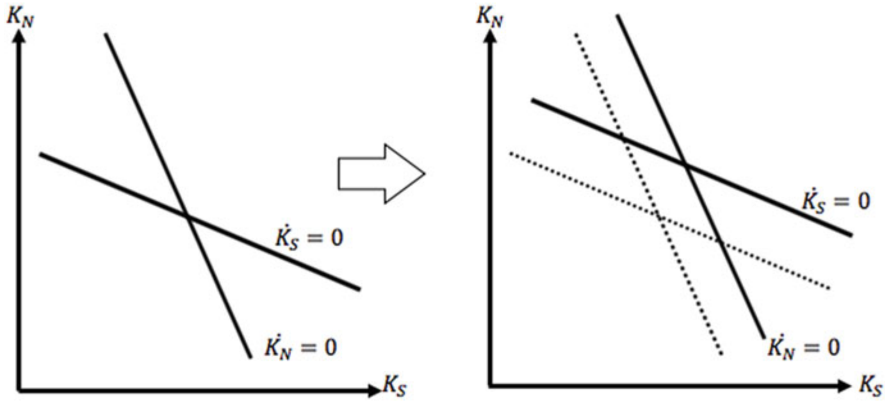

Fig. 1.4 Changes in the phase diagram due to rising wages in the north

the wage increase in the north begins, and the zero-profit curve starts to move to the upper right.

In the second phase, capital in the north will remain unchanged while capital in the south will decline as profits are negative. However, the industrial profit in the south enters positive territory, and the south begins to accumulate capital.

Then, in the third phase, as the zero-profit curve moves to the upper right, the south accumulates capital and catches up with the north's zero-profit curve. Here, the industrial profits in the north enter negative territory, the capital of industrial good 1 in the north begins to decrease, and capital accumulation in the south proceeds smoothly. In this third phase, labor is released due to a decrease in the capital accumulation of industrial good 1 in the north, and wage growth in the north will halt.

The released labor force moves to the production of industrial good 2, which was superior to industrial good 1 in the north. Then, since the wage increase has stopped, the movement of the zero-profit curve in the phase diagram also stops.

As described above, the capital accumulation of industrial good 1 that the north advanced first worsened the terms of trade in the north and improved the terms of trade in the south due to the increase in wages in the north as a result of labor constraints. Consequently, it eventually develops in the south.

On the other hand, looking at the growth path of industrial good 2, the profits were positive even in the third period, because they were superior to industrial good 1 in the north at the initial stage. The movement of the zero-profit curve also stops. Then, since labor moves from industry 1, the capital accumulation of industrial good 2 in the north resumes (Fig. 1.6).

The analysis above shows that even if the two goods preceded capital accumulation in the north compared to the south, each region would eventually grow in one good. However, even in this case, there is a difference in wages between north and south.

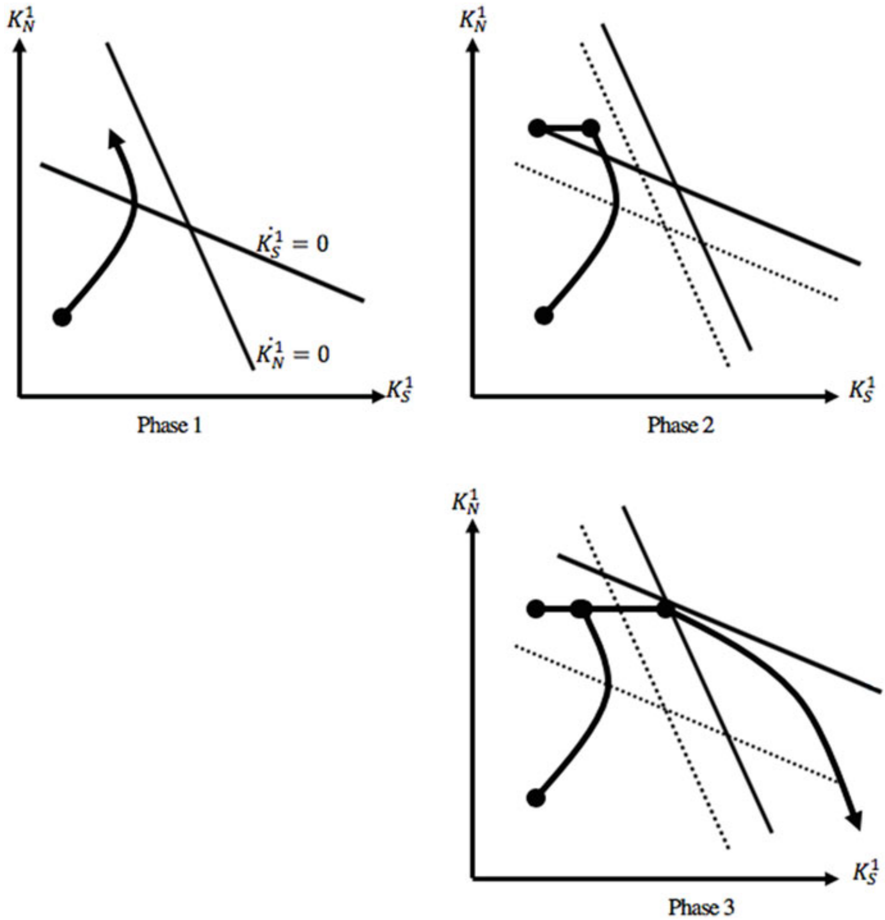

Fig. 1.5 Growth path of industrial good 1 in the north and south

Next, we find the final northern wage rate (w_N). In the third period, when the capital accumulation level is located at the intersection of the $\rho_N^1 = 0$ curve and the $\rho_S^1 = 0$ curve, wage increases in the north stop.

From Eqs. (1.21) and (1.23), the equations of the respective curves can be shown as follows:

$$\begin{aligned} \rho_N^1 = 0 \text{ curve} : \frac{\mu^1(1+w)\overline{L}}{K_N^1/c_N^1 + K_S^1/c_S^1} = v_N^1 w \\ \rho_S^1 = 0 \text{ curve} : \frac{\mu^1(1+w)\overline{L}}{K_N^1/c_N^1 + K_S^1/c_S^1} = v_S^1 \end{aligned} \quad (1.27)$$

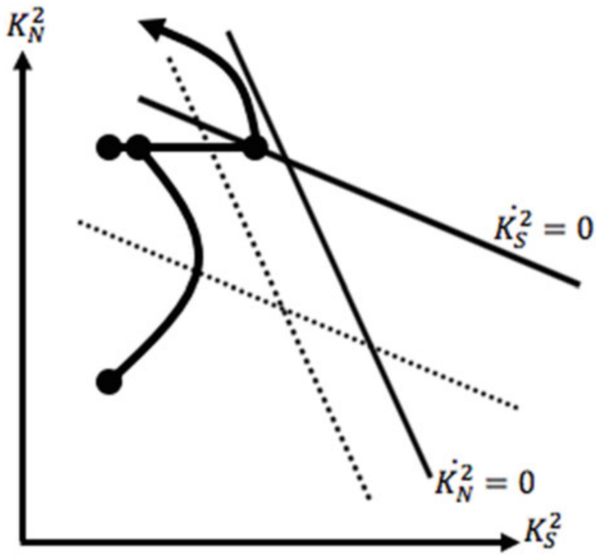

Fig. 1.6 Growth path of industrial good 2 in the north and south

From Eq. (1.27), the relative wage (w_N) is obtained as follows:

$$w_N = \frac{v(K_S^1)}{v(K_N^1)} \tag{1.28}$$

That is, the relative wage is equal to the labor productivity ratio of the two regions at the intersection of the $\rho_N^1 = 0$ curve and the $\rho_S^1 = 0$ curve in the third period.

1.4 Conclusion

In this paper, we introduce to Krugman's uneven development model between the north and south the assumption that there are two types of industrial goods and propose a model in which the north and south produce one good each and achieve equal development.

However, when at the beginning, the north accumulates capital earlier than the south in both goods, equal development was achieved in terms of capital accumulation, but there was a wage gap between north and south. This paper shows the mechanism that creates this north-south wage gap.

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Chapter 2
Ex Post Risk Management of Environmental Contamination of Municipal Water

Chisato Asahi and Kiyoko Hagihara

Abstract This chapter investigates the possibility of ex-post risk management for local governments facing the risk of tap water pollution; this is still required to deal with the difficulty of prediction and urgency, even after the ex-ante risk management method has been introduced into the tap water quality management system. In Sect. 2.1, we categorize three ex-post risk management methods. In Sect. 2.2, we analyse the efficiency of risk sharing using insurance contracts. Then, based on the implications of the analysis in Sect. 2.2, the applicability of insurance risk sharing in tap water pollution is discussed in Sect. 2.3.

By investigating the applicability of insurance by the agency theory, we showed that the subsidy-based risk sharing system is promising as an ex-post management system of water pollution risk. However, distortions in resource allocation due to the subsidy system are not negligible problems; it is necessary that a comprehensive comparison of the applicability of an ordinary private insurance system is conducted, which can better enjoy the efficiency of the market mechanism. The benefits of creating an integrated insurance system for comprehensive environmental risks including air pollution or soil pollution is discussed, which will bring benefits of risk pooling and lower insurance premium in the case that the insurance applicability fails because the water pollution risk from tap water alone has no marketability for small-sized businesses.

Keywords Tap water pollution · Risk management · Asymmetric information · Agency theory · Insurance

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This chapter is a revision of Asahi and Hagihara (2003). The affiliations of the authors at that time are as follows: Chisato ASAHI, Systems Research & Development Institute of Japan Kiyoko HAGIHARA, Center for Urban Science, Tokyo Metropolitan University

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Risk management regarding the safety of tap water in Japan is stipulated by the water supply law as follows: (1) compliance with water quality standards and implementation of water quality inspections, (2) compliance with structural and material standards of supply facilities, (3) health checkups of water purification workers, and (4) hygiene measures. The tap water quality standard had been established mainly for substances with a clear causal relationship to health damages, but the revision of the tap water quality standard in 1993 introduced the concept of risk management and subsequently built the basic system of water quality risk management (Asami 2016). In the revision, there are three features. First, with reference to the WHO Guidelines for Drinking-Water Quality (WHO 2011, version 2–3 at that time), the standards for new chemical substances were significantly updated, and guideline values based on lifetime carcinogenicity were provided. Second, both legally binding standards and targets for the standard value of lead were set, with effective, step-by-step targets, assuming that measures would take a long time. Third, the "monitoring items" section was established, and the process of monitoring new chemical substances and examining regulated substances on this basis was incorporated into the system.

Even after the introduction of such risk management methods, water quality problems have arisen, including new disinfectant by-products such as bromic acid and halogenated acetic acid, infectious diseases caused by chlorine-resistant microorganisms such as *Cryptosporidium*, and the presence of endocrine-disrupting chemicals and dioxins, in addition to trihalomethane. There are 4538 (as of 2019) water utilities in Japan, for which small-scale businesses often report health hazards due to improper disinfection methods. Additionally, in a large-scale water purification plant in the Tone River, there was an incident when water supply was cut off from 870,000 people because of the collection of aldehyde precursors (Asami et al. 2013). To deal with such situations, the Ministry of Health, Labour and Welfare established the provision of "Chemicals Difficult to Treat by Water Purification" in 2015. Other developments have also taken place, such as the proposal of quantitative analysis of microbial risk based on risk scenarios and integrated evaluation methods for microbial risk and chemical substance risk.

These water pollution issues have the characteristics of a typical environmental risk in that the unexpected and sudden damage is remarkable because the contamination occurs within a system with various interconnected factors. Local governments, such as the municipalities and prefectures that supply drinking water for domestic use as public water supply organizations, may therefore face risk-based decision-making challenges in supplying good quality tap water.

Risk management methods can be categorized as "ex ante" and "ex post." Ex ante methods are measures that address the cause of the damage before it occurs, while ex post methods are measures against the post-condition after the damage occurs. When the current water quality risk management methods are organized from an ex ante and ex post perspective, risk prevention is implemented in advance by public capital investment, such as through water purification treatment and a management system based on water quality standards. Subsequent allocations, such as compensation for damages by subsidies from the prefectural general account budget and subsidies for preventive investments made by water utilities, are also stipulated. If the cause of the damage can be attributed to a specific firm or water supplier, the ex post allocation is determined by the liability detailed in the lawsuit.

Chlorine-resistant pathogenic microorganisms, such as *Cryptosporidium* and other substances that are difficult to treat by water purification, occur intermittently, and chlorine disinfection is ineffective. This is a serious problem in water quality management, and simply applying ex ante risk management measures leads to the inevitability of water quality accidents.

In ex post methods, if the risk of contamination is intermittent or difficult to identify, then the system of allocating responsibility requires strict proof of the causal relationship, which increases transaction costs. Public subsidies from general accounts may sacrifice the efficiency of the burden and allocation in favor of compensation and preventive investment, and this can hinder people's risk reduction incentives.

Given that the current nature of such water pollution risks increases inefficiencies of current liability and public compensation schemes, it is worth considering a third approach to ex post management: insurance systems. The insurance system is expected to help lower transaction costs and improve risk reduction incentives through a premium price mechanism and eventually help achieve social efficiency. Viscusi (1992) pointed out that if ex post allocation can be used to incentivize preventive investment in advance, the functions of the ex ante method and the ex post method are mutually complementary. Previous research on risk sharing and resource allocation in ex post risk management include Sandler's (1993) work that analyses the functions of risk sharing through financial transfers and public goods, and Corne and Silva's (2000) study that analyses the system of interregional insurance and regional public goods in the federal system that extended the economic growth risks of EU countries. Lockwood (1999) discusses uncertainties about the demands, costs, and income of local public goods in terms of optimal subsidies and local public goods when there is information asymmetry between the central government and multiple local governments. Regarding environmental risk sharing, Konya (2001) focuses on the uncertainty of environmental issues and agricultural production and discusses the efficient design of agricultural mutual aid.

Based on the context discussed above, the purpose of this study is to examine the ex post risk management method for local governments facing risks related to water pollution to address the public investment cost of risk when supplying tap water. In Sect. 2.1, we categorize three ex post risk management methods. In Sect. 2.2, we analyze the efficiency of risk sharing using insurance contracts. Then, based on the implications of the analysis in Sect. 2.2, the applicability of insurance risk sharing in tap water pollution is discussed in Sect. 2.3.

2.1 Ex Post Risk Management Method

2.1.1 Institutional Types of Ex Post Management

The activities of households and businesses have various inherent risks such as loss of life, health, and property. If prior management of these risks is not effective, the ex post damage will be significant, thus impairing the financial stability of households and businesses. There is also the possibility of impairing basic survival and living ability, as well as affecting economic activities. Freeman et al. (2001) categorize ex post risk management schemes for transferring or sharing such risks to another party into three types: government benefit schemes, tort liability schemes, and insurance.

1. Government Benefit System

   The government benefit system refers to a public subsidy system in which the government provides compensation to lost households and businesses. Social insurance, unemployment insurance, long-term care insurance, national treasury subsidies, and local allocation tax grants (with the last two flexibly operating against disasters, etc.) are all categorized in this scheme. When looking at the subsidy system in terms of risk sharing, the notable feature is the emphasis on the fairness of burden rather than efficiency. In other words, it provides equal benefits to all beneficiaries at the same cost without discriminating against the financial position of the beneficiaries. The main source of funding for these subsidies is taxes.
2. The Tort Liability System

   The tort liability system is a mechanism for forcibly transferring risks from one entity to another by clarifying their responsibility. Thus, a person who has suffered a loss can use it to seek compensation through the judicial system from those who are responsible for the risk that caused the loss. The system deals with ex post risks to health, safety, and property based on regulations; the product liability law and the pollution and health damage compensation system are specifically included in it.
3. Insurance

   This is a system through which households and companies transfer the risk of damage from contracts to certain private insurance companies by paying insurance premiums. Insurance companies diversify their risks by paying future insurance benefits from the reserves that have accumulated premiums. Through this mechanism, insurance contracts can provide compensation for damage to property, disability, and loss of income. The insurance system covers a wide range of individual risks, such as life insurance, fire insurance, and liability insurance. For the insurance system to work, two conditions are required: insurability and marketability. Insurability is when risks that insurance companies are targeting can be priced properly as insurance premiums, which accurately reflect the risk attributes. To do so, it is necessary to be able to grasp risks quantitatively based on frequency and loss size (i.e., specify risks) and to set premiums according to the risk characteristics of the potentially insured persons (i.e., separate risks). Whether the risk can be specified quantitatively depends largely on scientific knowledge about the risk events. If the event that poses the risk is not scientifically elucidated, the frequency and magnitude of the loss cannot be determined, and neither can the premium be set. The marketability of insurance means that there is sufficient demand for supply prices offered by insurance companies. Insurance demand arises when the potentially insured person is risk averse and liability to a third party for compensation occurs. On the supply side, it is necessary that the risk can be quantified, the expected loss can be estimated, and the transaction cost for risk classification is not excessive.

2.1.2 Benefits and Limitations of the Ex Post Risk Management System

The main benefits and limitations of each of the three types of the risk management system are the efficiency between allocating benefits and the burden of funding and the size of the transaction costs required to determine insurance benefits. Efficiency between burden and allocation is achieved by a combination of the price and allocation such that there is a match between the willingness to pay (risk premium), in which the risk-averse individual maximizes utility, and the marginal cost of the risk-neutral insurance provider. To achieve efficiency, quantitative information and segregation of risks are indispensable. If the information is incomplete, the price deviates from the efficient level because of adverse selection or moral hazard. Here, the transaction cost represents the cost required to determine the burden and allocation (i.e., the cost required for collecting information, administrative procedures, litigation, etc.).

The three systems are characterized in terms of efficiency and transaction costs. Although the subsidy system is inefficient in terms of burden and allocation, it is characterized by low transaction costs. That is, since the funding is sourced through the tax system, the risk can be shared broadly at low cost. In addition, the transaction costs for decision-making are small because a certain amount of resources has already been secured for the benefits. On the other hand, because the burden and benefits do not always match the degree of risk exposure, the insured entity does not have the incentive to reduce the risk; hence, the price mechanism does not work well for efficient resource allocation.

The tort liability system using the judiciary system, in contrast to the subsidy system, has a high transaction cost; however, it is easier to achieve efficiency between burden and benefits. Since the system emphasizes the polluter pays principle, if the responsibility is verified, the benefits will be funded by the cause and then paid according to the exposure. However, the efficiency achieved here does not depend on the price mechanism, but rather on bilateral trading. In addition, since the burden of compensation is high when the party that is liable for causing the risk is accused, the risk reduction incentives also work to a certain extent. However, it is likely that this will increase the financial and time-related transaction costs, collection of information, and litigation that will make the responsible party and the victim correspond directly with each other.

Risk diversification utilizing a private insurance system lies between the two, the subsidy system and the tort liability system, and is a system that can enjoy the efficiency between burdens and benefits, as well as low transaction costs. In other words, the source of the benefits is from the insured who intend to share the loss, and the insurance policyholder who bears them receives the benefits so that efficiency by the price mechanism is achieved. Additionally, if the risks can be specified and separated, the transaction costs for determining the benefits are low. However, the efficiency and transaction costs are highly dependent on insurability and marketability. Insufficient quantitative identification and segregation of risks can lead to inefficient burdens and benefits because of adverse selection and moral hazard, or uncertainties in risk causality may result in high transaction costs. Therefore, the level of efficiency and transaction cost have a certain range. Figure 2.1 illustrates the conceptual positioning of the three systems in terms of efficiency (burden and benefit) and transaction costs.

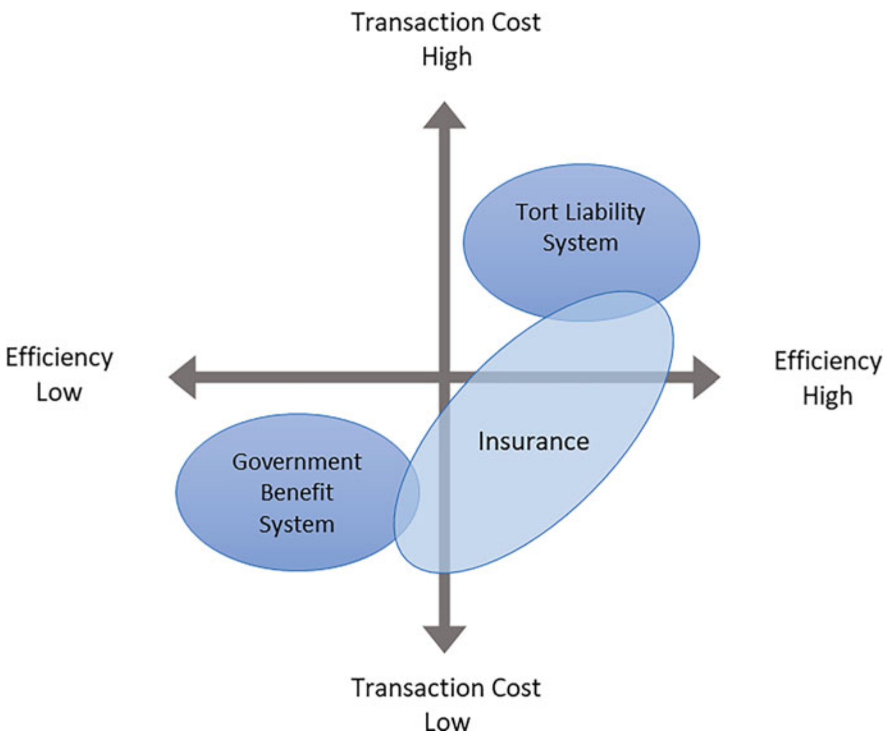

Fig. 2.1 Types of ex post management

2.1.3 Environmental Risk and Ex Post Management

In general, a specific characteristic of environmental risks is that it is often difficult to verify causal relationships because of uncertainty or unknowns because, for example, the toxicity evaluation of the substance is unknown, or because there are unknown aspects in the route to exposure. As a result, transaction costs for identifying risks increase. Therefore, the risk sharing by the tort liability system is likely to increase the legal element of the transaction cost. Comparatively, the low transaction cost of the subsidy system may offer a relatively better advantage. The transaction cost of insurance systems depends on the degree of uncertainty or unknowns. If the degree of uncertainty or unknowns is high, it is not possible to identify risks in detail and calculate the expected loss; hence, the precondition of insurance cannot be satisfied. Additionally, uncertainty increases insurance premiums, which may not satisfy the marketability condition. However, even if there is uncertainty, the provision of insurance is possible if certain risks can be identified. In such a case, the transaction cost is expected to be high in response to the degree of difficulty in identifying risks.

We compare the subsidy system and insurance, which are considered to be superior to the liability system with respect to transaction costs, from the viewpoint of the efficiency of burden and benefit. In the subsidy system, tax is a source of the subsidy money, so if the subsidy for the loss is regarded as an insurance benefit, the tax is a kind of compulsory premium. Therefore, when the distribution of subsidies (insurance benefits) is biased towards a specific taxpayer (insured), the inefficiency between burden and benefits increases. On the other hand, the insurance system is one in which the insured bears the insurance premium and is paid according to the identification of risks so that the efficiency between burden and benefits is maintained. However, if risk identification is inadequate, moral hazard and adverse selection will hinder efficient pricing. Therefore, the superiority of the subsidy system and the insurance system, in terms of efficiency, is determined by the degree of specificity of the targeted risks. When the transaction costs of risk are prohibitively high, the subsidy scheme is an efficient choice; in other words, if risks that are difficult to identify are considered noncompetitive and nonexclusive public goods because insurance cannot be provided, then efficient resource allocation is achieved by the subsidy system in which they are publicly borne as compulsory insurance. Conversely, if the transaction costs are low, the risk is regarded as an exclusive good that can be traded for ex post allocation, and applying an insurance system through which the potential insured bears the insurance premium can achieve more efficient allocation.

2.1.4 Tap Water Pollution Risk and Ex Post Management

Water pollution risk in recent years has been, on the one hand, attributed to various interrelated factors such as non-point pollution sources, sudden pathogenic bacteria such as *Cryptosporidium*, purification by-products such as trihalomethanes, and the fact that pollutants have exceeded purification limits due to the urbanization of upstream areas. On the other hand, factors linked to physical characteristics of infrastructure, such as rust colored water, have been decreasing.

In particular, this is affected by the characteristics of chlorine-resistant pathogenic microorganisms such as *Cryptosporidium*, which have become a problem in recent years, because their generation is intermittent and chlorination is ineffective. However, the detection and risk indicators of pathogenic microorganisms such as *Cryptosporidium* are not included in water quality standards that require inspection and compliance with the reference values even when the current water quality standards are revised. One of the main reasons for this is that since the *Cryptosporidium* generation is intermittent, its detection requires a very large amount (15 tonnes) of sample water, which is not practical in the current water purification management system (Health Science Council 2002). This shows the limitation of ex ante management as a measure against pathogenic microorganisms such as *Cryptosporidium*.

According to the Ministry of Health, Labour and Welfare (2000), water pollution accidents are defined as “the occurrence of water quality problems such that it falls below the water quality standards due to changes that water utilities cannot normally predict.” The definition of damage is “(1) water supply stops or is restricted, (2) water intake stops or is restriction, or (3) use of special chemicals.” (1) and (2) may be subject to compensation because they are considered social costs, while (3) is the direct cost of the water utility. Although the number of damaged enterprises in 2000 was not large (80, which was 0.5% of the total number of enterprises), 43% of the 137 accidents had unknown pollution causes. If the cause of pollution is unknown, it is impossible to ask the responsible polluters to bear the burden of the countermeasures; hence, the scale of the burden is difficult to predict.

In the case of tap water quality management, if pollution of a natural origin becomes apparent after the event, it is common for the compensation for damages to local residents and water utility’s preventive investment to be made through subsidies from the local government’s general account, which corresponds to the government benefits system and the liability system. The main focus of the problems in the current water quality management system is the intermittentness of pollution risk and the difficulty in identifying the cause. Thus, the transaction cost of the liability system that requires proof of the causal relationship will continue to increase. The government benefit system has an advantage in terms of transaction costs; however, from the perspective of improving the financial efficiency of the government sector that finances compensation, it is necessary to consider both the efficiency problem and the possibility of impairing risk reduction incentives. On the other hand, depending on the extent of the transaction costs, the insurance system, which is the third alternative of ex post management, may help improve efficiency.

Next, we discuss the risk sharing of water treatment investment by applying the concept of insurance. By referencing the standard implications of asymmetric information by agency theory, we consider the ex post-based action of water pollution risk by insurance systems.

2.2 Water Pollution Risk Sharing Model

2.2.1 Settings

It is assumed that homogeneous residents in multiple areas face water pollution risks when consuming tap water. Here, the "risk" is assumed to be water pollution risk and the occurrence of an accident, as described in Sect. 2.1.4. The water pollution level is represented by θ. The pollution level θ is a component of the state space Θ and takes values from the lowest pollution level $\underline{\theta}$ to the highest pollution level $\overline{\theta}$. It is assumed to be a stochastic variable that varies with weather conditions, regional characteristics, management, etc., which are pollution hazards and occur independently in each region. Assuming that θ takes a continuous value, the distribution function $F(\theta)$ and the density function $f(\theta)$ are expressed as follows:

$$\begin{aligned} &\theta \in \Theta, \Theta = \left[\underline{\theta}, \overline{\theta}\ \right] \\ &F\left(\theta\right) = \int \theta f(t)\mathrm{d}t,\ f\left(\theta\right) = 0,\ F\left(\theta\right) = \int \theta f\left(\theta\right)\mathrm{d}\theta = 1 \end{aligned} \tag{2.1}$$

The entity that conducts water supply business in each area is the regional government. In principle, the water supply business is stipulated by the water supply law to be operated by local governments such as municipalities and prefectures. These business entities and their local governments are similar in that they are located at the lower level of a hierarchical system in relation to administrative entities that are assumed to be providers of insurance and subsidies in ex post risk management or in relation to third-party insurance providers. Therefore, they are collectively referred to as regional governments here.

Regional governments have an obligation to implement pollution control by developing water treatment facilities. Assuming that the service level of the water treatment facility is g, the local government faces risks in determining g because the pollution level θ is a random variable. If the regional government is risk averse and there are insurance providers that are more risk neutral than the regional government, an insurance contract is assumed to be made as ex post management, which can adjust for the excess and shortage of the service after an event. Next, local residents' decision-making problems are shown. Local residents obtain utility from the consumption of private goods, c, and the service level of water treatment facilities, g. Let c be a numeraire. Here, the utility function is an additive form of $u(\cdot)$ and $v(\cdot)$ because, as described in Sect. 2.2.2, the insurance contract is described based on two rules, one for determining the service level g of the water treatment facility and the other for allocating insurance money G based on g:

$$U = U(g, \theta, c) = u(g, \theta) + v(c), \quad u_{\mathrm{g}} > 0, \quad u_{\theta} \langle 0, v_{\mathrm{c}} \rangle 0, v_{\mathrm{cc}} < 0 \tag{2.2}$$

The subscript represents partial differentiation. u is an increasing function of the service level g and a decreasing function of the pollution level θ. Local residents are risk averse, and $v(\cdot)$ is a second-order differentiable with a strict concave function. The local residents bear the cost of the service level g of the water treatment facility for pollution control. Let the income of the local residents be exogenously given as $\overline{I}$. The overlines indicate exogenous variables. The income constraint of local residents is as follows:

$$\overline{I} = c + t \tag{2.3}$$

The regional government observes the pollution level θ and determines the service level g. It is assumed that the service level g is an increasing function of the pollution level θ. Assuming that the price of water treatment facility development is p, the cost constraint of the regional government is expressed as follows:

$$t = \overline{p} g(\theta), \quad g_{\theta} > 0 \tag{2.4}$$

The utility function of local residents can be expressed as follows from income constraint and cost constraint:

$$U = u(g(\theta), \theta) + v\left(\overline{I} - \overline{p} g(\theta)\right) \tag{2.5}$$

When the contamination level θ varies, the following condition is satisfied in an optimal state from $\mathrm{d}U = 0$:

$$\frac{u_{\mathrm{g}}}{v_{\mathrm{g}}} = \overline{p} - \frac{u_{\theta}}{v_{\mathrm{g}} g_{\theta}} \tag{2.6}$$

The left-hand side shows the value of the service level of water treatment facilities as measured by the marginal rate of substitution with private goods. The value of the service level consists of the marginal rate of transformation ($=\overline{p}$) of the first term on the right side and the evaluation of the pollution level θ of the second term on the right side.

Considering that the pollution level θ is a random variable, the second term on the right side is a stochastic fluctuation factor in the valuation of the service level. There is possibly a demand for a system that shares the risk value because the local residents are assumed to be risk averse.

As a risk sharing system, we assume an insurance contract exists between a regional government and an insurance provider. For simplicity, it is assumed that the insurance provider is a public third party (including a senior government), and the regional governments are forcibly participating in insurance contracts. The regional government is responsible for the maintenance of water treatment facilities that meet the pollution level θ and receives insurance money G for the financial risk in case the service will be insufficient due to the stochastic occurrence of the pollution level θ. Insurance G is funded by mutual transfers between regional governments with different levels of θ. That is, when the level of θ is low in a region, the insurance money G is paid to another region where the level of θ is high. The insurance money G is assumed to be given while observing the service level g according to the pollution level θ and is expressed as $G = G(g(\theta))$.

2.2.2 Regional Government's Decision-Making Problem

The objective of the regional government is to maintain the water treatment facilities g to maximize the utility of local residents for a certain pollution level θ. Since the pollution level θ is known to the local residents ($\theta = \overline{\theta}$), the regional government's decision-making problem is to maximize the utility U of the representative local residents with respect to g. Here, $v(c) = v\left(\overline{I} + G\left(g\left(\overline{\theta}\right)\right) - \overline{p}g\left(\overline{\theta}\right)\right)$ because the insurance money G is distributed:

$$\max_{\mathrm{g}} U = u\left(g\left(\overline{\theta}\right), \overline{\theta}\right) + v\left(\overline{I} + G\left(g\left(\overline{\theta}\right)\right) - \overline{p}g\left(\overline{\theta}\right)\right) \tag{2.7}$$

Based on the first order condition, the valuation of water treatment investment is as follows:

$$\frac{u_{\mathrm{g}}}{v_{\mathrm{g}}} = \overline{p} - G_{\mathrm{g}} \tag{2.8}$$

Similar to Eq. (2.6), the left side shows the valuation of the water treatment facilities as measured by the marginal rate of substitution with private goods. The first term on the right side represents the marginal rate of transformation ($=\overline{p}$), and the second term represents the valuation of the additional water purification facilities in terms of insurance money. As shown in Eq. (2.6), if there is a risk sharing system, the risk valuation for the pollution level θ is expressed as the evaluation for the facility maintenance level.

2.2.3 Decision-Making Problem of Insurance Providers

Consider the choice problem of insurance providers when a regional government determines the maintenance level g, assuming the given insurance money G. When the pollution level θ occurs randomly in each region, the purpose of the insurance provider is to determine the optimal combination of insurance contracts (g_*, G_*) under the constraint where the maintenance level g of the local government is optimal (Eq. 2.8). The contamination level θ occurs according to the probability distribution function $F(\theta)$, as shown in Eq. (2.1). The insurance provider observes the pollution level θ in each region and decides the level g that the local government should improve and the allocation of the insurance money G. For example, if θ represents the concentration level of trihalomethane, the insurance provider observes it together with data such as the amount of chlorine necessary to supply purified water, the state of organic matter, and so on, in the river from which tap water is taken, and then determines the level of advanced water treatment facilities the local government should invest in and the level of insurance money. In deciding, as discussed in Sect. 2.1.1, the information on risk plays an important role as a condition of insurability and marketability for completing an insurance contract. In other words, the efficiency of the subsequent allocation based on the insurance contract differs depending on whether the insurance provider can observe the pollution level θ. Here, we present a benchmark case in which there is no information asymmetry between the regional government and the insurance provider and the pollution level θ is observable, in accordance with the standard procedure of agency theory dealing with asymmetric information. Subsequently, the case where the local government has informational advantage over the pollution level θ is discussed.

Benchmark Case

The decision-making problem of insurance providers is to maximize the local residents' expected utility EU with respect to g and G under the condition that the total amount of insurance transferred between the areas where the respective pollution levels θ occur is 0. This is expressed as follows:

$$\begin{aligned}&\max_{g,G}\mathrm{EU} = \int_{\underline{\theta}}^{\overline{\theta}} \left\{u\ (g\ (\theta)\,,\theta) + v\ \left(\overline{I} + G\ (g\ (\theta)\,,\theta) - \overline{p}g\ (\theta)\right)\right\} f\ (\theta)\,\mathrm{d}\theta \\ &\text{s.t.}\quad \int_{\underline{\theta}}^{\overline{\theta}} G\,(g\,(\theta)\,,\theta)\,f\,(\theta)\,\mathrm{d}\theta\end{aligned} \tag{2.9}$$

Solving the constrained optimization problem of expected utility yields the following conditions:

$$\lambda = v_{\mathrm{G}}\left(\overline{I} - \overline{p}g^{*}(\theta) + G^{*}(g(\theta), \theta)\right) \tag{2.10}$$

$$\frac{u_{\mathrm{g}}(g^{*}(\theta), \theta)}{v_{\mathrm{g}}(g^{*}(\theta))} = \overline{p} \tag{2.11}$$

(g^*, G^*) indicates the optimal distribution, and λ indicates the Lagrange multiplier. The marginal utility for insurance money is a constant (=λ) from Eq. (2.10), and the valuation of the water treatment facility maintenance is equal to the marginal rate of transformation (=p) from Eq. (2.11). According to the formula, it is optimal for the insurance provider to allocate a fixed amount of insurance money regardless of the pollution level θ. Since the insurance money G does not depend on the maintenance level g, the second term on the right side of Eq. (2.8) in the decision of the regional government is 0 so that Eq. (2.11) is satisfied. That is, when the insurance provider can observe the pollution level θ, the optimal resource allocation is achieved by allocating a fixed amount of insurance money independent of the pollution level θ (Table 2.1).

Asymmetric Information Case

To guarantee insurability, which is one of the conditions for establishing an insurance system, risks need to be quantitatively specified by the frequency and severity of damages. Here, our focus is on the pollution level, which is the severity

Table 2.1 Classification of Resource Allocation Status

Informational symmetricity of insurance market	Risk attitude of insurance consumer	Resident's evaluation of purification plant investment	Marginal rate of substitution of insurance premium for investment	Efficiency of resource allocation
Symmetric	Neutral/aversion	–	–	Efficient
Asymmetric	$v' = 1$ Neutral	–	–	Efficient
	$v'' < 0$ Aversion	$u_{g\theta} > 0$ For θ, measuring g is preferable or possible	$G_{g\theta} < 0$ Decreasing in θ	Inefficient
		$u_{g\theta} < 0$ For θ, measure g is not preferable or is impossible	$G_{g\theta} > 0$ Increasing in θ	Efficient

of damage, as the frequency of pollution is assumed to occur randomly. Regarding information about the pollution level θ, the regional government, which is the insurance consumer, is the observer of the pollution, and there is a possibility that the regional government has an information advantage over the insurance provider.

Since the insurance provider cannot observe the pollution level θ, the regional government will declare the pollution level θ to the insurance provider, and the provider will determine the allocation based on the claim. For example, suppose that the pollution level θ is for trihalomethane. The regional government will report a series of data on water quality (water quality of intake, chlorine input, treatment method, etc.) to the insurance provider. The obligation of reporting and the content of data to be reported shall be prescribed by the insurance contract between the two parties. The allocation based on those claims is denoted as $(\hat{g}, \hat{G})$. The insurance provider's decision-making problem is to determine the values of $(\hat{g}, \hat{G})$ that maximize the expected utility of the local residents under the declaration of pollution level θ. Here, to examine the observability of the pollution level θ, θ' is set to a level different from the pollution level θ actually faced by the local government and adds to the truth-telling condition, which is a constraint that declaring an untrue θ' is not an optimal choice. The insurance provider's decision-making problem is then expressed as follows:

$$\max_{\hat{g},\,\hat{G}} \mathrm{EU} = \int_{\underline{\theta}}^{\overline{\theta}} \left\{u\left(\hat{g}\left(\theta\right), \theta\right) + v\left(\overline{I} + \hat{G}\left(\hat{g}\left(\theta\right), \theta\right) - \overline{p}\hat{g}\left(\theta\right)\right)\right\} f\left(\theta\right) \mathrm{d}\theta' \tag{2.12}$$

$$\text{s.t.1} \quad \int_{\underline{\theta}}^{\overline{\theta}} \hat{G}\left(\hat{g}\left(\theta\right), \theta\right) f\left(\theta\right) \mathrm{d}\theta \tag{2.13}$$

$$\begin{aligned} \text{s.t.2} \quad & u\left(\hat{g}\left(\theta\right), \theta\right) + v\left(\overline{I} + \hat{G}\left(\hat{g}\left(\theta\right), \theta\right) - \overline{p}\hat{g}\left(\theta\right)\right) \\ & \geq u\left(\hat{g}\left(\theta'\right), \theta'\right) + v\left(\overline{I} + \hat{G}\left(\hat{g}\left(\theta'\right), \theta'\right) - \overline{p}\hat{g}\left(\theta'\right)\right), \quad \theta \neq \theta' \end{aligned} \tag{2.14}$$

Regarding the constraint of Eq. (2.13) on insurance money transfer, as the local residents are risk averse by assumption, the condition of Eq. (2.10) is satisfied only when the value of $G\left(g\left(\theta\right), \theta\right) - pg\left(\theta\right)$ is constant over all of the θ levels, similar to the benchmark case. In other words, the optimal allocation is obtained when the insurance provider guarantees $G\left(g\left(\theta\right), \theta\right) - pg\left(\theta\right)$ to a fixed amount regardless of the declared level of θ.

Regarding the constraint of Eq. (2.14) on the declaration, based on the assumption $G_g > 0$ and $g_\theta > 0$, there is an incentive for the regional government to report a pollution level that is more serious than the pollution level θ actually encountered. Therefore, the conditions for satisfying the fact-reporting constraint are considered. Assume θ is the pollution level the regional government is actually facing and $\theta^{'}$ is a more severe pollution level ($\theta^{'} > \theta$). The following relationship is established because the difference between the insurance money and the maintenance level of water treatment facility is a constant from the constraints of Eq. (2.13), where α is a constant:

$$\hat{G}\left(\hat{g}\left(\theta\right),\theta\right) - \overline{p}\hat{g}\left(\theta\right) = \alpha - \overline{I} \tag{2.15}$$

From the partial derivative with respect to the maintenance level $\hat{g}$, the result is:

$$\hat{G}g = \overline{p} > 0 \tag{2.16}$$

In other words, the sign of the change in insurance money due to an increase in marginal maintenance level is positive. Next, the following relationship is obtained between the pollution level θ and the distribution $(\hat{g}, \hat{G})$ by differentiating Eq. (2.16) with respect to θ:

$$\hat{G}_{\mathrm{g}}\hat{g}_{\theta} + \hat{G}_{\mathrm{g}\theta} = 0 \tag{2.17}$$

Since $\hat{G}_{\mathrm{g}} > 0, \quad g_{\theta} > 0$

$$-\hat{G}_{\mathrm{g}}\hat{g}_{\theta} = \hat{G}_{\mathrm{g}\theta} < 0 \tag{2.18}$$

This means that the marginal rate of substitution of the insurance money G for the maintenance g decreases with respect to θ. Based on the conditions stated above, the indifference curves at each state of θ for the combination (g, G) of the local government are as shown in Fig. 2.2. Since the optimal maintenance level g is

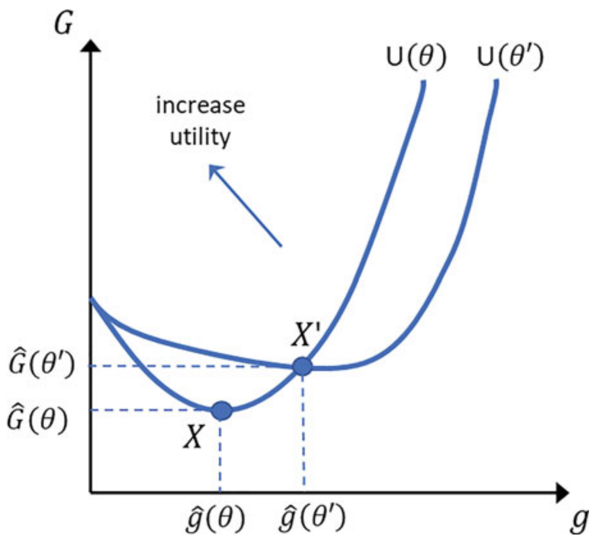

Fig. 2.2 Regional government's choice of insurance money and treatment facility level

achieved at $G_g = 0$ according to Eq. (2.11), the optimal distribution points at the maintenance levels θ and $\theta^{'}$ are X and $X^{'}$, respectively.

Next, the relationship between utility and pollution level θ is considered. Based on the condition derived from Eqs. (2.12) to (2.14), $\lambda = v_G$, and the relationship between $v(\cdot)$ and allocation is constant, so we focus on the relationship between $u(\cdot)$ and allocation. Even though $u_g > 0$ by assumption, $u_{g\theta}$ can be either positive or negative. That is, consider the case in which the marginal utility of the maintenance level g is positive, but the marginal utility due to the pollution level θ gradually increases or diminishes.

When $u_{g\theta} > 0$, if $\theta^{'} > \theta$, then $u(g(\theta^{'}), \theta) > u(g(\theta), \theta)$ holds. In the case where insurance money is distributed, $u(\theta^{'}) > u(\theta)$ in the region to the left of the intersection of $u(\theta)$ and $u(\theta')$ on the indifference curves; therefore, when the actual pollution level is θ, regional governments prefer to be at the point X' instead of the optimal point X. That is, when the insurance provider cannot observe the pollution level θ, the factual declaration condition in Eq. (2.14) does not hold; hence, the regional government declares $\theta^{'}$ and efficient allocation is not be achieved.

The condition $u_{g\theta} > 0$ that leads to inefficient allocation X' indicates that valuation with respect to the pollution level θ of the maintenance level g of the water purification treatment increases; that is, the marginal utility of the local residents also increases with the increase in the maintenance level. Therefore, if it is possible to take measures against the pollution level θ by improving the water treatment facility g, and the measures based on g are evaluated, the regional government will have the incentive to declare $\theta^{'}$, which results in the distribution level of the insurance money G being excessive and the maintenance level g also being excessive.

Conversely, when $u_{g\theta} < 0$, that is, when the valuation of the maintenance level g for the pollution level θ decreases, the marginal rate of substitution for g increases for θ of insurance money $G(G_{g\theta} > 0)$, the incentive to declare $\theta^{'}(>\theta)$ does not work, and the level of water treatment investment and insurance money will be efficient. $u_{g\theta} < 0$ indicates that the measures by the water treatment facility against the pollution level θ have not been preferred. There are cases in which pollution cannot be countered by the improvement of a water treatment facility in terms of types or levels, or private goods that can replace the water treatment facility may be preferred. In such cases, even if the pollution level θ is private information, the regional government will make an investment commensurate with the pollution level θ since the incentive to declare an excessive$\theta^{'}$ for insurance will not work.

2.3 Implications for Risk Sharing System

2.3.1 Implications of the Insurance System Applicability

Based on the model so far, we discuss the sharing system of water pollution risk from the viewpoint of the possible application of the insurance system. In a situation where efficient allocation is achieved, insurance premiums are imposed according to the probability distribution of pollution events so that the expected value of insurance money to be paid becomes zero. Therefore, even if the insurance money to be distributed is a fixed amount independent of the pollution level θ, the probability distribution of θ must be known to determine the premium. The causative substances of tap water pollution are roughly divided into chemical substances and pathogenic microorganisms according to the appropriate water quality standards.

Among the chemical pollutants, the main ones that have created problems in water quality management recently are leaching of arsenic from the soil, by-products (trihalomethane, etc.) from the water purification treatment by the rapid filtration method using chemicals such as chlorine, and measures against endocrine disruptors (environmental hormones). In the case of by-products of chemical water treatment and naturally occurring arsenic, the treatment technology has been established, so it is considered that the probability of contamination occurrence can be evaluated by accumulating the data. Therefore, it is possible to apply an insurance system for these pollution factors in combination with investment in water treatment. On the other hand, for endocrine disruptors, we do not necessarily have sufficient knowledge about the causal relationship of damage; that is, the uncertainty is too large to be able to quantify risks in detail. In such a case, the risk sharing by the insurance system does not hold.

Pollution caused by pathogenic microorganisms can be divided into fecal contamination and those caused by chlorine-resistant microorganisms such as *Cryptosporidium*, of which the contamination risk can be quantified using evaluation methods such as the United States Environmental Protection Agency's risk of microbial infection and the WHO's reference tolerance (Health Science Council 2002). Therefore, there is a possibility of applying an ex post management system such as the insurance system.

On the other hand, regarding the marketability of insurance, in the case of this model and based on the assumption of reliable insurance supply, the lack of demand may be a problem. The basic condition under which insurance demand arises is when the potentially insured is risk averse. The municipalities and prefectural governments that operate the water supply business are relatively risk averse because they have a smaller financial size than the administrative entities that are higher up in the hierarchy, and this will make them willing to pay risk premiums.

2.3.2 Implications for the Insurance System Design

To achieve efficient resource allocation through the insurance system, a quantitative understanding of risk is a necessary but not a sufficient condition. According to the model, in the case of a pollution factor for which the residents cannot take their own personal measures (i.e., when the public goods that are financed publicly are required), the insurance consumers' incentive to report excessive risk as their optimal decision results in the excessive allocation of insurance money and effort (the water treatment facility investment). This presents a dilemma—the higher the need for risk sharing by the public, the more inefficient the resource allocation.

To solve the issue of asymmetrical information, it is necessary for insurance providers who have inferior information to communicate the transaction cost risks so that insurance consumers disclose information. If those transaction costs are imposed on consumers as insurance premiums, the premiums may exceed the expected value of insurance claims, leading to unsatisfactory marketability of insurance.

The problem of transaction costs and insurance feasibility differs depending on whether the insurance provider is private or public. In the case of private insurance, if the transaction cost is high, it is directly exposed to the constraints of marketability, but profit incentives will be able to set efficient insurance premiums including transaction costs. In contrast, if a public entity (such as a higher-level government) operates insurance, there is an option to pay the transaction cost with public funds; however, the incentive to minimize transaction costs does not work.

2.3.3 No Applicability of the Insurance System

The insurance system is less applicable if the insurability is not satisfied because the risk quantification is not possible, if the transaction costs are high, and if the marketability is not met due to information asymmetry. Despite the actual risks, the lack of sharing using a price mechanism for the reasons mentioned above could be one of the major reasons for consensus on the option of sharing risks with subsidies.

Subsidies with inter-regional risk sharing functions include the national treasury subsidy, local tax allocation, and coordination with the general account. In the water supply business, the maintenance of advanced water treatment facilities and of radioactive contamination tests for the water supply source is covered in a subsidy system of the national treasury that is related to the risk of water supply pollution. As a policy aspect of subsidies related to water pollution, the Ministry of Health, Labour and Welfare's preliminary evaluation report (2002) on the subsidy project for water supply facilities shows that the subsidy system is intended for financial aid; however, from the viewpoint of pollution risk, it is the risk-sharing by subsidies that is intended.

2.4 Concluding Remarks

In this study, we investigated the possibility of ex post risk management for the risk of tap water pollution; this is still required to deal with the difficulty of prediction and urgency, even after the ex ante risk management method has been introduced into the tap water quality management system. By investigating the applicability of insurance by the agency theory, we showed that the subsidy-based risk sharing system is promising as an ex post management system of water pollution risk. However, distortions in resource allocation due to the subsidy system are not negligible problems; it is necessary that a comprehensive comparison of the applicability of an ordinary private insurance system is conducted, which can better enjoy the efficiency of the market mechanism. For example, if the insurance applicability fails because the water pollution risk from tap water alone has no marketability for small sized businesses, then creating an integrated insurance system for environmental risks such as air pollution or soil pollution will bring benefits of risk pooling and lower insurance premium. This may reduce the incentive of moral hazard due to information asymmetry. In the future, designing a more efficient risk sharing system will require considering various alternatives in terms of information symmetry and transaction costs.

As for water quality risk management in Japan, based on the *New Water Supply Vision*, the development of a “water safety plan” is in progress according to the concept advocated by WHO in 2005 (WHO 2005). Although there is improvement in scenario analysis and the integrated assessment of microbial risk and chemical substance risk that may occur in the future, they are still within the ex ante risk management framework. Ono et al. (2019) reported how the response to nonstationary risks, such as disaster risks, differs depending on the study of public programs. Regarding microbial risk in the water environment field, progress in scenario analysis is reported based on quantitative analysis. In the field of disaster risk management, the scope of application of earthquake insurance against nonstationary events is also being studied. When risk is expressed by a risk curve consisting of the probability of occurrence and the severity of an event, insurance coverage is low in the area of residual risk that falls outside the scope of the risk curve; however, it is highly applicable in the area of unexpected loss in which the probability of occurrence and degree of impact is moderate. In other words, for the insurance system to be applicable, it is necessary to quantitatively indicate the probability of occurrence of risk events and their severity. Itoh (2016) proposed a method to evaluate microbial risk and chemical substance risk in an integrated manner, with different properties using disability-adjusted life years as an index for quantifying the global disease burden. Such efforts not only enhance the effectiveness of ex ante risk management but also contribute to the accumulation of basic information for ex post risk management by expanding the scope of insurance. It is becoming increasingly necessary to have more efficient management of rising environmental risks under declining populations, and we hope that further knowledge on ex post risk management will be gathered effectively and efficiently.

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Chapter 3
Endogenizing the Reservation Value in Models of Land Development over Time and Under Uncertainty Revisited

Amitrajeet A. Batabyal and Basudeb Biswas

Abstract The notion of a *reservation value* is a key feature of most contemporary dynamic and stochastic models of land development. It is clear that the magnitude of the reservation value has a fundamental bearing on the decision to develop or preserve land. This notwithstanding, many studies that analyze land development in a dynamic and stochastic setting treat a landowner's reservation value as an exogenous variable. Therefore, the purpose of this chapter is to *endogenize* the reservation value in the context of a model of land development over time and under uncertainty. Our analysis shows that the optimal reservation value is the solution to a specific maximization problem. In addition, we also show that there exist theoretical circumstances in which the optimal reservation value is unique.

Keywords Dynamics · Endogenous reservation value · Land development · Uncertainty

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3.1 Introduction

The question of land development in an intertemporal setting has interested economists and regional scientists since Weisbrod (1964). Since then, researchers such as Markusen and Scheffman (1978), Arnott and Lewis (1979), and Capozza and Helsley (1989) have studied various aspects of the land development question in a deterministic environment. However, we now know that when the land development decision is irreversible, the use of a certainty framework will bias results about when land ought to be developed. In fact, as we have learned from the investment under uncertainty literature,[1] uncertainty will generally impart an option value to undeveloped land and delay the development of land from, say, agricultural to urban use. Therefore, if we are to really understand when land ought to be developed in the presence of an irreversibility, it is essential that we explicitly account for uncertainty.

Recently, Capozza and Helsley (1990), Batabyal (2003), Batabyal and Yoo (2003), and others have examined the question of land development over time and under uncertainty. In the context of a "first hitting time" problem,[2] Capozza and Helsley (1990) show that land ought to be converted from rural to urban use at the first instance in which the land rent exceeds the reservation rent. Batabyal (2003) first supposes that a landowner has a reservation value in mind, say \$$A$, below which he will not agree to develop his land. Batabyal then shows that this landowner's decision rule is to accept the first bid to develop land that exceeds \$$A$. Batabyal and Yoo (2003) analyze the properties of a decision rule that calls for land development as long as the dollar value of a bid exceeds a stochastic reservation level of revenue. These authors show that although the likelihood of developing land with the above decision rule is always positive, on average, a landowner who uses this decision rule will always end up preserving his land.

Newburn and Berck (2011) analyze a model of exurban development and show that the willingness to pay for exurban use from households with higher preferences for lot size may exceed an agricultural landowner's reservation price on future suburban use for a range of distances from the city boundary. This results in a "feasible zone" for exurban leapfrog development and another fundamental reason for scattered development in the urban-rural fringe. Di Corato et al. (2013) analyze the impact of uncertainty on the optimal land conversion policy and discuss land conversion dynamics under alternate policy scenarios. Specifically, these researchers demonstrate that even if the presence of uncertainty induces conversion postponement in the short run, this same uncertainty increases the average rate of deforestation and reduces the expected time for total conversion in the long run. Finally, Di Corato (2018) studies a model of rural land development under uncertainty and with hyperbolic discounting when the pertinent landowner

[1]For more on this literature, see Pindyck (1991), Dixit and Pindyck (1994), and Hubbard (1994).

[2]For additional details on this, see Dixit and Pindyck (1994, pp. 83–84) and Ross (1996, pp. 363–366).

has dynamically inconsistent preferences. In this model, rural land yields rent that is stochastic, but the net returns from land development are fixed and known. In this setting and given the dynamic inconsistency in the landowner's preferences, he shows that land development is accelerated because the landowner displays "present bias."

As this review of the theoretical literature shows, many models of land development over time and under uncertainty have utilized the notion of a reservation value. In addition, the work of Barnard and Butcher (1989), Tavernier and Li (1995), and Tavernier et al. (1996) tells us that even the empirical literature on land development has made use of the concept of a reservation value. A perusal of these theoretical and empirical papers tells us that the magnitude of a landowner's reservation value has a significant impact on the decision to develop or preserve land. This notwithstanding, in most of the papers that we have just discussed, the reservation value is exogenous to the analysis. Consequently, we use a theoretical model of land development over time and under uncertainty to *endogenize* the reservation value. Our subsequent analysis will demonstrate that a landowner's optimal reservation value is the solution to a particular maximization problem. We shall also show that there exist theoretical circumstances in which this optimal reservation value is unique.

The rest of this chapter is organized as follows. Section 3.2.1 provides a detailed description of the theoretical framework. Section 3.2.2 uses this framework to set up a maximization problem for our landowner. Section 3.2.3 shows that the optimal reservation value is the solution to the above maximization problem. Section 3.2.4 presents a numerical example and discusses the dependence of our results on the underlying assumptions. Section 3.3 concludes and offers suggestions for future research on the subject of this chapter.

3.2 Land Development over Time and Under Uncertainty

3.2.1 The Theoretical Framework

Our model is based on the discussion in Batabyal (2003), Batabyal and Yoo (2003), and Ross (2003, pp. 288–301). Consider a landowner who owns a plot of land. The decision problem faced by this owner concerns when to develop his plot of land. Consistent with the analysis in Batabyal (2003) and in Batabyal and Yoo (2003), we suppose that the development decision is indivisible. In other words, the possibility of partial development of the plot is excluded. The landowner solves his problem in a dynamic and stochastic setting. The setting is stochastic because the decision to develop depends fundamentally on the receipt of nonnegative and dollar-valued bids to develop land. Following Batabyal (2004), we suppose that these bids are received in accordance with a stationary or homogeneous Poisson process with time-independent rate $\phi > 0$.[3] The decision-making framework of our chapter is dynamic in the sense that this framework requires the landowner to decide when land ought to be developed on the basis of his observations—over time—of the Poisson bid receipt process.

To keep the subsequent analysis interesting, we suppose that each bid to develop land is the value of a continuous random variable with density function $h(b)$. Now, once a bid is received by our landowner, he must decide whether to accept it (agree to develop his land) or to reject it (preserve his land) and wait for additional bids. When our landowner decides to preserve his land, he incurs benefits and costs. The benefits arise from things like the preservation of the option to develop land later and the costs arise from things like the need to prevent encroachment and the need to maintain the plot of land under study. As such, when a decision to preserve land has been made, our landowner incurs net costs (in $) at a rate of $c > 0$ per unit time until the land is developed.

Our landowner's objective is to maximize his expected total profit where total profit equals the dollar amount received upon acceptance of a bid less the net cost incurred. Now, consistent with the approach taken in Capozza and Helsley (1990), Batabyal (2003), and Batabyal and Yoo (2003), we suppose that our landowner's reservation value is $r > 0$ and that this landowner will accept the first bid that exceeds r in dollar terms. The task before us now is to endogenously determine the optimal value of this reservation value r.

3.2.2 The Maximization Problem

To determine the optimal value of r, we shall first calculate our landowner's expected total profit when the decision rule described in the previous paragraph is used. Then we shall choose the value of r that maximizes the expression for our landowner's expected total profit.

Let $B > 0$ denote the value of an arbitrary bid and let $H^c(b)$ denote the tail distribution of this bid. In symbols, we have $H^c(b) = \text{Prob}\{B > b\} = \int_b^\infty h(w)\mathrm{d}w$. Now note that each bid will exceed the reservation value r with probability $H^c(r)$. Therefore, we can tell that these sorts of bids will be received by our landowner in accordance with a Poisson process with rate $\phi H^c(r)$. Accordingly, the time until a particular bid is accepted by our landowner is an exponentially distributed random variable with rate $\phi H^c(r)$.

[3]In addition to the literature on land development over time and under uncertainty, the Poisson process has been widely used in the natural resource economics and ecology literatures. For a more detailed corroboration of this claim, see Uhler and Bradley (1970), Pielou (1977), Arrow and Chang (1970), and Batabyal (2004). For lucid textbook accounts of the Poisson process, see Ross (1996, pp. 59–97) or Ross (2003, pp. 269–348).

Now let us denote the total profit from the decision rule that involves accepting the first bid that exceeds r by $\Pi(r)$. Then it should be clear to the reader that the expectation of this total profit is $E[\Pi(r)] = E$[accepted bid] $-$ $E[c$(time until bid accepted)]. Mathematically, the equation we get is

$$E\left[\Pi(r)\right] = E\left[B|B > r\right] - \frac{c}{\phi H^{c}(r)}. \tag{3.1}$$

The conditional expectation on the right-hand side (RHS) of Eq. (3.1) can be simplified further by using the notion of a conditional density function. This simplification yields

$$E\left[B|B > r\right] = \int_{0}^{\infty} b h_{B|B>r}(b)\mathrm{d}b = \int_{r}^{\infty} b\frac{h(b)}{H^{c}(r)}\mathrm{d}b. \tag{3.2}$$

Using Eq. (3.2), we can now rewrite our landowner's objective function, i.e., Eq. (3.1). We get

$$E\left[\Pi(r)\right] = \frac{\int_{r}^{\infty} bh(b)\mathrm{d}b - c\phi^{-1}}{H^{c}(r)}. \tag{3.3}$$

We now have our landowner's objective, i.e., expected total profit in the form in which we would like. To determine the optimal reservation value, our landowner will need to choose r to maximize the RHS of Eq. (3.3). We now turn to this task.

3.2.3 The Optimal Reservation Value

As indicated in the previous section, to compute the optimal r, our landowner solves

$$\max_{\{r\}}\left[\frac{\int_{r}^{\infty} bh(b)\mathrm{d}b - c\phi^{-1}}{H^{c}(r)}\right]. \tag{3.4}$$

Taking the derivative of the maximand in Eq. (3.4) and then setting it equal to zero gives us the first-order necessary condition for an optimum. We get

$$\int_{r}^{\infty} bh(b)\mathrm{d}b - \frac{c}{\phi} = rH^{c}(r). \tag{3.5}$$

Now using the fact that $rH^{c}(r) = r\int_{r}^{\infty} h(b)\mathrm{d}b$, we can simplify Eq. (3.5). This simplification gives

$$\int_{r}^{\infty} (b - r)\, h(b)\mathrm{d}b = \frac{c}{\phi}. \tag{3.6}$$

The landowner's optimal reservation value, $r*$, is the solution to Eq. (3.6).

Is the above solution unique? To answer this question, let us investigate this solution in somewhat greater detail. To this end, let us define k^+ to be equal to k if $k > 0$ and to be equal to 0 otherwise. With this definition in place, note that the left-hand side (LHS) of Eq. (3.6) can be written as

$$\int_r^\infty (b-r)\,h(b)\mathrm{d}b = E\left[\left(B-r\right)^+\right]. \tag{3.7}$$

Now observe that $(B-r)^+$ is a *nonincreasing* function of r. Therefore, from well-known properties of the expectation operator,[4] it follows that $E[(B-r)^+]$ is also a nonincreasing function of r. This last result tells us that the LHS of Eq. (3.6) is a *nonincreasing* function of r. Given this line of reasoning, we can now see that if $c/\phi > E[B]$, then there is *no* solution to Eq. (3.6), and it is optimal for our landowner to agree to develop his land upon receipt of any bid. In contrast, if $c/\phi \le E[B]$, then the optimal reservation value $r*$ is the *unique* solution to Eq. (3.6). The reader will note that there is nothing in our model that would suggest that the condition $c/\phi \le E[B]$ is unreasonable. Consequently, we conclude that reasonable theoretical circumstances exist in which the landowner's optimal reservation value is unique.

3.2.4 A Numerical Example

We now illustrate the working of our model with a numerical example. For the purpose of this example, we suppose that $\phi = 2,\ c = \$3$ and that the probability distribution function $h(\cdot)$ is uniform over the range from \$0 to \$100. This tells us that the tail distribution function $H^c(r) = (100-r)/100$. Substituting these values in Eq. (3.3) and then simplifying the resulting expression, we get

$$E\left[\Pi(r)\right] = \frac{9700-r^2}{200-2r}. \tag{3.8}$$

Now maximizing the RHS of Eq. (3.8) with respect to r yields a quadratic equation in r and that equation is $2r^2 - 400r + 19,400 = 0$. The solutions to this equation are $r_1^* = 117.32$ and $r_2^* = 82.68$. Hence, it is clear that in this example, the landowner's optimal reservation value is $r* = \$82.68$.

The results of the analysis of a mathematical model typically depend on the underlying assumptions employed in this model, and our chapter is no exception to this generalization. Having said this, the reader should note that two important functions in our analysis, i.e., the $h(\cdot)$ function and the $H^c(\cdot)$ function, are general.

[4] See Ross (2003, pp. 97–179).

The only specific assumption that we have employed in our analysis is to model the bid receipt process with a Poisson process. However, as indicated in footnote 3, the Poisson process has been widely used to model natural resource and related phenomena. Therefore, our results are quite general.

A question of some interest to our landowner concerns the *number* of bids that he is likely to receive in any given time interval. We can shed light on this "number of bids" question with a simple generalization of the stationary Poisson bid receipt process that we have been working with thus far in this chapter. To this end, suppose that the nonnegative and dollar-valued bids are now received in accordance with a nonstationary or nonhomogeneous Poisson process with intensity function $\phi(t)$ rather than the time-independent rate ϕ. In addition, suppose that the mean value function[5] associated with this nonstationary Poisson bid receipt process is given by

$$m(t) = t^2 + 2t, \quad t \geq 0. \tag{3.9}$$

Given this description of events, suppose that our landowner would like to know, for instance, the probability that $n \in \mathbb{N}$ bids will be received between the times $t = 4$ and $t = 5$. In this case, standard computations tell us that the probability we seek is given by $1/e^{11}\{11^n/n!\}$. So, the probability that $n = 5$ bids will be received by our landowner between the times $t = 4$ and $t = 5$ is approximately 0.02. We now conclude our discussion of the endogenization of the reservation value in the context of land development by pointing out some other ways in which the analysis in this chapter might be generalized.

3.3 Conclusions

The decision to develop or preserve land is fundamentally contingent on the magnitude of a landowner's reservation value in many contemporary models of land development over time and under uncertainty. This notwithstanding, the reservation value concept is typically an exogenous variable in present-day analyses of the land development problem. As such, we used an intertemporal and probabilistic framework to show that the reservation value can be usefully *endogenized*. We first showed that the optimal reservation value r^* is the solution to a particular maximization problem. We then pointed out that reasonable theoretical circumstances exist in which this optimal reservation value is unique.

The analysis in this chapter can be extended in a number of directions. In what follows, we suggest two possible extensions. First, the reader will note that we studied a situation in which a landowner knows that the stochastic bid receipt process is a Poisson process. As pointed out in Sect. 3.2.1, this is a routinely used

[5] See Ross (2003, pp. 316–317) for a textbook account of the mean value function of a nonstationary Poisson process.

stochastic process in the land development literature in particular and in the natural resource economics literature in general. Even so, it would be useful to see how the underlying analysis changes when the bid receipt process is described by a more general renewal process. Second, it would also be useful to determine what happens to the optimal reservation value when the net cost per unit time incurred by a landowner is not constant but varying over time. Studies that analyze these aspects of the problem will provide additional insights into the role that endogenous reservation values play in the development of land over time and under uncertainty.

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Chapter 4
Illegal Dumping of Industrial Garbage and an Optimal Tax System

Hirofumi Fukuyama and Tohru Naito

Abstract This study is intended to examine an optimal tax policy necessary to establish an efficient industrial garbage disposal system. The amount of industrial waste created by various processes of production in Japan has remained at a high level over the last several years. This, in turn, results in a shortage of disposal space, engendering frequent cases of illegal disposal. We analyze environmental policies instituted to regulate illegal disposal and establish a social optimum. As a result, we show that a subsidy policy works better than a strict monitoring policy.

Keywords Industrial waste · Illegal dumping · Tax policy · Monitoring · GIS

JEL classification H21, Q28

4.1 Introduction

In recent years, the fear has arisen in Japan of a lack or shortage of garbage incinerators owned and operated by local governments due to expected increases in the amount of industrial garbage produced. New surface-treatment locations, which are considered as the final spaces for the treatment of garbage in Japan, are predicted to overflow within 17 years if the current pace of increase in garbage generation is maintained (Minister of the Environment Japan, 2019a). The amount of industrial garbage generated is about nine times the amount discharged by households; it amounted to 384 million tons in 2017 (Minister of the Environment Japan, 2020). Although treatment services for household garbage are supplied by all local

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Table 4.1 Introduction of environmental tax by the government

Pref. (city)	Mie pref.	Akita pref.	Aomori pref.
Date	2004.4	2004.1	2004.1
Pref. (city)	C. of Kitakyushu	Iwate pref.	Okayama pref.
Date	2003.1	2004.1	2003.4

governments, industrial garbage requires treatment not by local government, but by firms specializing in its disposal, because of the complicated processes involved, which must take into account the hazards of spreading of chemical substances and various changes in manufacturing technique. The treatment of industrial garbage thus requires expert knowledge. Local governments have become unable to manage such disposal. Further, as the market for industrial garbage disposal has grown in recent years, it has become highly competitive. Some garbage haulers have an incentive to reduce treatment costs to become more competitive. For that reason, some haulers do not perform proper disposal, which involves high technology and treatment costs. Instead, they dispose of garbage illegally, dumping it into rivers or in secluded mountainous spots, to save treatment costs. According to Minister of the Environment Japan (2019b), the number of cases of illegal garbage disposal in 2018 was 155—about 0.12 times lower than the number in 1998. Moreover, the amount of abandoned garbage illegally amounted to about 157,000 t in 2018—about 0.37 times lower than the amount in 1998. This reduction was because of the Industrial Garbage-treatment Act, promulgated in 2000 and further amended in 2017; it prescribes strict punishment for garbage haulers that treat or dispose of industrial garbage illegally.

On the other hand, with the Decentralization of Power Authority Act, that came into effect in April 2000, it became possible for local governments to introduce specific-purpose taxes into the local governments' system of taxation. In line with this, some local governments have considered or introduced taxes on industrial garbage disposal because of the potentially serious impact of such waste on the environment. For instance, a regulation to tax industrial garbage was passed in the Mie prefectural assembly in June 2001. The Ministry of General Affairs has enforced it since April 2002, after assenting to it. Moreover, the Aomori, Iwate, and Akita prefectures put a similar tax into effect jointly. The introduction of such taxation is also under consideration in the Okayama and Fukuoka prefectures (See Table 4.1).

Figure 4.1 maps the amount of illegal dumping across administrative divisions in 2000, 2005, 2010, and 2015 using the Geographic Information System (GIS). Figure 4.2 maps the administrative divisions that introduced a tax on industrial garbage by 2000, 2005, 2010, and 2015. The colored administrative divisions have introduced a tax in that time. From Fig. 4.2, it can be seen that, between 2001 and 2009, many administrative divisions took up inhibition policies in the form of a tax policy. As a result, the amount of illegal dumping has been decreasing in these administrative divisions from 2000 to 2015. For example, in the Mie prefecture, which introduced the tax in 2003, the largest amounts of garbage were illegally

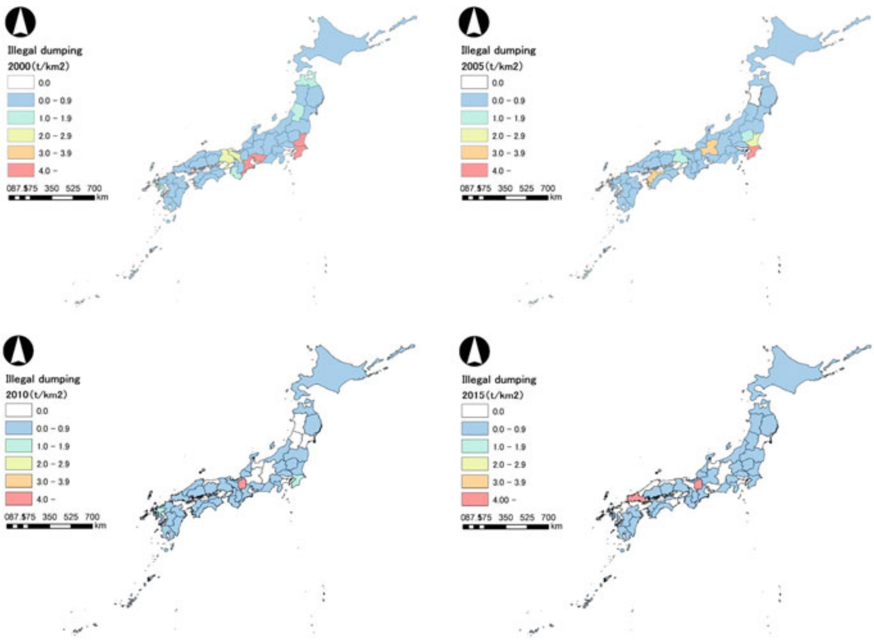

Fig. 4.1 The amount of illegal dumping across administrative divisions from 2000 to 2015

dumped before that, in 2000. However, the amount of illegal dumping has been decreasing since 2005 (See Fig. 4.1).

Generally, two methods exist for imposing an environmental tax on industrial garbage. The first involves taxing the discharger producing garbage, while the other involves taxing the firm treating the garbage: the hauler. Our consideration of the garbage tax focuses only on taxation of the discharger and not the hauler. An industrial garbage tax is introduced for the purpose of dealing with the increasing cost of reclamation by the lack of reclaimed land, inhibition of inflow of industrial garbage from other regions, and the promotion of its recycling. This tax revenue allays the operating costs of any environmental policy and monitoring efforts.[1]

Numerous studies have specifically addressed topics related to garbage disposal. Fullerton and Kinnaman (1995) and Fullerton and Wu (1998) analyze a general equilibrium model that includes the cycle of goods from consumption to abandonment. Dinan (1993) and Walls and Palmer (2001) specifically address this cyclical model, including disposal and recycling of consumption goods, from the point of view of producer accounts. These studies have analyzed the disposal process of garbage in detail by taking account of the material balance of the disposal and recycling of garbage. Notwithstanding this, these studies do not take account of

[1] See Yamaya (2002) for a detailed explanation of proper and illegal disposal of industrial garbage.

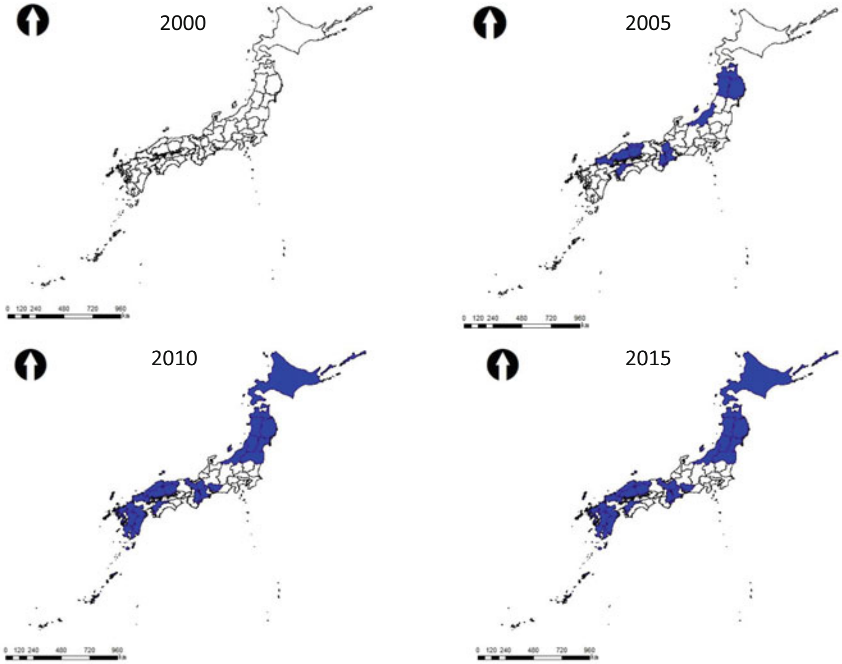

Fig. 4.2 Administrative divisions where a tax on industrial garbage has been introduced between 2000 and 2015

illegal abandonment of garbage. On the other hand, Choe and Fraser (1999) consider the possibility of illegal abandonment as a way to treat the waste disposal problem. However, households yield the garbage in their model, and they do not discuss the recycling and treatment of garbage yielded in the production sector. As we have observed, the greatest amounts of garbage are discharged from industry. Moreover, illegal abandonment or the difficult and complicated disposal of industrial garbage has become an object of public concern.

We consider two types of policies aimed at constructing an efficient disposal system for industrial garbage. The first is an optimal monitoring policy to restrain illegal abandonment by haulers using low technology. Under this policy, the government imposes an industrial garbage tax on dischargers and uses this revenue to pay for the costs of monitoring. The other is a subsidy policy in which the government provides a subsidy to haulers who treat industrial garbage legally. In this case, the government uses the tax revenue to provide this subsidy. The remainder of this paper is organized as follows. The next section presents the basic model and explains the behavior of each player. Section 4.3 deals with the socially optimal equilibrium and the equilibrium under each policy. The final section concludes this paper.

4.2 The Model

The economy in our model comprises dischargers, haulers, landfill operators, and government. First, we consider the behavior of each agent under a single-region model.

4.2.1 Dischargers

In our model, there are m homogeneous dischargers that produce industrial garbage in a single region. They discharge a certain amount of industrial garbage, W, as a result of their economic activities.[2] Therefore, the total amount of garbage discharged by the dischargers is given as mW. Now, we assume that W is constant and positive. The dischargers must undertake the recycling of garbage according to a certain fixed ratio or commission; the haulers process the garbage according to the "Expansion producer responsibility Law. " Let r represent the recycling ratio that exists, ranging from zero to one. The amount of garbage recycled by each discharger is given as rW. The amount of garbage that the discharger commissions the haulers to treat is given as $(1-r)W$. When the dischargers themselves recycle the garbage they produce, according to the recycling ratio r, they must pay the recycling expense. We define this cost as $C(rW) = a(rW)^2/2$, where the parameter a denotes that the marginal recycling cost is positive. On the other hand, the dischargers commission the haulers to treat the garbage that is not recycled by them. The haulers are obliged to treat this garbage by receiving the disposal price p. Here, the government collects the industrial garbage tax of τ per unit of garbage from the dischargers. Consequently, the dischargers are obliged to pay $p + \tau$ for the treatment of each unit of garbage. Therefore, each discharger faces the following cost minimization problem:

$$\min_{r} \quad C(rW) + (1 - r)W(p + \tau). \tag{4.1}$$

The discharger determines the optimal recycling ratio of garbage r^*, where the marginal cost of recycling it is equal to the marginal commission cost of garbage; that is,

$$r^* = \frac{p + \tau}{aW}. \tag{4.2}$$

[2] Because we focus on the stream of garbage disposal, we do not examine the aspects of production or consumption of goods.

Moreover, introducing the optimal recycling ratio r^* into $(1-r)W$, we can derive the optimal amount of non-recycled garbage as follows:

$$(1-r^*)W = W - \frac{p+\tau}{a}. \tag{4.3}$$

4.2.2 Haulers and Landfill Operators

Based on the dischargers' commission, haulers choose whether they treat industrial garbage properly or illegally. Illegal disposal is defined as illegal abandonment of garbage by a hauler. We first consider a case in which the haulers treat the garbage commissioned by dischargers properly. Its disposal costs firms α per unit of garbage. However, each hauler incurs different costs for its treatment. We assume that the cost ranges from zero to $\overline{\alpha}$ and that $\alpha \in (0, \overline{\alpha}]$, where this distribution of α is uniform with density one. As a result, we can denote the number of haulers by $\overline{\alpha}$. Moreover, we assume that each hauler can treat only one unit of garbage and $mW < \overline{\alpha}$ is about the amount of garbage. This assumption implies that the total amount of garbage produced in a region mW is not larger than the amount of garbage that all haulers can treat.[3]

Moreover, all economic agents know the distribution of α, though the treatment cost of garbage is each hauler's private information. Each hauler who treats one unit of garbage properly commissions the landfill operators to reclaim it at its place of final disposal by paying q.

Let d represent the marginal cost of reclaiming the garbage treated by haulers properly: it is constant and positive. We assume that the reclamation market has perfect competition and that there are numerous landfill operators. Consequently, we can express a profit function of landfill operators, π_r, as

$$\pi_r = (q-d)X, \tag{4.4}$$

where X is the total amount of garbage dealt with in the reclamation market. Because we assume that this market has perfect competition, we can derive the reclamation price q, which is equal to the marginal cost of reclamation d. The hauler receives the garbage from the dischargers with p, treats it properly, and commissions the landfill operators to reclaim it at the final place of disposal by paying $q = d$. When the hauler treats it properly, the profit function of haulers is as follows:

$$\pi_t = p - (\alpha + d). \tag{4.5}$$

[3]The treatment cost parameter α differs among the haulers. As we assumed before, α satisfies $\alpha \in (0, \bar{\alpha}]$. This setting regarding the cost parameter implies that a technical gap exists among haulers because of the recent rapid growth of the industrial garbage treatment market.

Next, we consider the case in which some haulers have an incentive to abandon the garbage illegally. Any hauler who has to pay a relatively high treatment cost has an incentive not to treat the garbage properly, but to abandon it illegally. Let v $(0 < v < 1)$ and F represent the probability that illegal abandonment will be revealed by reports of residents, and the penalty for illegal abandonment, respectively.[4] The expected profit of the hauler abandoning garbage is

$$(1 - v)p + v(p - F) = p - vF. \tag{4.6}$$

A hauler with cost α selects a method of treating garbage that yields a higher profit after comparing $p - (\alpha + d)$ with $p - vF$.[5] As shown in Fig. 4.1, the treatment method selected by haulers depends on the treatment cost α, the probability that illegal abandonment will be discovered, the price of reclamation services, and the penalty for illegal abandonment. In other words, even though an increase of v or F engenders the decrease of illegal abandonment, this decreases as the price of reclamation services increases. We describe the behavior of haulers with cost α in Fig. 4.1. As shown in Fig. 4.1, if α is $0 < \alpha \leq vF - d$, the hauler has an incentive to treat his garbage properly. On the other hand, if it is $vF - d < \alpha \leq \bar{\alpha}$, the hauler has an incentive to abandon the garbage illegally.

Finally, having examined the behavior of dischargers, haulers, and landfill operators, we present a chart of industrial garbage flow in Fig. 4.1.

4.2.3 Tax Expenditure

We have described the behavior of dischargers, haulers, and landfill operators. Next, we discuss tax expenditures by the local government. The local government imposes an industrial garbage tax on dischargers who commission haulers to carry out the disposal of their non-recycled garbage. On the other hand, no hauler has an incentive to treat garbage properly, and is likely to abandon garbage illegally in mountains or rivers if p is low and $q(= d)$ is high. If any hauler abandons garbage illegally, it may cause serious damage to the environment of that region. Consequently, the local government uses tax revenues to prevent illegal abandonment. The government might use the tax revenue to fund either a strict monitoring policy or a subsidy policy. A strict monitoring policy entails strong government surveillance to prevent illegal abandonment. In contrast, with a subsidy policy, the government gives haulers a subsidy for proper disposal, which thereby provides an incentive for proper disposal by haulers. We analyze the effects of those environmental policies on social welfare in subsequent sections.

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[4]This F is an upper limit. For this setting, our model depends on Becker (1968). He maintains, in that study, that a person who disobeys the law should be punished with the maximum penalty.

[5]When $p - (\alpha + d)$ is equal to $p - vF$, we assume that the hauler selects proper disposal.

Local government determines the tax ratio and the environmental policy according to which the tax revenue is utilized to minimize the social cost, which is defined by the sum of costs for disposal and reclamation of garbage and the value of environmental damage.

4.3 Optimal Tax Rate in the Single-Region Model

We consider a model covering a single region and compare the situation under each policy with the social optimum. Because we consider a single-region model here, there is no movement of garbage between regions. Comparing the situation under each policy with the social optimum, we analyze the optimal tax rate under each policy.

4.3.1 Social Optimum

First, we must consider the socially optimal recycling rate and the number of haulers as a benchmark. Before analyzing these variables, we must set in the following assumption: The cost of environmental damage created by illegal abandonment is higher than the sum of costs of proper disposal and reclamation by the most inefficient hauler; that is, $D > \overline{\alpha}$, where D and α are the damage to the environment and the treatment cost of the hauler, respectively. That assumption means that proper disposal costs with the most inefficient haulers are lower than the social cost incurred as a result of haulers with α carrying out illegal abandonment. In such a case, it is desirable for society to never abandon garbage illegally, but to always treat it properly. Figure 4.2 represents this assumption graphically. Therefore, the socially optimal solution is derived by minimizing the social cost incurred by the combination of recycling, treatment, and reclamation costs of garbage, where the marginal social cost to proper disposal is equal to the marginal recycling cost, as in Fig. 4.3. Consequently, this minimization problem can be expressed as follows:

$$
\begin{aligned}
\min_{r}\ SC &\equiv mC(rW) + \int_0^{m(1-r)W} (\alpha + d)d\alpha \\
&= m\frac{a}{2}(rW)^2 + \frac{1}{2}(m(1-r)W)^2 + m(1-r)Wd \\
& s.t. \quad 0 \leq r \leq 1.
\end{aligned} \tag{4.7}
$$

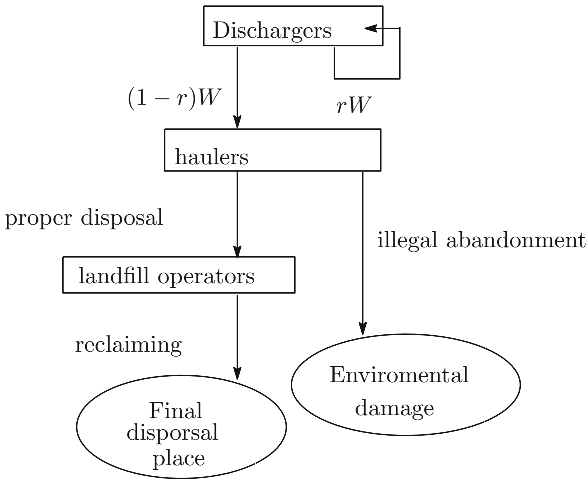


Fig. 4.3 The industrial garbage flow

For simplification, we normalize the number of dischargers m. Solving the minimization problem without constraint, we can derive the optimal recycling rate as follows:

$$r^{FB} = \frac{d + W}{aW + W}. \tag{4.8}$$

Here, we assume that the other is $d < C^{'}(W) = aW$. This assumption dictates that the marginal recycling cost of garbage W is higher than the sum of the costs of proper treatment and garbage reclamation. In other words, it is desirable for society to commission haulers to treat a part of the garbage rather than for all garbage to be recycled by a discharger. Setting in this assumption, we can consider only an interior solution of the recycling rate in terms of a social optimum. This is an interior solution because this solution is satisfied with assumption 3 ($0 < r^{FB} < 1$). We do not consider a solution in which the recycling rate is derived as a corner solution, that is $r = 1$. Supposing that r is one, no garbage exists in the market. Therefore, we exclude such a case. The optimal amount of treated garbage X^{FB} can be derived as follows (Fig. 4.4):

$$X^{FB} = (1 - r^{FB})W = \frac{aW - d}{a + 1}. \tag{4.9}$$

We know that the hauler with α in $(0, \frac{aW-d}{a+1})$ treats garbage properly in society. Having derived these optimal solutions, we can compare them with the equilibria achieved in other situations.

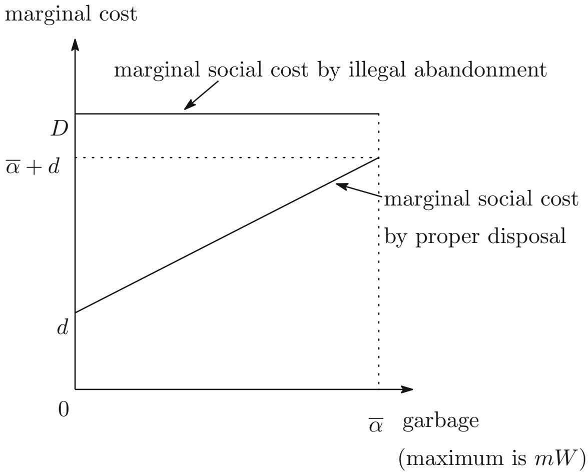


Fig. 4.4 Proper disposal and illegal abandonment

4.3.2 Equilibrium Without a Tax Policy

We consider the recycling rate and the amount of treated garbage to be in equilibrium when the trade of garbage between dischargers and haulers is carried out in the garbage market. First, we discuss the case without garbage taxation by the local government and assume that this garbage market is in perfect competition here. Dischargers determine the recycling rate r^* to minimize the sum of the recycling cost and commission cost under any given disposal price p. This r^* is derived from (1) and $\tau = 0$; that is,

$$r^* = \frac{p}{aW}. \tag{4.10}$$

The amount of garbage $S(p)$ that the discharger commissions the haulers to treat is given as

$$S(p) = (1 - r^*)W = W - \frac{p}{a}. \tag{4.11}$$

If‘ the garbage disposal price p is positive, each hauler purchases one unit of garbage in the garbage market. The hauler's profit over the treatment cost α can be expressed as follows:

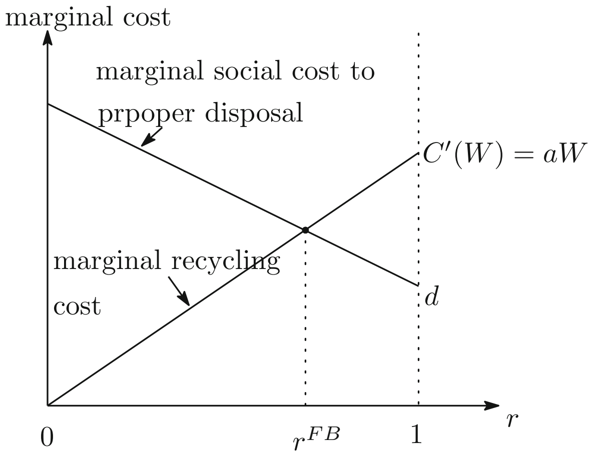
- If the hauler treats it properly, the profit is

$$p - (\alpha + d).$$

- If the hauler treats it illegally, the profit is

$$p - vF.$$

Fig. 4.5 First-best solution



This hauler supplies one unit-demand of garbage, if any is positive within the gain of these cases. The hauler with α decides whether the hauler treats garbage properly or not under the change of garbage disposal price, as given. Point A in Fig. 4.5 is the price and the amount of traded garbage at equilibrium at the garbage market, where the supply is equal to demand in the garbage market. Haulers with cost $\alpha \in (0, vF - d)$ treat garbage properly at equilibrium. On the other hand, a hauler with cost $\alpha \in (vF - d, W - \frac{vF}{a})$ abandons garbage illegally at equilibrium. If the equilibrium disposal price is given as $p = vF$, the recycling rate at equilibrium is

$$r^* = \frac{vF}{aW}. \tag{4.12}$$

Consequently, we can derive the following proposition:

Proposition 1 *The equilibrium under the case in which the local government does not impose a tax on firms is characterized as follows:*

- *Haulers with cost* $\alpha \in (vF - d, W - \frac{vF}{a})$ *dump garbage illegally at equilibrium.*
- *The equilibrium recycling rate is lower than the optimal recycling rate,*

$$r^* < r^{FB}.$$

As a result, if the expected penalty for illegal abandonment vF is sufficiently low under the situation without any environmental policy instituted by the local government, the haulers have an incentive to abandon garbage illegally.[6] Next, we consider the case in which the local government uses tax revenue to monitor haulers' behavior.

4.3.3 Strict Monitoring Policy

The local government can choose between either a strict monitoring or a subsidy policy as the means to prohibit illegal abandonment. Here, strict monitoring means monitoring with a higher probability of discovery of illegal dumping, strengthened by revenue from the industrial garbage tax. After selecting the policy, the local government uses revenue raised from taxation imposed on the dischargers. Haulers pay this tax to the government after receiving both p and τ from dischargers. Let T and $\beta(T)$ represent the total tax revenue and the probability of discovering the illegal abandonment, respectively. $\beta(T)$ is an increasing function with respect to T; that is, $d\beta/dT > 0$. This fact means that the government can monitor illegal abandonment more strictly because the expenditure for it is larger. Needless to say, we cannot deny the possibility of discovering illegal abandonment of garbage through reports by residents. Therefore, we assume that the probability of discovering illegal dumping of garbage is denoted by $\beta(0) = v$ when the government does not carry out monitoring. If the government discovers illegal abandonment, it punishes illegal firms with a penalty, F. If we assume that the hauler can perform illegal abandonment without cost, we can express their expected profit as

$$\beta(T)(p - F) + (1 - \beta(T))p = p - \beta(T)F, \tag{4.13}$$

where $\beta(T)F$ means an expected penalty that the haulers face when they abandon garbage illegally. Here we define $\beta(T)F$ as $M(T)$. However, if tax revenue is zero, we assume that their expected penalty is v, where $\beta(0)F = vF = M(0)$. So, we can express the expected profit in the following way when they carry out illegal dumping of garbage:

$$p - M(T). \tag{4.14}$$

Haulers compare their profit under proper disposal to the expected profit under illegal abandonment and choose the behavior through which they can earn a higher profit. When the total tax revenue T of some industrial garbage tax is added, we can

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[6]We assume vF to satisfy the condition that $vF < \frac{a(W+d)}{a+1}$. No hauler deals with garbage under a situation without a tax policy when the assumption in footnote 7 does not hold. That is, there is no α holding for $\alpha \in [vF - d, W - \frac{vF}{a}]$. We consider the case in which it is possible to have haulers with an incentive to dump garbage illegally under the situation without any policy; we name a parameter to satisfy this assumption. Furthermore, we discuss the deterrent effect of a strict monitoring policy on illegal abandonment using industrial garbage tax revenue.

express in the following way the processing cost of the hauler where the profit under proper disposal is indifferent to the expected profit under illegal abandonment:

$$\begin{cases} \alpha \leq \alpha^* = M(T) - d \Rightarrow \textit{the proper disposal.} \\ \alpha > \alpha^* = M(T) - d \Rightarrow \textit{illegal dumping.} \end{cases}$$

Because α^* is a function of total tax revenue T, we can set the level of α^* by choosing T. Total tax revenue T depends both on the total amount of garbage commissioned by dischargers and the tax rate per unit of garbage τ. We can derive the total tax revenue T as a function with respect to τ.

$$T(\tau) = \tau(1 - r^*)W = \tau\left(W - \frac{p + \tau}{a}\right). \tag{4.15}$$

We can then consider how the change in industrial garbage tax affects the haulers' behavior. Taking account of the expected penalty, $M(T)$, which is an increasing function with respect to total tax revenue T, we can show the relation between the expected penalty and the rate of tax per unit of industrial garbage in Fig. 4.7. If the rate of industrial garbage tax is relatively low, the effect of raising this rate on the total tax revenue increase is superior to the effect of raising the recycling rate by increasing the tax on the total tax revenue decrease. The increase of τ raises the expected penalty by the increase of total tax revenue. On the other hand, if the rate of industrial garbage tax is relatively high, the effect of raising τ on the total tax revenue increase is not superior to the effect of decreasing tax revenue. In this case, the increase of τ decreases the total tax revenue and the expected penalty.[7] We consider the optimal rate of industrial garbage tax based on the above-mentioned arguments.

We can now consider the case in which the local government chooses a strict monitoring policy. The cost of policy performance is covered by the industrial garbage tax revenue. The probability of discovering illegal dumping is proportional to the amount of money spent on monitoring. Therefore, the expected penalty is an increasing function with respect to this amount of money. This section presents the analysis of the effect of adopting a strict monitoring policy on the behavior of dischargers and haulers and the equilibrium in the garbage market.

As discussed above, the discharger determines the recycling rate to minimize the sum of the recycling cost and the commissioning cost of garbage under the commission price p and industrial garbage tax τ, as given. Therefore, we can derive the supply function of garbage in the market as follows:

$$S(p, \tau) = W - \frac{p + \tau}{a}.$$

[7] If the elasticity of the garbage disposal function $W - \frac{p+\tau}{a}$ with respect to τ is greater than one, the expected penalty M is the decreasing function with respect to τ. Otherwise, if that elasticity is lesser than one, the increase of τ raises the expected penalty.

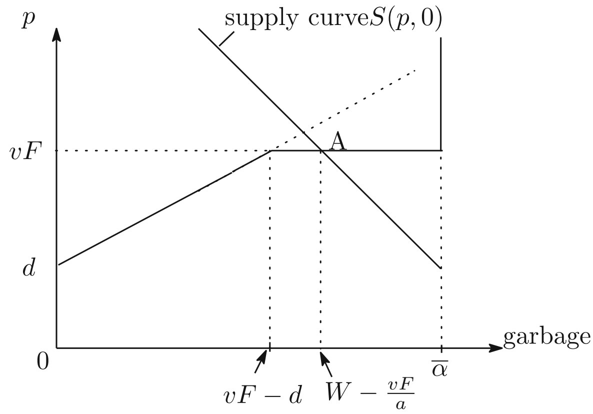

Fig. 4.6 The equilibrium under an absence of policy

The hauler determines his own behavior under p and τ, as given. We should remember that his behavior involves either proper disposal or illegal abandonment of garbage. Therefore, we can express the profit of the hauler that selects either proper disposal or illegal abandonment by (3) or (4). The hauler's behavior is described in Fig. 4.6. The supply function of garbage $S(p, \tau)$ is a decreasing function with respect to p. If the industrial garbage tax rate τ goes up, this supply function shifts down. On the other hand, the demand function of garbage forms a refracting function. If τ is relatively low, the increase of τ make this demand function shift upward. This upward shift implies that the number of haulers that treat garbage properly goes up because of the increase of τ. If τ is relatively high, the increase of τ makes the function shift downward, meaning that the number of haulers that treat garbage properly goes down because of the increase of τ. We can thus infer the industrial garbage tax rate τ that inhibits haulers from abandoning garbage illegally. This is the case in which the total number of proper haulers is larger than the supply at $M(T(\tau))$ and τ is satisfied with the following condition:

$$M(T(\tau)) - d \geq W - \frac{M(T(\tau)) + \tau}{a}, \tag{4.16}$$

where τ satisfying this condition exists within $[\tau^*, \tau^{**}]$ in the following Fig. 4.7. The recycling rate and traded garbage at equilibrium under an industrial garbage tax τ to restrain illegal abandonment by haulers are as follows:

$$r^m = \frac{d + W + \tau}{aW + W} \tag{4.17}$$

$$x^m = \frac{aW - d - \tau}{a + 1}. \tag{4.18}$$

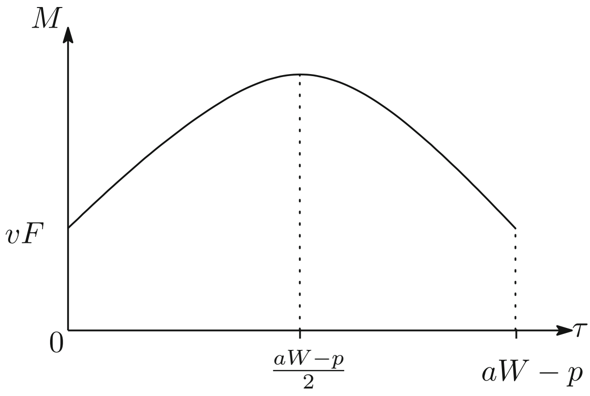

Fig. 4.7 Expected penalty function

Comparing these equilibrium solutions with the socially optimal solutions r^{FB}, x^{FB}, the relation between them is $r^m > r^{FB}, x^m < x^{FB}$. In other words, the equilibrium recycling rate under the strict monitoring policy is greater than the socially optimal recycling rate. Moreover, the amount of treated garbage in equilibrium is smaller than the socially optimal amount. The difference in the rate and amount of treated garbage between the equilibrium solution and socially optimal solution are $\frac{\tau}{aW+W}$ and $\frac{\tau}{a+1}$, respectively. Therefore, the industrial garbage tax rate τ under the restrictive monitoring policy should be as small as possible in order to agree with both solutions. So, we can derive the following proposition because the tax rate τ exists within $[\tau^*, \tau^{**}]$ in Fig. 4.7:[8]

Proposition 2 *If the local government uses the revenue from the industrial garbage tax to reinforce stricter monitoring,*

- *The industrial garbage tax to deter illegal dumping by haulers is within* $[\tau^*, \tau^{**}]$ *where the optimal industrial garbage rate is described by* τ^*.
- *The equilibrium recycling rate is larger than the socially optimal recycling rate, that is,*

$$r^m > r^{FB}.$$

[8]Because Fig. 4.7 describes inequality (16), proposition 2 holds only in the case in which the point of intersection in Fig. 4.7 exists. As the reviewer pointing out, it is not necessary that the point of intersection in Fig. 4.8 exists to an arbitrary extent. If it is supposed that there is no point of intersection in Fig. 4.7, that is, inequality (16) is not satisfied, illegal abandonment will always take place under every tax rate. Thus, Proposition 2 holds only in the case in which the shape of the expected penalty function M has the point of intersection in Fig. 4.7.

4.3.4 Subsidy Policy

We next address the case in which the local government uses revenue from an industrial garbage tax to provide a subsidy to haulers who treat their garbage properly. This subsidy gives haulers an incentive to treat their garbage properly. For that reason, this subsidy policy has a similar effect to the strict monitoring policy. In other words, the subsidy policy encourages haulers to treat their garbage properly, while the strict monitoring policy prohibits them from abandoning garbage illegally. In this section, we consider the effect of subsidy policy on the behavior of haulers and discuss whether or not this policy establishes social optimality. The method to provide haulers with subsidy is as follows. To begin with, landfill operators pay the amount to the haulers that is deducted from subsidy. Moreover, landfill operators receive the total amount of subsidy from the local government by declaring the amount of garbage that they take charge of.[9] The behavior of dischargers under the subsidy policy is similar to that under the strict monitoring policy. Therefore, we can express the amount of garbage that dischargers supply in the garbage market as $S(p, \tau)$. Haulers can receive subsidy s from the local government if they treat their garbage properly. Hence, the profit of a hauler with cost α is

$$p - (\alpha + d) + s.$$

Because the revenue from the industrial garbage tax is used for this subsidy, the level of monitoring is not strengthened. For that reason, the expected profit that the haulers earn is $M(0) = vF$. We can express the expected profit of haulers if they abandon their garbage illegally as:

$$p - vF.$$

In Fig. 4.8, the increase in industrial garbage tax τ shifts the demand curve downward. On the other hand, the increase in subsidy s shifts it upward. As shown in Fig. 4.8, the combination of industrial waste tax and subsidy to deter illegal abandonment of waste (τ, s) is as follows:[10]

$$vF - d + s \geq W - \frac{vF + \tau}{a}. \tag{4.19}$$

[9]Because the government pays out subsidy to the landfill operators, it cannot identify which haulers treat garbage properly. We assume that landfill operators do not falsify reports about the garbage.

[10]Here, the total number of haulers that treat garbage properly is larger than the total amount of garbage supplied at price $p = vF$.

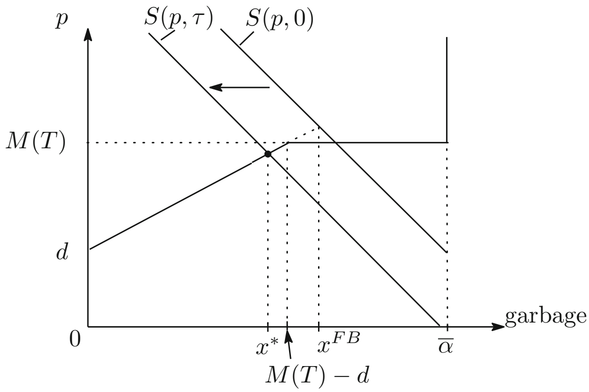

Fig. 4.8 Strict monitoring policy

Dischargers must determine the recycling rate of their garbage under the government's environmental policy as given. Consequently, the recycling rate under the subsidy policy is

$$r^S = \frac{d + W + \tau - s}{aW + W},$$

which depends on the tax rate τ and subsidy s. Because the socially optimal recycling rate r^{FB} must be equal to the equilibrium recycling rate r^s under the subsidy policy, the following equation is satisfied:

$$r^{FB} = \frac{d + W}{aW + W} = r^S = \frac{d + W + \tau - s}{aW + W}. \tag{4.20}$$

The industrial waste tax and subsidy to establish the socially optimal recycling rate are satisfied at

$$\tau = s. \tag{4.21}$$

The socially optimal amount of treated garbage is equal to the equilibrium amount of treated garbage under the subsidy policy. No illegal dumping exists at equilibrium, and the revenue from the industrial garbage tax is equal to the total amount of subsidy in this situation ($\tau = s$). For those reasons, the budget constraint of local government is satisfied by the balance of tax revenue and tax expenditure. Therefore, we can derive the following proposition:

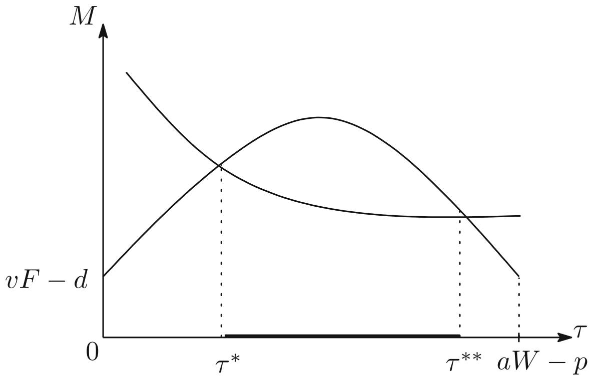

Fig. 4.9 Tax rate to deter illegal abandonment

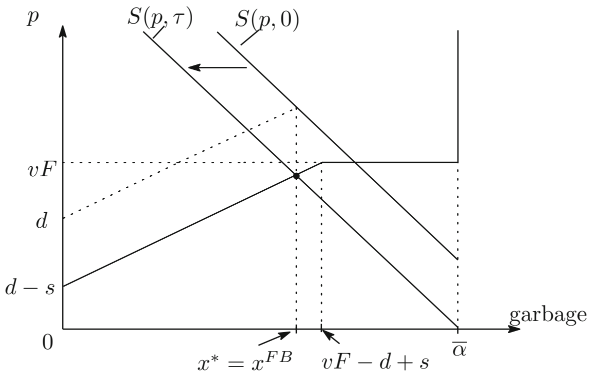

Fig. 4.10 Subsidy policy

Proposition 3 *When the local government uses revenue from an industrial garbage tax as a subsidy for haulers that treat garbage properly, and τ and s are satisfied by the following equation, the subsidy policy can establish a socially optimal recycling rate r^{FB}.*

$$\tau = s \geq \frac{a(W+d) - vF(a+1)}{a+1}.$$

Comparing the subsidy policy to a strict monitoring policy, we can derive the following corollary (Figs. 4.9 and 4.10).

Corollary 1 *Rather than a strict monitoring policy, it is desirable to use revenue from an industrial garbage tax for a subsidy policy.*

4.4 Concluding Remarks

We constructed a model that explicitly describes the disposal stream of industrial garbage. We analyzed the ratio of industrial garbage tax and the use of revenue from it to construct an efficient industrial garbage disposal system. When the local government uses tax revenue for a strict monitoring policy, it must impose a larger tax on dischargers to deter illegal abandonment by haulers and cover the cost of carrying out this policy. Therefore, a strict monitoring policy cannot engender a socially optimal recycling rate (Proposition 2). On the other hand, when the local government adopts a subsidy policy, imposing the tax creates income transfer from the dischargers to the haulers. Because this subsidy policy does not distort the garbage market, the subsidy policy can lead to a socially optimal recycling rate (Proposition 3).

We have neglected the analysis of some questions in this paper. Although only haulers are punished in the discovery of illegal abandonment, dischargers are required to reconfirm whether the haulers have treated the commissioned garbage properly. Consequently, we must also take account of their responsibility for illegal abandonment. It is also important to include this factor into our model. Next, future studies must address cases in which either the dischargers or landfill operators can abandon the garbage illegally. Moreover, it might be interesting to construct a model that includes the consumption and production of goods within this framework. Furthermore, although we considered a disposal system comprising dischargers, haulers, landfill operators, and government in our model, it is interesting to consider a system in which landfill operators treat garbage and put garbage in landfills. Comparisons of such a system with the system posited in this study might yield interesting results.

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Chapter 5
Natural Disasters, Disaster Recovery Policies, and Regional Economy

Daisuke Ikazaki

Abstract In this paper, we analyze disaster recovery policies in disaster-affected areas and their impact on regional economic activities and on migration. We first integrated the elements of natural disasters into a simple model related to agglomeration. It is assumed that agglomeration increases not only productivity but congestion costs as well. When a natural disaster occurs, it damages production factors and increases the firms' costs. At that point, productivity and income decrease in the disaster-affected area. Consequently, people move to other cities. Next, we extended the model to analyze regional loyalty. Presuming that there is little difference between living in the original home and living in other regions, people will continue to stay in their hometown because monetary gains from migration are lower than the cost (including nonmonetary costs) of moving and living in a new town. Multiple steady states exist when regional royalties are taken into consideration. Finally, we consider the case where productivity depends on public capital, which is degraded by a natural disaster. Once a population drain occurs due to migration, fiscal policies intended to recover public capital might be an overinvestment that could deteriorate the regional economy further. In that case, such policies might induce further population outflow.

Keywords Natural disaster · Disaster recovery policies · Interregional migration

5.1 Introduction

This study considers how disaster recovery policies affect household welfare, firm behavior, and the regional population in a disaster-affected area. It is often said that natural phenomena such as earthquakes are not the only causes of natural disasters. Climate change may increase the extreme weather, which also induces

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damage. For example, the Energy and Climate Intelligence Unit (2017) analyzed 59 papers published after COP 21 and focused on climate change and extreme weather. According to the Energy and Climate Intelligence Unit, 41 papers concluded that climate change has increased the risks of a given type of extreme event. If so, we can predict an increase in natural disasters, at least in the short run.

From an empirical perspective, some researchers determine that natural disasters have negative impacts on the growth rate. Natural disasters that destroy production factors and decrease productivity will have a severe and negative impact on economic growth (Benson and Clay 2000, 2004). On the other hand, some papers show that the positive effects of a natural disaster may surpass its negative impacts. For example, firms might replace and update facilities or machines (Tol and Leek 1999). Reconstruction demand might create multiplier effects (Albara-Bertrand 1993). Loayza et al. (2012) insisted that moderate disasters can have a positive growth effect in some sectors but severe disasters do not.

Although some theoretical models considered how natural disasters affect economic dynamics (e.g., see Lopez (2009) and Ikefuji and Horii (2012)), many natural disasters cause damage in relatively confined geographical areas, even if those areas seem fairly large. Many natural disasters tended to not have serious impacts on the total national economy for very long. Therefore, we specifically focused on the regional economy rather than the national economy. We discussed how natural disasters affect the output, firm behavior, regional population change, and other important variables in disaster-affected areas.

To consider regional economic activities, we used the monopolistic competition model (Dixit and Stiglitz 1977) that is broadly used in urban economics, including in new economic geography (Krugman 1991; Fujita et al. 1999, and others). The monopolistic competition model allows us to deal with increasing returns to scale in the economic model. It contributes to an explanation of the agglomeration of firms or households in particular cities or regions. We draw a basic model of monopolistic competition and agglomeration in Sect. 5.2. By using this model, we can analyze the relationship between regional population and regional income (or productivity) and how cities are formed.

Section 5.3 integrates the elements of natural disasters into the model. We assumed externalities of two types related to agglomeration. On the one hand, agglomeration increases the variety (the number of goods) that consumers can enjoy. On the other hand, some negative externalities related to congestion exist. There is only one steady state in which the regional population becomes constant over time. Natural disasters pull down production factors and, therefore, degrade productivity. The positive effects of agglomeration decrease, and people living in the disaster-affected area will move to other regions. That is, population drain occurs.

Section 5.4 extends the model in Sect. 5.3 by considering regional loyalty. Migration to other regions involves some costs. These costs reflect regional loyalties and include social capital that people have built up through daily life activities; moving costs, including psychological burdens; and so on. Damage induced by natural disasters decreases the utility of each household. However, if the utility between the household in the affected region and the utility in other regions are not so different after the disaster, people might remain in their hometown even if migration could increase their expected monetary gains. In this case, natural disasters do not cause a population drain.

Section 5.5 presents the case in which productivity depends on public capital, which will be degraded severely by a natural disaster. People living in this region may migrate to other regions after a natural disaster occurs because utility, as well as productivity, decreases as a result of a decrease in public capital. In this section, we mainly discuss the effects of fiscal policies developed to recover public capital. The results show that once migration and a population decrease occur, such fiscal policies might cause a deterioration of the regional economy. An excess supply of public capital increases the burden on the region to maintain the public capital, and this will decrease the utility of a household. If so, disaster recovery policies might encourage further population outflow.

Section 5.6 presents some examples of population dynamics and regional economic activities of affected areas after the external shock. Section 5.7 summarizes the main conclusions of this paper.

5.2 The Basic Model of Natural Disasters and the Regional Economy

In this section, we provide a framework of the model. Each household utility depends on the consumption of differentiated goods and the negative externality of congestion. Household j's utility function is defined as follows:

$$U_j = C_j - h(L) = \left(\int_0^n c_{ij}^{\xi} \mathrm{d}i \right)^{\frac{1}{\xi}} - h(L), \tag{5.1}$$

where n is the measure of a variety of differentiated goods, C_j represents the index of consumption,[1] c_{ij} denotes the consumption of ith differentiated good, and L is the population. We also assume that $0 < \xi < 1$. We focus on the regional economy and disaster-affected area discussed in the next section. In that case, L should be interpreted as a regional population. The function $h(L)$ is the negative externalities of congestion. It is assumed that $h(0) = 0$, $h'(L) > 0$, and $h''(L) > 0$. The problem of each household[2] is to maximize C_j subject to its budget constraint, which is shown as

$$\int_0^n p_i c_{ij} \mathrm{d}i = I_j,$$

[1]The subscript j denotes the household j throughout this paper. For the original setting of this type of function, see Dixit and Stiglitz (1977).

[2]Note that each household takes the value of $h(L)$ as given.

where p_i denotes the price of the ith differentiated good and I_j represents the disposable income of household j. Then we obtain

$$c_{ij} = \frac{p_i^{-\sigma}}{\left(\int_0^n p_i^{1-\sigma} \mathrm{d}i\right)^{\frac{-\sigma}{1-\sigma}}} C_j, \tag{5.2}$$

where $\sigma \equiv 1/(1-\xi) > 1$ represents the elasticity of substitution among differentiated goods.

Next, we consider the supply side of the economy. Labor is the only production factor of the differentiated goods. Each firm has to hire f units of labor for a fixed cost. Furthermore, a units of labor is needed to produce one unit of the ith good. That is.

$$L_i = f + ax_i, \tag{5.3}$$

where L_i represents the labor input required to produce x_i units of the ith good. Then, the profit function of firm i is

$$\pi_i = p_i x_i - w\ (f + ax_i)\,. \tag{5.4}$$

By using the demand function of the ith good,[3] we can show the price of the ith intermediate good as $p_i = \frac{1}{\xi} a w$, where w is the wage for workers. (Note that neither firm's behavior affects the price index of the intermediate goods market.) Without loss of generality, let us choose a unit such that $a = \xi = (\sigma - 1)/\sigma$. Thus, $p_i = w$.

Firms can enter freely into the manufacturing sector. In the equilibrium, no firm earns a strictly positive profit. The zero-profit condition implies $x_i \equiv x = f\sigma$ because $(p_i - wa)x_i - wf = 0$. The labor market clearing condition is $n(ax + f) = L$, where L is the labor supply. Here we assume that each household has one unit of labor. So, L denotes the labor supply as well as the population in this economy. The number of firms that produce differentiated good is.

$$n = L/f\sigma. \tag{5.5}$$

[3]The demand function is $C_i \equiv \int c_{ij} dj = \frac{p_i^{-\sigma}}{\left(\int_0^n p_i^{1-\sigma} di\right)^{\frac{-\sigma}{1-\sigma}}} \int C_j dj$, where C_i is the total demand of the ith good. Note that $C_i = \int c_{ij} dj = x_i$ in equilibrium.

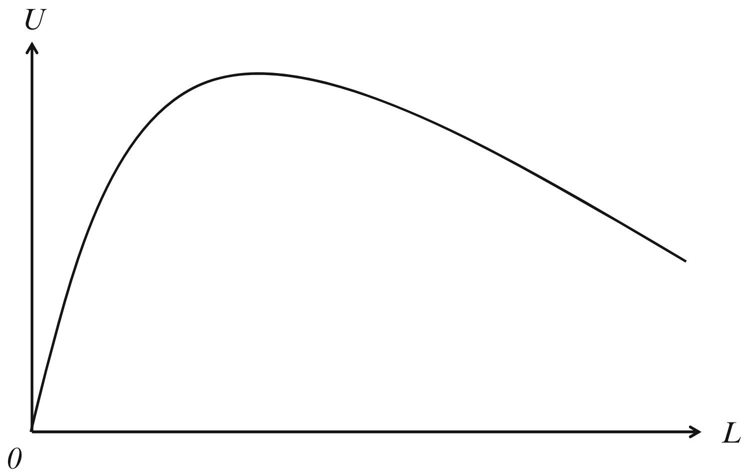

Fig. 5.1 Relationship between L and U

Then we can rewrite the index of household consumption as

$$C_j = C = \left(\frac{L}{f\sigma}\right)^{\frac{1}{\sigma-1}}. \tag{5.6}$$

We assume that $\sigma > 2$ so that $1/(\sigma - 1) < 1$. Note that C_j is positively related with a population. Each household can enjoy the benefit of a love of variety as the population increases. If we regard each differentiated good as an intermediate good and C_j as a final good, the manufacturing sector becomes more productive as the population increases because of increasing returns.

We can draw the relationship between population and the utility of each household as show in Fig. 5.1. Each household enjoys the same utility level because we assume the households are symmetrical. So, we write $U_j = U$. The positive effects of agglomeration predominate the negative externalities of congestion if L is small. The negative effects increase and exceed the positive effects of agglomeration as L becomes large. So, we can show an inverted U-shaped relationship between the population and utility of each household.

5.3 Natural Disaster and Interregional Migration

Next, we analyzed how natural disasters affect economic activities and interregional migration. We assume that the common utility level of households is established for other regions. Let U' represent that common utility level. This view is similar to the open city model. Therefore, households living in this region (later, we assume

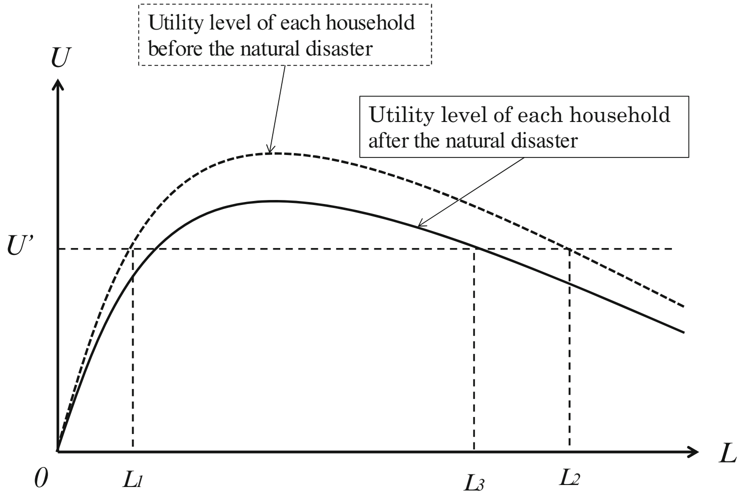

Fig. 5.2 Relationship between L and U

that the disaster hits this region) can enjoy welfare level U' if they migrate to other regions. The discussion here is similar to Ikazaki (2016). Ikazaki (2016) used a matching theory to focus on the labor market and unemployment rate in the disaster-affected areas.[4] However, we employed a monopolistic competition model based on Dixit and Stiglitz (1977) here and assumed full employment. By doing so, we can analyze the firms' entry and exit into the market.

Let us consider the situation before the natural disaster. Households in this region consider the level of U' as a given. The utility of each person is given as $U_j = U = \left(\frac{L}{f\sigma}\right)^{\frac{1}{\sigma-1}} - h(L)$. The households in other regions have an incentive to migrate to this region and the population in this region increases if $U > U'$. On the other hand, the population in this region decreases if $U < U'$. Fig. 5.2 presents how the natural disaster affects the utility level of each household.

Presuming that the population given in the initial stages is smaller than L_1 or larger than L_2, the households here have an incentive to migrate to other regions because $U < U'$. On the other hand, the households in other regions migrate to this region if $L_1 < L < L_2$. Therefore, the stable equilibria are 0 and L_2; the unstable equilibrium is L_1. Note also that this city disappears if the initial population is less than L_1.

We want to know how natural disasters affect population dynamics. It is assumed that the population level is L_2 before the natural disaster. That is, the economy is in a stable steady state. Assume that a natural disaster occurs at some date and

[4]For a matching theory, see Diamond (1982), Mortensen and Pissarides (1994), Pissarides (1985, 2000), and others.

that it has harmful effects on a firm's activities in that region. In this paper, we assume natural disasters increase the fixed cost of production, f. This assumption may be reasonable when f includes the cost to construct or maintain factories and/or production facilities and natural disasters damage some part of them. Here, we assume that f becomes sf after the natural disaster ($s > 1$). Then, we can show that

$$U^{\text{after}} = \left(\frac{L}{sf\sigma}\right)^{\frac{1}{\sigma-1}} - h(L), \tag{5.7}$$

where U^{after} is the utility level after the natural disaster. Natural disasters have negative effects on the utility level. This paper presents a specific examination of the negative effects of natural disasters because we want to evaluate the effects on the economy in affected areas rather than on the national economy.

We have assumed $L = L_2$ before the disaster. The steady state value of the regional population declines after the natural disaster (see Fig. 5.2). In this case, the consumption index of each household declines through two channels. First, the production sector becomes less productive because a fixed cost for each firm increases from f to sf. Second, a fall in the population counteracts the positive effect of agglomeration. The index of consumption becomes $\left(\frac{L_3}{sf\sigma}\right)^{\frac{1}{\sigma-1}}$ rather than $\left(\frac{L_2}{f\sigma}\right)^{\frac{1}{\sigma-1}}$ after the natural disaster, where L_2 and L_3 are given in Fig. 5.2.

In this simple setting, the natural disaster reduces the population as well as the index of consumption of each household (assuming that $L = L_2$ before the natural disaster). The population outflow continues until the level of U becomes U'. So, the economic activities shrink, population decreases, but the utility level is unchanged. This is because the population drain alleviates congestion.

Some important points should be noted. In this section, we assumed that the production function is increasing returns to scale. Therefore, the positive effects of agglomeration exist. However, this assumption is not essential to our main results if we only focus on positive and stable equilibrium. Suppose that the labor production function is diminishing returns to scale (e.g., let us consider a typical neoclassical production function). Then, there are two negative effects of agglomeration. First, per capita output will decrease as regional population increases. Second, there are negative externalities of congestion (note also that we need not assume the negative effects of congestion if we assume a typical neoclassical production function). The utility is a decreasing function of the regional population. In this case, the model has only one stable equilibrium. Suppose that a natural disaster occurs at some date and it decreases productivity. The utility curve shifts downward (the utility of each household for a given regional population will decline) and population drain occurs.

It is also important to consider firms' decision-making. Natural disasters increase the fixed cost. To cover the fixed cost, each operating firm must sell more differentiated goods. This means that employment per firm must increase after the natural disaster. Because we assume that the labor market clears, the number of firms in the disaster-affected area will decrease after the natural disaster. That is, some firms pull out of the affected area.

Finally, we should point out that we have only one steady state with a positive population in Sect. 5.3. That is, we focused on the relatively large region in which the negative externalities of congestion predominate. Our results here may be too restrictive. So, we extended this model in Sect. 5.4.

5.4 The Model of Multiple Equilibrium

In this section, we extended the model introduced in Sects. 5.2 and 5.3. Following Ikazaki (2016), we assumed that migrating to other regions involves some costs. These costs are reflected the attachment an individual has to his or her hometown, social capital that was constructed during a lifetime; moving costs, including psychological burdens; and so on. Note that these costs include nonmonetary costs. We call them costs related to regional loyalties. We express these costs as M and M'. Households in other regions have an incentive to migrate to this region if the utility level in this region is higher than $U' + M'$ (we defined U' in Sect. 5.3). The utility of each household in other regions is U'. The cost of moving to this region from the other region is M'. So, they will migrate to this region if the utility of this region exceeds the sum of "the utility in other regions" and "the burden related to migration." On the other hand, households in this region migrate to other regions if the utility level in the other region is higher than $U + M$, where M represents the cost of moving to other regions from this region. We maintain other assumptions that we made in Sects. 5.2 and 5.3. If a natural disaster strikes, the fixed cost of each firm becomes sf rather than f.

First, we examined the circumstances that prevailed before the natural disaster. We depicted this case in Fig. 5.3. Presuming that the population at time 0 is smaller than L_1 or larger than L_6, then the households have an incentive to migrate to other regions because the utility level established in this region is less than $U' - M$. If the initial value of the regional population is smaller than L_1, then this region disappears because the population converges to 0 in the long run. If the initial value of the regional population is larger than L_6, then the regional population converges to L_6.

If the population in this region is between L_1 and L_3, or between L_4 and L_6, then the population remains unchanged. If the population in this region is between L_3 and L_4, then the regional population converges to L_4. In the steady state (with positive population), the regional population is between L_1 and L_3 or between L_4 and L_6. In the model we considered in Sect. 5.3, L_2 in Fig. 5.2 is the only stable equilibrium. However, if one considers the costs related to regional loyalties, there are many steady states. By introducing the idea of regional loyalties, we can analyze the case of a relatively small city as well as a big city.

Presuming that a natural disaster occurs at some date and the fixed cost for each firm becomes sf, then the utility curve shifts downward (see Fig. 5.4). We also assume that the economy is in a steady state before the natural disaster. If

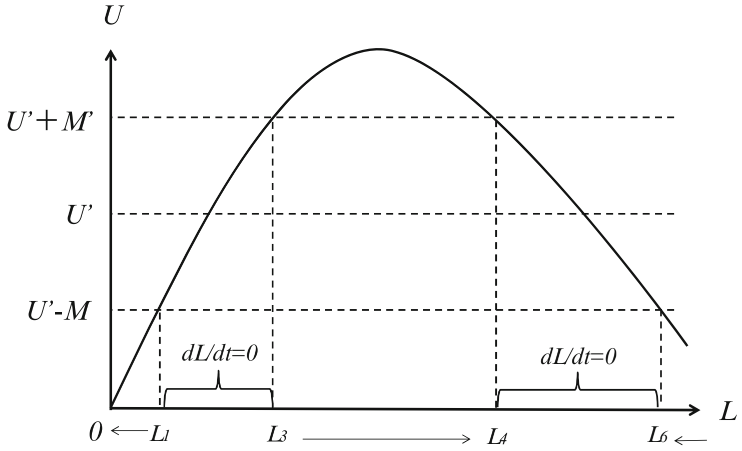

Fig. 5.3 Relationship between *L* and *U* before the natural disaster when utility includes regional loyalties

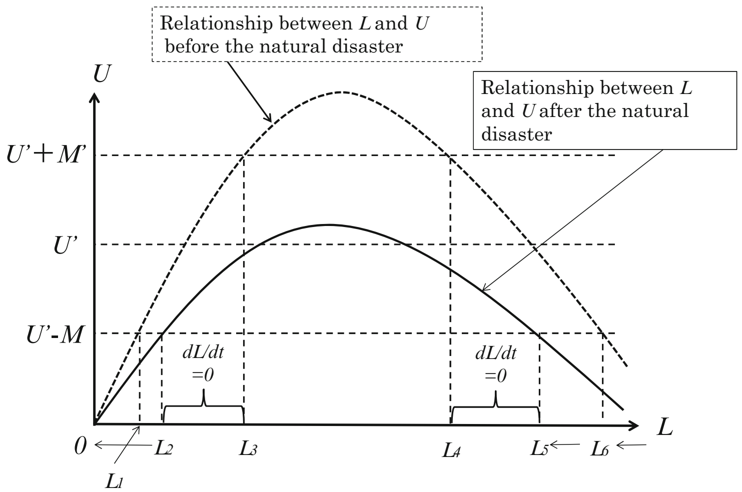

Fig. 5.4 Relationship between *L* and *U* before and after the natural disaster when utility includes regional loyalties

the population before the natural disaster is between L_1 and L_2, then the regional population converges to 0. If the population before the natural disaster is small, then the natural disaster makes it impossible for the affected region to maintain economic activities.

If the population in this region before the natural disaster is given as between L_2 and L_3, or L_4 and L_5, the regional population remains unchanged. However, the natural disaster has negative effects on the utility of each household in the affected area.

If the regional population before the natural disaster is between L_5, and L_6, then the post-disaster regional population converges to L_5 (population drain occurs). The utility level of the individual decreases after the natural disaster unless the initial level of the population is L_6. In the model we analyzed in Sect. 5.3, the natural disaster affects the regional population, but the utility level of the household remains unchanged. In the extended model here, not only the population distribution but also the utility level will be altered.

5.5 Production Function with Infrastructure

In this section, we introduced another production function to the model. The presumption is that the fixed cost of each firm also depends on infrastructure. Here the fixed cost is defined as f/G^{β}, rather than f, where β (<1) is a parameter and G is public capital or infrastructure. Each firm takes the value of G as a given. The government provides public capital. Other settings are explained as before.

To provide public capital G, the local government in this region must hire εG units of labor. If public capital is provided by a central government, then we can regard εG as the maintenance cost of G. If public capital is provided by a local government, then εG includes not only the maintenance cost but also the construction cost. This difference does not influence the main conclusions here.

Presuming that the local government imposes a tax on wages, the budget constraint of the local government is given as $\tau w L = w \varepsilon G$. In this case, $C_j \equiv \left(\frac{G^{\beta}}{f\sigma}\right)^{\frac{1}{\sigma-1}} \frac{(L-\varepsilon G)^{\frac{\sigma}{\sigma-1}}}{L}$ in equilibrium.[5] The increments of G exert two opposite effects on the consumption index. On the one hand, it will decrease the fixed cost of production and increase the number of differentiated goods. Then, the consumption index increases because households can enjoy the love of variety. On the other hand, G will decrease employment in the manufacturing sector. These effects decrease the number of differentiated goods; they then have a negative impact on the consumption index.

In Fig. 5.5, we present a graph of C as a function of G for a given value of regional population L. We can draw an inverted U-shaped relation between C and G because $C_j \equiv \left(\frac{G^{\beta}}{f\sigma}\right)^{\frac{1}{\sigma-1}} \frac{(L-\varepsilon G)^{\frac{\sigma}{\sigma-1}}}{L}$ in equilibrium. The optimal value of G (denoted as G^*) can be derived as

$$G^* = G^*(L) = \frac{\beta\,(1-\xi)\,L}{\varepsilon\,(1+\beta\,(1-\xi))} \equiv gL. \tag{5.8}$$

[5] See Appendix for details.

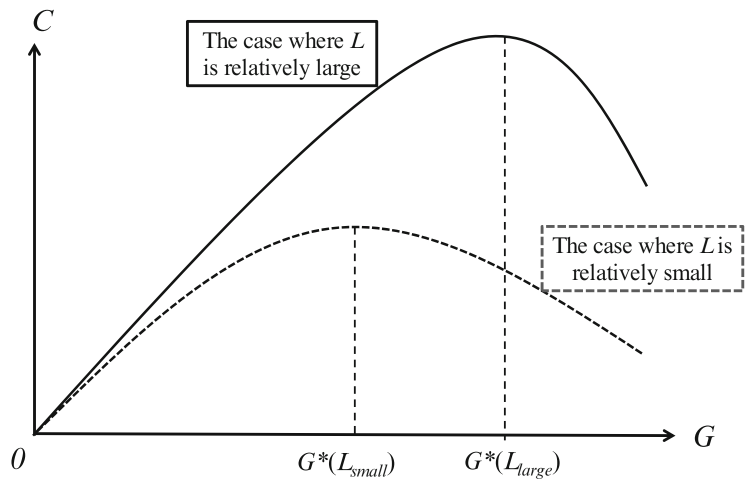

Fig. 5.5 Relationship between G and C

That is, the optimal value of G is represented as a function of the regional population, L. If a regional population increases, then the graph of C in Fig. 5.5 shifts upward. The optimal value of public capital increases with the regional population (see Eq. (5.8)). Using Eq. (5.8), the index of consumption of each household is given as

$$C_j = C = \left(\frac{1}{f\,(\beta+\sigma)}\right)^{\frac{\sigma}{\sigma-1}} \sigma f g^{\frac{\beta}{\sigma-1}} L^{\frac{1+\beta}{\sigma-1}}. \tag{5.9}$$

We assume that $\sigma > 2+\beta$ so that $\frac{1+\beta}{\sigma-1} < 1$.

From Eq. (5.9), it is possible to show an inverted U-shaped relationship between the regional population and the utility of a representative household. Therefore, we can use Figs. 5.3 and 5.4 again to analyze interregional migration.

We assumed that natural disasters occur at some date and that public capital is degraded. Let us define q so that public capital becomes qG ($q < 1$) rather than G in the aftermath of the natural disaster. We focused on the case where the economy is in a steady state before the natural disaster. That is, the regional population before the natural disaster (denoted as L^{before}) was between L_1 and L_3 or between L_4 and L_6 in Figs. 5.3 and 5.4.[6] As discussed in Sect. 5.4, the natural disaster not only lowers the consumption level but also the utility of each household. If the population before the natural disaster was between L_1 and L_2, the regional population converges to 0. If

[6]Of course, the value of L_i here, and the values in Sect. 5.4 have a different values. We provide the qualitative analysis here.

the population in this region before the natural disaster was between L_2 and L_3, or L_4 and L_5, the regional population remains unchanged. If the regional population before the natural disaster was larger than L_5, then the post-disaster regional population converges to L_5. These results are similar to those described in Sect. 5.4.

We then examined the case in which $L_5 < L^{\text{before}} < L_6$. As previously discussed, a natural disaster decreases the regional population from L^{before} to L_5. Public capital changes from gL^{before} to $qgL^{\text{before}} \neq gL_5$.

Fiscal policies designed to recover public capital (disaster recovery policies) were analyzed for their effects on regional economic activities. We focused on the case where the government tries to promote public investment to return public capital to gL^{before} from qgL^{before}. We assumed that this reconstruction planning was promoted by a central government. This is a natural assumption because the central government tends to take the initiative for disaster recovery policies after a large-scale disaster. As for the financial burden, this solution is probably more desirable for the disaster-affected areas. We also assumed that once reconstruction was carried out by the central government, the local government is responsible for the future maintenance costs. As before, to provide or maintain one unit of G, εL units of labor must be employed in the public sector in that region.

Note that gL^{before} is no longer optimal if the regional population becomes L_5. Let us interpret $L_{\text{large}} = L^{\text{before}}$ and $L_{\text{small}} = L_5$, where L_{large} and L_{small} are given in Fig. 5.5. Presuming that $qG^*(L^{\text{before}}) > G^*(L_5)(qgL^{\text{bef}}\text{o}^{\text{re}} > gL_5)$, then $\partial C/\partial G < 0$ at $G = qG^*(L^{\text{before}})$ and $L = L_5$. Then, the reconstruction plans for public investment reduce the consumption index (see Fig. 5.6). This is because public capital is in excess supply if we consider the fact that the population after the natural disaster is L_5 rather than L^{before}. The burden of a local government in the affected area is too high after such policies are carried out. In this case, such fiscal policies will accelerate the population drain because they decrease the utility of each household. That is, the graph of the utility in Fig. 5.4 shifts downwards further, and the population in the steady state becomes lower than L_5.

The results here may change if we consider the situation where the central government contributes funding for the maintenance cost as well as for the recovery cost. However, it is unlikely that the central government will bear the maintenance cost permanently. If the central government covers a certain part of the maintenance cost, the probability that the fiscal policy accelerates the population drain will decrease.

If $qG^*(L^{\text{before}}) < G^*(L_5)(qgL^{\text{before}} < gL_5)$, then $\partial C/\partial G > 0$ at $G = qG^*(L^{\text{before}})$ and $L = L_5$. In this case, public investment to recover public capital might increase or decrease the consumption index. The utility of residents in the region might increase. However, once people migrate to other regions, it might be difficult to increase the number of households to the original level (see the discussion in Sect. 5.6). Therefore, once the economy attains a new steady state, it might be difficult for a government to restore population to an affected area. The government must conduct fiscal policy promptly to maintain populations in affected areas.

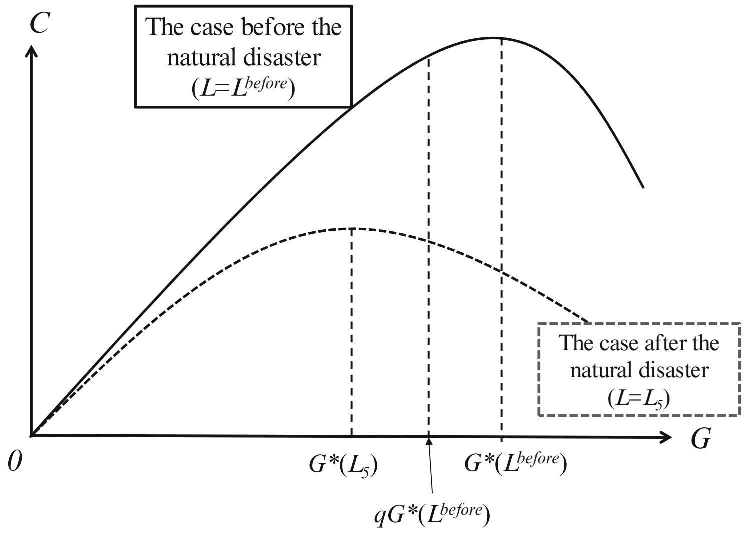

Fig. 5.6 An example of before and after the natural disaster

5.6 High-Demand City and Low-Demand City[7]

Vigdor (2008) demonstrated that the effects of the natural disaster on long-run equilibrium depend on whether or not the disaster-affected area is a "high-demand city."[8] Ikazaki (2016) showed several examples of high-demand and low-demand cities. The examples of the high-demand city are Chicago and San Francisco (Vigdor 2008). The Chicago fire of 1871 and the San Francisco earthquake of 1906 did not affect the city population dynamics in the long run. Both cities were in periods of steady growth when disaster struck. After the fire and the earthquake, both cities experienced positive population growth. This is because these cities were regarded as high-demand cities.

On the other hand, the historical examples of Dresden[9] and New Orleans can be regarded as "low-demand cities." Both cities were experiencing negative population growth in the periods before the disaster and the war. Dresden had 630,000 inhabitants at the outbreak of World War II. After World War II, the city's population stabilized at around 50,000 within a few years after 1945 (Davis and Weinstein 2002).

[7]The discussion of this section depends heavily on Ikazaki (2016).

[8]Although we do not have a clear definition of high-demand city, it is a city such that demand is high, economy is active, and population is growing.

[9]The example of Dresden was not so much a disaster as a war.

New Orleans had a population of about 628,000 in 1960. But the population had decreased to about 484,000 by 2000. After Hurricane Katrina (2005), the federal government devoted huge amounts of money to reconstruct the affected area. However, compared to 2000, the population had decreased by about 30% by 2010 (population there in 2010 is about 344,000; United States Census Bureau 2019). These two examples of a low-demand city are consistent with our model predictions given in Sects. 5.4 and 5.5.

Ikazaki (2016) also discussed the examples of the areas affected by the Great East Japan Earthquake in 2011. In Iwate, Miyagi, and Fukushima (the main disaster-affected areas), the rate of population change in 2005–2010 was −4.0%, −0.5%, and −3.0%, respectively (Ministry of Internal Affairs and Communications, Japan 2021). They can also be considered low-demand cities. So, we can predict that the negative effects of natural disasters on such cities tend to be more serious. Actually, the population decreased by 7.7%, 1.8%, and 9.0% respectively in Iwate, Miyagi and Fukushima (Ministry of Internal Affairs and Communications, Japan 2021). According to another survey carried out by NHK (Japan Broadcasting Corporation), about 85% of people who had evacuated Fukushima after the Great East Japan Earthquake did not think the disaster victims were able to return to their hometown as planned (NHK 2018). So, the negative effects of an earthquake might overcome the regional loyalties that we discussed in Sect. 5.5.

The Japanese government asked the local governments of the disaster-affected areas to share the financial burdens after 2016. If afflicted people who have migrated from the affected area do not come back to their hometowns, the burden of people in those areas will increase. This may result in further population outflow.

5.7 Conclusion

In this paper, we analyzed how natural disasters affect regional economic activities and the effects of disaster recovery policies on regional population dynamics as well as a firm's behavior in a disaster-affected area. A similar discussion was given by Ikazaki (2016) that extends a simple matching model to analyze how natural disasters affect unemployment in the affected area. This paper uses the monopolistic competition model introduced by Dixit and Stiglitz (1977), which is explained in detail in Sect. 5.2.

In Sect. 5.3, we integrated the elements of natural disasters into the model in Sect. 5.2. The main results of Sect. 5.3 are as follows. First, natural disasters produce a population drain and decrease the number of operating firms. Ikazaki (2016) showed that the unemployment rate will increase after the disaster occurs in affected areas. In this paper, we used a full employment model and did not refer to the unemployment rate. Instead, we showed that the number of firms in an affected area will decrease, which was not discussed in Ikazaki (2016). Second, the household utility remains unchanged. On the one hand, the expected consumption level will decline because of the population drain. On the other hand, the negative costs of congestion also decrease. These two effects offset each other and explain why the utility of each household remains unchanged.

In Sect. 5.4, we introduced regional loyalties. People tend to pay costs of some kind when they migrate to other regions from their hometowns. If one considers regional loyalties as additional costs of moving to other regions, natural disasters need not reduce the regional population even if it reduces the utility of a representative household. We also pointed out the possibility of multiple steady states.

In Sect. 5.5, we introduced public capital that can reduce the fixed cost of each firm. It is assumed that natural disasters damage public capital. We considered how fiscal policies to recover public capital affect regional population and firms' behavior in that region. Regional population might decrease just after a natural disaster occurs. If so, the previous level of public capital is excessive. Households in the disaster-affected area must incur the maintenance cost with fewer people. If so, fiscal policies that supply too much public capital may be harmful to that region because the local government has to pay for the maintenance cost of the infrastructure and the consumption level may have decreased. In that case, fiscal policy might accelerate the population outflow and decrease the number of firms in disaster-affected areas.

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Appendix

Here, we explain the model in Sect. 5.5 in detail. The demand side of the economy remains unchanged. For the supply side of the economy, the profit function of firm i is rewritten as.

$$\pi_i = p_i x_i - w\left[\left(f/G^{\beta}\right) + a x_i\right]. \tag{5.10}$$

The price of the ith intermediate is again given as $p_i = \frac{1}{\xi} a w = w$. The zero-profit condition implies $x_i \equiv x = f\sigma/G^{\beta}$. The labor market clearing condition is $n(ax + f/G^{\beta}) + \varepsilon G = L$. The number of the good is

$$n = (L - \varepsilon G)\ G^{\beta}/f\sigma. \tag{5.11}$$

Then the index household consumption becomes $C_j \equiv C = \left(\frac{G^{\beta}}{f\sigma}\right)^{\frac{1}{\sigma-1}} \frac{(L-\varepsilon G)^{\frac{\sigma}{\sigma-1}}}{L}$ in equilibrium. Furthermore, we can show the optimal tax rate (τ^*) becomes

$$\tau^* = \frac{\beta(1-\xi)L}{(1+\beta(1-\xi))}$$

because $\tau^* wL = \varepsilon wG^*(L) = \varepsilon wgL$ implies $\tau^* = \varepsilon g$ in the optimum.

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Chapter 6
An Investigation of Hierarchical Central Place Systems and Optimal Spatial Structures for Improving Regional Welfare

Daisuke Nakamura

Abstract Central place theory, as used in market area analysis, explains how economic activity is spatially organised, and how the systematic organisation of such activity can optimise it. However, this work has devoted little attention to problematic issues in rural areas, which are nearly free of the diseconomies associated with urbanisation, such as pollution and congestion, but which often have difficulty accessing goods and services. This paper will demonstrate how an alternative spatial economic structure can be organised within the framework of central place theory and describe what sort of regional system is required to sustain the availability of goods and services in rural areas.

Keywords Central-place system · Market areas · Transportation costs · Cooperative behaviour · Regional development

6.1 Introduction

Hierarchical central place systems are a part of central place theory, which was originated by Christaller (1933 [1966]) and Lösch (1938, 1944 [1954]). Although they were first developed in the domain of geography and the location of economics, central place systems can also be used to classify financial and administrative

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systems (Parr 2008). In the theoretical work, these central place structures are typically associated with large metropolitan areas, including capital cities. Such centrality can result from a variety of spatial, historical, and economic factors, but it can also lead to problematic disparities when it comes to well-being and quality of life in rural regions. This paper examines how spatial economic organisation can be used to sustain regional welfare, by coordinating access to goods and services in ways that support local populations and their economic activity.

Regional welfare can be enhanced, at least in part, through the economies of agglomeration. These economies are referred to as externalities, with Baumol and Blinder (2016: 304) having categorised spatially unconstrained economies into those marked by beneficial externalities versus detrimental externalities. The difference between these types of economies turns on incidental costs that are borne by others who receive no compensation for any resulting damage to their well-being. Such costs are positive in cases of beneficial externality, but negative in cases of detrimental externality. Furthermore, Parr (2002) proposes a classification of spatially constrained economies that are external to the firm; he divides these into localisation economies, urbanisation economies, and activity-complex economies.

Although localisation and activity-complex economies are commonly linked with manufacturing industries, urbanisation economies are not necessarily connected with aspects of firms and industries. In addition, urbanisation economies also have detrimental externalities such as pollution and congestion, which are referred to as urbanisation diseconomies. These concepts need to be expanded to analyse issues of regional welfare in general and the welfare of rural areas in particular. As demonstrated by Nakamura (2010), rural areas tend to enjoy less availability of goods and services due to the profit-maximisation priorities of firms, which choose to maximise profits rather than revenues. This paper analyses how goods and services can nonetheless be more securely distributed in these areas, arguing that such well-organised distribution systems may partly contribute to improving regional welfare levels.

The economics of welfare was first formally investigated by Pigou (1932), though the limited scope of his analysis was criticised by Robbins (1938), Little (1957), and others. While successors of welfare economics such as Bergson (1938), Hicks (1939), Kaldor (1939), Scitovsky (1941), and Samuelson (1947) attempted to develop the conceptual framework further, this later work gave rise to theoretical contradictions and other problems (Arrow 1950; Arrow and Scitovsky 1969). Later, in a remarkable expansion of the approach, Sen (1974) managed to extend welfare analysis but without creating methodological difficulties, and Stiglitz et al. (2009) built on this work to provide an index of well-being that informed the better-life index of the Organisation for Economic Co-operation and Development (OECD) (see also Stiglitz et al. 2010). Relatedly, Sustainable Development Goals (SDGs) were proposed by the United Nations; these goals include several aspects of well-being in rural as well as urban areas.[1] Some of the goals involve quality of life (QOL), and economists have developed various approaches related to this subject of study. For example, Blomquist et al. (1988) and Glaeser et al. (2001) focused on the attractiveness of urban areas when it comes to QOL. Greenwood and Hunt (1989) explored how metropolitan migration has been shaped by considerations of employment and also amenities. For their part, Jensen and Leven (1997) compared and contrasted life in suburbs with life in central cities, and Ifcher and Zarghamee (2011) investigated quantitative metrics for well-being. These studies established that QOL is typically higher in urban areas, although those areas also have negative factors such as congestion and high crime rates.

More recently, Jackson et al. (2012) revealed the importance of cooperative behaviour in society, using the conceptual framework of social quilts and neighbour communication networks. Desmet and Rossi-Hansberg (2013) developed an index of welfare in urban areas that includes governments' budgetary constraints as well as externalities to amenities in those areas. Jones and Klenow (2016) provided another index of welfare using micro-data for several countries that could argue about existing studies which extend beyond GDP-based measurements.

With these previous studies mainly focusing on the evidence of the agglomeration forces of economic activity, the present paper explores what sort of economic system is required to create optimal regional welfare in rural areas. Here, the argument assumes that rural areas offer benefits that offset negative factors in urban areas, such as a rich environment of natural resources. Better access to goods and services is still required in rural areas, however especially necessary goods and services. Access to the market and inputs were studied by Weber (1909 [1928]) via a location triangle model. While the original study investigated the optimal plant location under the calculus of minimum transportation costs, which encompass a combination of two types of input and a single final product, this model can be generalised for an analysis of the optimal locations for the distribution of goods and services and those locations' corresponding transportation costs.

The paper is organised as follows. In Sect. 6.2, which draws on ideas from central place theory, a spatial model in a simple framework is introduced to examine regional welfare and rural spatial attributes of the central place system used in the model. Then, alternative spatial organisations, proposed via hypothetical analyses, are introduced in Sect. 6.3, and issues of regional sustainability are considered in Sect. 6.4. Section 6.5 indicates further possible expansions of the analysis, with Sect. 6.6 providing concluding comments.

[1]See the Division of Sustainable Development Goals of the United Nations at sustainabledevelopment.un.org/sdgs

6.2 A Spatial Model

In order to use the framework of central place theory to investigate regional welfare in rural areas from the standpoint of the availability of goods and services, it is first necessary to employ established market area analysis originating from Lösch (1944 [1954]) and Mills and Lav (1964) and summarised as follows by Nakamura (2007). First, the total revenue, TR, of a representative profit-maximising firm under a spatial monopoly with a regularly formed circular market area can be stated using the following expression:

$$\mathrm{TR} = \frac{1}{3} D t \pi U^3 (a - btU), \tag{6.1}$$

where D ($D \geq 0$) = density of demand, t ($t \geq 0$) = unit distribution transportation cost, $\pi \approx 3.14159$, U ($U \geq 0$) = maximum market area radius, and a and b ($a \geq 0$, $b \geq 0$) = components of the given demand curve. Here, note that there is no demand beyond the maximum radius of the market area.

Second, the total cost, TC, can be expressed as:

$$\mathrm{TC}(q) = ckq^2 + F_{\mathrm{T}}, \tag{6.2}$$

where c ($c \geq 0$) = a unit cost to use as input for production, k ($k \geq 0$) = technological indicators for efficiency of production, q ($q \geq 0$) = quantity of output, and F_{T} ($F_{\mathrm{T}} \geq 0$) = the fixed or terminal cost for the distribution of goods and services. Regarding parameter k, as more efficient production becomes available, the indicator k approaches 0.

In order to solve the optimal market area radius of the representative firm, the marginal revenue and the marginal cost should be found under the spatial monopoly condition. The marginal revenue, MR, is immediately available from Eq. (6.1):

$$\mathrm{MR}(U) = \frac{1}{3} D t \pi U^2 (3a - 4btU). \tag{6.3}$$

Meanwhile, the marginal cost can be derived from Eq. (6.2), which is replaced by a function of the market area radius u. The conversion uses the following equation for a circular spatial configuration with an additional variable μ ($\mu \geq 0$) representing a physical obstacle to accessibility between different locations:

$$q = \mu \pi u^2. \tag{6.4}$$

To sum up, the marginal cost, MC, as a function of the market area radius becomes:

$$\mathrm{MC}(u) = \partial \frac{ck^2 \mu^2 \pi^2 u^4}{\partial u} 4u^3 ck^2 \mu^2 \pi^2. \tag{6.5}$$

Since U in Eq. (6.3) can be treated as u, the optimal market area radius, u^*, can be specified by equalising Eq. (6.5) to Eq. (6.3):

$$u^* = \frac{3at}{4\left(bt^2 + 3k^2\mu^2\pi c\right)}. \tag{6.6}$$

Also,

$$\frac{\partial u^*}{\partial b}, \frac{\partial u^*}{\partial t}, \frac{\partial u^*}{\partial k}, \frac{\partial u^*}{\partial \mu}, \frac{\partial u^*}{\partial c} < 0 \quad \text{and} \quad \frac{\partial u^*}{\partial a} > 0. \tag{6.7}$$

In this way, producers determine the size of their market area. In other words, there are consumers who are not able to obtain goods and services in question beyond the optimal market area radius. Nakamura (2010) characterises this situation in spatial terms as "consumer exclusion." Such spatial consumer exclusion may cause households in the affected areas to accept lower availabilities of goods and services than households in large metropolitan areas.

While services necessary to the public can be supplied by local or municipal authorities in the form public services, those authorities' budget constraints are generally tighter in industrialised countries due to the ageing of the total population, for instance. Under such circumstances, it is necessary to develop a well-organised regional system for the distribution of goods and services. The system can be expected to reduce the level of consumer exclusion and increase regional welfare levels, even when the region in question involves rural areas with small-scale economies.

6.3 Hypothetical Analysis

This section demonstrates how to avoid creating spatial consumer exclusion, over the longer term, in rural areas. In Fig. 6.1, the origin O_1 is the centre of a large metropolitan area where many goods and services are available—based on the idea of central place theory. The horizontal axis shows the physical distance from the centre O_1. The maximum market area radius is point B, and there are still targeted households at this point. Beyond that point, households are able to obtain their goods and services from other central places, as indicated in Eq. (6.1). The vertical axis depicts price levels. As the distance increases from O_1, these price levels rise. Correspondingly, under the condition of a "freight on board" (f.o.b.) pricing system for market area analysis, actual spending in households increases due to transportation costs.

In Fig. 6.1, the price level p_m shows the maximum reserve price of households for a representative commodity or service. In that case, the commodity or service which has a price p_1 cannot be bought by households that are located beyond point A. As a result, as Fig. 6.1 illustrates, households located between point A and point

Fig. 6.1 Price and distance of goods and services

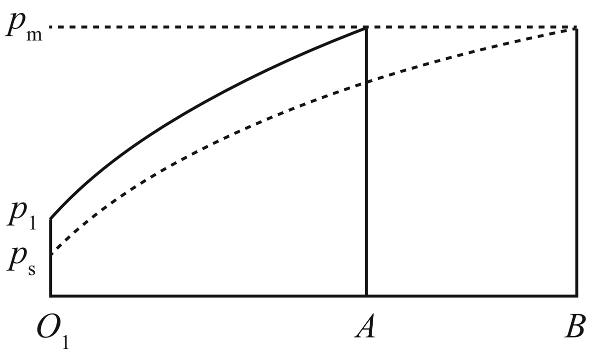
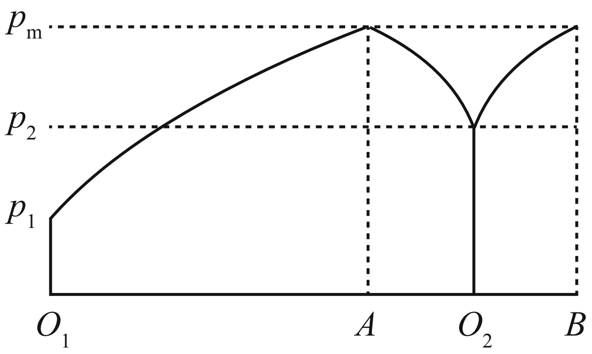


Fig. 6.2 Local lower hierarchical central place system



B face consumer exclusion unless mill price decreases to p_s and transportation costs for distribution also decrease.

An alternative framework is shown in Fig. 6.2. The figure has a centre O_2 which is a local hierarchical central place. The maximum market area radius may be $B - A$, where $AO_2 = BO_2$ on an economic plane without any physical obstacles. In this case, a high price p_2 is still acceptable, and the difference $p_2 - p_1$ can be devoted to the management of the local central place O_2. Management of this sort is needed because O_2 will be in a more inefficient situation, due to the limitations of large-scale economies, than the central place O_1.

A problem may appear where there is spatial market competition between the centre O_1 and the local centre O_2. As illustrated in Fig. 6.3, this can be observed when the price of O_1 declines to the level p_s or, perhaps, together with a reduction of distribution transportation costs from the centre O_1. The actual problem is that the local centre O_2 loses its territory $h - A + B - z$ within the market area radius. If the remaining market area, which is not a regularly formed circular market area, falls below the point where normal profit levels can be managed, a spatial structure of this sort is not sustainable for the distribution of goods and services from the local central place O_2.

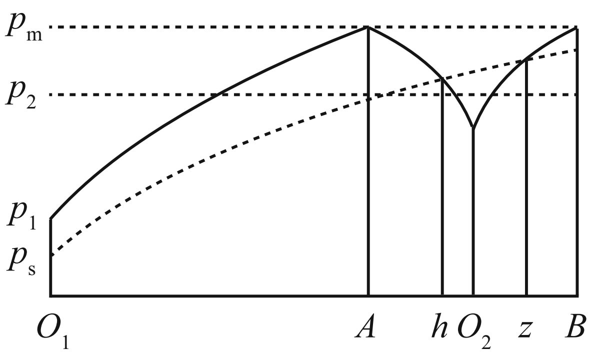


Fig. 6.3 Hierarchical central place system

This situation corresponds to a shrinking of the demand curve for O_2 that reduces the value a. Further, applying Eq. (6.7) to this situation shows that the optimal market area radius also decreases on average, due to the altered shape of the circular formation after that shift.

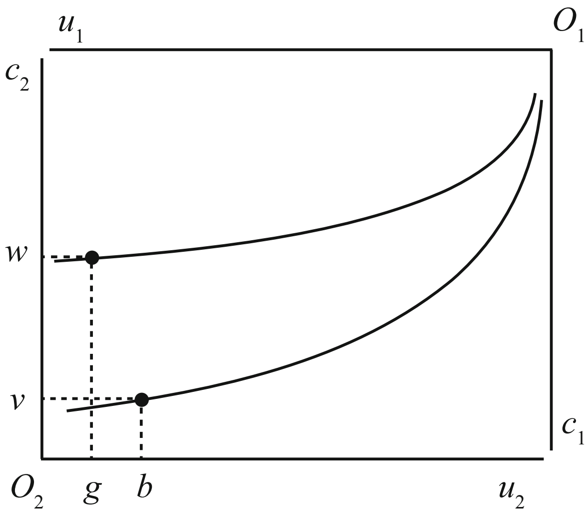
6.4 Regional Sustainability

The previous section demonstrated that spatial market competition under a hierarchical spatial structure may cause severe problems with regional sustainability when it comes to distributing goods and services. As depicted in Fig. 6.4, where the horizontal axis and the vertical axis, respectively, show the size of market area and the level of operating cost at the local central place O_2, a nonoverlapped market area situation satisfies bv (wider market area radius and less cost), while an overlapped market area gives rise to the area gw (narrower market area radius and more cost) for the local central place O_2.

Here, costs to distribute goods and services from the local centre O_2 become higher when the original market area is partly eroded by the centre O_1, since the economies of a larger scale on the centre O_1 may allow for a further reduction of costs by the narrowing of the market area of the local centre O_2. That pushes up the mill price and transportation costs for distribution from the local centre O_2. Eventually, more spatial consumer exclusion appears over the longer term, if the centre O_1 attempts to engage in spatial competition as a short-run entry deterrence behaviour. In that circumstance, regional coordination systems might be necessary to restore operational efficiency of the local central system O_2.

While online stores can be an alternative method for distributing goods and services, there may be more household utility in actual, face-to-face shopping, as long as maximum information and immediate use are key priorities for a given household. In addition, a competitive explicit price set by an online merchant, p_0 ($p_0 \geq 0$), should theoretically satisfy $p_0 \leq p_m$ where p_m represents the maximum

Fig. 6.4 Territorial overlaps



reserve price of households mentioned earlier. Since online stores generally involve longer waiting periods after purchases and also less complete product information than actual, brick-and-mortar shopping, those aspects of online shopping can be added as implicit costs. Such costs can be expressed by $\sigma(\sigma \geq 0)$, with the actual price then being $p_0 + \sigma$. Hence, the sufficient condition for online stores to prevail over physical stores would be $p_0 + \sigma \leq p_\mathrm{m}$. As long as such firms are not directly related to a given region, when it becomes apparent that the distribution of goods and services to that region is unprofitable, their decision to cease business operations may be reached much faster than the decision of locally oriented firms that use the local central place system O_2.

Highly ranked central places, such as capital cities and financial centres of the country, commonly face heavy spatial concentration. These are reasons why many countries enact decentralisation policies as part of top-down, national land-planning, and policy-making initiatives. However, such measures may not work well in the long run if they involve only cost-saving opportunities such as taxation rewards in rural areas. Above and beyond such opportunities, firms must remain in place once they have migrated to those regions. In other words, it is necessary to provide a secure environment for economic activity over the longer term, to ensure that every economic agent can maintain a satisfactory level of utility or profit.

However, the provision of a secure economic environment of this kind should not be expected under the condition where each individual or firm's sole aim is to maximise its utility or profit level. Instead, a bottom-up approach is needed to maximise regional welfare. To be concrete, when households purchase goods and services at lower prices, their doing so may naturally expand the market share of the larger central places outside the region. It would be ideal if these market areas would

Table 6.1 Pay-offs among different selections

A/*B*	Together	Individual
Together	A_{11}, B_{11}	A_{12}, B_{12}
Individual	A_{21}, B_{21}	A_{22}, B_{22}

then steadily and reliably have goods and services distributed to them. Otherwise, rural areas will face a severe spatial consumer exclusion.

A simple two-player normal-representative form in Table 6.1 can describe the situation at issue. The table shows that there are two local households, person A and person B. Each player can either choose strategy 'together' or 'individual'. Here, 'together' implies that the player purchases items always via the local central place system, while 'individual' represents the player who pursues only individual utility maximisation, by purchasing from the lower-price market (O_1). Also, note that $A_{12} \approx A_{21} > A_{11} > A_{22}>$ and $B_{12} \approx B_{21} > B_{11} > B_{22}$. In the long run, it is apparent that the combination (A_{11}, B_{11}) is the best solution for all, ensuring that regional welfare in terms of availability of goods and services is maximised. However, the players' actual selection is a different combination, (A_{22}, B_{22}), which results in much lower payoffs for all than the combination (A_{11}, B_{11}). The reason for this selection derives from other potential patterns—namely, (A_{12}, B_{12}) and (A_{21}, B_{21})—since a player who selects 'individual' can earn a larger payoff in a non-cooperative game.

However, a regional system might be able to consider organising a cooperative game rather than a non-cooperative one in this connection. If there is a referee (i.e., regional planners) and if that referee offers the possibility for cooperative behaviour by providing sufficient information (i.e., informing players about the payoff matrix that results from sustaining the local central place system O_2 versus continuing to select an 'individual' node), an infinitely repeated game may lead local households to select 'together' unless others deviate from the triggering strategy. To minimise any risk of deviation, beneficial externality across the region needs to be arranged by substantially increasing its attractiveness.

6.5 Further Avenues for Inquiry

The framework outlined in this paper may also be applicable to local firms that obtain inputs either via a local central place system or from somewhere else outside the region. Once all relevant economic agents, including those in the governmental sector, are included in the model framework, the impact of utilising the local central place system on the regional economy can be evaluated by input-output analysis. Thus, in an expanded version of the approach sketched here, a regional econometric input-output model (REIM) can provide regional economic forecasting, in the manner originally established by Israilevich et al. (1997). This analysis can then be connected with community-level central place theory through the economic-based approach proposed by Parr et al. (1975), the lower-hierarchical forecasting model developed by Chalmers et al. (1978), and the economic-based approach, involving linkage between different hierarchical sectors, developed by Mulligan (1979). Likewise, the analysis will be able to address Robinson's (1997) model of problematic factors in household economies, by attempting to establish a direct link between the input-output model and central place system proposed by Sonis and Hewings (2003). It can factor in, too, the Löschian market area analysis via input-output analysis presented in Sonis (2007).

To sum up, the sustainable local central place would become necessary, and its sustainability guaranteed more securely, if local economic agents had constant access to the local central place system as a result of cooperative behaviour undertaken to maximise regional welfare over the longer term—as opposed to non-cooperative behaviour undertaken to maximise short-run individual utility. In the long run, moreover, increased regional welfare also raises individual utility levels. This pattern can be connected, in turn, with Parr's (2015) analysis of what he calls 'regional externalities'.

6.6 Concluding Comments

This paper has explored an optimal spatial economic system for improving regional welfare by means of the secure distribution of goods and services. Using the approach of market area analysis within the framework of central place theory, the paper indicates that rural areas, where local population and economic activity do not reach a sufficient level of scale, find it difficult to compete for the distribution of goods and services from outside the region. Hence, for them to be sustainable in the long run, it is necessary to enhance beneficial economies by promoting cooperative behaviour within rural regions.

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Chapter 7
Agglomeration and Dispersion Mechanism of City System with Interior Structure

Hiroyuki Shibusawa, Daisuke Ito, and Yuzuru Miyata

Abstract Recently, the importance of urban agglomeration increases by the progress of the globalization of the world economy. This paper is a general equilibrium analysis on the urban agglomeration economy brought about by the product variety and agglomeration diseconomy by the congestion in a city in a three-city system model. The main discussion is about the impacts that the interregional transportation cost gives to the urban concentration and dispersion. Our main conclusion is that dispersion necessarily appears when the interregional transportation cost is sufficiently low. We also implement numerical simulations using specific parameter values and depict the transition from dispersion to agglomeration and then re-dispersion when the interregional transportation cost monotonically decreases over time. In the numerical simulation using realistic data values, imperfect agglomeration appears. In this case, the agriculture sector with the high productivity prevents the outflow of manufacturing industries resulting in the existence of urban functions even with the less population.

Keywords Population dispersion · Product variety · Urban agglomeration

7.1 Introduction

The degree of urban agglomeration is determined by the balance between the forces of concentration and dispersion. Various elements, including political factors, influence this, but the cost of transportation between cities is the most important factor. In recent years, the development of transportation technology and information and communications technology has led to drastic reductions in transportation costs in a broad sense. In addition, globalization has progressed because of the significant easing of regulations among countries, such as in the EU, and cities,

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and the importance of cities and regions is increasing as the boundaries between countries become ambiguous. The impact of interregional transportation costs is thus increasing, which in turn is increasing the importance of analyzing the influence and mechanisms of urban agglomeration. A vast trove of research on this topic exists, including Alonso (1964), Henderson (1974), Krugman (1991), and Fujita et al. (1999). Among them, Tabuchi (1998) incorporated both interregional and intra-urban transportation costs and studied the transitions between concentration and dispersion of workers and the relevant mechanisms in a two-city model that factors in the market for land. However, most of the research in this field employs analysis of a two-city model, and few studies deal with multiple cities. Papers such as Akamatsu et al.'s (2010) employ multicity models but exclude the land market. The purpose of this study is therefore to expand Tabuchi's model to a three-city model and to clarify the mechanisms of urban agglomeration and dispersion resulting from transportation costs.

7.2 The Model

7.2.1 Household Behavior

This model consists of three circular cities on a homogeneous plain with no characteristics. We assume that only one central business district (CBD) exists in the center of each city and that residential areas spread outward from the center. In this and the next chapters, we standardize the total population at 1, of which μ are industrial workers and $(1 - \mu)$ are agricultural workers. Additionally, while an equal number of agricultural workers live in each city (i.e., $(1 - \mu)/3$), industrial workers move freely among the cities depending on differences in utility. Workers in each sector are of uniform quality. Also, all industrial goods are produced at location 1 in the CBD with the same production technology. At this point, industrial workers' commuting costs depend on the distance of the commute, so commuting expenses increase as the distance increases. Workers lease land from absentee landlords not belonging to any city and pay rent to such landlords. If an industrial worker living in city k is L_k, then $\mu = L_1 + L_2 + L_3$. While the agricultural sector is completely competitive, it produces only one homogeneous good using a set harvesting technology, while the industrial sector is monopolistic and produces a wide range of differentiated goods using technology with increasing returns.

Workers appropriate all heir wage income to the consumption of industrial goods, residential land, and agricultural goods. At this point, industrial workers living in City 1 adhere to the following utility maximization behavior. The same applies to Cities 2 and 3.

$$\max U_1 = C_{M1}^{\mu} C_{S1}^{\gamma} C_{A1}^{1-\mu-\gamma} = \left[\left(\sum_{k=1}^{3} \sum_{i=1}^{N_1} c_{i1k}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)} \right]^{\mu} C_{S1}^{\gamma} C_{A1}^{1-\mu-\gamma} \tag{7.1}$$

subject to

$$\sum_{k=1}^{3}\sum_{i=1}^{N_1}\frac{p_{ik}c_{i1k}}{\tau_{k1}}+r(x)C_{S1}+\mathrm{C}_{A1}+T(x)=w_1 \tag{7.2}$$

Here, C_{Mk}, consumption of industrial goods in city k; $c_{ikk'}$, consumption in city k of the goods of firm i, which is from city k'; C_{Sk}, consumption of residential land in city k; C_{Ak}, consumption of agricultural goods in city k; σ, elasticity of substitution; x, distance from CBD; $r(x)$, rent at location x; $T(x)$, general commuting cost; N_k, number of firms or types of goods in city k; p_{ik}, price of good i in city k; w_k, wage rate of industrial workers in city k; and $\tau_{k'k}$, cost parameter for interregional transportation from city k' to city k.

Dispersion parameters μ and γ of the utility function take positive values, and $\mu + \gamma < 1$. In addition, elasticity of substitution is denoted by σ and $\sigma > 1$. C_{Mk} represents a partial utility for a group of differentiated industrial goods (individual goods) and is a synthesized index showing the consumption of industrial goods. With the differentiation index as i, N_k types of individual goods are produced in each city k. Assuming a *CES*-type utility function suggests that workers prefer product diversity if other conditions are equal.

As shown in the income constraint Eq. (7.2), agricultural goods are numeraires with a price of 1, and no cost is incurred to transport them. However, interregional transportation costs for industrial goods are premised on the Samuelson iceberg model. The iceberg theory assumes that a portion of the products will reach the transportation destination. For example, in trade between two cities (taking the transportation cost parameter between two cities as τ), when transferring one unit of goods from City 1 to City 2, only τ units will arrive in City 2. Therefore, for one unit of goods to reach City 2, it is necessary to produce $1 \times 1/\tau$ times goods in City 1, and the price in City 2 will increase by $1/\tau$ over the price in City 1. In other words, τ is an inverse indicator of interregional transportation costs.

Solving the utility maximization problem (7.1) with income constraint Eq. (7.2) yields industrial goods consumption, residential land consumption, and agricultural goods consumption as follows:

$$C_{Mk}=\frac{\mu\left(w_k-T(x)\right)}{G_{Mk}} \tag{7.3}$$

$$C_{Sk}=\frac{\gamma\left(w_k-T(x)\right)}{r(x)} \tag{7.4}$$

$$C_{Ak}=(1-\mu-\gamma)\left(w_k-T(x)\right) \tag{7.5}$$

In each demand function from Eqs. (7.3)–(7.5), the ratio of industrial goods consumption to disposable income after deducting commuting expenses from wages is confirmed to be μ, the residential land consumption rate is confirmed to be γ, and the agricultural goods consumption rate is confirmed to be $(1 - \mu - \gamma)$. Additionally, if C_{Mk} in the industrial goods demand function is maximized with $\mu(w_k - T(x)) = P_{Mk}C_{Mk}$ as a constraint, the consumption of each individual good becomes $c_{ikk'}$. By differentiating this with p_{ik}, we see that the price elasticity of demand is constant at σ in all cases, be they interregional, intra-urban, or goods.

Furthermore, we can derive the prices of industrial goods in each city, expressed as price index G_k.

$$G_k = \left(\sum_{k'=1}^{3} \sum_{i=1}^{N_{k'}} \left(\frac{p_{ik'}}{\tau_{k'k}} \right)^{1-\sigma} \right)^{1/(1-\sigma)} \tag{7.6}$$

This suggests that, depending on a consumer's diversification preferences, if the type of goods offered N_k increases, the price index will decline, and the cost to achieve a given utility level will go down.

7.2.2 Firm Behavior

In the production of industrial goods, economies of scale exist at the level of the good for each type of good. Agricultural goods, however, are assumed to be produced with a set harvesting technology. Thus, the production function includes fixed costs and variable costs and is expressed as follows for all firms:

$$l_{ik} = \alpha + \beta q_{ik} \tag{7.7}$$

Here, l_{ik}, the labor input volume of firm i in city k; α, fixed labor cost; β, marginal labor cost; and q_{ik}, volume of individual goods of firm i in city k.

Because the firm must produce $1/\tau$ times the consumption volume in order to transport the good to the city of demanding, we get $q_{ik} = c_{ikk'}/\tau_{k'k}$. In addition, firms from city k act to maximize profit π_k. Therefore, profit π_k is expressed as follows:

$$\pi_{ik} = p_{ik}q_{ik} - w_k\,(\alpha + \beta q_{ik}) \tag{7.8}$$

Assuming free entry and exit of firms, profit in equilibrium will be zero. Additionally, the conditions in the first level of the profit maximization problem yield balanced prices for individual goods, production volumes, and labor input volumes and industrial goods types (number of enterprises) in city k as follows:

$$p_{ik} = \frac{\sigma\beta}{\sigma - 1} w_k,\ q_{ik} = \frac{\alpha\,(\sigma - 1)}{\beta},\ l_{ik} = \alpha\sigma,\ N_k = \frac{L_k}{\alpha\sigma} \tag{7.9}$$

At this point, firms from city k achieve the same equilibrium price and equilibrium production volume, regardless of the type of good. Therefore, we omit the expression i hereafter.

7.2.3 Indirect Utility Function

Substituting goods demand functions (7.3), (7.4), and (7.5) for the utility function (7.1) and operating with (7.9) yield the indirect utility function for each city. Here, taking the ratios between the cities, we derive the following indirect utility function ratio. This will be solved for each connection among Cities 1, 2, and 3, but here, we address only the connection between Cities 1 and 2:

$$\frac{U_1}{U_2} = \left(\frac{w_1 - T(x_1)}{w_2 - T(x_2)}\right)\left(\frac{f_1 w_1^{1-\sigma} + f_2\left(\frac{w_2}{\tau_{21}}\right)^{1-\sigma} + f_3\left(\frac{w_3}{\tau_{31}}\right)^{1-\sigma}}{f_1\left(\frac{w_1}{\tau_{12}}\right)^{1-\sigma} + f_2 w_2^{1-\sigma} + f_3\left(\frac{w_3}{\tau_{32}}\right)^{1-\sigma}}\right)^{\frac{\mu}{\sigma-1}} \tag{7.10}$$

Here, x_k, urban boundary distance in city k, and f_k, ratio of industrial workers in city k to all industrial workers ($f_k \equiv L_k/(L_1 + L_2 + L_3) \in [0,1]$).

Long-term equilibrium is achieved when the indirect utility function ratio between cities equals 1.

7.2.4 Rent Curve

Land consumption, which is not considered in Krugman's model, is added here for residential land. Workers in this model consume industrial goods, residential land, and agricultural goods to maximize utility under their income constraints (7.2). These initial conditions lead to the Muth condition, illustrated as follows:

$$r'(x)C_{Sk}(x) + T'(x) = 0 \tag{7.11}$$

This suggests that at each location x, the marginal commuting cost $T'(x)$ is equal to the marginal reduction in land costs $- r'(x)C_{sk}(x)$. In other words, as location x moves farther from the CBD, the cost of land decreases while commuting expenses increase. At the same time, the proximity to the location to the CBD lowers the commuting cost but increases the cost of land.

In addition, the Muth condition is organized with respect to $C_{Sk}(x)$, and using residential land demand function (7.4) yields the following differential equation:

$$-\int \frac{1}{w_k - T(x)} \mathrm{d}T(x) = \gamma \int r(x)^{-1} \mathrm{d}r(x) \tag{7.12}$$

Solving this and using the boundary condition $T(0) = 0$, $r(0) = r_{0\,\mathrm{to}}$ yields the following rent curve.

$$r(x) = r_0\left(1 - \frac{T(x)}{w_k}\right)^{1/\gamma} \tag{7.13}$$

Here, r_0, rent in the CBD.

This confirms that as the distance x from the CBD increases, the intraregional transportation cost, namely, the commuting cost, increases while the rent decreases.

7.2.5 Population of Industrial Workers

The population density at location x is derived by the reciprocal of residential area consumption per capita as follows:

$$\frac{1}{C_{Sk}(x)} = \frac{r_0\left(1 - \frac{T(x)}{w_k}\right)^{\frac{1}{\gamma}-1}}{\gamma w_k} \tag{7.14}$$

We next describe the population of industrial workers in each city. Since the cities in this model have a circular form with a single core, the population in locations x to $x + \mathrm{d}x$ is expressed as $2\pi x\mathrm{d}x/C_{Sk}(x)$. As the urban population in each city is equivalent to the population of industrial workers, the equilibrium value of the industrial workers' population in each city is derived by integrating the CBD and the city limits.

$$L_k = \int_0^{x_k} \frac{2\pi x}{C_{Sk}(x)}\mathrm{d}x = \frac{2\pi r_A \int_0^{x_k} x(1 - T(x)/w_k)^{1/\gamma-1}\mathrm{d}x}{\gamma w_k(1 - T\ (x_k)\ /w_k)^{1/\gamma}} \quad \text{for } k = 1, 2, 3 \tag{7.15}$$

7.2.6 Urban Income

Total disposable wages of industrial and agricultural workers in each city are derived as follows:

$$Y_k = \frac{1-\mu}{3} + \varphi_k w_k L_k \quad \text{for } k = 1, 2, 3 \tag{7.16}$$

Here, Y_k, total income in city k; φ_k, ratio of disposable wages to total wages.

$$\varphi_k \equiv \frac{\int_0^{x_k} x\left(1-\frac{T(x)}{w_k}\right)^{\frac{1}{\gamma}} \mathrm{d}x}{\int_0^{x_k} x\left(1-\frac{T(x)}{w_k}\right)^{\frac{1}{\gamma}-1} \mathrm{d}x} \quad \text{for } k=1,2,3 \tag{7.17}$$

φ_k is defined as the ratio of disposable wages to total wages. That is, it is the net wage rate after deducting commuting expenses and ranges in value from 0 to 1. Total disposable wages in city k equal to the sum of total wages less commuting costs from the CBD to the city limits.

The first term on the right side of Eq. (7.16) represents agricultural labor income. This model assumes that agricultural workers are evenly distributed among the cities, that agricultural goods are produced using a set harvesting technology and that no transportation costs are incurred. For this reason, the incomes of agricultural workers in each city are equal. Furthermore, since the price of agricultural goods is a numeraire, if one assumes that the production function of the agricultural sector is $C_{Ak} = (1-\mu)/3$, the wages of all agricultural workers equal 1 under conditions of zero profit. Therefore, more precisely, the first term on the right-hand side is the product of the agricultural population in the above formula times the wages of agricultural workers, which is 1. The second term on the right side represents the disposable wages of industrial workers. Total disposable wages of industrial workers is expressed by multiplying the disposable wages of each worker $\varphi_k w_k$ by the number of industrial workers L_k.

7.2.7 Industrial Wage Equation

As mentioned above, the production volume of each firm is $1/\tau$ times the consumption volume of individual goods. Therefore, when the following conditions are satisfied, a firm in city k can achieve production of a volume that satisfies the consumption of all cities:

$$q_k = \frac{\left(\mu \sum_{k'=1}^{3} \frac{Y_k\left(\frac{p_{k'}}{\tau_{k'k}}\right)^{-\sigma}}{G_k^{1-\sigma}}\right)}{\tau_{k'k}} \tag{7.18}$$

We rearrange this for p_k and enter it into Eq. (7.9) to derive the industrial wage equation for city k as follows:

$$w_k = \left(\frac{\sigma-1}{\sigma\beta}\right)\left(\frac{\mu\beta}{\alpha(\sigma-1)} \sum_{k'=1}^{3} Y_{k'} \tau_{k'k}^{\sigma-1} G_{k'}^{\sigma-1}\right)^{\frac{1}{\sigma}} \tag{7.19}$$

At this point, industrial workers' wages tend to go up as income levels grow, the transportation cost parameter between markets approaches 1 (freer trade) and the price index rises (competition in the market is weak). Although industrial wages as given in the wage equation are also defined for cities where no industrial sector exists, these wages represent the maximum payable wages by firms that are considering entry into the target city.

7.3 Theoretical Considerations

The main focus of this study is how changes in interregional transportation costs affect urban systems. Particular attention is paid to the stable equilibrium between urban agglomeration and dispersion. Since this model's equation structure is complicated, analytical results are more easily derived where interregional transportation costs are either infinite ($\tau_{k'k} = 0$) or 0 ($\tau_{k'k} = 1$). Generally, as interregional transportation costs decrease over time, a situation in which τ is low implies a developing transportation infrastructure, while a situation in which τ is high implies circumstances in which the transportation infrastructure is being adequately maintained for the present or future.

7.3.1 The Case of Infinite Interregional Transportation Costs ($\tau_{k'k} = 0$)

When the interregional transportation cost is infinite, each city is self-sufficient because trade between cities involves very high costs. Therefore, we can derive the following proposition.

Proposition 7.1 *When transportation costs between all cities become infinite, under the following conditions (Eq. 7.20), urban agglomeration in City 1 is at a stable equilibrium:*

$$\mu > (\sigma - 1)/\sigma \tag{7.20}$$

Proof First, in utility function ratio (7.10) between Cities 1 and 2, assuming that $f_1 = 1$, where all industrial workers are concentrated in City 1, and that interregional transportation costs among all cities are equal at τ, the result is the following:

$$\frac{U_1}{U_2} = \left(\frac{w_1 - T(x_1)}{w_2}\right)\tau^{-\mu} \tag{7.21}$$

Here, for simplicity's sake, the measurement units are set so that marginal labor costs $\beta = (\sigma - 1)/\sigma$ and fixed labor costs $\alpha = \mu/\sigma$. Therefore, under the above assumptions, the price index (7.6) is simplified as follows:

$$G_1 = w_1, \quad G_2 = G_3 = \frac{w_1}{\tau}, \tag{7.22}$$

Similarly, the industrial wage Eq. (7.19) of Cities 1 and 2 is expressed as follows:

$$w_1 = Y_1 + Y_2 + Y_3 \tag{7.23}$$

$$w_2 = (Y_1 + Y_2 + Y_3)^{\frac{(\sigma-1)}{\sigma}} \left\{ \tau^{1-\sigma} \left(Y_1 \tau^{2(\sigma-1)} + Y_2 + Y_3 \tau^{\sigma-1} \right) \right\}^{\frac{1}{\sigma}} \tag{7.24}$$

Finally, from (7.21), (7.23), and (7.24), we see that when τ approaches 0, $U_1/U_2 = +\infty$ under the conditions of Eq. (7.20). This suggests that agglomeration in City 1 (the situation in which all industrial workers are concentrated in City 1) is a stable equilibrium. Additionally, since the cities are symmetrical and homogeneous, this holds for the other cities as well. This therefore proves Proposition 7.1.□

As shown in Eq. (7.20), urban agglomeration occurs when (a) elasticity of substitution σ is low and (b) the consumption rate of industrial goods (employment rate of industrial workers) μ is high in a situation where interregional transportation costs are abnormally high ($\tau \to 0$). When this happens, since each individual good is strongly differentiated, consumers who prefer variety enjoy various goods through agglomeration. Also, a high μ indicates a less number of agricultural workers, which is the same as low dispersion of latent demand in each city being. For this reason, dispersion forces weaken and agglomeration strengthen. However, since there is generally little interest in economies with such a strong agglomeration mechanism, we established conditions such as the following, which is premised on the nonexistence of a black hole. This serves as the inverse of inequality Eq. (7.20):

$$\mu \leq (\sigma - 1)/\sigma \tag{7.25}$$

Here, contrary to Proposition 7.1, this suggests that stable equilibrium would be a state of equal dispersion to each city. In fact, this is in line with the results shown in the numerical calculations in Chap. 4.4. Under the conditions of the nonexistence of a black hole, the dispersion occurs when (a) the elasticity of substitution σ is high and (b) the consumption rate of industrial goods (industrial worker employment rate) μ is low. In this situation, the individual goods are homogeneous, making trade uneconomical because of high transportation costs, and if agglomeration occurs, competition will intensify among firms producing homogeneous goods, resulting in the dispersion of industries.

7.3.2 The Case when Interregional Transportation Costs Are 0 ($\tau_{k'k} = 1$)

Here, no interregional transportation cost is incurred, and it becomes possible to trade without consuming goods that incorporate interregional transportation costs. In other words, each city is economically integrated. This leads to Proposition 7.2:

Proposition 7.2 *When transportation costs between all cities go to 0, dispersion ($L_1 = L_2 = L_3 = \mu/3$) is the only stable equilibrium at various parameter values.*

Proof First, assuming that no transportation costs between cities $\tau_{k'k} = 1$, the utility function ratio (7.10) between Cities 1 and 2 is expressed as follows:

$$\frac{U_1}{U_2} = \left(\frac{w_1 - T(x_1)}{w_2 - T(x_2)}\right) \tag{7.26}$$

Likewise, the wage Eq. (7.19) does not depend on the ratio of industrial population f_k and is simplified as follows:

$$w_1 = w_2 = w_3 \tag{7.27}$$

Further, since it is assumed that commuting expenses will increase with longer commuting distances, the following equation holds:

$$\frac{dT(x_1)}{dx_k} > 0 \tag{7.28}$$

Here, from Eq. (7.28) and the initial-stage condition of the industrial worker population Eq. (7.15), the following is derived. This too does not depend on the ratio of the industrial population f_k.

$$\frac{\partial L_k}{\partial x_k} > 0 \tag{7.29}$$

Therefore, independent of the parameter value for f_k, the following holds.

$$\frac{d\left(\frac{U_1}{U_2}\right)}{df_1} < 0 \tag{7.30}$$

The inequality Eq. (7.30) suggests that if the number of industrial workers in City 1 increases, the urban boundary of City 1 expands, and commuting expenses increase, lowering the utility level vis-a-vis City 2. Furthermore, this also applies to other cities. In other words, this suggests that $(L_1, L_2, L_3) = (\mu/3, \mu/3, \mu/3)$ is the only stable equilibrium, and the above proves Proposition 7.2.□

Proposition 7.2 demonstrates that, irrespective of the initial conditions and parameter values, the definitive finding is that dispersion ultimately does occur in urban systems. When technological innovation reduces interregional transportation costs to a negligible level, firms and workers will disperse. In other words, urban agglomeration will cease in the future. This is attributed to the disappearance of the benefits of urban agglomeration, and with industrial workers dispersing their locations, it will become possible to consume a wide variety of industrial goods while enjoying large-scale consumption of residential land and commuting with little congestion.

7.4 Numerical Simulations

Due to the nonlinear structure of the equations, the analysis thus far has been limited to extreme cases. Therefore, from this section onward, we perform numerical calculations using specific parameters to advance the analysis.

7.4.1 Simulation Concepts

The simulation is conducted as shown in Fig. 7.1. First, initial values are assigned to the total population of all cities L, population of industrial workers L_M, population of agricultural workers L_A, commuting cost per unit distance t, elasticity of substitution σ, consumption rates μ and γ, agricultural rent r_A, fixed labor cost α, marginal labor costs β, and agricultural wage rate w_A. Next, interregional transportation cost τ and the industrial worker allocation f_k are fixed, and the initial values of CBD rents r_0 and city limits x_k are given. After that, the ratio of disposable wages φ_k; total income Y_k; price index G_k; demand functions C_{Mk}, C_{Sk}, and C_{Ak}; and the utility function U_k are calculated. Furthermore, the distance to the city limit x_k is calculated using the Newton-Raphson method; in addition, rent r_0, individual goods prices p_k, labor input l_k, and the number of firms N_k in the CBD are calculated. Finally, the industrial worker wage w_k is calculated, and the calculation is repeated until convergence is reached. In the previous analyses, the city's total population was standardized at 1, but in the numerical analysis, the calculation is performed using an arbitrary population L. Here, L_k is the number of industrial workers in city k, and L_A is the number of agricultural workers in all three cities. Furthermore, $T(x) = tx$ where t is a constant that represents commuting cost per unit distance, and the production function of agricultural workers is specified as $C_A = a_A L_A$. In such a case, urban income (7.16) is expressed as $Y_k = \varphi_k w_k L_k + a_A L_A/3$. Solving for the ratio of disposable wages (7.17) determines each variable, as shown in Fig. 7.1.

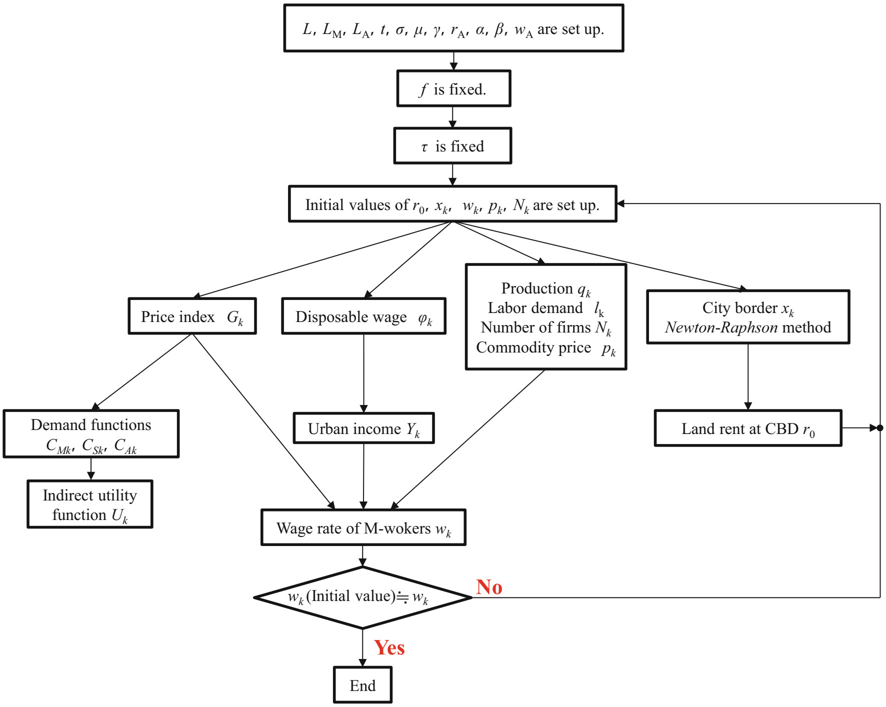

Fig. 7.1 Simulation flow

7.4.2 Setting Parameters and Simulation Cases

Each exogenous variable parameter is set using Toyohashi City as reference, with $L = 300{,}000$, $L_M = 0.89\ L = 225{,}000$, $L_A = 0.11\ L = 75{,}000$, $t =$ ¥35/m/year, $\sigma = 5$, $\mu = 0.74$, $\gamma = 0.15$, $r_A =$ ¥60/year, $\alpha = 2$, $\beta = 0.8$, and $w_A =$ ¥2 million/year. As shown in Proposition 7.1, since the elasticity of substitution σ is high and the industrial goods consumption rate μ is low, the condition of the black hole being absent is satisfied, and uniform dispersion becomes the stable equilibrium.

In addition, the simulation sets the interregional transportation cost τ to be equally variable among all cities. Furthermore, calculations are performed assuming that all industrial workers are concentrated in City 1 but half of them move to City 2 and half move to City 3 afterward.

7.4.3 Simulation Results

Numerical calculations are performed with respect to all τ[0, 1] and f_1[0, 1] values, and by removing the unstable equilibrium from the population ratio in which the utility ratio becomes 1, a stable equilibrium distribution for the industrial workers' population is derived, as shown in Table 7.1. Since the number of industrial workers in Cities 2 and 3 is the same, it is expressed as $L_{2,3}$. In addition, L_1 takes various values within [L_M, $2L_M/3$], and $L_{2,3}$ takes various values in [0, $L_M/3$]. Case classification is consistent with Fig. 7.3.

Next, to visualize the stable equilibrium distribution of industrial workers based on changes in transportation costs between cities, the industrial worker dispersion of City 1 f_1 (called "City 1 M-workers ratio" in the figures), which is a stable equilibrium, is depicted in Fig. 7.2. Furthermore, to visualize changes in the stable equilibrium due to changes in τ, Fig. 7.3 shows the utility level of each city for each industrial worker dispersion (f_1 [0, 1]). Since the utility levels of Cities 2 and 3 are equal, they are expressed as $U(2, 3)$. Also, the black circles in the figure represent stable equilibria, while the white circles represent unstable equilibria.

As shown in Table 7.1 and Fig. 7.2, industrial workers and firms disperse when interregional transportation costs increase or when interregional transportation costs become sufficiently low ($\tau = 0.7$ or above in this simulation). In contrast, agglomeration occurs discontinuously when transportation costs decline to some extent between these two extremes. In this simulation, agglomeration is imperfect. While many industrial workers flow into City 1 within the $0.48 < \tau \leqq 0.7$ range, some industrial workers choose to live in Cities 2 and 3. Also, within the $0.52 \leqq \tau < 0.7$ range, many industrial workers flow into Cities 2 and 3, but some choose to stay in City 1. The agglomeration phenomenon that acfirms declining transportation costs can be considered a straw effect or phenomenon. However, even if population is absorbed by the straw effect, the entire population cannot realistically drain away. From this perspective, in this simulation an imperfect population agglomeration (outflow) phenomenon is probably more realistic.

Also, the existence of multiple equilibria means that the situation is uncertain. In particular, near the extremes at which agglomeration occurs, it seems that the form of the city can change significantly depending on factors such as traffic congestion, which would be unlikely to occur in reality.

These changes in urban structure are explained below for each case:

Case (1)

Case (1) is a situation in which interregional transportation costs are very high (τ is close to 0), and goods brought in from other cities are very expensive because of these transportation costs. Therefore, each city is virtually self-sufficient. In this case, the workers disperse among all the cities. Under these conditions, the utility

Table 7.1 Stable equilibria and case classifications for the industrial worker population

Transportation cost			City 1	City 2	City 3	M-workers distribution	Equilibrium state	Case classification
τ	High	0.0–0.48	$L_M/3$	$L_M/3$	$L_M/3$	M-workers equally distributes to the three cities	Dispersion equilibrium	Case (1)
	–	0.48–0.52	$L_M/3$	$L_M/3$	$L_M/3$	M-workers equally distributes to the three cities	Multiple equilibria	Case (2)
			L_1	$(L_M - L_1)/2$	$(L_M - L_1)/2$	Most of M-workers concentrate in City 1. A part of M-workers remains in Cities 2 and 3		
		0.52–0.70	L_1	$(L_M - L_1)/2$	$(L_M - L_1)/2$	Most of M-workers concentrate in City 1. A part of M-workers remains in Cities 2 and 3	Agglomeration equilibrium	Case (3)
			$L_M - 2L_{2,3}$	$L_{2,3}$	$L_{2,3}$	Most of M-workers concentrate in Cities 2 and 3. A part of M-workers remains in City 1		
		0.7	L_1	$(L_M - L_1)/2$	$(L_M - L_1)/2$	Most of M-workers concentrate in City 1. A part of M-workers remains in Cities 2 and 3	Multiple equilibria	Case (4)
			$L_M/3$	$L_M/3$	$L_M/3$	M-workers equally distributes to the three cities		
	Low	0–1.00	$L_M/3$	$L_M/3$	$L_M/3$	M-workers equally distributes to the three cities	Dispersion equilibrium	Case (5)

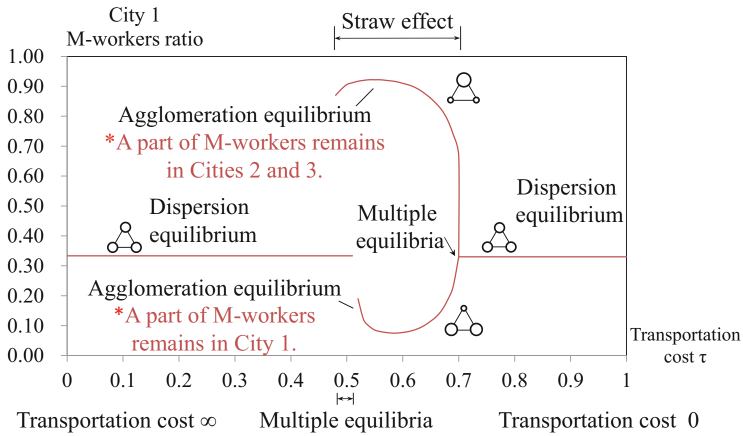

Fig. 7.2 Evolution of stable equilibrium distributions for industry caused by interregional transportation costs

level of each city is determined by residential land consumption and the diversity of industrial goods within the city.

$U(1)(f_1 < 0.07)$, $U(2,3)(0.89 < f_1)$: In this range, as f_1 increases, $U(1)$ continues rising and $U(2, 3)$ continues declining. This is explained as follows.

This case represents positive externalities due to the diversity of industrial goods. In short, as the number of industrial workers increases, the price index declines, and the consumption of industrial goods rises, resulting in an increase in the utility level. At the same time, negative externalities exist, such as an increase in rents and a decline in goods consumption due to a decline in disposable wages due to the expansion of urban areas. However, within this range, positive externalities resulting from the diversity of industrial goods exceed this. Meanwhile, with the outflow of industrial workers in Cities 2 and 3, consumption of industrial goods decreases due to a reversed mechanism from City 1, leading to a decrease in utility levels.

$U(1)(0.07 < f_1 < 0.61)$, $U(2,3)(0.15 < f_1 < 0.89)$: In this range, $U(1)$ continues declining, and $U(2, 3)$ continues rising as industrial workers flow to City 1. This is explained as follows.

Price indices, wage rates, and goods prices rise due to the high cost of shipping to cities with small industrial bases. Therefore, residents of cities with small industrial bases are affluent. In this situation, consumption consists mostly of agricultural goods and residential land. However, in cities with large industrial bases, the price index declines due to the diversity of locally produced industrial goods. At the same time, this lowers wage rates and goods prices. Here, consumption mainly comprises industrial goods, while consumption of agricultural goods and residential land remains minor.

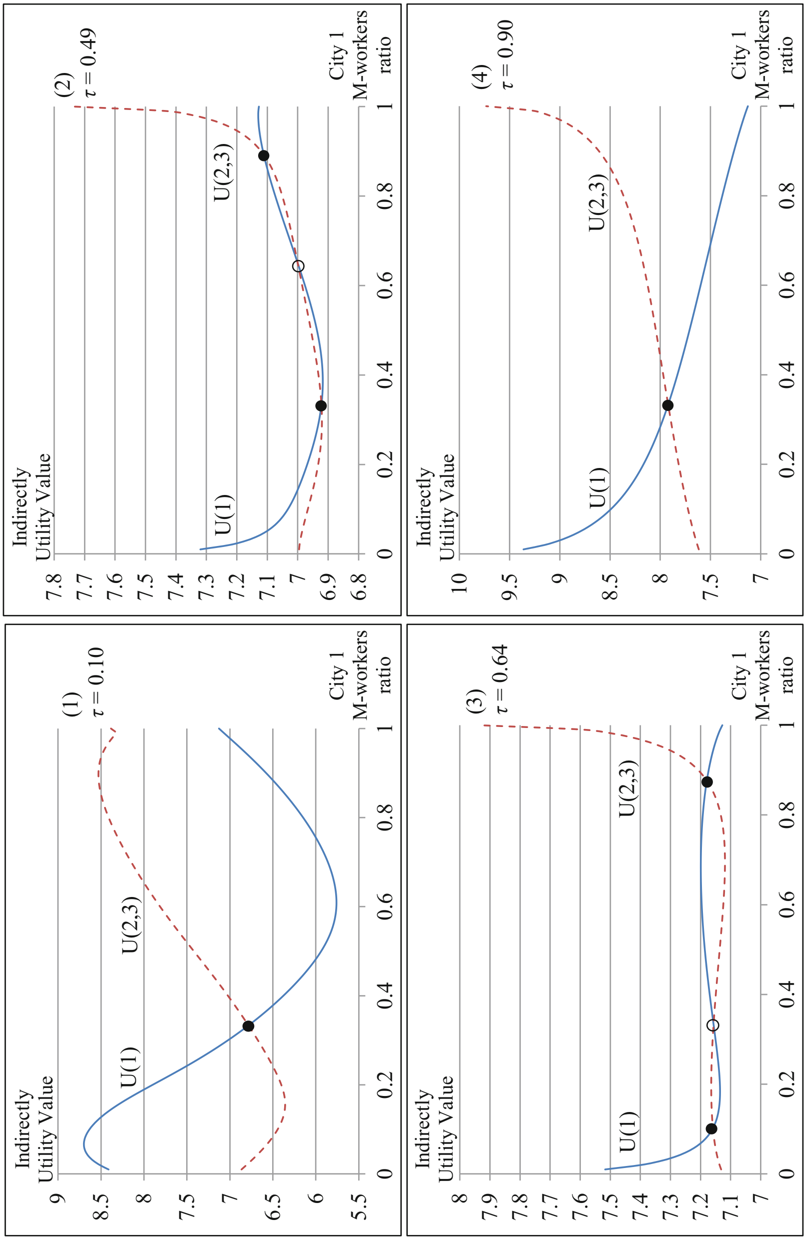

Fig. 7.3 Evolution of equilibrium due to changes in transportation costs

In other words, cities with an inflow of industrial workers will have a diversity of locally produced industrial goods, but residential land consumption will trend downward as rents rise. Additionally, as wages decline, so do disposable wages; thus, the proportion of wage income taken up by commuting costs will rise, causing relative congestion costs to follow the same. As a result, while cities receive positive externalities from the diversity of goods with an influx of industrial workers, such negative externalities as overcrowding (a decline in residential land consumption) and congestion, along with an increase in industrial workers, will cause the utility level to decline. In this situation, the consumption of residential land and agricultural goods is critical for workers.

$U(1)(0.61 < f_1)$, $U(2,3)(f_1 < 0.15)$: In this range, as f_1 increases, $U(1)$ continues rising and $U(2, 3)$ continues declining. This is explained as follows.

When focusing on utility $U(1)$ in City 1, the price index in City 1 rises due to the increasing prices of industrial goods brought in from Cities 2 and 3, and wage rates and goods' prices rise accordingly. As a result, the consumption of goods increase, and an increase in residential land consumption due to declining rents leads to an increase in the utility level.

Case (2)

When interregional transportation costs decline, as in Case (2), discontinuously imperfect agglomeration becomes the stable equilibrium, which turns into multiple equilibria with the addition of the dispersion equilibrium. The change in the utility level is simpler in this case than it was in Case (1). Looking at $U(1)$, when the industrial base is small, the affluent citizens of City 1 mentioned above will consume agricultural goods and residential land on a large scale and achieve high levels of utility. An influx of industrial workers causes the utility level to decline as a result of negative externalities, but the utility level will rise again due to further inflows of diverse goods. Here, similar to Case (1), the inflow of industrial workers causes disposable wage rates to decline, resulting in increased congestion costs, but the diversity of goods had more impact than in Case (1). In this situation, the decline in τ will strengthen agglomeration from the diversity of goods.

Cases (3) and (4)

When interregional transportation costs decline beyond the extreme value ($\tau = 0.52$), the dispersion equilibrium becomes unstable, and most industrial workers agglomerate in a certain city. Lower interregional transportation costs will encourage the export of industrial goods produced in large cities, and disparities among cities in terms of the price index, wages, and prices will tend to fall.

In this situation, the price index trends downward due to the influx of industrial workers, and consumption of industrial goods tends to increase. In contrast, consumption of residential land and agricultural goods tends to decline. The distance to the city limit expands with the inflow of industrial workers, and residential land consumption decreases, but the population increase has caused the urban land area to expand. Also, because this leads to higher commuting expenses, disposable wages will go down. Therefore, in Cases (3) and (4), the diversity (agglomeration mechanism) of industrial goods becomes more important than the shortage of residential land and the rise in commuting expenses (dispersion mechanism), leading to a higher utility level.

However, looking at $U(1)$, the allocation of ample disposable wages to inexpensive land and industrial goods when the industrial workforce is small makes it possible to achieve a higher level of utility than $U(2, 3)$. Here, the reduction in the city limits functions to increase disposable wages and acts as an agglomeration mechanism that increases the utility level.

In this case, while the influx of industrial workers leads to the enjoyment of a diversity of goods, negative externalities such as rising commuting expenses and reduced residential land consumption increase. Also, as the city develops into a major industrial hub, utility slopes downward.

Case (5)

In this case, the interregional transportation costs for importing goods from other cities are negligible, and free trade becomes possible. Therefore, re-dispersion occurs because there is little value in agglomerating in a single city to enjoy a variety of goods. Residential space is important in this case. When industrial workers flow in and the city limits expand, consumption of goods continuously declines in line with the decline in disposable wages and the increase in rents. Due to this reason, an increase in the city size lowers the utility level. When this happens, the aforementioned negative externalities come into play and industrial workers and firms disperse.

Changes in Distance to City Limits

Next, we focus on changes in the distance to the city limits caused by changes in the industrial workers' population and interregional transportation costs. In a situation wherein transportation costs are low enough for industrial workers to redisperse, city limits tend to expand with the inflow of workers. However, this trend does not occur during the initial dispersion period, when the interregional transportation costs are very high. At this point, the urban area rapidly expands with the influx of workers, but when workers continue arriving, the urban area first shrinks and later re-expands. As mentioned previously, the sudden expansion at the beginning of the inflow is due to the fact that most of the relatively high wages are allocated to the consumption of cheap land. However, the continuing influx causes the price index to decrease, thus decreasing wage rates and urban income. Also, higher rents will accelerate the decline in residential land consumption, causing the urban area to shrink. After that, the high prices of imported goods will drive up the price index, wages, and even urban income, and the urban area will again expand due to the increase in residential land consumption and workers.

When focusing on the equilibrium utility level, it continues to rise as a result of lower interregional transportation costs. However, agglomeration suddenly takes place at extreme values. In this simulation, the utility level increases catastrophically. From the standpoint of social welfare, this indicates that the agglomeration equilibrium is better than the dispersion equilibrium. In fact, in Case (2), which has multiple equilibria, the agglomeration equilibrium achieves a higher utility level than the dispersion equilibrium does. For this reason, urban planning for regional decentralization is economically irrational when interregional transportation costs are high. However, when interregional transportation costs are sufficiently low [Cases (4) and (5)], the utility curve slopes downward. In these two cases, the dispersion equilibrium is better than the agglomeration equilibrium. Also, because the dispersion equilibrium is stable as well as being the only stable equilibrium, it is achieved even with minimal government intervention.

Moreover, in this simulation, the agricultural sector was set to be highly productive. As mentioned above, agglomeration in this simulation is imperfect. While these areas become depopulated, it seems that they retain some urban functions and can be self-sustainable. Thus, the existence of a highly productive agricultural sector prevents the complete outflow of the industrial sector and shows that urban functions can be maintained even as depopulation occurs.

7.5 Conclusion

This study presents a general equilibrium model of the agglomeration and dispersion of firms and workers in a three-city system model that takes urban space into consideration. Proposition 7.1 derives the conditions for agglomeration and dispersion in a situation where interregional transportation costs are very high. Proposition 7.2 showed that dispersion will always take place when interregional transportation costs are sufficiently low.

In addition, the numerical simulations depict the transition from industrial dispersion → agglomeration → re-dispersion as interregional transportation costs decline. In this case, the utility level rises catastrophically at the time of agglomeration. This suggests that agglomeration is better than dispersion from the standpoint of social welfare. In fact, when multiple equilibria are achieved, the utility level for agglomeration is higher than that for dispersion. For this reason, urban planning for regional decentralization is economically irrational when transportation costs are high. As re-dispersion is the only stable equilibrium, it is easy to achieve even with minimal government intervention.

Finally, in the case using realistic numbers, the agricultural sector is set to have high productivity. In such a situation, agglomeration becomes imperfect. Because of this, the existence of a highly productive agricultural sector prevents the outflow of the industrial sector, and it is shown that urban functions can be retained even as depopulation occurs.

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Chapter 8
Emission Standards Versus Emission Taxes with Foreign Firms

Tsuyoshi Shinozaki and Minoru Kunizaki

Abstract Extending Lahiri and Ono's (2007) model of an oligopoly with emission regulation, by incorporating a foreign rival, we compare the effectiveness of a relative emission standard versus an emission tax. We consider following two cases. In the first case, where only the home/domestic country unilaterally implements policies, an emission standard is Pareto superior to an emission tax, whereas it is unclear which policy is better for the foreign country. In the second case, where both countries simultaneously choose environmental protection, the home country prefers a standard to a tax, while foreign country prefers a tax to a standard.

Keywords Emission standard · Emission tax · Open economy · Pollution · Duopoly

8.1 Introduction

It is well-known in environmental economics that a Pigouvian tax and emission standard have an equivalent effect on pollution and welfare. This effect has played a central role in environmental protection policy. However, as pointed out by Weitzman (1974), it breaks down under uncertainty. Lee (1975) concludes that the optimal level of a pollution tax, for an oligopoly, depends on market competitiveness.

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Besides these studies, there is a large body of literature on Pigouvian taxation in oligopolistic markets. Conrad and Wang (1993) point out that the optimal pollution tax highly depends on market structures, and Katsoulacos and Xepapadeas (1995) consider the implications of free entry for optimal Pigouvian taxes.

On the contrary, using a similar framework to that of Katsoulacos and Xepapadeas (1995), Lahiri and Ono (2007) consider which is Pareto superior between a relative emission standard and an emission tax. They also pay special attention to the role of free entry. In so doing, they find that an emission standard is superior to a pollution tax under restricted entry, whereas this ranking may be reversed under free entry.

The main purpose of this paper is to revisit Lahiri and Ono's (2007) result, using an open-economy model. The model is very simple but suffices to achieve our aim. We consider a country's market in which a home firm competes with a foreign rival. Another deviation from Lahiri and Ono (2007) is that we allow two distinct cases. In the first case, the home country implements environmental policies, while the foreign country observes laissez-faire. The second case describes a situation in which both countries simultaneously choose environmental protection. This difference in unilateral and bilateral choice of policies has a significant effect on results.

We arrived at two results. In first case, the home/domestic country (hereinafter home country) prefers an emission standard to an emission tax, but it is unclear whether the same is true of the foreign country. In second case, we found an intriguing result that the home country prefers a standard, while the foreign country prefers a tax. This implies that multilateral harmonization of environmental policies is difficult to achieve voluntarily, and some negotiation is needed to harmonize interests.

This paper is structured as follows. Section 8.2 presents the basic model. Section 8.3 considers the first case in which only the home country implements environmental policies. Section 8.4 presents the second case, where both countries employ environmental protection. Section 8.5 concludes.

8.2 The Model

Consider a market with a homogeneous product, in a country in which a home firm competes with a foreign firm in a Cournot fashion. Home country's inverse demand function is $p(x^h + x^f)$ with property $p^{'} < 0$, where p, x^h, and x^f are the price, the outputs of the home firms, and the outputs of the foreign firms, respectively. With cost denoted by $c^i(x^i, \cdot)$, where $c^i_{x^i} > 0$ and $c^i_{x^i x^i} > 0$, each firm chooses output to maximize profit $\pi^i = px^i - c^i(x^i, \cdot)$. We then obtain the first-order condition for profit maximization: $p - c^i_{x^i}\left(x^i, \cdot\right) = -p'x^i$.

Following Lahiri and Ono (2007), the amount of pollution generates (before any abatement) by the firm is $\theta(x^i)$, where $\theta^{'} > 0$, $\theta'' \geq 0$, and $\theta(0) = 0$. The cost of abating pollution by amount a is $\gamma^i = \gamma^i(a)$, where $\gamma^i(0) = 0$, $\gamma^{i'} > 0$, and $\gamma^{i''} > 0$.

8.3 Unilateral Environmental Policies

Sections 8.3.1 and 8.3.2 compare the welfare effects of two alternative environmental protection policies: a relative emission standard and an emission tax. For this purpose, we consider two distinct cases. In the first case, only the home government implements environmental policies and the foreign government observes laissez-faire. In contrast, Sect. 8.4 deals with the case in which both countries simultaneously choose policies. This difference in government behavior will play a significant role in our argument. This section focuses on the case with environmental regulation as undertaken only by the home government.

Before examining the welfare effects of the policies, it is helpful to specify the foreign firm's costs. We assume that production costs and abatement costs are separable: $c^f\left(x^f, e^f\right) = \overline{c}\left(x^f\right) + \gamma^f\left(\theta^f\left(x^f\right) - e^f\right)$, where e^f is the total post-abatement emission level of a firm in the foreign country. Profit maximization with respect to e^f implies that $c_e^f\left(x^f, e^f\right) = -\gamma^{f\prime}\left(\theta^f\left(x^f\right) - e^f\right) = 0$. The value of e^f, which satisfies this condition, becomes a function of x^f, as $e^f(x^f)$, where $e_x^f = \theta^{f\prime} > 0$. Substituting this into the definition of cost above, we find that foreign firm's cost is a function of only x^f: $c^f\left(x^f\right) = \overline{c}^f\left(x^f\right) + \gamma^f\left(\theta^f\left(x^f\right) - e^f\left(x^f\right)\right)$, where $c_x^f = \overline{c}_x^f > 0$ and $c_{xx}^f = \overline{c}_{xx}^f > 0$. The foreign country's welfare is assumed to consist of foreign firm's profit, minus negative externalities from pollution: $W^f = \pi^f - \varphi^f(Z^f)$, where φ^f, which is increasing, is the damage function from total amount of pollution in foreign country and Z^f is the amount of pollution in the foreign country.

8.3.1 Emission Standard

The home government specifies the relative emission standard as z^h, that is, the maximum allowance for pollutants per unit of output. Since home firm generates $\theta^h(x^h)$ units of pollutants, we attain $a^h = \theta^h - z^h x^h$, and its cost becomes $c^{Q,h}\left(x^h, z^h\right) = \overline{c}^h\left(x^h\right) + \gamma^h\left(\theta^h\left(x^h\right) - z^h x^h\right)$, where $c_x^{Q,h} = \overline{c}_x^h + \gamma'\left(\theta' - z^h\right)$, $c_{xx}^{Q,h} = \overline{c}_{xx}^h + \gamma'\theta'' + \gamma''\left(\theta' - z^h\right)^2$, $c_{xz}^{Q,h} = -\left[\gamma' + \gamma''\left(\theta' - z^h\right)x^h\right]$, and $c_z^{Q,h} = -\gamma' x^h < 0$. The superscript Q refers to the relative emission standard (emission quota). Under this scheme, home country's welfare is composed of the profit, π^h; consumer surplus, CS^h; and damage from pollution of home firm, $\varphi^h(Z^{Q,h})$, represented by $W^{Q,h} = \pi^h + CS^h - \varphi^h(Z^{Q,h})$, where pollution in home must satisfy $Z^{Q,h} = x^h z^h$.

Now, we will examine the comparative statics results. First, differentiating the first-order conditions for profit maximization, the effects of z on Cournot outputs are:

$$\begin{bmatrix} \Phi^{Q,h} & K^{Q,h} \\ K^* & \Phi^* \end{bmatrix} \begin{bmatrix} \mathrm{d}x^h \\ \mathrm{d}x^f \end{bmatrix} = \begin{bmatrix} c_{x^h z^h}^{Q,h} \\ 0 \end{bmatrix} \mathrm{d}z.$$

Given the second-order conditions $\Phi^{Q,i} = 2p' + p''x^i - c^{Q,i}_{x^i x^i} < 0$, $K^{Q,\,i} = p' + p''x^i < 0$, $\Phi^* = 2p' + p''x^f - c^f_{x^i x^i} < 0$, and $K^* = 2p' + p''x^f < 0$, we obtain:

$$\frac{\mathrm{d}x^h}{\mathrm{d}z^h} = \frac{c^{Q,h}_{x^h z^h}\Phi^*}{\Delta} > 0 \quad \text{and} \quad \frac{\mathrm{d}x^f}{\mathrm{d}z^h} = -\frac{c^{Q,h}_{x^h z^h}K^*}{\Delta} < 0, \tag{8.1}$$

where $\Delta = \Phi^{Q,\,h}\,\Phi^* - K^{Q,\,h}K^* > 0$.

Equation (8.1) immediately leads to the effect on total supply in the home country:

$$\frac{\mathrm{d}D^h}{\mathrm{d}z^h} = \frac{\mathrm{d}x^h}{\mathrm{d}z^h} + \frac{\mathrm{d}x^f}{\mathrm{d}z^f} = \frac{c^{Q,h}_{x^h z^h}}{\Delta}\left(\Phi^* - K^*\right) > 0.$$

Based on these results, a change in pollution in the home country and the profits of each firm are obtained as follows:

$$\frac{\mathrm{d}Z^{Q,h}}{\mathrm{d}z^h} = x^h + z^h\left(\frac{\mathrm{d}x^h}{\mathrm{d}z^h}\right) = x^h + z^h\frac{c^{Q,h}_{x^h z^h}\Phi^*}{\Delta} > 0,$$

$$\frac{\mathrm{d}\pi^h}{\mathrm{d}z^h} = p'x^h\frac{\mathrm{d}x^f}{\mathrm{d}z^h} - c^{Q,h}_{z^h} = \frac{-p'x^h c^{Q,h}_{x^h z^h}K^*}{\Delta} - c^{Q,h}_{z^h}$$

and

$$\frac{\mathrm{d}\pi^f}{\mathrm{d}z} = p'x^f\frac{\mathrm{d}x^f}{\mathrm{d}z^h} = \frac{p'xc^{Q,h}_{x^h z^h}\Phi^*}{\Delta} < 0.$$

Finally, welfare changes are derived by differentiating W^h and W^f, defined above:

$$\begin{aligned}\frac{\mathrm{d}W^{Q,h}}{\mathrm{d}z^h} &= \frac{\mathrm{d}\pi^h}{\mathrm{d}z^h} + \frac{\mathrm{d}CS^h}{\mathrm{d}z^h} - \varphi^{h\prime}\frac{\mathrm{d}Z^{Q,h}}{\mathrm{d}z^h}\\ &= -\left[\frac{p'c^{Q,h}_{x^h z^h}}{\Delta}\left\{x^h K^* + D^h\left(\Phi^* - K^*\right)\right\} + c^h_{z^h}\right] - \varphi^{h\prime}\frac{\mathrm{d}Z^{Q,h}}{\mathrm{d}z^h}\end{aligned} \tag{8.2}$$

and

$$\begin{aligned}\frac{\mathrm{d}W^f}{\mathrm{d}z^h} &= \frac{\mathrm{d}\pi^f}{\mathrm{d}z^h} - \varphi^{f\prime}\frac{\mathrm{d}Z^f}{\mathrm{d}z^h}\\ &= p'x^f\frac{c^{Q,h}_{x^h z^h}\Phi^f}{\Delta} - \varphi^{f\prime}\frac{\mathrm{d}Z^f}{\mathrm{d}z^h} = \frac{c^{Q,h}_{x^h z^h}}{\Delta}\left[p'x^f\Phi^* + \varphi^{f\prime}\theta^{f\prime}K^*\right].\end{aligned} \tag{8.3}$$

8.3.2 Emission Tax

Now, we will examine another environmental policy: an emission tax, denoted by t. Under this policy, the home firm must incur production costs, $\overline{c}^h\left(x^h\right)$, abatement costs, $\gamma^h(\theta^h(x^h) - e^h)$, and tax payments, $t^h e^h$. Therefore, its total cost is expressed by $c^{T,h}\left(x^h, \cdot\right) = \overline{c}^h\left(x^h\right) + \gamma^h\left(\theta^h\left(x^h\right) - e^h\right) + t^h e^h$, where superscript T stands for an emission tax. Let us eliminate e^h from the equilibrium system by using an optimality condition with respect to e^h. The first-order condition with respect to e^h is $t^h - \gamma^{h'}(\theta^h(x^h) - e^h) = 0$. Hence, the solution to this condition can be expressed by $e^h = e^h(x^h, t^h) = \theta^h(x^h) - \gamma^{h'-1}(t^h)$, with $e^h_{x^h} = \theta^{h'}$ and $e^h_{t^h} = -\frac{1}{\gamma^{h''}}$. Accordingly, home firm's cost becomes a function of output only: $c^{T,h}\left(x^h, t^h\right) = \overline{c}^h\left(x^h\right) + \gamma^h\left(\theta^h\left(x^h\right) - e^h\left(x^h, t^h\right)\right) + t^h e^h\left(x^h, t^h\right)$, with the properties of $c^{T,h}_{x^h} = \overline{c}^h_{x^h} + t^h\theta^{h\prime}$, $c^{T,h}_{x^h x^h} = \overline{c}^h_{x^h x^h} + t^h\theta^{h\prime\prime}$, $c^{T,h}_{x^h t^h} = \theta^{h\prime}$, and $c^{T,h}_{t^h} = e^h$. Under this scheme, the home country's welfare is:

$$W^{T,h} = \pi^h + CS^h + t^h Z^{T,h} - \varphi^h\left(Z^{T,h}\right).$$

Totally differentiating the first-order conditions for profit maximization under the home country's emission tax, yields:

$$\begin{bmatrix} \Phi^{T,h} & K^{T,h} \\ K^* & \Phi^* \end{bmatrix} \begin{bmatrix} \mathrm{d}x^h \\ \mathrm{d}x^f \end{bmatrix} = \begin{bmatrix} c^{T,h}_{x^h t^h} \\ 0 \end{bmatrix} \mathrm{d}t^h.$$

In view of the second-order conditions, $\Phi^{T,h} = 2p' + p''x^h - c^{T,h}_{x^h x^h} < 0$, $\Phi^* = 2p' + p''x^f - c^f_{x^f x^f} < 0$, $K^T = p' + p''x^h < 0$, and $K^* = p' + p''x^f < 0$, we obtain the following comparative statics results:

$$\frac{\mathrm{d}x^h}{\mathrm{d}t^h} = \frac{\theta'\Phi^*}{\Delta^T} < 0, \qquad \frac{\mathrm{d}x^f}{\mathrm{d}t^h} = -\frac{\theta' K^*}{\Delta^T} > 0,$$

where $\Delta^T = \Phi^{T,h}\,\Phi^* - K^h K^* > 0$.

Using these results, the home country's demand changes according to:

$$\frac{\mathrm{d}D^h}{\mathrm{d}t^h} = \frac{\mathrm{d}x^h}{\mathrm{d}t^h} + \frac{\mathrm{d}x^f}{\mathrm{d}t^h} = \frac{\theta'}{\Delta^T}\left(\Phi^* - K^*\right) < 0,$$

Moreover, the effects on pollution, $Z^{T,h}$; home firm's profit, π^h; and the foreign firm's profit, π^f, are derived as:

$$\frac{\mathrm{d}Z^{T,h}}{\mathrm{d}t^h} = \left\{\frac{\left(\theta'\right)^2\Phi^*}{\Delta^T} - \frac{1}{\gamma''}\right\} < 0,$$

$$\frac{\mathrm{d}\pi^h}{\mathrm{d}t^h} = p'x^h\frac{\mathrm{d}x^f}{\mathrm{d}t^h} - c^{T,h}_{t^h} = \frac{-p'x^h\theta' K^*}{\Delta^T} - c^{T,h}_{t^h} < 0$$

and

$$\frac{\mathrm{d}\pi^f}{\mathrm{d}t^h} = p'x^f \frac{\mathrm{d}x^h}{\mathrm{d}t^h} = \frac{p'x^h\theta'\Phi^*}{\Delta^T} > 0$$

respectively.

Furthermore, using these results enables us to obtain the welfare effect:

$$\begin{aligned}\frac{\mathrm{d}W^{T,h}}{\mathrm{d}t^h} &= \frac{\mathrm{d}\pi^h}{\mathrm{d}t^h} + \frac{\mathrm{d}CS^h}{\mathrm{d}t^h} + Z^h - \left(\varphi^{h\prime} - t^h\right)\frac{\mathrm{d}Z^{T,h}}{\mathrm{d}t^h} \\ &= -\frac{p'\theta'}{\Delta^T}\left[\left\{x^h K^* + D^h\left(\Phi^* - K^*\right)\right\}\right] - \left(\varphi^{h\prime} - t^h\right)\frac{\mathrm{d}Z^{T,h}}{\mathrm{d}t^h}\end{aligned} \tag{8.4}$$

and

$$\begin{aligned}\frac{\mathrm{d}W^f}{\mathrm{d}t^h} &= \frac{\mathrm{d}\pi^f}{\mathrm{d}t^h} - \varphi^f\frac{\mathrm{d}Z^f}{\mathrm{d}t^h} \\ &= p'x^f\frac{c^{T,h}_{x^h t^h}\Phi^*}{\Delta^T} - \varphi^f\frac{\mathrm{d}Z^f}{\mathrm{d}t^h} = \frac{c^{T,h}_{x^h t^h}}{\Delta^T}\left[p'x^f\Phi^* + \varphi^{f\prime}\theta' K^*\right].\end{aligned} \tag{8.5}$$

8.3.3 Comparison of the Two Policies

Based on the results above, we proceed to compare the welfare effects under these two alternative schemes. Since it is extremely difficult to compare the welfare effects without any restriction, we make two convenient assumptions following Lahiri and Ono (2007). First, we assume that $t^h = 0$ and $z^h x^h = \theta^h(x^h)$ initially holds, that is, neither policy is implemented. Second, we focus on the situation in which any environmental restriction has a positive welfare effect: $\mathrm{d}W^h/\mathrm{d}t^h > 0$ and $\mathrm{d}W^h/\mathrm{d}z^h < 0$.

Note here that $c^{Q,h}_z = 0$, $c^{Q,h}_{xz} = -\left(\theta^{h\prime} - z^h\right)\gamma^{h\prime\prime}x^h$ and $c^{Q,h}_{xx} = c^{T,h}_{xx} - \left(\theta^{h\prime} - z^h\right)^2\gamma^{h\prime\prime}$ given $\gamma^{h'}(0) = 0$. Therefore, the change in the home country's welfare, under an emission standard, is rewritten as:

$$\begin{aligned}\mathrm{d}W^{Q,h}\Big|_{\theta^h = z^h x^h} = -&\left[\frac{-p'\left(\theta^{h\prime} - z^h\right)\gamma^{h\prime\prime}x^h}{\Delta}\left\{x^h K^* + D^h\left(\Phi^* - K^*\right)\right\}\right] \\ &\times \mathrm{d}z^h - \varphi^{h\prime}\mathrm{d}Z^{Q,h}.\end{aligned}$$

Similarly, the change in the home country's welfare under an emission tax, evaluated at $t = 0$, becomes:

$$\mathrm{d}W^{T,h}\Big|_{t^h=0} = -\frac{p^{\theta^{h\prime}}}{\Delta^T}\left[\left\{x^h K^* + D^h\left(\Phi^* - K^*\right)\right\}\right]\mathrm{d}t^h - \varphi^{h\prime}\mathrm{d}Z^{T,h}.$$

When changes in z^h and t^h are emission-equivalent, they generate the same change in total emissions Z^h, that is, $dZ^{Q,h} = dZ^{T,h}$. Thus, the difference between dW^Q and dW^T is:

$$\left[dW^{Q,h} - dW^{T,h}\right]\Big|_{\substack{t^h=0\\ \theta^h=z^h x^h}}$$

$$= -p'\left\{K^* + D\left(\Phi^* - K^*\right)\right\}\left[\frac{\left(\theta^{h\prime} - z^h\right)\gamma^{h\prime}x^h}{\Delta}dz - \frac{\theta^{h\prime}}{\Delta^T}dt\right]. \tag{8.6}$$

Note that $dZ^{Q,h} = dZ^{T,h}$ implies:

$$dz^h = \left(\frac{\Delta^T - \left(\theta^{h\prime}\right)^2\Phi^*\gamma^{h\prime\prime}}{\left\{\Delta - z^h\left(\theta^{h\prime} - z^h\right)\gamma^{h\prime\prime}\Phi^*\right\}\Delta^T}\right)\left(\frac{-\Delta}{x^h\gamma^{h\prime\prime}}\right)dt^h. \tag{8.7}$$

Substituting Eq. (8.7) into Eq. (8.6), we find that the difference in welfare effects on the home country becomes:

$$\left[\frac{dW^{Q,h} - dW^{T,h}}{dt^h}\right]\Bigg|_{\substack{t=0\\ \theta=zx}} = \left\{x^h K^* + D^h\left(\Phi^* - K^*\right)\right\}p' z^h \Omega^U > 0, \tag{8.8}$$

where $\Omega^U = \{\Delta^Q - z^h(\theta^{h'} - z^h)\gamma^{h''}\Phi*\}^{-1} > 0$.

The difference between the welfare changes of the foreign country is similarly derived:

$$\left[\frac{dW^{Q,f} - dW^{T,f}}{dt^f}\right]\Bigg|_{\substack{t^h=0\\ \theta^h=z^h x^h}} = -z^h\left(x^h p'\Phi^* + \varphi^{f\prime}\theta^{f\prime}K^*\right)\Omega^U. \tag{8.9}$$

Now, we have arrived at:

Proposition 8.1: *Under the home country's unilateral adoption of environmental policies, an emission standard improves the home country's welfare more than an emission tax, while it is unclear whether foreign country's welfare improves as a result of the environmental policies. However, if $\varphi^{f'}\theta^{f'}$ is sufficiently small, the emission standard is Pareto superior to an emission tax for the foreign country.*

8.4 Bilateral Environmental Policies

This section presents another scenario: both countries simultaneously choose environmental protection. For simplicity, we assume that the firms in both countries are completely symmetric. Since the analytical procedures are the same as in the previous section, it is necessary to sketch only the outline of the argument.

8.4.1 Emission Standard

Let us first address the case of an emission standard. Each firm's cost is $c^{Q,i}\left(x^i, z^i\right) = \overline{c}^i\left(x^i\right) + \gamma^i\left(\theta^i\left(x^i\right) - z^i x^i\right)$, and the foreign country's welfare is $W^{Q,f} = \pi^f - \varphi^f(Z^{Q,f})$.

The total differentiation of the system of first-order conditions for profit maximization results in:

$$\begin{bmatrix} \Phi^{Q,h} & K^{Q,h} \\ K^{Q,f} & \Phi^{Q,f} \end{bmatrix} \begin{bmatrix} \mathrm{d}x^h \\ \mathrm{d}x^f \end{bmatrix} = \begin{bmatrix} c_{xz}^{Q,h} \\ 0 \end{bmatrix} \mathrm{d}z^h + \begin{bmatrix} 0 \\ c_{xz}^{Q,f} \end{bmatrix} \mathrm{d}z^f,$$

which in turn, results in:

$$\left.\frac{\mathrm{d}x^h}{\mathrm{d}z^i}\right|_{\substack{x^h=x^f \\ z^h=z^f \\ c^h=c^f}} = \left.\frac{\mathrm{d}x^f}{\mathrm{d}z^i}\right|_{\substack{x^h=x^f \\ z^h=z^f \\ c^h=c^f}} = \frac{c_{xz}^Q\left(\Phi^Q - K^Q\right)}{\Lambda} > 0,$$

where $\Lambda = \Phi^{Q,h}\,\Phi^{Q,f} - K^{Q,h} K^{Q,f} > 0$. Then, the home country's demand changes according to:

$$\left.\frac{\mathrm{d}D^h}{\mathrm{d}z}\right|_{\substack{x^h=x^f \\ z^h=z^f \\ c^h=c^f}} = \left.\left[\frac{\mathrm{d}x^h}{\mathrm{d}z} + \frac{\mathrm{d}x^f}{\mathrm{d}z}\right]\right|_{\substack{x^h=x^f \\ z^h=z^f \\ c^h=c^f}} = \frac{2c_{xz}^Q\left(\Phi^Q - K^Q\right)}{\Lambda} > 0.$$

Iterating the procedures in Sect. 8.3, the effects on pollution, profits, and welfare are obtained as follows:

$$\left.\frac{\mathrm{d}Z^{Q,i}}{\mathrm{d}z}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = x^i + z^i \frac{\mathrm{d}x^i}{\mathrm{d}z} = x^i + z^i \frac{c_{xz}^Q(\Phi^Q - K^Q)}{\Lambda} > 0,$$

$$\left.\frac{\mathrm{d}\pi^i}{\mathrm{d}z}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = p' x^i \frac{\mathrm{d}x^j}{\mathrm{d}z} - c_{z^i}^{Q,i} = \frac{p' x^i c_{xz}^Q\left(\Phi^Q - K^Q\right)}{\Lambda} - c_z^Q, \tag{8.10}$$

$$\left.\frac{\mathrm{d}W^{Q,h}}{\mathrm{d}z}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \frac{\mathrm{d}\pi^h}{\mathrm{d}z} + \frac{\mathrm{d}CS^h}{\mathrm{d}z} - \varphi^{h\prime}\frac{\mathrm{d}Z^{Q,h}}{\mathrm{d}z}$$

$$= \left[\frac{p' x c_{xz}^Q}{\Lambda}\left(\Phi^Q - K^Q\right) - c_z - \frac{2Dp' c_{xz}^Q}{\Lambda}\left(\Phi^Q - K^Q\right)\right]\mathrm{d}z - \varphi^{h\prime}\frac{\mathrm{d}Z^{Q,h}}{\mathrm{d}z}$$

and

$$\left.\frac{\mathrm{d}W^f}{\mathrm{d}z}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \frac{\mathrm{d}\pi^f}{\mathrm{d}z} - \varphi^{f\prime}\frac{\mathrm{d}Z^f}{\mathrm{d}z}$$

$$= \frac{p' x c_{xz}^Q\left(\Phi^Q - K^Q\right)}{\Lambda} - c_z - \varphi^{f\prime}\frac{\mathrm{d}Z^f}{\mathrm{d}z}. \tag{8.11}$$

8.4.2 Emission Tax

Now, we consider the case of an emission tax in which the home country's welfare is represented by $W^{T,f} = \pi^f + tZ^T - \varphi^f(Z^{Q,f})$. Cournot equilibrium outputs are affected by an emission tax as follows:

$$\begin{bmatrix}\Phi^{T,h} & K^{T,h}\\ K^{T,f} & \Phi^{T,f}\end{bmatrix}\begin{bmatrix}\mathrm{d}x^h\\ \mathrm{d}x^f\end{bmatrix} = \begin{bmatrix}c_{x^h t^h}^{T,h}\\ 0\end{bmatrix}\mathrm{d}t^h + \begin{bmatrix}0\\ c_{x^f t^f}^{T,f}\end{bmatrix}\mathrm{d}t^f,$$

This system immediately yields:

$$\left.\frac{\mathrm{d}x^h}{\mathrm{d}t^h}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \left.\frac{\mathrm{d}x^f}{\mathrm{d}t^f}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \frac{c_{xt}^T\left(\Phi^T - K^T\right)}{\Lambda^T} < 0$$

and

$$\left.\frac{\mathrm{d}D}{\mathrm{d}t}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \left.\left[\frac{\mathrm{d}x^h}{\mathrm{d}t} + \frac{\mathrm{d}x^f}{\mathrm{d}t}\right]\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \frac{2c_{xt}^T\left(\Phi^T - K^T\right)}{\Lambda^T} < 0.$$

where $\Lambda = \Phi^{T,\,h}\,\Phi^{T,\,f} - K^{T,\,h}K^{T,\,f} > 0$.

Using these comparative statics exercises, the effects on pollution, profits, and welfare in each country are derived as:

$$\left.\frac{\mathrm{d}Z^T}{\mathrm{d}t}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \left\{\frac{(\theta')^2(\Phi^T - K^T)}{\Lambda^T} - \frac{1}{\gamma''}\right\} < 0,$$

$$\left.\frac{\mathrm{d}\pi^i}{\mathrm{d}t}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = p'x^i\frac{\mathrm{d}x^j}{\mathrm{d}t} - c_t^{T,i} = \frac{p'xc_{xt}^T\left(\Phi^T - K^T\right)}{\Lambda^T} - c_t^T$$

$$\left.\frac{\mathrm{d}W^{T,h}}{\mathrm{d}t}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \frac{\mathrm{d}\pi^{T,h}}{\mathrm{d}t} + \frac{\mathrm{d}CS^{T,h}}{\mathrm{d}t} + Z^{T,h} - \left(\varphi^{h\prime} - t\right)\frac{\mathrm{d}Z^{T,h}}{\mathrm{d}t}$$
$$= \left[\frac{p'xc_{xt}^T}{\Lambda^T}\left(\Phi^T - K^T\right) - c_t + Z^{T,h} - \frac{2Dp'c_{xt}^T}{\Lambda^T}\left(\Phi^T - K^T\right)\right]\mathrm{d}t - \left(\varphi^{h\prime} - t\right)\frac{\mathrm{d}Z^T}{\mathrm{d}t} \tag{8.12}$$

and

$$\left.\frac{\mathrm{d}W^{T,f}}{\mathrm{d}t}\right|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f}} = \frac{\mathrm{d}\pi^{T,f}}{\mathrm{d}t} + Z^{T,f} - \varphi^{f\prime}\frac{\mathrm{d}Z^{T,f}}{\mathrm{d}t}$$
$$= \frac{p'x^jc_{xt}^T\left(\Phi^T - K^T\right)}{\Lambda^T} - c_t^f + Z^{T,f} - \left(\varphi^{f\prime} - t\right)\frac{\mathrm{d}Z^f}{\mathrm{d}t}. \tag{8.13}$$

8.4.3 Comparison of the Two Policies

We are now in a position to prove the second main result. Noting that $\mathrm{d}Z^{Q,\,i} = \mathrm{d}Z^{T,\,i}$ implies:

$$\mathrm{d}z = \left(\frac{\Lambda^T - \left(\theta'\right)^2\left(\Phi^T - K^T\right)\gamma''}{\left\{\Lambda - z\left(\theta' - z\right)\gamma''\left(\Phi^Q - K^Q\right)\right\}\Lambda^T}\right)\left(\frac{-\Lambda}{x\gamma''}\right)\mathrm{d}t.$$

We find that the welfare effects on the home and foreign untries are given by:

$$\left[\frac{\mathrm{d}W^{Q,h} - \mathrm{d}W^{T,h}}{\mathrm{d}t}\right]\Bigg|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f\\ t^i=0\\ z^i x^i=\theta^i}} = (x-2D)\, p' \left(c^Q_{xx} - p'\right) z\Omega^{\mathrm{B}} > 0 \tag{8.14}$$

and

$$\left[\frac{\mathrm{d}W^{Q,f} - \mathrm{d}W^{T,f}}{\mathrm{d}t}\right]\Bigg|_{\substack{x^h=x^f\\ z^h=z^f\\ c^h=c^f\\ t^i=0\\ z^i x^i=\theta^i}} = xp' \left(c^Q_{xx} - p'\right) z\Omega^{\mathrm{B}} < 0 \tag{8.15}$$

respectively, where $\Omega^{\mathrm{B}} = \{\Lambda - z(\theta' - z)\gamma''(\Phi^Q - K^Q)\}^{-1} > 0$.

Proposition 8.2: *Under bilateral adoption of environmental policies, (1) the emission standard improves the home country's welfare more than a tax, while (2) the opposite holds true for the foreign country.*

8.5 Conclusion

We have theoretically evaluated the relative performance between an emission standard and an emission tax, in a simple model of oligopoly, with a foreign competitor. We have shown that the presence of a foreign firm can easily make Lahiri and Ono's (2007) result, based on a closed-economy model, invalid. However, our attempt aims to be a complement to Lahiri and Ono (2007).

It is of particular significance that the home and foreign countries have the opposite preference for an emission standard versus an emission tax, when they bilaterally adopt environmental policies. This result implies that some worldwide harmonization and negotiation over environmental protection are necessary for reconciling interests.

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Chapter 9
Budget Deficits of the Central Government and the Decentralization of Local Governments

Akifusa Fujioka

Abstract This chapter shows that (1) the financial situation of the country in the 1990s deteriorated significantly; (2) the financial deterioration of the country in the 1990s had an adverse effect on local public finance, and the trinity reform was implemented before the adverse effect was corrected; and (3) the need for a Do-shu-system has increased due to the increase in “non-residential villages” or “non-residential areas” due to the decrease in migration.

Keywords Decentralization Reform Act · The local allocation tax · Local bond · Municipal merger · Do-Shu-system

9.1 Introduction

The local systems in Japan have entered a period of great reform. The first Omnibus Decentralization Act was enacted in the year 2000. In December 2006, to facilitate a new Omnibus Decentralization Act, the Promotion of Decentralization Reform Act was enacted, and the Committee on the Promotion of Decentralization Reform was launched in April 2007. In terms of public finances, a trinity reform was carried out from 2004 to 2006, but economic reforms have not stopped there, and a new trinity reform is now set to be implemented. Regarding the revision of local tax allocations, a pillar of the trinity reform, not only has the scale of

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these allocations been reduced, but in April 2007, a new kind of tax allocation was implemented to simplify allocation standards. Because the trinity reform has reduced financial resources, we are currently in the midst of a great Heisei period merging of municipal governments for reformation purposes. Discussion around reforming the prefectures by integrating them into a smaller number of states has also begun in earnest. Furthermore, to facilitate plans for national land development, the former Comprehensive National Land Development Act was revised in 2005 and was renamed the National Spatial Planning Act. Thus, the reform of various local government systems is now underway.

In this paper, I clarify that (1) a lack of moderation in the 1990s precipitated a change in tone in public finances, (2) fiscal measures conducted in the 1990s took a form that dragged in local governments and therefore harmed local public finances, and (3) before this harm could be corrected it was first considerably worsened through the implementation of the trinity reforms. Furthermore, I identify the possibility that the decentralization of power and integration of the prefectures may produce new problems if they are implemented without assurances of economic support.

9.2 The Changing Tone of National Finances

9.2.1 The Rapid Increase in the National Debt

The national finances deviated from the doctrine of balanced budgets when government bonds were issued in the revised budget for the 1965 fiscal year. Following the inclusion of the issuance of construction bonds in the initial budget for the following fiscal year, the issuance of special bonds known as deficit bonds were included in the revised budget for 1975 (the 50th year of the Showa era). These special bonds were scheduled to be repaid in 10 years. However, the repayment period was extended to 60 years, similar to construction bonds, because the poor economic climate of 1985 had resulted in insufficient financial resources (Showa 60). Furthermore, the issuance of refunding bonds was permitted to ensure the necessary financial resource availability. However, efforts were made to suspend the issuance of special bonds as soon as possible, an objective that was realized in the fiscal year 1990 (Heisei 2) after the fortunate support of the natural increase in tax revenues caused by the bubble economy.

In the 1990s, the economic climate worsened because of the collapse of the bubble economy, and the Heisei recession began. However, the government emphasized that it had been able to bring the issuance of special bonds to zero through great pains and was reluctant to embark on new ambitious fiscal policies. Therefore, monetary policy replaced fiscal policy, with cuts made to the official discount rate. However, monetary policy was insufficient as an economic measure following the collapse of the bubble and the economic climate continued to worsen.

Criticized for their inept response to the Heisei recession, the era of single-party government by the LDP collapsed with the establishment of a coalition government in August 1993 (Heisei 5).

The confusion of Japanese politics in the 1990s destabilized the administration; financial rules loosened, the budget deficit expanded each year, and the national debt increased rapidly, resulting in fears of the financial collapse of Japan (Kaizuka and Krueger 2007, pp. 5–20).

9.2.2 A Change in the Administration of Public Finances

A detailed look at the administration of public finances in the 1990s highlights a variety of problems. Among these, the next five points are particularly important. First, despite the considerable slump in tax revenues, a review of annual expenditure was postponed. Second, initial budgets attempted to maintain a zero ceiling. Third, full-scale economic policy was conducted in revised budgets (Fujioka 2009). Fourth, fiscal policy measures were conducted in a form that dragged in municipal governments. Fifth, loans to special accounts for local tax allocations and transfer taxes were used as local fiscal measures to increase financial resources (Higo and Nakagawa 2001, pp. 15–17). These five problem points were instrumental in causing the accumulation of a large national debt. In this sense, it might be said that the change in the tone of public finances occurred because of a loss of fiscal moderation.

A direction for fiscal reforms was revealed when it became impossible to ignore the change in national finances. The reforms included, first, the establishment of a framework for the total national annual expenditure, exemplified by the fiscal structure reforms implemented by the Hashimoto Cabinet. A second reform was a reduction in the amount of local tax allocations and subsidies to local governments, which was realized in the trinity reforms.[1] Third, local governments were asked to take on tasks previously handled at the national level, actualizing the decentralization of power (Hayashi 2005, pp. 27–41). Fourth, to reinforce local power, municipalities were merged and the integration of the prefectures came under consideration as a way to accomplish this more fully.[2] Fifth, the national development scheme that had been used for local development since the end of WWII was suspended and replaced by the introduction of a new local development scheme, the National Spatial Plan.

[1]Konishi (2003), describes local tax allocation reforms based on reductions as preferable, and examines how and why the local tax allocation system is flawed. Regarding policies for reducing the amount of local tax allocations and shouldering these debts through extraordinary financial measure loans, see Umehara (2002).

[2]See Matsumoto (2006) for a general exposition of the integrated prefecture system and Hayashi (2008) for a criticism of the integrated prefecture system as unconstitutional and destructive of resident autonomy.

9.2.3 Problems with the Reforms

Despite having been appropriate for their respective individual goals, a comprehensive examination of these reforms raises questions. First, considering that the level of the burden taken on by the citizenry, including the social security burden, is still lower than the burden in European nations, one problem is that the reforms only rashly reduced the scale of annual expenditure. The relative relationship between reduced expenditure and increases in revenue caused by an increase in taxes must be considered. In this sense, including a consideration of tax increases in the combined reform of yearly revenue and expenditure is appropriate. Instead, they do not go beyond a mid-term perspective in that they merely aim to achieve the limited goal of primary balance. Second, the trinity reforms (Sato 2007, pp. 2–50) failed to address the problem of insufficient independent sources of local government funds. Therefore, an examination of not only the transfer of funds from the nation, but also increases in local taxes is necessary (Kuroda 2007, pp. 126–158). Third, whether long-centralized government activities can be swiftly decentralized is under question. Local government independence is required, which includes the problem of the lack of powers transferred from the nation. Fourth, whether the integration of the prefectures can stimulate independence in local governments is similarly under question. Securing economic power is necessary to increase this independence, but if the integration of the prefectures is implemented without it, then the disparities between regions may increase further.[3] Fifth, the regional division assumed in the prefectural integration system does not necessarily align with the regional division in the National Spatial Plan. As a result, the fear remains that further local development may be inefficient; this includes the division of government roles.

There are other important problems besides these. First, if economic activity does not recover, the various reforms will have been largely ineffective. The fact that the maintenance of annual expenditure is impossible if tax revenue cannot be collected also makes this clear. Second, economic activity is now strongly influenced by the effects of globalization. As a result, companies are able to cross national borders in choosing the optimal location for their business. Many local governments have failed by entrusting their hopes to offering reduced local taxes and subsidies in a bid to attract companies to their region. Third, the relative lack and loosening or abolition of restrictions is damaging. For example, the closed-off nature of Japanese agriculture and the resulting inaccessibility of Japanese agricultural products have hampered the conclusion of free trade agreements (FTAs) and economic partnership agreements (EPAs) that would promote the liberalization of manufactured goods. Japan is therefore disadvantaged in its attempts to compete not only with advanced countries, but also with developing ones.

[3] Doi (2007) contains a theory supporting a transition to integrated prefectures (pp. 1–3) as well as an explanation of how a financial adjustment system between the newly formed states would function (p. 10).

Thus, although the reforms were intended to be beneficial, their lack of consistency and degree of implementation, among other problems, have instead led to weaker results.

9.3 Initial and Revised Budgets

9.3.1 Introducing the Correction Rate

Economic policy measures sometimes use initial budgets and sometimes revised budgets. If they use an initial budget, then the scale of economic measures can be understood by looking at the growth rate of the previous fiscal year's initial budget (or in some cases, revised budget). However, the growth rate from the previous fiscal year's revised budget is not appropriate if the policy measures employ a revised budget. We therefore introduce a "correction rate" as an indicator of how much the initial and revised budgets differ. The correction rate is obtained by subtracting the initial budget from the revised budget and then dividing by the initial budget.

$$\text{Correction rate} = (\text{Budget amount after revision} - \text{initial budget amount})\,/\text{initial budget amount}$$

This correction rate allows us to relatively compare the relationship between the size of the revised budget conducted during the fiscal year and the scale of the initial budget. A large correction rate means that a large revision was conducted in proportion to the scale of the budget. It may, therefore, indicate the scale of new government activity conducted during the fiscal year.

The correction rates for general account total annual expenditures for each fiscal year are shown in Fig. 9.1, illustrating that the correction rate of the nation's finances increased considerably in the middle of the 1970s, at the end of the 1980s, and in the 1990s during the Heisei recession. We determine the reason for this by reexamining the change between the taxes and revenue in the initial and revised budgets as shown

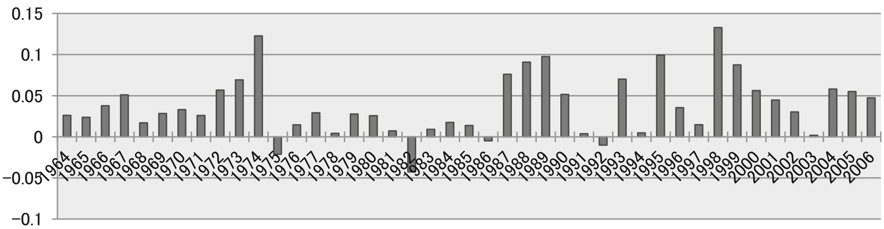

Fig. 9.1 Correction rate of general account expenditure. (Based on data on general account initial and revised budgets in "Chapter 5 Public Finances" of the "Long-term Japan Statistical Series" at the homepage of the Japan Statistics Bureau, http://www.stat.go.jp/data/guide/download/index.htm)

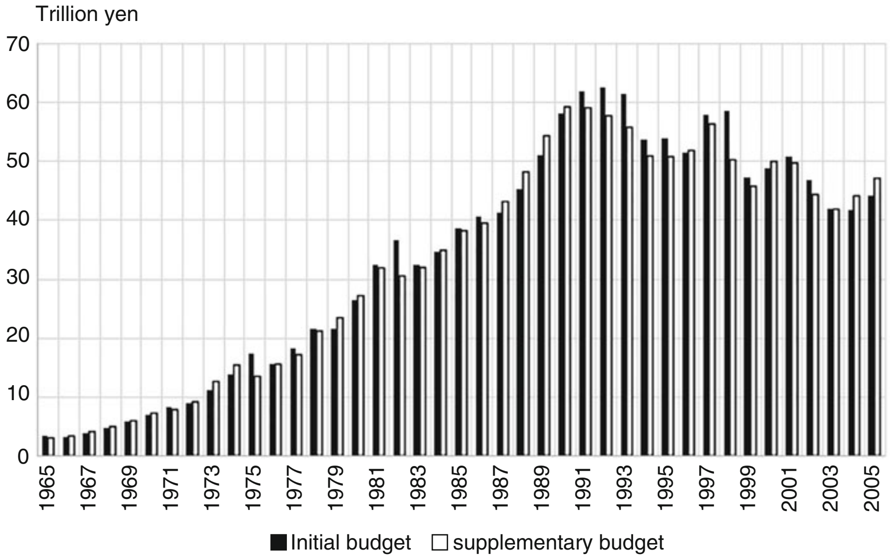

Fig. 9.2 Tax and stamp revenues. (Based on data on general account initial and revised budgets in "Chapter 5 Public Finances" of the "Long-term Japan Statistical Series" at the homepage of the Japan Statistics Bureau, http://www.stat.go.jp/data/guide/download/index.htm)

in Fig. 9.2. According to Fig. 9.2, the bubble economy period from the middle of the 1980s until the beginning of the 1990s produced a significant natural increase in tax revenues during the fiscal year. In fact, for the four fiscal years from 1987 to 1990, the revised budget included more tax revenue than the initial budget. Government expenditures were increased in the revised budget to consume this tax revenue and the correction rate therefore grew larger.

The middle of the 1970s saw the oil crisis and the accompanying recession. As a result, excluding 1976, between 1975 and 1978 tax revenue in the revised budget decreased in comparison with that in the initial budget. Similarly, the Heisei recession in the 1990s following the bubble collapse resulted in a smaller tax revenue in the revised budget in comparison with the initial budget from 1991 to 1999, excluding 1996. Accordingly, the correction rate increased as a result of fiscal policy measures taken during both periods. Furthermore, during the Heisei recession, there were periods of continuous implementation of large-scale policy measures during the fiscal year. That is, in fiscal years 1993, 1995, 1998, and 1999, large-scale revised budgets were assembled for the fiscal policy purposes and the correction rate grew larger during these fiscal years.

From these facts, it can be said that full-scale economic policy measures were implemented twice in the post-war Japanese economy: during the period of slow growth that followed the oil crisis in the 1970s (October 1973) and during the Heisei recession after the collapse of the bubble in the 1990s (February 1991). However, despite the increased growth rate in the initial budget during the oil crisis, the scale of economic measures in the revised budget was comparatively small. Accordingly, we can say that the economic measures in the revised budget exceeded the growth rate in the initial budget only during the 1990s.

9.3.2 Economic Monetary Policy and the Issuance of Government Bonds

Government bonds are issued to procure the necessary financial resources to implement policy measures, which are not only implemented in the initial budget, but also in the revised budget. Therefore, Fig. 9.3 shows the growth rate of the issuance of government bonds in the initial budget and the corrected rate of the issuance of government bonds. The growth rate and corrected rate are relatively small from the late 1960s to the 1970s because of the government bond issuance restraint policy of the Ministry of Finance. However, in August 1971, antirecession policies were implemented because of the Nixon Shock, as it was predicted that the Japanese economy would enter a recession. This resulted in increases in the corrected rate for the issuance of government bonds in 1971 and the growth rate for the issuance of government bonds in the initial budget of 1972. However, in terms of the issuance of government bonds, no economic monetary policy was undertaken

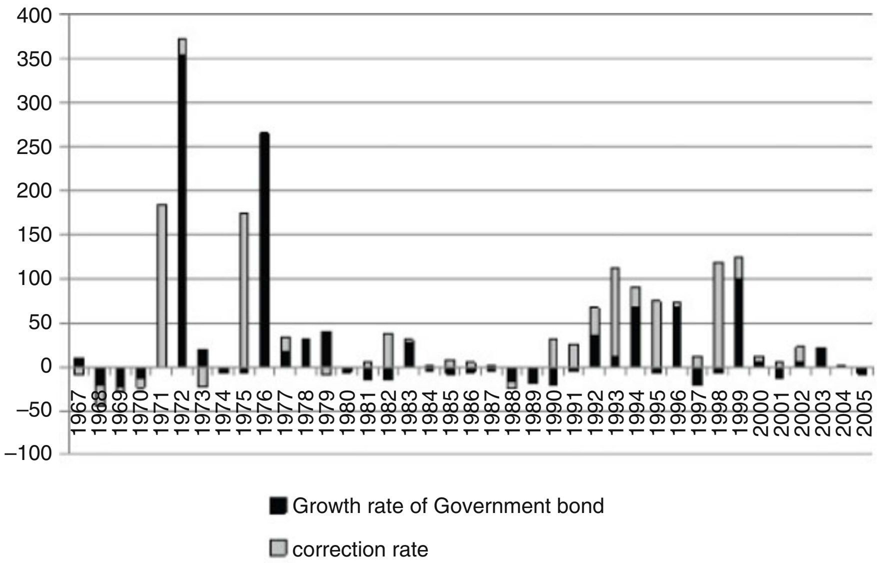

Fig. 9.3 Growth rate of government bond and correction. (Based on data on general account initial and revised budgets in "Chapter 5 Public Finances" of the "Long-term Japan Statistical Series" at the homepage of the Japan Statistics Bureau, http://www.stat.go.jp/data/guide/download/index.htm)

between the first oil shock in 1973 and the initial budget of 1975. Finally, policy measures were once again undertaken in the revised budget for fiscal year 1975. This continued until the initial budget for the 1979 fiscal year. However, there was no further implementation beginning with the revised budget for the 1979 fiscal year, and, regardless of the second oil crisis in 1979, none were implemented until the initial budget of the 1982 fiscal year. The corrected rate for the issuance of government bonds in fiscal year 1982 and the initial budget for the issuance of government bonds in fiscal year 1983 both increased, and although measures were implemented, from 1984 to 1991 the growth rate of the issuance of government bonds continued to be negative. Starting with the revised budget in fiscal year 1991, the growth rate for the issuance of government bonds in initial and revised budgets for the implementation of policy measures increased.

In the 1990s government bonds were issued on a large scale in the name of economic policy measures each fiscal year, so the national debt increased rapidly. The national debt was expected to reach 547.722 trillion JPY in 2007.

9.4 Worsening Local Finances

9.4.1 The Initial and Revised Budgets of Local Governments

To begin, it must be noted that local government budgets have different characteristics than national budgets. The initial budgets of local governments are called "skeleton budgets" and are compiled without sufficient information. This is because, despite the finances of local governments being largely dependent on subsidies and local tax allocations, the official amount of these allocations cannot be confirmed until some later point in the fiscal year. When the receipt of a given subsidy or other source of revenue from the nation is confirmed, a revised budget is compiled. Revised budgets are therefore compiled often. Because of national circumstances, subsidies may become available as late as March, meaning that a revised budget must be hurriedly compiled at the end of March. Accordingly, the compilation of revised budgets for local governments is different than the compilation of a revised budget for the nation and does not reflect the intentions of the local government. As a result, the consideration of correction rates, which has meaning at the national level, is not appropriate for local governments.

Furthermore, because the compilation of local government budgets may be controlled by subsidies or the allocation of taxes, it is even possible for the behavior of the local government to be manipulated by national trends or inclinations.

9.4.2 The Relationship Between Public Works Spending and Normal Construction Funds

To confirm the use of the normal construction funds of local government finances in national economic policy measures, we examine the public works spending in the initial budget and revised budgets and its relationship with local governments' normal construction funds.

To begin, examining these three correlations in budgets from fiscal years 1965–2004, the correlation between normal construction funds and public works spending in revised budgets (0.959) is slightly higher than the correlation with public works spending in initial budgets (0.943), but the difference is not large. However, looking at the initial and revised budgets for public works spending from fiscal year 1990 to fiscal year 2000 and their correlations with normal construction spending, it can be seen that the correlation between normal construction spending and public works spending is clearly higher (0.728) for public works spending in revised budgets than public works spending in initial budgets (0.554). Accordingly, normal construction funds may be manipulated by the nation to cooperate with economic policy measures.

9.4.3 The Role of Local Tax Allocations

Local tax allocations are a general subsidy system established as a national special account system that transfers funds from the national government to local governments (Ishihara 2000). What is important in the role of the local tax allocation is its financial adjustment function, which corrects disparities in resources between local public entities. Its next most important function is the function of assuring financial resources. However, with respect to the function of assuring financial resources, a problem has been identified in which local governments receive tax allocation distributions in proportion to how small they are, meaning that smaller governments receive a wealth of public services (Okamoto 2002, pp. 57–63). The same problem exists for the other important role of local tax allocations, the financial resources adjustment function.

For example, according to the results of the "Annual Local Government Financial Statistics Report" (2006 edition), of the 47 prefectures, Tokyo was the only government body not allocated ordinary tax allocations. The other 46 prefectures were distributed some local tax allocations. Thus, the fact that all prefectures with one exception were subject to allocations must be called a major flaw in the system.

In order to examine how disparities changed as a result of adjustments caused by the local tax allocation system, we define an indicator called the degree of deviation from the mean.

Degree of deviation from the mean is:

$$\text{Degree of deviation} = (\text{maximum value} - \text{minimum value})\ /\text{mean value}$$

Based on this indicator, it is possible to compare local governments with large- and small-scale finances in the same way.

According to the result values for prefectures in 2004, in contrast to the prior degree of deviation in local taxes per resident capita of 0.72, the degree of deviation from the mean of the "later per resident capita local tax + local tax allocation + local special allocation funds" was 0.9. That is, the prior degree of deviation of 0.72 was expanded to 0.9 after the allocations. Accordingly, the local tax allocation system is not fulfilling its function of adjusting financial resources and is instead expanding differences between regions.[4]

As for why the local tax allocation system is not fulfilling the financial resources adjustment function, it seems that it has come to perform excessive transfers of financial resources through the expansion of the financial security system. Accordingly, it is important to curtail the financial security function of the present local tax allocation system to bring back the financial resources adjustment function.[5]

9.4.4 Special Accounts in the Local Tax Allocation System

Why has the local tax allocation system changed from fulfilling a financial resources adjustment function to a financial security function? This is because, during the long Heisei recession of the 1990s, local governments suffered from a lack of financial resources. The Japanese government held huge fiscal deficits and could only obtain financial resources through the issuance of government bonds, initially conducting a policy of public investment and later increasing the local tax allocation. Direct fiscal policy measures could be taken by expanding national expenditure on public works. However, the discussion becomes somewhat complicated with respect to increases in local tax allocations. This is because the local tax allocation system has adopted a special accounting system in which funds are transferred from the national treasury to a special account and then distributed from that account to each local government as local tax allocations.

The funds for local tax allocation are transferred into a special account, but if these resources are insufficient then the special account may also allowed obtain its own loans. Accordingly, it is possible that the amount of national local tax-allocation expenditure and the local tax allocation distributed to local governments do not

[4] An analysis of the fiscal adjustment effects of normal tax allocation at the municipal level is contained in Chapter 4 of Takabayashi (2005).

[5] Yamashita et al. (2002) empirically suggest that the local tax allocation system may present a moral hazard for local governments.

coincide. Therefore, by comparing the amount of national expenditure on local tax allocation and the amount of local tax allocation distributed to local governments, we can examine how the special account for local tax allocations has been managed. Therefore, the amount of local tax allocation assumed in local fiscal plans will be used as the distributed amount of local tax allocations. We then examine the deviation rate between the amount of allocated tax in the local fiscal plans and the national expenditure on local tax allocation.

Deviation rate = (local tax allocation in local fiscal plans − final amount of local tax allocations) / final amount of local tax allocations

Changes in this deviation rate are as shown in Fig. 9.4.

As is clear from Fig. 9.4, the deviation rate for local tax allocations is high briefly in the 1970s, but from fiscal year 1984 onward, it instead becomes negative. It then continues to be negative until the beginning of the 1990s. In the 1990s, it once again increases before becoming negative in 2004. This shows that even if the special accounts for local tax allocations borrow money to increase the amount distributed to local governments, over the long term this borrowing eventually stops, after which the amount distributed to local governments decreases in order to repay the borrowed amount. In addition, the period during which the disagreement rate for local tax allocation is negative continues for as long as it takes the loans to be repaid. During the 1980s exactly this happened, as local tax allocations that should have been distributed to local governments were reduced to aid in the repayment of loans. Furthermore, similar to the 1970s, the 1990s were a period when local tax allocations were distributed widely to local governments through borrowing in

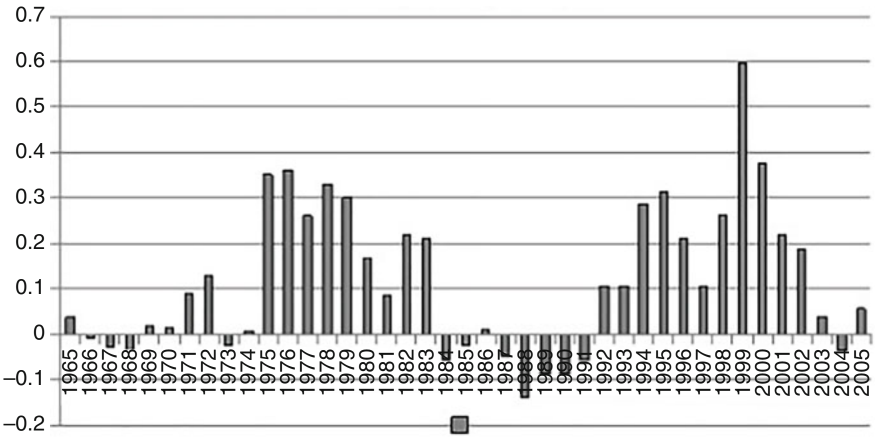

Fig. 9.4 Local allocation tax and divergence rate. (Based on data on local tax allocations from "Chapter 5 Public Finances" of the "Long-term Japan Statistical Series" at the homepage of the Japan Statistics Bureau and "Local Financial Plans" of the Ministry of Internal Affairs and Communications, http://www.stat.go.jp/data/guide/download/index.htm)

the special accounts. In the 2000s, this kind of irregular financial management was short-lived, instead turning more toward the repayment of the loans borrowed by the special accounts. As a result, the amount of local tax allocations distributed to local governments was smaller than the amount of national expenditures on local tax allocations.

9.5 Changes in Local Populations

9.5.1 Population Increases

Population increases are composed of two elements: natural and social increases. Whether the population of a given area is increasing or not is determined by whether the combined total of natural and social increases is positive or negative. A high natural increase in population occurred in Japan during the period of high economic growth, but the social increases were far larger than this natural increase. The migration rate at this time was usually above 7% and sometimes even above 8%. This means that the entire population of Japan moved once within a 12.5-year period. This was truly a period of great migration. Today, the migration rate has fallen to only 2.35% in 2006. This means that for the national population to move once it would take 42.6 years. Yet, an annual migration of 5.56 million people is still notable. Population migration is a vital factor in regional development.

9.5.2 The Population Increase Rate

The increase rates of the post-war population for the three major metropolitan areas (the Tokyo area, Osaka area, and Nagoya area) and the regional areas (prefectures aside from the three major metropolitan areas) are shown in Fig. 9.5.

The three major metropolitan areas have a significant population increase rate from the 1960s until the first half of the 1970s during the period of rapid economic growth. The Taiheiyo Belt was formed during this period. Cued by the first oil shock, the population increase rate falls rapidly beginning in the second half of the 1970s up until 1980. Entering the 1980s, it rises slightly. However, from about the middle of the 1980s, it once again begins to fall, and during the Heisei recession after the collapse of the bubble, it falls once again. Beginning in 1995, the rate rises again, after which it tends to continue to rise.

The population increase rate in the regional areas is low in the 1960s, but begins to increase in the 1970s and stays at a high level throughout the decade. However, entering the 1980s, the regional rate falls to a much lower level than that in the three major metropolitan areas. During the bubble period, it maintains a low level of approximately 0.1%. Once the bubble collapses and the Heisei recession begins,

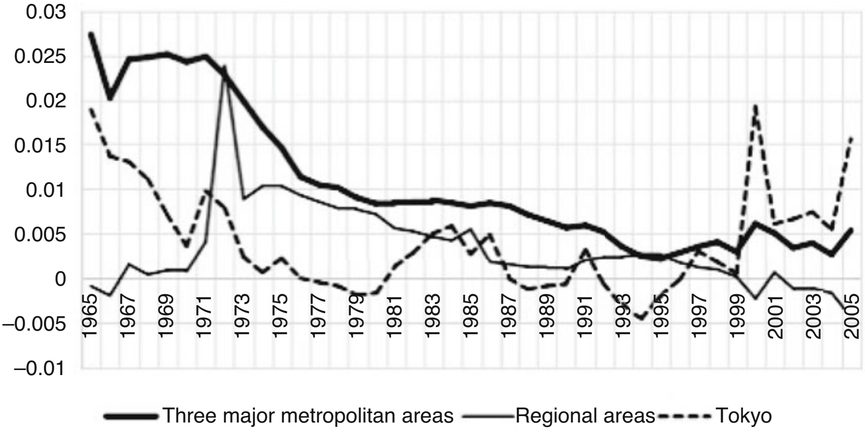

Fig. 9.5 Population growth rate. (Created from the author based on data in Table 3 of "Chapter 2 Population" of the "Long-term Japan Statistical Series" at the homepage of the Japan Statistics Bureau, http://www.stat.go.jp/data/guide/download/index.htm)

it rises slightly, exceeding the metropolitan rate marginally in both 1994 and 1995. However, after 1995, the regional rate begins to fall, reaching a negative growth rate in 2000.

The population increase rate in Tokyo begins to fall after the rapid economic growth period and maintains a negative growth rate from 1977 until 1980, becoming positive again in the 1980s. This was the period of overconcentration in Tokyo. However, when the bubble economy begins, Tokyo's population increase rate falls, only returning to a positive growth rate in 1991, with an otherwise negative rate from 1987 until 1996. From 1997 onward it becomes positive and remains positive during the 2000s. Today, the population increase rate is even higher than during Tokyo's overconcentration period, signaling a new overconcentration period in Tokyo.

9.5.3 In-Migration Rates in Large Cities

The in-migration rate in 16 large cities in 2005 and 2006 is shown in Fig. 9.6. It is clear from Fig. 9.6 that in 2005 and 2006, Yokohama, Shizuoka, Sapporo, Kawasaki, Sendai, the special wards of Tokyo, Kyoto, Hiroshima, Chiba, Kobe, Kitakyushu, and others have positive in-migration rates. In comparison, Fukuoka, Osaka, Nagoya, Saitama, and others have negative in-migration rates. Looking only at these numbers, Fukuoka, Nagoya, Saitama, and other cities have populations that are socially decreasing and might be considered regions in decline. However, looking at in-migration rates by prefecture, the prefectures where each of these cities is located all have increasing populations. Accordingly, it is appropriate to think of

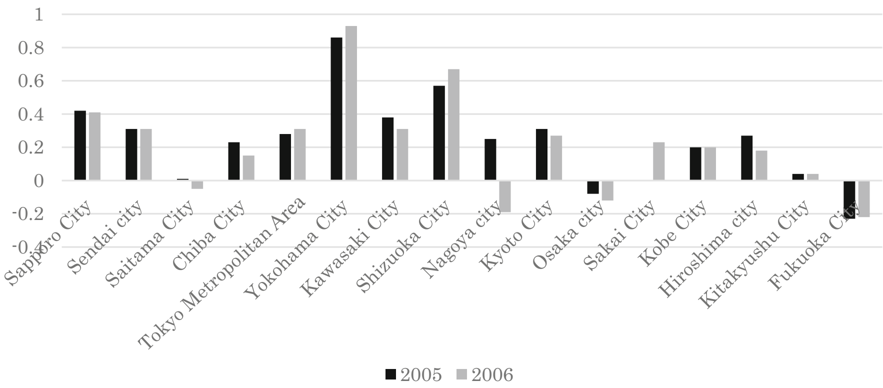

Fig. 9.6 Population growth rate of 16 major cities. (Created from the author based on data in Table 3 of "Chapter 2 Population" of the "Long-term Japan Statistical Series" at the homepage of the Ministry of Internal Affairs and Communications, http://www.stat.go.jp/data/guide/download/index.htm)

the residents of these cities as in the process of moving from the city center to the suburbs. That is, these cities have entered a new stage of population movement.

Thus, there is currently a concentration of the population in Japan's central cities.

9.5.4 The Merging of Municipalities and Discussions Around Integration of Prefectures (Introducing a Do-Shu System)

Today, the great merging of the Heisei era is taking place. That is, given the expectations of an increase in municipalities that cannot continue resident services because of a future decrease in population, attempts are being made to increase the efficiency of administration through the merging of municipalities to deal with the lack of financial resources. However, municipal mergers that take place without taking steps to deal with the negative assets, or municipal bonds, that they inherit in the process do not contribute to improving financial circumstances. An increase in efficiency is being attempted through these mergers, but there is no guarantee that their effects will be sufficient to offset these negative assets (Miyazaki 2008, pp. 17–18).

The future financial burden represented by municipal bonds can to some extent be seen in local tax allocations. However, even if the scale of local tax allocations does not change, if the portion of financial resources used to repay municipal bonds increases, the remaining financial resources will diminish. If the scale of the local tax allocations is curtailed in the future, the portion of financial resources available for purposes aside from municipal bonds will decrease even further. As such, these bonds weigh heavily on local governments.

In addition, even when municipal mergers do take place, it is necessary to pay attention to the possibility of an inverse relationship between increasing administration efficiency and improving the quality of administrative services. Meticulous administrative services provided to residents are relative to how small the provisioning government is.[6] If the scale of the government increases, the possibility that problems with administrative services may occur also increases. Accordingly, in regions where municipal mergers have taken place, it is necessary to be prepared for a reduction in administrative services.

One problem with the municipal mergers that have recently taken place is that the municipalities themselves have not supported them. They have instead taken place for reasons of national convenience. Furthermore, they have been executed in a manner that does not search for the most appropriate combination of municipalities and instead merely combines municipalities wherever possible. However, considering the future full-scale decrease in population, it is preferable to implement municipal mergers strategically. The merger standards in these cases may or may not be connected to increases in economic power. If the mergers that do occur do not increase the economic power of the municipality, then they will cause outfluxes of residents and a decrease in population. As a result, any benefits of the merger may be offset by further decreases in efficiency.

Discussions around integrating the prefectures (introducing a Do-Shu system) are based on the same principle as municipal mergers: that merging prefectures and delegating national authority will encourage increases in the efficiency of administration in local governments (Fujita 2006, pp. 143–147). However, as with municipal mergers, there is no guarantee that administrative services and efficiency will be improved simply by integrating prefectures. In particular, the integration of prefectures without economic support will lead to entities that cannot support themselves, with most of the integrated states declining in influence.[7]

The government is introducing other policies for regional regeneration aside from municipal mergers and the introduction of integrated prefectures. One of these is the Regional Revitalization Plan which was implemented beginning in April 2005. The government is also recognizing special deregulation zones, which were introduced around the same time, as experimental zones where regulations are loosened. However, a characteristic of this system is that it has a narrow range of operation. In comparison, the Regional Revitalization Plan allows for the delegation of authority, and the simplification of administrative procedures, among others, permitting a somewhat broad range of operation. As a part of the Regional Revitalization Plan, cross-ministry grants known as Regional Revitalization Infras-

[6] See Oates (1972) for the decentralization theorem that forms a basis for decentralization of power.

[7] Hashimoto and Yoshida (2004) argue that, based on the current system of government finances, even if an integrated prefecture system were introduced, all the newly formed states except for Tokyo would lack sufficient financial resources.

tructure Reinforcement Grants have been established. However, as these subsidies are strongly dependent on national authority, they cannot be said to follow the trend towards decentralization.

9.5.5 Important Points Regarding Prefectural Integration

Considering that population concentration is occurring in the central cities of each region, the partition of regions in integrating the prefectures should be based on these shifts in population. By partitioning cities with concentrated populations as administrative centers, it will be possible to divide regions into integrated prefectures from a functional standpoint. For example, Shimonoseki is often classified as part of the Chugoku/Shikoku region, when its economic relationships are actually stronger with Fukuoka. Accordingly, classifying Shimonoseki as part of the Kyushu region will raise economic interdependence.

9.6 Conclusion

Japan's local governments are currently facing many problems, the basis of which is economic. Accordingly, systemic reforms that are not accompanied by measures to resolve these economic problems will eventually end in failure. The current economic problems are strongly influenced by economic globalization, which must be considered when engaging with the problems of municipal mergers and prefectural integration.

Even if integrated prefectures are introduced, these newly formed states will merely lose population and have difficulty implementing independent administrative activities if they lack economic power. Accordingly, in introducing an integrated prefecture system, it is preferable to partition regions not according to the current population distribution but instead by promoting "regional overconcentration" centered on large cities whose population will become more concentrated in the future.

Based on the circumstances of loans in national and regional finances, financial flexibility is not expected to be possible for a number of years, so inducing population movements to certain regions by shuffling financial resources is not a desirable policy. It is therefore necessary to leave this redistribution to population movements caused by economic power and to endorse regional overconcentration and take it into account in considering regional policy.

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Part II
Empirical Research in Policy Evaluation

Chapter 10
Socioeconomic Factors Affecting the Innovativeness of Start-Ups in Japan: Comparative Analysis Between Social Enterprises and Commercial Enterprises

Shinichi Furuzawa, Lily Kiminami, and Akira Kiminami

Abstract There have been many empirical researches about the entrepreneurship of start-ups by focusing on the entrepreneurial motivations, the institutional, and social factors. However, there is few on the factors affecting the innovativeness of star-ups by comparing social enterprises and commercial enterprises.

Since the 2000s, social enterprises have reached a certain scale in terms of value added and employment in Japan. Although, social enterprise which executes dual-mission has potential to contribute to the inclusive growth and development of the society, it is not easy for social enterprises to solve social problems through a sustainable development of business through creating innovative products and services.

The purpose of this study is to clarify the socioeconomic factors affecting the innovativeness of start-ups through comparative analysis between social enterprises and commercial enterprises in Japan. Specifically, the quantitative analytical methods such as exploratory and confirmatory multivariate analyses are applied in this research to the micro-data at enterprise level based on the *Survey on Actual Conditions of Start-Ups in 2013* (conducted by the Japan Finance Corporation Research Institute). Some policy implications and practical suggestions will be

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drawn for the development of the social enterprises in Japan based on the analytical results.

Keywords Innovativeness · Start-up · Social enterprise · Commercial enterprise · Japan

10.1 Introduction

In Japan, social enterprises have grown since the 2000s, achieving a certain scale in terms of added value and employment. However, they are still facing difficulties to solve social problems and realize sustainable development of business while creating innovative products and services.[1] Social enterprises that carry out dual missions have the potential to contribute to the comprehensive growth and development of society. A social enterprise is an entity that works on profit-making businesses using business methods for the purpose of solving social problems and is also called "social business." There are various definitions and criteria of social enterprises (Defourny and Nyssens 2006)[2] that reflect the differences in context and institutional conditions in each country and region. However, it has dual missions of economy and sociality as a common framework, and it is a mixed organization (hybrid organization) of for-profit enterprises (FPO) and nonprofit organizations.

On the other hand, the existing empirical researches on start-ups have mainly focused on entrepreneurial motivation, institutional, and social factors. There are few studies focusing on the factors that affect the innovativeness of a start-up company by comparing social enterprises with commercial enterprises.

Therefore, the purpose of this study is to clarify the factors that influence the innovativeness of start-ups in Japan using quantitative analysis methods. Also, we will clarify the specific factors of social enterprises based on comparative analysis between social enterprises and commercial enterprises. Finally, we will draw policy

[1]As for the scale of activities of social enterprises in Japan, it is estimated that the number of social enterprises is 205,000, value added is 16.0 trillion yen, and the number of employees is 5,776,000. The value added and the employee of social enterprise in the economy account for 3.3% and 13.2% respectively (Mitsubishi UFJ Research and Consulting Co., Ltd. 2015). According to Kaneko (2013), innovative cases of social enterprises in Japan have emerged since the 2000s. However, the business itself has a lot of deficits, and many enterprises receive subsidies, donations, and other business income in order to maintain the business (Japan Finance Corporation 2014b). In addition, only less than 10% of consumers buy and use just because they are the products and services of social enterprises (Japan Finance Corporation 2014a).

[2]Among these, the EMES (European Social Enterprise Research Network) presented the most comprehensive and clear criteria. Standard of ideal type of social enterprises, four economic standards, (a) the economic production and sale of goods and services, (b) autonomy, (c) management of financial risks, and (d) paid labor, and five social standards, (e) community interests, (f) citizen initiatives, (g) decision-making not based on capital ownership, (h) participation, and (i) restrictions on profit sharing.

implications conducive to the development of social enterprises in Japan based on the analytical results.

10.2 Literature Review and Hypotheses

10.2.1 Literature Review

In the following, we conduct a literature review on the research on human capital, the characteristics and the entrepreneurship of social entrepreneurs, and the organizational characteristics and social networks as factors affecting the innovativeness of social enterprises.

Estrin et al. (2016) clarified that the higher the education level, the higher the probability of becoming a social entrepreneur by studying the differences of the effects of human capital between social entrepreneurs and commercial entrepreneurs. Also, Munro and Belanger (2017) showed that the development of social enterprises is influenced by the environment of university education. Therefore, it is considered that the level of human capital has an impact on the innovativeness of enterprises. Moreover, Stephan and Drencheva (2017) pointed out that both social entrepreneurs and commercial entrepreneurs start their businesses based on endogenous motives after reviewed the existing empirical researches on the personal characteristics and entrepreneurial motives of social entrepreneurs.[3] However, many pieces of research showed that social entrepreneurs have a strong prosocial and altruistic attitude (Germak and Robinson 2014; Christopoulos and Vogl 2014; Miller et al. 2012).

Social enterprises generally enter into the business areas where existing enterprises have not entered. Their behavior can be viewed as a strategy to develop a business while creating social value in addition to an economic value. The dynamic capabilities of organizations are enhanced by collaborating with various outside stakeholders in an effort to expand their social impact. Therefore, social enterprises often adopt the niche strategy as one of Porter's three main competitive strategies and the strategy of creating shared value (CSV) (Porter and Kramer 2011).

There are many empirical analyzes on organizational characteristics and networks of social enterprises (Bacq et al. 2013; Tan and Yoo 2015; Ferri 2014; Van Ryzin et al. 2009; Matsunaga 2012; Stevens et al. 2014). Bacq et al. (2013) pointed out that social enterprises have high organizational capabilities and generate many social and economic values when governance is implemented based on the latter

[3]There are a lot of existing researches that have studied the personal traits of social entrepreneurs. Please see Omorede (2014), Yangui and Jarboui (2013), Sastre-Castillo et al. (2015), and Christopoulos and Vogl (2014), for example.

from the perspectives of agency theory and stewardship theory.[4] It emphasizes the philosophy of participatory management, a sense of trust, long-term orientation, improved performance, and culture of collectivism and empowerment as social structural factors. Also, Tan and Yoo (2015) clarified high collective effectiveness and organizational innovation ability as organizational conditions that affect the implementation of social business in existing NPOs in Singapore through factor analysis and regression analysis. However, it has been clarified that resource constraints and risk orientation have no effect. Therefore, the more the management is conducted in line with the idea of emphasizing self-realization and intrinsic motivation assumed by stewardship (e.g., for internal labor market management, the benefits and flexibility of working styles), the more innovative of social enterprises.

The research on the use of external networks in the start-up phase of social enterprises and commercial enterprises reveals that social enterprises have more diverse external networks and their access to intangible resources is important. (Folmer et al. 2018).

10.2.2 Hypotheses

Based on the above literature review, we set up the following two hypotheses for statistical verification in this research:

H1: Highly innovative social enterprises have the same social attributes (human capital), endogenous motivations, and managerial abilities as highly innovative commercial enterprises.

H2: Highly innovative social enterprises have special factors in business strategy, internal labor market management, and external networks comparing to highly innovative commercial enterprises.

10.3 Analytical Method and Analytical Results

10.3.1 Analytical Method and Data

The data used for analysis is "Survey on Actual Conditions of Start-ups in 2013" (Japan Finance Corporation Research Institute). The survey target is 6854 companies (including those before start-up) within 1 year after receiving the loan from Japan Finance Corporation and 1618 recovered (23.8% recovery rate). Among these, 1452 companies without missing variables are analyzed in this study. The

[4]Stewardship theory (Davis et al. 1997, p. 38) assumes that "people are collective self-actualizers who achieve utility through organizational achievement."

survey consists of an overview of the project, the owner, family and income status, the history of opening, preparation for opening, management policies and activities, management after opening, etc. The total number of questions is 51. In this research, the reason for using the individual company data of the survey is that it is possible to compare with that of commercial enterprise in addition to identify the presence or absence of social enterprise and innovativeness.

Here, companies that answered "Yes" to the question "Q2 (4) Do you think that your start-up business falls under the social (community) business? A social (community) business is a company that operates with the main purpose of solving social and regional issues" were considered as social enterprises. In our sample, 386 companies (about 26.5%) were classified as social enterprises.

There are various forms of social enterprise organizations such as private for-profit enterprises, nonprofit organizations, cooperatives, and foundations. Our sample consists of two main forms of personal management (58.8%) and corporation (37.1%) and nonprofit organizations (0.9%) and other forms (3.2%).

"Innovativeness" is evaluated by answering the question "Q2 (2) Is there anything new in the business content (such as products, service content, targeted markets, etc.) compared to existing peers?". In the order of answers as "great extent," "some extent," "few," and "nothing at all," "innovativeness" was rated "high," "mid-high," "mid-low," and "low." This research classifies the presence or absence of innovativeness focusing on whether it realizes the production of new goods and services or whether it targets new customers. Therefore, it can be said that we analyze the factors that mainly affect product and marketing innovation, because innovation is not just technical development but also involves the creation of new value.[5]

The proportion of firms that responded to have a high level of innovativeness for social enterprises is larger than for commercial enterprises as shown in Table 10.1.

The variables used for our analysis are as shown in Table 10.2. The degree of innovativeness is used as the explained variable, and an ordered logit model is used for estimation due to the ordinal data. Among the explanatory variables, socioeconomic attributes (age of entrepreneur, gender, education level, business operation experience, organizational form) are used as control variables. Next, variables for entrepreneur are divided into two levels: the variables related to entrepreneurship, preferences, and business strategies and the variables related to management ability. The former is related to entrepreneurs' attitudes which are not easily changed, but the latter is considered to be changed by provision of training opportunities and policy interventions. As for entrepreneurial motives, two factors were extracted as a result of analysis using principal component analysis:

[5]Innovation is the new combination of means of production, resources, labor, and so on in economic activities (Schumpeter 1934). Innovation can be further divided into five types: (1) product, (2) processes, (3) marketing, (4) acquisition of new raw materials and sources, and (5) organizations.

Table 10.1 Innovativeness of social enterprises and commercial enterprises

		Innovativeness (%)			
		Low	Mid-low	Mid-high	High
		0	1	2	3
Social enterprise	($n = 386$)	3.4	17.9	49.7	29.0
Commercial enterprise	($n = 1066$)	5.5	31.4	51.1	11.9
Total	($n = 1452$)	5.0	27.8	50.8	16.5
P-value		(0.093)	(0.000)	(0.641)	(0.000)
		*	***		***

Source: Author's calculation from the data
Note: *P*-value of the table indicates the result of two-sample test (two-sided) for equality of proportions between SE and CE
"*," "**," and "***" indicate statistically significant at 10%, 5%, and 1% respectively
Result of Fisher's exact test for independence is *P*-value (=0.000)

(1) extrinsic motives and (2) manager-oriented motives. Both of them are used as variables (see Table 10.3).

Furthermore, the efforts to enhance the motivation and ease of work for employees are used as variables related to internal labor market management and the partner of management consultation as a variable related to external network in the research.

10.3.2 Analytical Results

Table 10.4 summarized the estimation results. In the following, we will look at the estimation results of the variable selection model out of the two results of the all-variable model and the variable selection model. When each variable is significant, it is interpreted as a factor that affects both social enterprises and commercial enterprises in common. Also, if the cross-term dummy of social enterprise is significant, it is interpreted that there is a factor specific to social enterprise.

Next, in socioeconomic attributes, age (−) and education (+++) were significant, and in entrepreneurial motives, motivation 1 (extrinsic-endogenous) was significant. And, in the managerial ability, the determination (++), the action (+++), the planning (+++), and the fund raising ability (+) are significant, and in the cross-term dummy of social enterprises, "business experience, knowledge, and technology (+)" were significant. Therefore, "H1: A highly innovative social enterprise has the same level of social attributes (human capital), endogenous motivation, and management ability as a highly innovative commercial enterprise" has been verified.

And in business strategy, adaptation to environmental change (+++), product development orientation (+++), and risk appetite (+) are significant in common. On the other hand, although the client development intention is positive (+++) as a

Table 10.2 Description of variables

	Variables	Contents	Mean
Dependent variables	Innovation	Having original new business: 0–3 (great extent = 3, at some extent = 2, few =1, nothing at all = 0)	1.79
Socioeconomic attributes	Age	Numerical value	41.7
	Male	Male = 1, female = 0	0.85
	Education	Junior/high = 0, junior college = 1, univ. = 2, graduate school =3	1.08
	Mcareer1	Having experiences to run business =1, others =0	0.07
	Form	Joint stock company =1, others = 0	0.37
Motivation, preference, and habits of entrepreneurs	Motivationpc1	Scores of principal component 1	−0.01
	Motivationpc2	Scores of principal component 2	0.01
	Adaptation	Having adaptation to environmental change: 0–3 (yes = 3, would rather yes = 2, would rather no = 1, no = 0)	2.37
	Customer	Having new customer orientation rather than existing customers: 0–3 (yes = 3, would rather yes = 2, would rather no = 1, no = 0)	1.40
	Development	Good at developing products rather than improving efficiency: 0–3 (yes = 3, would rather yes = 2, would rather no = 1, no = 0)	1.68
	Risk	High risk and high return orientation: 0–3 (yes = 3, would rather yes = 2, would rather no = 1, no = 0)	0.74
	Niche strategy	Niche strategy orientation: 0–3 (yes = 3, would rather yes = 2, would rather no = 1, no = 0)	1.92
	Time	Emphasizing short term prospects: 0–3 (yes = 3, would rather yes = 2, would rather no = 1, no = 0)	1.43

Notes: Binary data is used for variables about the management ability, internal labor market management, and external network
Management ability: response to the "Q14. Please select management abilities which you have advantages (up to three)"
Internal labor market management: response to the "Q36. Please select practices implanted by your enterprise for enhancing the desire to work and improving the working environment for regular executives and full-time employees"
External network: response to the "Q49. Please select items which you can consult with about the management (multiple choice)"

whole, it is negative (−) in the interaction term dummy. Also, the niche strategy was also a cross-term dummy (+). In the management of the internal labor market, the

Table 10.3 Principal component analysis on entrepreneurial motives

	Score of principal component 1	Score of principal component 2
1. Increasing income	0.293	0.521
2. Working flexibly	0.538	−0.352
3. Interested in job of management	0.064	0.564
4. Starting business based on the ideas and skills	−0.342	0.091
5. Using job's experience and knowledge	−0.397	−0.223
6. Utilizing specialty and hobbies	−0.037	−0.130
7. Contributing the society	−0.438	−0.063
8. Working regardless of age and gender	−0.055	−0.338
9. Free pressure of time and feelings	0.375	−0.294
10. Nothing to adequate work opportunities	−0.002	−0.082
11. Others	−0.093	−0.028
Cumulative ratio of contribution	13.2%	25.5%
Interpretation of components	Extrinsic motivation–Intrinsic motivation	Manager orientation (high-low)

Notes: "Q4 What is your motivation for starting your business, please answer three applicable items in order of importance"
The data for principal component analysis was used after it puts following scores: first place, 3 points; second place, 2 points; third place, 1

presentation of wages according to work results and abilities (++) was common and significant, but in the cross-term dummy, creating an atmosphere that makes it easy to take a vacation (−), benefits out of legal status (++), improvement of welfare (++), and introduction of at-home work system (++) were significant.

Furthermore, in the external network (the advice received at the time of opening the business), the founding support organization of the private sector (−) was significant in common, but in the cross-term dummy, the official founding support organization (−), Japan Finance Corporation (++), and others (−) were significant. In addition, business owners in different industries were positive (+++) overall, but negative (−−−) in cross-term dummy.

Therefore, "H2: Highly innovative social enterprises have special factors in business strategy, internal labor market management and external networks comparing to highly innovative commercial enterprises" has been verified.

Table 10.4 Results of estimation

		Full variable model				Variable selection model			
		Variables		Interaction dummy (social enterprise)		Variables		Interaction dummy (social enterprise)	
		Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Socioeconomic attributes	Age	−0.007	−0.928	−0.014	−1.048	−0.011	−2.066 * *		
	Male	0.167	0.893	0.001	0.004				
	Education	0.247	3.554***	−0.155	−1.068	0.213	3.618***		
	Mcareer1	0.117	0.419	0.290	0.641				
	Form	−0.009	−0.063	−0.183	−0.641				
Motivation, preference, and habits of entrepreneurs	Motivationpc1	−0.197	−3.640***	0.027	0.252	−0.190	−4.205***		
	Motivationpc2	0.041	0.742	−0.065	−0.567				
	Adaptation	0.278	2.931***	0.047	0.231	0.293	3.572***		
	Customer	0.208	3.113***	−0.269	−1.947*	0.207	3.162***	−0.269	−2.049 * *
	Development	0.304	4.289***	0.026	0.166	0.308	4.996***		
	Risk	0.141	1.852*	−0.267	−1.784*	0.136	1.833*	−0.212	−1.490
	Niche strategy	−0.071	−1.020	0.298	2.020 * *	−0.076	−1.120	0.240	1.773*
	Time	−0.048	−0.728	0.048	0.369				
Management ability	Determination	0.283	1.946*	−0.066	−0.226	0.249	2.095 * *		
	Leadership	−0.056	−0.295	0.319	0.893				
	Activity	0.312	2.306 * *	0.164	0.598	0.347	3.151***		
	Management	0.050	0.226	−0.149	−0.387				
	Planning	0.631	3.244***	0.358	1.017	0.756	4.866***		
	Personal network	−0.041	−0.280	0.527	1.725*	−0.057	−0.409	0.423	1.574
	Adaptation to environment	0.026	0.174	0.351	1.117				

(continued)

Table 10.4 (continued)

		Full variable model				Variable selection model			
		Variables		Interaction dummy (social enterprise)		Variables		Interaction dummy (social enterprise)	
		Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
	Public relations	0.554	1.955*	0.390	0.699	0.560	2.390 * *		
	Fund raising	0.772	1.564	−0.487	−0.601	0.667	1.768*		
	Steady	−0.043	−0.314	0.159	0.544				
	Experiences, knowledge, and skill on the enterprises	−0.062	−0.462	0.537	1.947*	−0.050	−0.399	0.422	1.746*
	Knowledge on accounting and legal affairs	−0.148	−0.520	−0.170	−0.291				
	Others	−0.546	−0.700	1.083	0.952				
Internal market management	Offering high salary	0.094	0.387	0.217	0.447				
	Offering salary based on the performance and abilities	0.364	1.988 * *	−0.304	−0.900	0.278	1.984 * *		
	Good atmosphere to take holidays	0.210	0.967	−0.474	−1.177	0.258	1.282	−0.660	−1.958*
	Flexible working hours	−0.177	−0.943	−0.178	−0.495	−0.215	−1.417		
	Nonobligatory welfare	0.001	0.004	1.398	2.189 * *	0.053	0.156	1.245	2.085 * *

	Working at home	−0.462	−0.493	3.333	2.173 ∗∗	−0.502	−0.544	3.205	2.106 ∗∗
	Opportunities to exchange opinions in the organization	−0.059	−0.294	0.188	0.526				
	Shifting authorities	0.380	1.551	−0.264	−0.647	0.271	1.464		
	Support to have qualifications	−0.073	−0.271	−0.043	−0.099				
	Others	0.499	0.567	−1.302	−0.822				
	Nothing	−0.040	−0.111	0.391	0.480				
Network (consult with)	Manager of the same industry	−0.090	−0.691	−0.216	−0.804				
	Manager of different industry	0.544	3.441∗∗∗	−1.259	−4.092∗∗∗	0.534	3.438∗∗∗	−1.207	−4.144∗∗∗
	Management consultant	−0.047	−0.183	0.403	0.857				
	Licensed tax accountant, accountant	0.094	0.694	0.121	0.444	0.168	1.527		
	Chamber of commerce and industry	−0.132	−0.665	0.169	0.434				
	Public support organization for starting business	0.885	1.110	−2.224	−1.959∗	0.892	1.122	−2.190	−1.986 ∗∗

(continued)

Table 10.4 (continued)

	Full variable model				Variable selection model			
	Variables		Interaction dummy (social enterprise)		Variables		Interaction dummy (social enterprise)	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Private support organization for starting business	−1.410	−1.378	0.802	0.629	−0.986	−1.661*		
Private financial company	−0.096	−0.296	0.399	0.632				
Japan finance corporation	−0.008	−0.021	1.483	2.407 * *	−0.050	−0.137	1.404	2.446 * *
Friends and acquaintances	0.151	1.123	0.340	1.278	0.173	1.320	0.373	1.470
Family	0.096	0.634	−0.219	−0.704				
Others	0.630	1.029	−1.922	−1.879*	0.628	1.051	−1.737	−1.749*
Nobody to consult with	0.078	0.291	−0.741	−1.309	0.130	0.526	−0.719	−1.430
Social enterprise dummy	0.924	0.876			0.680	1.756*		
1|2	−1.111	−2.317			−1.260	−3.370		
2|3	1.351	2.854			1.191	3.272		
3|4	4.172	8.577			3.980	10.468		
AIC:	3189.517				3096.357			
LR	346.681				325.840			
Pr Ch2	0				0			
Number of samples	1452				1452			

Note: "*," "**," and "***" indicate that there is a statistically significant difference at 10%, 5%, and 1% in the two-sided test, respectively

10.4 Conclusions

In this study, we analyzed the factors that affect the innovativeness of new start-up of social enterprises in Japan. As a result, it was revealed that highly innovative social enterprises share some common points with highly innovative commercial enterprises, as well as having their own unique factors. This shows that it is effective to establish a policy and support system (OECD 2013) for new start-ups while targeting social entrepreneurs and social enterprises. Therefore, in order to promote the development of social enterprises in Japan, policy and support system that match the characteristics of social enterprise such as the management strategies, internal labor market management, and external networks are necessary. However, the objective evaluation on the innovativeness of social enterprises after capturing their business impacts on solving social issues including noneconomic effects is also important. This will be our next research agenda.

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Chapter 11
Multi-Agent Simulation for Prediction of Human Behavior During a Hypothetical Earthquake

Seiichi Kagaya

Abstract Through the experiences of the Great 1994 Hanshin-Awaji earthquake and the Great 2011 East Japan earthquake, it has been important for local governments to build the comprehensive evacuation program on a large earthquake occurrence in near future. According to the experts' forecast, huge earthquakes will occur around the coast areas of Pacific Ocean in Japan in near future. Therefore, it is indispensable to give appropriate information and knowledge on human behavior for the evacuation time. It is also necessary to urge the residents to select rational behaviors. Therefore, a new methodology based on behavior-oriented agent system should be developed to show our community activities. In this study, the production rules of each agent were constructed due to the expected activities based on the questionnaire survey. Next, by using the set of production rules composed of such data, multi-agent system models were built for analyses on both the evacuative behavior and the behavior of return trips to home during a hypothetical large-scaled earthquake. The simulations were tried by using specific data including those of the Person Trip Survey. It comes to the conclusion that the human behaviors during the earthquake were simulated by multi-agent system model and as a result, the appropriate evacuation method was discussed and the possibility of the return home was found in view of the conditions of the roads and the human attributes.

Keywords Multi-agent simulation · Human behavior · Huge earthquakes · Comprehensive evacuation program · Person trip survey · Return home people · Questionnaire survey

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11.1 Introduction

When not only earthquake disaster but also the other natural disasters such as flooding, landslides occur, it is necessary for the community to decide immediately the evacuative measures of the people who are living in damaged areas. The emergent evacuation is important to secure the inhabitants from the natural disaster. Thus, we should examine the characteristics of human behavior during the evacuation time. In Japan through the experiences of the Great 1994 Hanshin-Awaji earthquake and the Great 2011 East Japan earthquake, it has been important for the people to build the comprehensive evacuation program on an occurrence of large earthquake. In particular, it is substantial to establish the evacuation system including both public organization and communities synthetically. According to the experts' forecast, huge earthquakes will occur around the coast areas of Pacific Ocean in Japan in near future. Therefore, it is indispensable to give the people the appropriate information and knowledge on human behavior for the evacuation period. It is also necessary to urge the residents to choose rational behaviors. Considering the emergent evacuation system, it is difficult to grasp the characteristics of human behavior towards the disaster (Batty 2001). It is because human behavior is various in terms of unusual conditions of psychological impacts. In other words, when many people evacuate simultaneously due to the occurrence of large earthquake in an area, they may think and judge how to act independently and then behave by themselves differently. Moreover, they also give influences to each other. It is also difficult to know the whole evacuation behavior stochastically due to a simple individual activity (Ulieru and Norrie 2000). Therefore, A new methodology based on behavior-oriented agent system should be developed to show our community activities.

In this study we discuss the method of multi-agent simulation as a new technology examining such a complex system in case of the disaster. We also construct multi-agent system to apply the evacuation behaviors with an occurrence of earthquake (Negishi et al. 2004). The previous research prepared us several alternative cases using the multi-agent simulation model in terms of two conditional parameters on "following" and "knowing the located site of evacuation shelter." As the result, it was obtained that the evacuation of the inhabitants was delayed due to both the dependency of other people and the unknown evacuation areas. However, questions are left as follows: if the production rules of behaviors are appropriate or not and if the other characteristics affecting on the evacuation behaviors exist or not. Moreover, the existing studies also have the problem on applying the virtual model to the realistic world and reflecting the experimental results on the simulation model.

In view of such backgrounds, the objectives of this study are to build the simulation models for human activities during an earthquake disaster based on the production rules and to execute some measures for safety of human lives by using the models.

Specifically, those multi-agent models are applied to the analyses on both the evacuative behavior against Tsunami and the behavior for returning home during a hypothetical large-scaled earthquake.

11.2 Multi-Agent Simulation for Disaster Behavior

11.2.1 Human Behavior and Intelligent Agents

The human behavior is generally complicated and various psychologically during an earthquake disaster. It is because the circumstances are suddenly changed and the living conditions are unusual for inhabitants. So, it is necessary for the system to introduce several agents possessing autonomy and self-organization. An agent is anything that can be viewed as perceiving its environment through sensors and acting on that environment through effectors. A human has five senses for sensors, and hands, legs, mouth, and other body parts for effectors (Horvitz et al. 1988). Thus, the acts of an agent substitute for human behavior including both sensors and effectors. Basically, a rational agent is one that does the right thing using his intelligence. Rational activity also depends on the performance measure, the percept sequence, the knowledge of the environment, and the performance of action. In other words, a definition of an ideal rational agent is for each possible percept sequence, an agent should do whatever action is expected to maximize its performance measure based on the evidence provided by the percept sequence and whatever built-in knowledge the agent has (Wilson 1991). In this system, an agent necessarily does not have high knowledge and a full global view. An agent has only characteristics like partially independent, self-aware and autonomous.

We should decide how to reproduce a real system to implement the mapping form percepts to action. Thus, four types of agent programs will be considered like simple reflex agent, agents keeping track of the world, goal-based agents, and utility-based agents. Humans have many connections such as a condition-action rule written as "if the order of evacuation announcing then initiate-evacuation." Figure 11.1 illustrates the structure of a simple reflex agent showing how the condition-action rules make the agent to connect from perception to action. This is a basic type agent model, namely, simple reflex agent model (Russell and Norvig 1995).

Figure 11.2 shows another case of agent system with internal state. This model also shows how the current perception is combined with the old internal state to

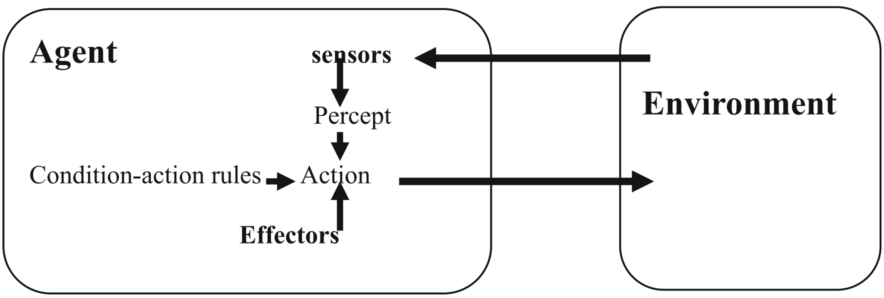

Fig. 11.1 Diagram of a simple reflex agent

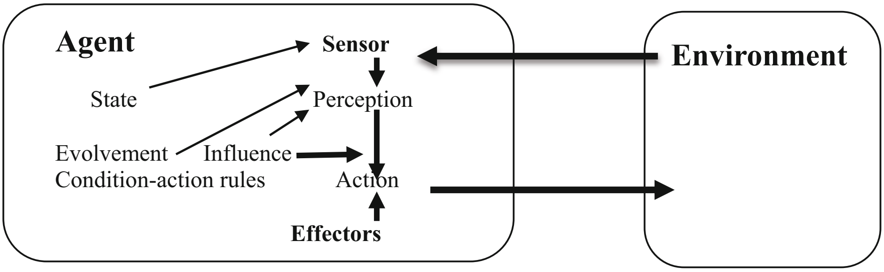

Fig. 11.2 Diagram of a reflex agent with internal state

generate the updated description of the current state. Some options for perception are added.

In the goal-based agent model, we discuss goals in the stage of action. On the other hand, the utility-based agent model adds an evaluation stage due to utility after the percept stage. This study adopts a reflex type or a reflex type with internal state.

Here, the production system, that is, the rule-based system is defined as the combination between perceptions and action in terms of database, production rule bases and an interpreter, the inference engine. It is generally given in the following form:

If "list of conditions" then "list of actions," where "list of conditions" corresponds to elements in the database and "list of actions" consists of primary actions such as changing database elements.

11.2.2 Multi-Agent Simulation

An agent is a physical or virtual entity. A physical entity is something that acts in the real world. On the other hand, a software component is virtual entity, since they have no physical existence. Agents are capable of acting, which is fundamental for multi-agent systems. The concept of action is based on the fact that the agents carry out actions which are going to modify the agents' environment and their future decision-making. Agents are endowed with autonomy. They are directed by a set of tendencies. Agents have only a partial representation of their environment. The agent is thus a kind of living organism which is aimed at satisfying its needs and attaining its objectives on the basis of all the other elements (Ferber 1999).

The multi-agent system is applied to a system comprising the following elements, that is, an environment, a set of objects, an assembly of agents, an assembly of relations, and an assembly of operations and operators. The technology of multi-agent simulation contributes to the construction of evacuation behavior model and its simulation. Multi-agent is generally composed of a set of agents that act for themselves beneficially in terms of their strategies. It has also some two-way

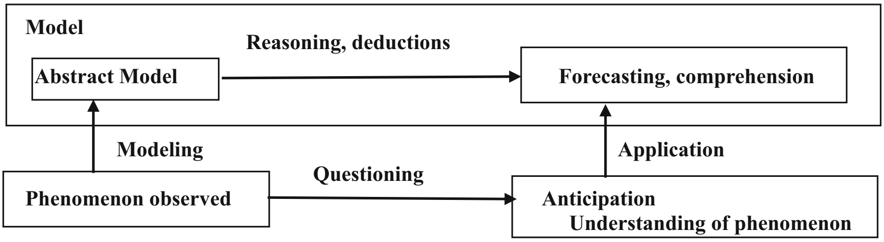

Fig. 11.3 Model building for multi-agent system

relationships among them. Multi-agent simulation is to simulate the system that is established in terms of computer program.

Models are generally created as an aid to predicting and understanding phenomena. In the case of the multi-agent modeling, several techniques should be used as shown in Fig. 11.3. First of all we observe phenomenon that is translated into the form of an abstraction. This can be manipulated to obtain results that can help us to improve our understanding or to predict future situations. As the phenomenon based on human behavior is usually complicated, we often use questionnaire in order to understand it more and to anticipate the future. In the modeling of multi-agent system, we should utilize this process effectively. We build an abstract model and, then, promote deduction, reasoning and calculations. As the result, we can forecast and comprehend human behaviors. It is necessary to introduce the anticipated results of phenomena into the model as operational information of the behavior (Batty 2003).

11.2.3 Concept of Simulation and Procedure

The multi-agent system in this study is applied to the human activities such as the evacuation and return home during the earthquake hazard. When the large-scaled earthquake like the Great 2011 East Japan Earthquake occurs, various phenomena will affect on human behavior in concurrence with it. First of all, we suppose such a condition and evoke the human behavior with evacuation after the occurrence of an earthquake disaster due to multi-agent model. In this case, each agent is included in a family and a community simultaneously. The agents usually act on the multi-agent system interacting with the other agents. The interactions here are characterized by three conditions of mobility such as (i) the following the other agents, (ii) the lead to the other agents, and (iii) the inhibition of travel with congestion. Considering such a social environment and interactions, the rule bases of the agent actions are built as the following procedure (Kagaya and Shinada 2002):

Fig. 11.4 illustrates the procedure of multi-agent simulation analysis that we constructed. Here, first of all, we prepare the space, the agents, and the environment in a study area. The evacuation sites are established a large one and several small

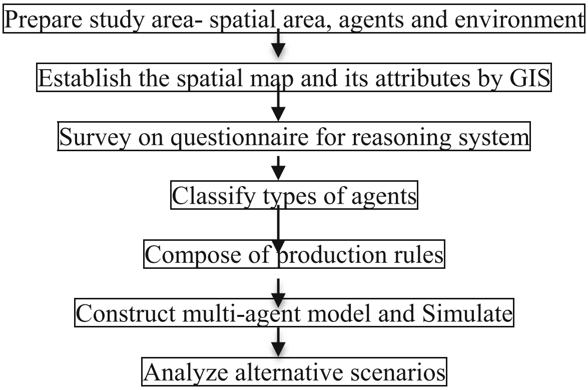

Fig. 11.4 Outline procedure of multi-agent simulation analysis

sites within the area. Next, a digital map of space is prepared for the area in terms of GIS. Then, we survey on the questionnaire for human behavior during earthquake disaster to make the reasoning system and also classify several types of agents using the results from the questionnaire due to cluster analysis. The production rules to simulate multi-agent system are also composed. After that, we construct multi-agent model and choose the optional agents due to Monte Carlo method. Based on the database, it is simulated by using the multi-agent model. Finally, we analyze some alternative scenarios as well. Using this procedure, two specific models of multi-agent simulation are built. One is the behavioral model during the evacuation against a Huge Tsunami. Another is the model for return home simulation after an earthquake.

11.3 Several Preparations for Simulation Analysis

11.3.1 Execution of the Preliminary Model

The preliminary model prior to the specific model simulation carried out several simulations.

In this case, spatial area is in the range of 2 km*2 km, namely, 4 km^2.

Once a local government orders the instruction of evacuation, the inhabitants start evacuation as soon as possible. This is a simple example to evacuate. If they do not know the evacuation shelter or cannot find reliable person to follow, it will be difficult for them to approach there. Here the differences are clarified between better and worse conditions, namely, with enough information and guide on the shelter or not. Total number of agents is 1000, and the kind of gender and the distribution of generations depend on the state of supposed area. The simulation times are 10 by the random generated samples. The value of the results is the average one of whole values. The analytical area is a district of Sapporo City. Figures 11.5 and 11.6 show

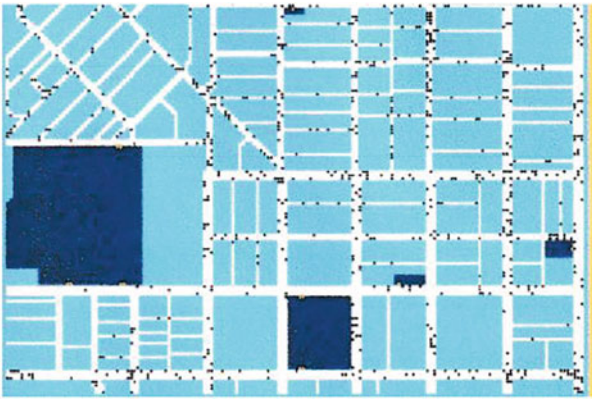

Fig. 11.5 Agents' activities in case of unknown evacuation sites and nobody followed (after 25 min)

Fig. 11.6 Agents' activities in case of known evacuation sites and leaders followed (after 25 min)

the results to apply to evacuative activities after occurrence of an earthquake by the preliminary model simulation. The black dots show the evacuating agents. Figure 11.5 describes the simulation result in the case that inhabitants do not know the evacuation sites and follows nobody in 25 min after the evacuation advisory. We understand it is difficult for inhabitants to achieve the objective sites. On the other hand, Fig. 11.6 represents the results in the case that they know the evacuation sites and follow the reliable persons. In the same time, most of the inhabitants achieve the aim of evacuation. As shown in these figures, the differences of information of the evacuation sites and the existence of leaders affect the evacuation achievement and efficiency.

The analyses were carried out by using MAS (Arisoc).

11.3.2 Motivation of Evacuation Activity

In general, an evacuation behavior during disaster is considered as a swarm activity like the ones of the insects or birds. In view of swarm intelligence, the important points regarding to the evacuation behavior are inductivity and followability (Kagaya and Uchida 2010). The activities of residents are determined by their selections based on destinations and evacuation routes so that they are influenced by the inductivity and the followability around their circumstances. Thus, it is vital to grasp the characteristics of activity, the mind, and decision of residents to evacuate. Here, we discuss such issues in terms of the results due to interviewing. A discussion is, for example, even if accurate scientific information is given, it is difficult for residents to complete the evacuation. Because they often do not connect the information to their own activities appropriately.

It is, for instance, similar to reducing the users of trains due to the transit resistance. So it is necessary for evacuees to connect the information with the activity without the resistance. It may be desirable for the Tsunami disaster to give inhabitants Analog information better than Digital one.

The appropriate evacuation behavior depends on the accurate information and the induction based on it. The effect on evacuation is brought by the inhabitant's ability to comprehend and act on such the conditions.

From a practical viewpoint, it is more important to take measure to meet the activities of aged or disabled people. In these analyses, we discuss characteristics of inhabitants in the case of the countermeasure of an assumed landslide disaster. This idea can be helpful for the evacuation during earthquake and Tsunami disasters. Here, the problem on evacuative response is examined during an announcement of disaster information. The timing of announcement is considered as three phases, namely, the phases of the warning of disaster, the evacuation advisory, and the evacuation order seriously. In order to observe the difference of generations, the ideas of young and elderly people were surveyed.

Figure 11.7 represents the rates of intention and determination of the evacuation activities in the case of young households according to the phased announcement on evacuation relatively. The rate of decision-making (DM) is defined as the proportion of number of people to decide evacuation activities. In this figure the rate in those households are almost same as both ideas. On the other hand, the same rates in elderly households are shown in Fig. 11.8. Their intentions are similar to those in the young households. However, their doing activities are significantly different from those of the young households. These results mean the elderly households cannot act for themselves easily, even if they hold the minds of evacuation.

Fig. 11.9 represents the effects in case that the information is shared among the residents and the information is transmitted to the elderly households more rapidly. Moreover, Fig. 11.10 indicates the effects of evacuation activities in case that the family or neighborhood residents support the evacuation of elderly people. From these analyses, the decision of evacuation is accelerated by the joint-ownership of information, calling out each other. On the other hand, community organization and

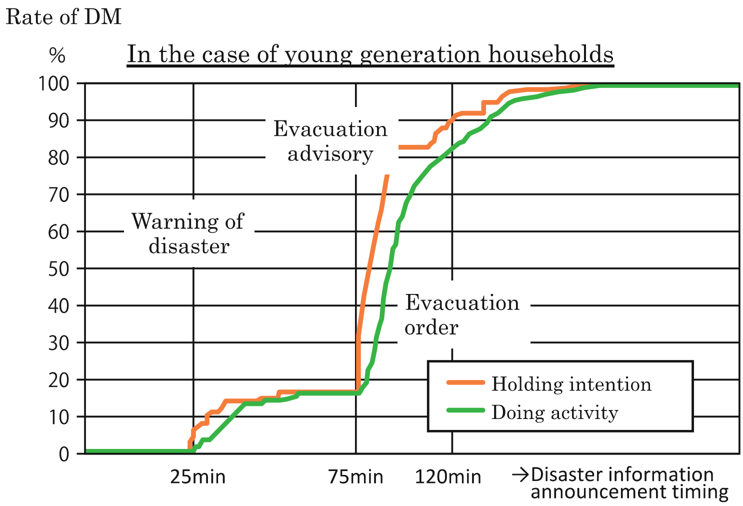

Fig. 11.7 Relationship between disaster information announcement timing and human decision-making (in the case of young households)

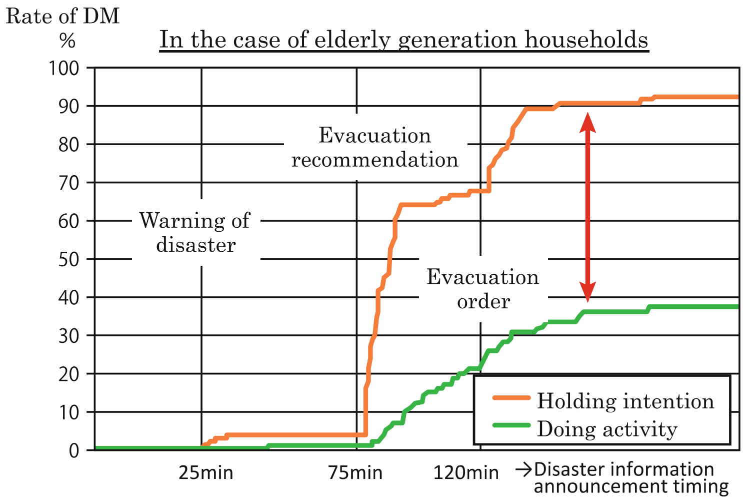

Fig. 11.8 Relationship between disaster information announcement timing and human decision-making (in the case of elderly generation households)

enterprises increase the rate of decision-making and the timing of decision in aged generation by their supports for evacuation. Therefore, it is essential for the elderly people to receive evacuation information as soon as possible and communicate with each other.

In order to reduce damages, the neighborhood and the local community should be cooperating with one another. For realizing such relationships, it is necessary to

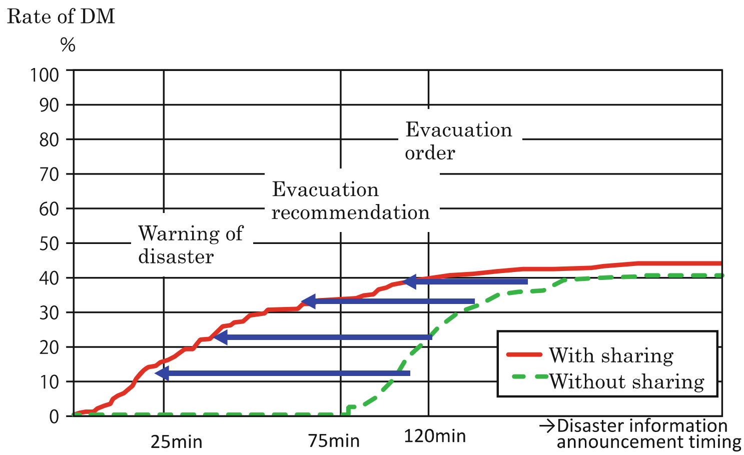

Fig. 11.9 Effects on sharing of disaster information (in the case of elderly generation households)

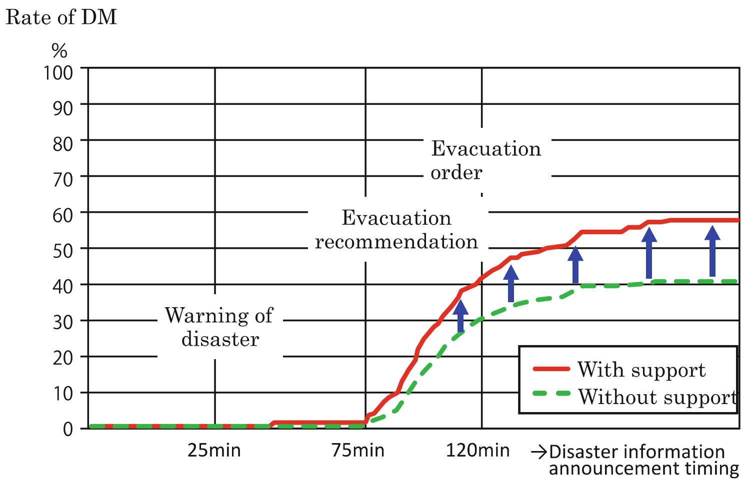

Fig. 11.10 Effects on the support of family or neighborhood residents (in the case of elderly generation households)

make daily relationship among neighborhood more closely and social participation of elderly people. It is useful for initial stage of disaster prevention to construct such a society.

11.4 Simulation on Evacuation of Inhabitants Against Tsunami Disaster

11.4.1 Hypothetical Earthquake and Tsunami

In Japan several huge earthquakes occurred everywhere in whole country. Tsunami disasters happened along the coast simultaneously. As Japanese topological feature, many rivers flow towards the sea, and some of towns or cities are located at the mouth of the rivers. That is, the areas available for urban functions exist under such topological conditions. Once a tsunami occurs, serious damage was suffered from the huge natural force. Here, the simulation models are applied to the evacuation during tsunami occurrence. Once an earthquake centered in the ocean occurs, tsunami happens almost at the same time. Therefore, the municipality should promptly give the evacuation orders. Based on such orders, the residents will get away from the flow of tsunami. According to the past example like the East Japan Huge Earthquake, the flow of tsunami often goes upstream through the mouth of the river. So the inhabitants living in upstream areas desire to evacuate together. As in the snowy cold regions like Hokkaido Japan, various worse conditions are obstacles to walk away. It is difficult to secure the sheltering sites in winter season. Considering such conditions, the simulation model should be constructed as an inspection of evacuation.

The simulation is executed in a hypothetical town of eastern Hokkaido.

11.4.2 Survey on Evacuation Behavior

The action rule bases depend on the standard of judgment based on individual characteristics such as the age, the experiences on earthquake disaster, etc. So it is necessary to survey a questionnaire in order to complete the human evacuation behavioral rules. Actually, the survey was executed for the citizens in Kushiro City, in Hokkaido. They have experienced several earthquake and tsunami disasters until now. The features of the evacuation behavior can be grasped in terms of the data obtained by the questionnaire. The objective of this analysis is to clarify the relationship between the evacuation behavior and the personal attributes and experiences in the earthquake disaster (Kagaya et al. 2011).

The main question is how to do if the evacuation is required during a large-scaled earthquake with tsunami. The outline of survey is shown in Table 11.1.

Several results were obtained by the questionnaire survey as follows. Figure 11.11 shows the proportion of the response for the question “What will you do with your family and neighborhood inhabitants when you evacuate during the earthquake disaster?”

In corresponding with neighborhood people, the answers were distributed separately. The answer of “To evacuate with no consideration” is about 25%. Meanwhile,

Table 11.1 General outline of survey

Date of survey	From 19th, December to 21st December in 2003
Distribution and collection method	Home distribution and mail collection
Survey site	A district in Kushiro City
Number of samples (distribution)	600
Number of samples (collection)	220 (rate of collection 36.7%)
Main components of question	– Attitude and activity on the earthquake in 2003 – Behavioral evacuation on the earthquake – Personal characteristics, etc.

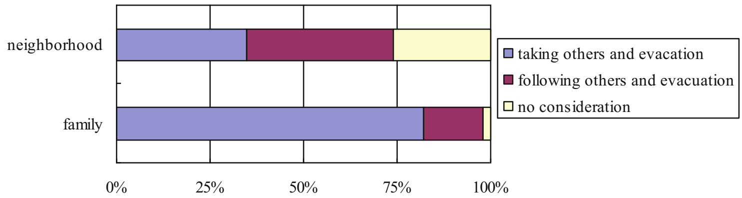

Fig. 11.11 Relationship of evacuees with their circumstances

Table 11.2 People with experiences of earthquakes more than intensity of 3

Experiences		Number of earthquakes experienced in Kushiro			
Generation		0–2	3–4	More than 5	Total
Age	10–19	8	3	0	11
	20–29	8	9	0	17
	30–39	15	14	0	29
	40–49	13	28	2	43
	50–59	14	19	2	35
	60–69	21	37	3	61
	>69	3	10	4	17
Total		82	120	11	213

by observing the relationship among family, rate of taking them is higher than neighborhood people. In this case, it reaches to almost 80%.

Table 11.2 shows the respondents experienced the earthquakes in the surveyed area. Here, the relationship between the age and the evacuation behavior was examined. The same table is the cross table which represents relationship between the age and the behavior with neighborhood. The difference was found in the distribution at 1% significant probability, when χ^2value test was carried out. In case of teenagers and 70s, the answer of "To evacuate following after someone" was counted more. After all, the relationship between the generation and the evacuation behavior can be found.

We can understand most of people have some experiences.

Table 11.3 People with relationship between generation and behavioral characteristics

Behavior		Behavior characteristics with neighborhood			
Generation		Take someone	Follow someone	No consideration	Total
Age	10–19	0	8	3	11
	20–29	3	7	7	17
	30–39	8	6	15	29
	40–49	13	14	16	43
	50–59	13	9	13	35
	60–69	25	20	16	61
	>69	2	11	4	17
Total		64	75	74	213

Table 11.4 Clusters obtained by characteristics of the evacuation behavior

			Activity with others		
Cluster	Generation (age)	Evacuation place	Family	Neighborhood	Rate (%)
C-1	–19	Unknown	Following	Following	10.2
C-2	20–39	Known	Taking	Independent	12.4
C-3	20–39	Unknown	Taking	Independent	9.1
C-4	40–59	Known	Taking	Taking	21.5
C-5	40–59	Known	Taking	Independent	18.8
C-6	60–	Known	Following	Following	12.4
C-7	60–	Known	Taking	Following	15.6

Table 11.3 illustrates the relationship between the generation and the behavioral characteristics. It was almost same between dependency and independency among neighbor people.

11.4.3 Classification of Human Evacuation Behavior Patterns

As mentioned above, the relationship between the age and the evacuation behavior was found. Then, the cluster analysis was carried out using data of the question for evacuation behavior such as "Do you know the evacuation place?", "What kind of action do you choose when the earthquake occur?", and the respondent's attributes as well. As a result of the analysis, it was possible to classify into seven clusters (Kagaya et al. 2011).

Table 11.4 shows the characteristics of the evacuation behavior with each cluster.

In order to build the multi-agent model, it is very important to grasp the appropriate behavior of each agent. Using the result of cluster analysis, we can make up the whole characteristics of human behaviors in case of the evacuation system. Each agent has each pattern of behavior. Therefore, an ideal model of multi-agent is to include the characteristics of each agent directly. However, it is not practical to examine such a simulation. So we use the abovementioned results and

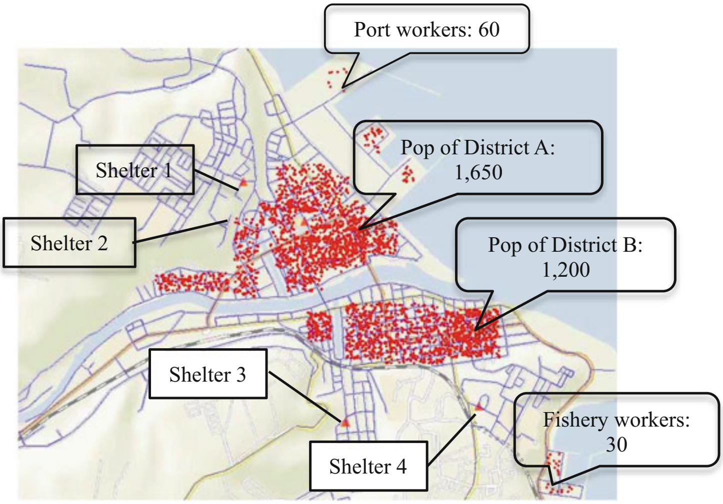

Fig. 11.12 Map of case study area (hypothetical town)

simulate multi-agent due to the cluster patterns of behavior. The cluster analysis is available for adjusting the comprehensive behaviors. The obtained clusters should be considered to reflect the total activity. We define these clusters as agent types C1–C7.

11.4.4 Establishment of Simulation Space (Fig. 11.12)

11.4.5 Action Rule Bases of Agent as Evacuee

The rule bases of agents' activity with evacuation were represented as seven patterns based on the results of cluster analysis as shown in the previous results of survey. In this simulation, the total amount of the agents is 3000 approximately. Based on the proportion shown previously in Table 11.5, the random behavior was simulated in terms of Monte Carlo method divided each number of the agent group from type C-1 to type C-7. Three parameters introduced by questions of "Does the agent know the evacuation shelter?", "how does the agent act with a family?", and "how does the agent also act in the neighbor people?" were applied to the multi-agent system simulation.

The item of initial setting for the other agents is shown as follows:

1. Initial coordinates: It is randomly placed on the roads in a map every trial.
2. Moving speed: The speed of the type C-6 agents and the type C-7 agents is 0.8 m/s, and the speed of the other group is 1.4 m/s.

Table 11.5 Selected scenarios and conditions of scenario

Simulation scenario	Conditions of scenario				
	Season	Walking speed (m/s)	Sidewalk width (m)	Evacuation shelter	Starting time
Case 1	No snow and no ice (except winter)	1.4	3.5	4	After 0 min (10%) 0–5 min (20%)
Case 2	Snow and ice (winter)	0.84	2.0	4	5–10 min (50%) 10–15 min (20%)
Case 3				3	After 0 min (10%) 0–5 min (10%)
Case 4				4	5–10 min (30%) 10–15 min (50%)

3. Family: A set of the family agent was composed of maximum three persons together as a single family.

Simulation was progressed by repeating the step in every 5 s. In this simulation, they began to.

evacuate after they had decided what to do, so all agents did not evacuate simultaneously.

Next, we explain how each agent will evacuate after it determines the evacuation. To begin with, evacuators look for the evacuation lots within their range of vision. If they find an evacuation place, they move to that direction. If not, each agent has different activity with each group. Figure 11.13 shows action rules of the type C-1 agents.

The type C-1 agents search for the family or the neighborhood that helps to evacuate for it in its range of vision. And then, the agent moves to the objective point where such helpers (someone in the family or neighborhood) exist. If the agents cannot find their family or their neighborhood, they oblige to move for themselves selecting the random routes.

Figure 11.14 shows the action rules from the type C-2 agents to the type C-5 agents.

In the case of the type C-2 agents and the type C-3 agents, they meet their speed with their families, when other families follow them. The type C-2 agents move along the routes to be approached to the evacuation place. The type C-3 agents move along the random routes. In the case of the type C-4 agents, when the family or neighborhood follows the agents, they correspond to their moving speed with some persons with the family or neighborhood. In the case of the type C-5 agents, their speeds correspond to the moving speed with their family. The type C-4 agents and type C-5 agents move for selecting the route to approach an evacuation shelter.

Fig. 11.15 shows the production rules in the case of the Type C-6 and C-7 agents. In this case they know the evacuation shelters and follow the family members or the neighborhood people. The type C-6 agents are composed of the people following

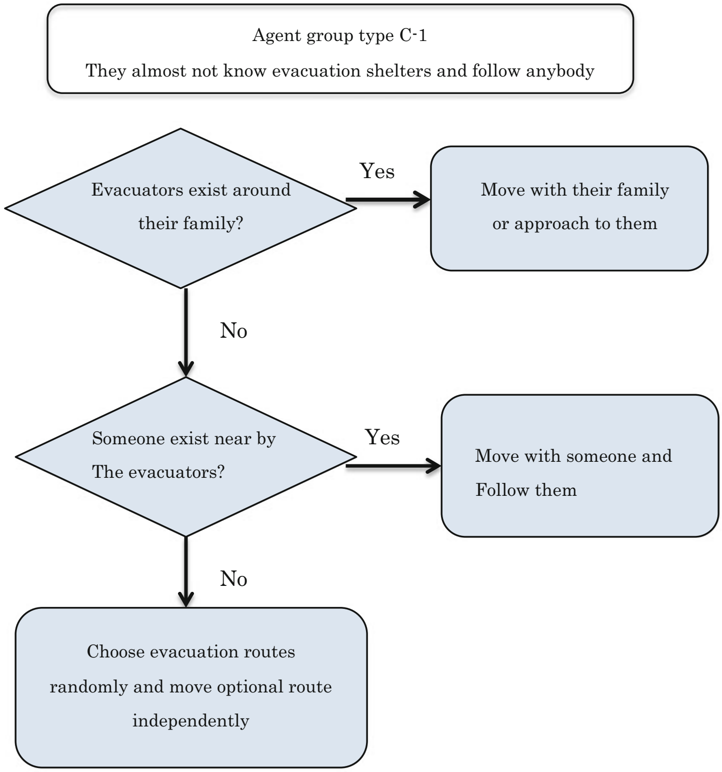

Fig. 11.13 Production rules in the system of the type C-1 agents

with other family members, while the type C-7 agents consist of the people taking with other family members.

Using these production rules, the computer program is constructed. The production rules is basically composed of structure “IF a condition is A, B is selected as the behavior.” The simulation is operated in terms of the set of several production rules simultaneously.

The computer simulation was calculated by MAS (multi-agent simulation language). MAS is based on BASIC with some options as a computer language. Therefore, it is advantageous to make the simulation program (Yamakage and Hattori 2002).

Agents are generated from their own housings or offices where they stayed during the tsunami occurrence. The method of generation is introduced due to random data using Monte Carlo method. In this study, we applied the rules obtained by the results analyzed questionnaire. The behavior that is impossible to forecast such as panic situation can be applied. Thus, alternative options also are introduced into the simulation program specifically.

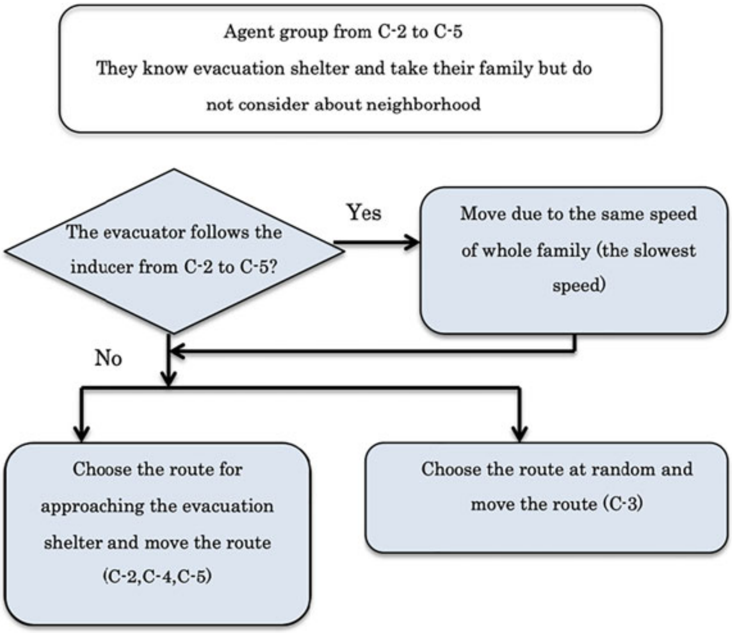

Fig. 11.14 Production rules in the system of the agent group type C-2, C-3, C-4, C-5

11.4.6 Practical Simulation Analysis on Evacuation Due to Tsunami Disaster

Table 11.5 shows the cases for discussion on the simulation of evacuation. In these cases, the conditions during cold and snowy terms are added to the usual case. The case 1 indicates the evacuees' walking towards four shelters and the starting times are four different times. The case 2 and the case 4 represent to add the condition during cold and snowy terms, and the walking speed is reduced by 60%. In the case 3 the evacuees' starting time is different from the case 2. That is, the starting time of people is later than the other term because of winter season.

Figure 11.16 describes the simulation result of evacuation activities during 25 min after evacuation order in the case 1. In this case about 62% of people are possible to reach the shelters, but the remainder of people cannot arrive there. The other cases were simulated by the same method. As a result, the comparison among the rates of completion for evacuation is shown in Table 11.6.

Meanwhile, almost all of the people can also evacuate there within 60 min in except winter season. On the other hand, about 41% of the evacuees can reach the shelters within 25 min in winter. This result means the difficulty of activity in winter. Moreover, if number of shelters decrease from 4 to 3 spots, the rate of evacuation goes down about 19%. When the evacuation order is delayed more, the rate is also falling.

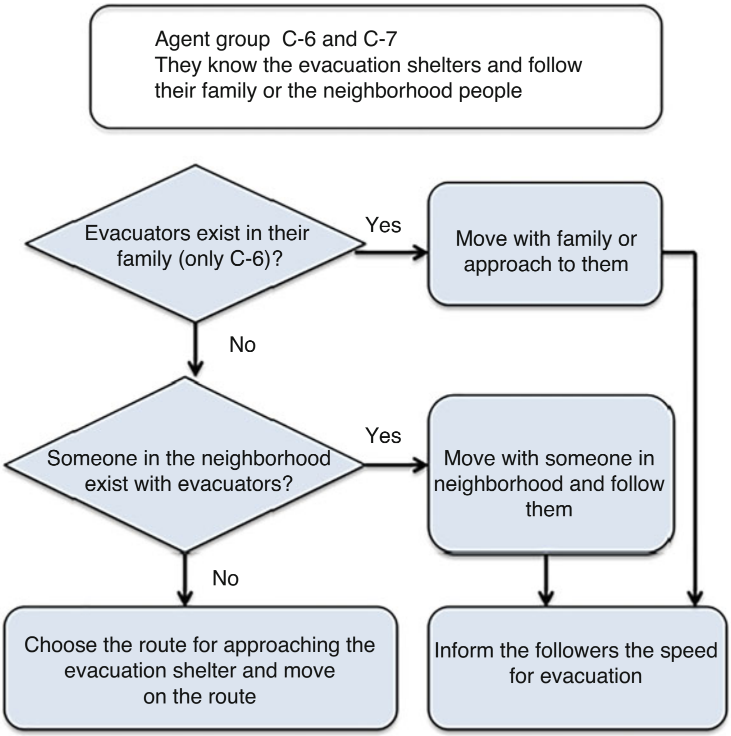

Fig. 11.15 Production rules in the system of the Agent group type C-6, C-7

The discussion can be summarized into three points as follows:

1. The activities among evacuees can be complicated, because they consist of various generations. In particular, it is hard for elderly or disabled people to move themselves as soon as possible.
2. The time to need to evacuate safely is within almost 1 h. The tsunami, however, will arrive several towns during less than 1 h, so the evacuation should be prepared within its time.
3. For example, the results of simulation indicates about 30% of people are not able to take shelters in usual case within 25 min. Many tsunamis have made rapidly attack against the coastal towns in Japan until now, so that it is necessary to prepare measures for the prevention more quickly.
4. In the case of cold and snowy area, the bad conditions of winter are added to the tsunami disaster. In this simulation, worse results are estimated to remain many people in risky areas.
5. So it is necessary to prepare not only hardware but also software measures such as dairy communication and supporting system simultaneously.

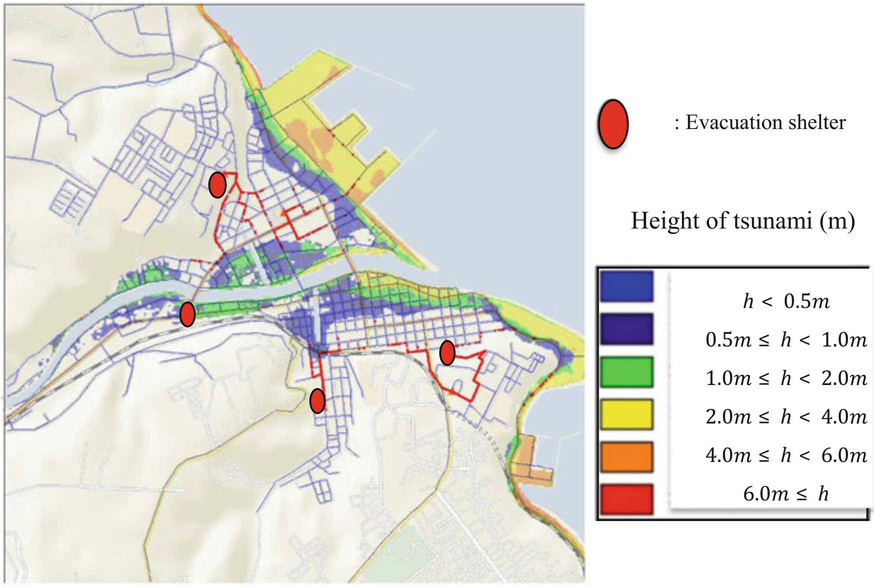

Fig. 11.16 Simulation result of evacuation in case 1

Table 11.6 Comparison among the rates of completion for evacuation

Evacuation scenarios	After 25 min	After 60 min
Case 1: Except winter and 4 shelters	61.9	99.6
Case 2: Winter and 4 shelters	41.1	94.7
Case3: Winter and 3 shelters	18.8	88.8
Case4: Winter, 4 shelters, and delayed	33.5	93.2

11.5 Analyses of Simulation on Return Home During Earthquake Disaster

11.5.1 Outline of Model Building

Once a large earthquake happens in an urban area, the urban functions are interrupted, and residents and workers become confused by the emergency. In particular, the influences on public transportation bring a serious panic in many sites of the cities. If all the transportations stop in the whole downtown area, a lot of people who are working and shopping there want to go home or confirm their families' safety. However, it is difficult for them to move themselves because of the interruption of transportation. Even if they begin to go home, they will only move a little distance. So many people are obliged to stay in downtown area, so-called, people who have difficulty to return home emerge increasingly. In an example of the Great 2011 East Japan earthquake, a report by a think tank estimated that about 2.6

million people had difficulty to return home, because the operation of all railways and other public transport was suspended. Furthermore, many people altogether tried to go back home. However, the fact was that tens of thousands of people stayed in Tokyo metropolitan area. Thus, it is a large problem whether people should decide to return home or stay in whereabouts.

Sapporo city, which is a target city of study, announced in its report that if a large-scale earthquake were to hit the city, many people would be unable to return home. According to that report, the worst-case estimate was 44,066 people stranded in summer and 83,142 people stranded in winter.

In this model, people returning home are based on their rule base of behavior characteristics. Such a behavior is built due to data of the Person Trip Survey and questionnaire survey. Each person, namely, an agent selects either return home or stay in the downtown at first. The decision-making depends on the result in terms of random utility theory, actually, random utility model. The model is constructed by the assumed hour of return home, the safety of their families, and condition of their environment using binomial logit modeling.

A flow chart of outline on multi-agent simulation is built on basis of those concepts mentioned above. Figure 11.17 shows the flow chart of agents to return home in this model.

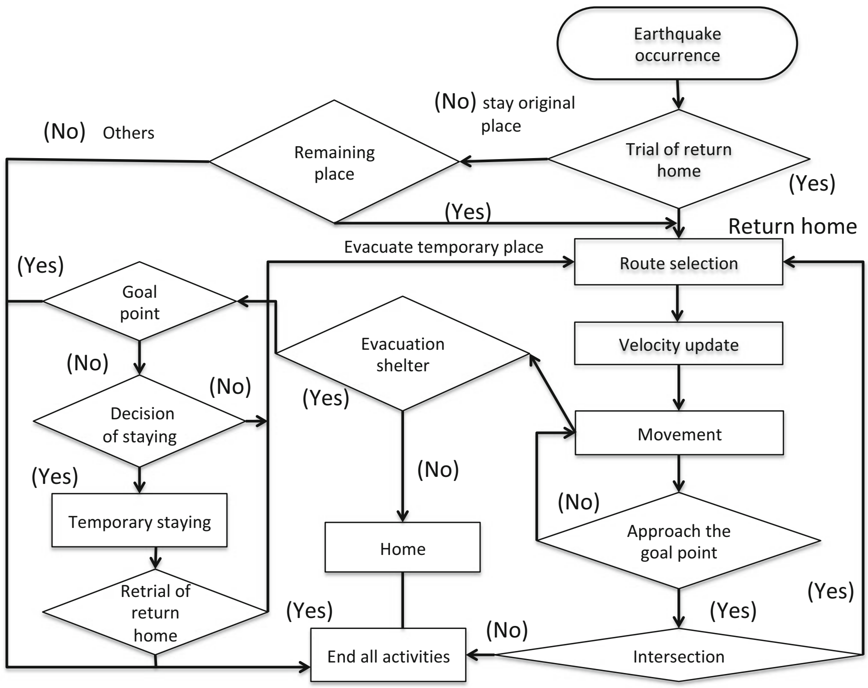

Fig. 11.17 Outline flow chart of return home

Figure 11.17 also represents the behavior of a return agent in simulation model as a process. In simulation the agents were introduced as people who decide to return home. An agent returning home chooses the route at every crossroad (a node), and it goes out of the map. Furthermore, it also removes itself changing the walking speed in terms of the congestion level in each time. The route choice is promoted on other two stages. Three kinds of agents are prepared. Those are the people agents to return home, the node agents, and the goal agents with simulation in the multi-agent system. The people agents to return home are composed of their existing coordinates, personal attributes, walking speed, the information on nodes and links, and intersection information. The node agents are distributed on intersections. The people agents returning home acquire the information of routes from the node agents with route choice attributes and the shelters. The goal agents are also located at the returning points and are used to recognize their arrivals. Using the agents, the multi-agent simulation model is built by the software MAS as the previous example (Kagaya 2010).

11.5.2 Hypothetical Earthquake and Practical Study Area

The actual study area is Sapporo city that is the fifth largest city in Japan. The population of the city is about 1.9 millions. A lot of business buildings and commercial shops are locating in the downtown area. In daytime many office workers and customers gather into the downtown area. A practical study is to return home from the downtown district to the residential area, that is, North Ward and East Ward. These wards have vulnerability for earthquake disaster and estimated significant damage by the disaster. If an earthquake occurs around the area, most of the transportation networks will not work and a lot of people who want to return their home are obliged to move by walk only.

Here, the hypothetical earthquake is introduced with the maximum scale considered in study area. Namely, the inland earthquake is supposed to occur, which has the magnitude 7.3, and the maximum seismic intensity is 7. The season is winter with deep snowfall. Moreover, we suppose it occurs at 18:00 in weekday when the number of trips is maximum in the downtown area (Kagaya et al. 2011).

11.5.3 Surveys on Return Home Trip Behaviors

The action rule bases depend on the standard of judgment due to individual characteristics such as the age, the experiences on earthquake disaster, etc. So it is necessary to survey a questionnaire in order to construct the return trip behavioral rules. It is also important to execute the precise survey, because the actual activities of people should be observed accurately and be reflected in the simulation.

Table 11.7 Outline of questionnaire survey

Distribution and collection method	Distribution to home and collection by mail
Respondents: Visitors in CBD (including commuters)	The central business district in Sapporo city
Number of total samples distributed	1000
Number of samples obtained	452 (rate of collection 45.2%)
Main component questions	Behavioral types for returning home (decision of return, route of return, single or group behavior for return)

As shown in Table 11.7, the total number of sampling were 1000 and 452 sheets were collected afterward. The main contents of the questionnaire are behavioral type of returning home, determination of return, selection of route for return and single or group activity for return, etc. Based on the survey, the following results were obtained:

1. Average allowable walking time is 1.72 h, and the maximum walking time is 2.93 h. Namely, it can be difficult for residents to walk for more than 3 h.
2. The age of travelers, the distance of returning home, and the location for trip objectives affect on the behavior of returning home. Here, the distance of returning was classified into three divisions, namely, the distance of 0–5.4 km, 5.5–9.4 km, and greater than 9.5 km due to the survey. The districts where residents return exist in such three ranges of distance. The eight district in the Eastward and the Northward of Sapporo City were selected as the practical districts. These are mentioned as the following Fig. 11.18.
3. Using the cross tabulation, the statistical significance of chi squire was reasonable for the data of returning distance and the location. Based on this result, home-coming people were classified by the distance of returning home, the location, and their attributes such as a rate of return, preference of road, and knowledge of road condition.
4. The utilized road is selected due to five conditions that are the minimum distance, the high density, the low density, many numbers of shelters, and no road selected. The characteristics of each agent are composed of the above whole attributes. The agents with different characteristics act due to their own thinking, when an earthquake happens. And then agents' actions are defined as four characteristics, that is, guidance, following and cooperative or independent.

These results are introduced into the production rules of each agent in the simulation model. Whole agents are classified into seven groups and the agents in same group have same production rules. Spontaneous agents generate in terms of random numbers obtained by Monte Carlo Method. These are similar to the case of the evacuation during tsunami as the previous discussion.

Fig. 11.18 Simulation space and return points

Table 11.8 Average distances between the downtown point and each residential district

District	East 1	East 2	East 3	East 4	North 1	North 2	North 3	North 4
Average distance(km)	3	4	6	7	4	6	10	12

11.5.4 Establishment of the Simulation Space

Figure 11.4 represents a conceptual map used for simulation. This is also made of the actual map in Sapporo city. The district as an origin point is displayed by the deep color part in the center of the map. The scale of simulation space is 10 km in length and 12 km in width by the real distance. The designated emergent roads by the municipality are introduced in the simulation. The points in the map represent the location of returning, namely, the destination areas. In this case to return home indicates a concentrated mark of a district. A node agent is distributed at an intersection. Thus, a returning agent selects some links acquiring the road information on the route condition. When a returning agent arrives at his/her house (the mark of district), the goal agent acts to eliminate the return agent from the map.

The roads colored red in this figure are represented as the damaged ones by the large earthquake (Fig. 11.18). Most of damaged roads are supposed to be caused by liquefaction during earthquake. The evacuees are forced to take detour to avoid those roads.

Furthermore, the approximate average distances between the downtown point and each residential district is represented in Table 11.8.

The average distances from the downtown area to the residential zone are about 3 km in the shortest case or about 12 km in the longest case. It can be assumed that the difference of a physical and mental burden depends on a distance to return home.

11.5.5 Number of Agents Used with Simulation and Their Attributes

In this analysis, the experimental agents are obtained with the past Person Trip (PT) Survey. Table 11.9 indicates the result in calculation of returned residents in each destination with three aims to visit in the city center.

Based on the Person Trip Survey, two wards are divided into eight districts. The number of visitors from eight districts to the downtown district is estimated by PT data. The points to return home are supposed corresponding to population in each district. Namely, the point to return home is determined in terms of population size in each district. In general, the larger the population is in each district, the many the return points are there.

Individual average of walking speed is given as the probabilistic value. The value is based on the normal distribution. The speed is reduced by 70% of it in the case of snowfall. The individual walking speed is different due to average walking speed, road congestion, damage of road, etc. Figure 11.19 shows traffic congestion and walking velocity respectively.

On the other hand, width of pedestrian road is supposed about 2 m on the main road and about 1 m on the other general road with one-way. It is generally assumed the pedestrian moves on only one way. The reduction rate of walking speed is determined by the intensity of liquefaction. Table 11.10 represents the relationship between the intensity of liquefaction and the redaction rate of walking speed.

A choice model is mainly built for determination of returning home when a huge earthquake occurs. Namely, it is important for people remaining in downtown to

Table 11.9 Number of people to return home and to return points

	Number of people staying in downtown (each attribute)			
Medium zone area	Office workers	Shoppers	Passengers	Return points
East 1	6111	1168	743	42
East 2	11,771	2109	1338	74
East 3	8478	1750	908	45
East 4	6905	1207	536	39
North 1	10,904	2815	1717	52
North 2	10,204	621	1093	62
North 3	6510	508	1000	30
North 4	9578	1048	976	47

Census data of person trips in Sapporo city in 20

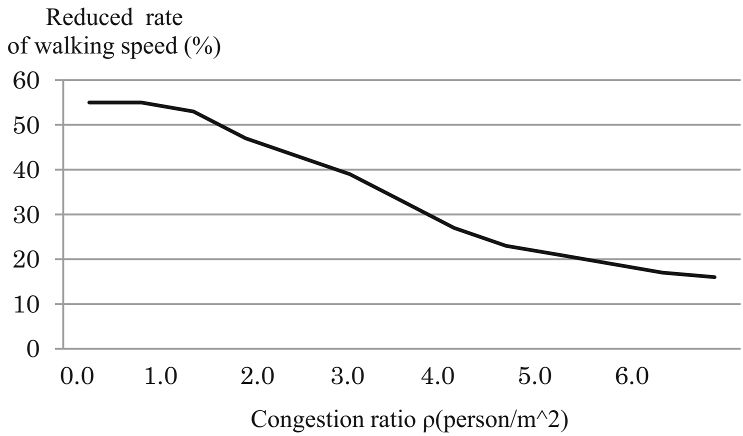

Fig. 11.19 Relationship between reduced rate of speed and congestion ratio

Table 11.10 Relationship between damaged road and reduction rate of walking speed

Intensity of liquefaction	Reduction rate of walking speed
Large	0.65
Medium	0.85
Small	0.95
Minimum	1.00

determine if they return home or not. Here, we introduce several factors to decide their behavior and then analyze the choice model. Binomial logit modeling builds the behavioral choice models.

The walking speed is reduced by 0.65 in the case of severe liquefaction. If traffic congestion and liquefaction on the road happen simultaneously, evacuation roads are difficult to use and make a negative chain reaction.

11.5.6 Choice Model of Return Home

$$\Delta V_i = \alpha + \sum_{k=1}^{K} \beta_{ik} x_{ik} \tag{11.1}$$

$$P\left[\text{go}\right] = \frac{1}{\left(1 + e^{-\Delta V_i}\right)} \tag{11.2}$$

ΔV_i, utility function of return home; x_{ik}, explanatory variables k of utility i; β_{ik}, parameter of each explanatory variables; P[go], probability on return home.

The models represent choice behavior to return home for office workers, students, shoppers, and passengers. The equations are based on (1) and (2). Equation

(11.1) represents random utility function for return home and Eq. (11.2) shows a probability on the return home. The analytical results obtained by the model also show Table 11.11 and Fig. 11.20. The conditions on waiting mean that people stay in temporary shelters for a few days by preparing the necessities of life.

In this model, the nearer home is from downtown, the faster the walking speed is, and the more difficult the confirmation of safety for family is, the higher the probability to return home is.

People to return home choose the minimum distance and minimum angle from the direction of objective point. Finally, the route is chosen in terms of calculation of the utility depending on road condition and gathered people to return home. Furthermore, joint points of returning are prepared on the way to home.

Table 11.11 Choice model of return home for office workers and students

Parameter	Factors	Unit	Estimate	t-value	ρ-value
α	Constant		1.8442	13.344	0.000***
β_{11}	Season	0: Winter1: Summer	0.00000.6556	7.057	0.000***
β_{21}	Walking time	Minute	−0.0082	−10.560	0.000***
β_{12}	Safety for family	0: Unchecked1: Checked	0.0000−0.4947	−5.332	0.000***
β_{22}	Conditions on waiting	0: Bad1: Good	0.0000−1.1456	−12.366	0.000***

Notes: significance level; 1%***; 5%**

Fig. 11.20 Rate of decision to return home for office workers and students

11.5.7 Some Results of Simulation in the Existing Case

In the simulation here, we prepared several scenarios to change the rate to obtain safety for family and the rate to improve the condition of temporary shells dynamically. Each case is simulated with 30 times trials, and then the average of output value was calculated as the results of simulation.

Next, using the simulation model, the appropriate locations of temporary waiting shelters were found in terms of the information on the distribution of shells and agents with physical fatigue due to walking long time.

The results in the case of existing condition are represented as follows:

The rate to confirm the safety of family was supposed to be at 39% immediately after earthquake occurrence and at 50% after 1 h. The rate of good condition on office buildings and schools, for preparing the temporary evacuation shells, was supposed to be increased by 50%. The supposition included the above conditions was defined as the existing case. The results of the number of whole agents who stayed in downtown are represented in Table 11.12.

As shown in Table 11.12, the remarkable differences among each district were clarified. In particular, when the distance between downtown and each district was more than 10 km, the achievement rate of return is very low. So it is difficult for agents to get their home in the case of long distance.

11.5.8 Analysis on Changes of Return Home Activities in Assumed Scenarios

Based on assumed scenarios, we executed simulations by using the model. The cases are composed of the following seven scenarios: (1) existing case, (2) bad condition on staying facilities, (3) good condition on staying facilities, (4) no confirmation of safety for family, (5) confirmation of safety for family, (6) the worst scenario, and (7) the best scenario. Thus, scenarios 2–5 means the ones that each described content. The results of simulations are shown in Table 11.13.

Scenario 1 was prepared for the existing condition. This is the most probable result as a usual case. Scenario 2 indicates more people try to return home because the temporary staying sites cannot expect to be kept. The result is more people act for returning home but rate of safe return is not so high. Namely, it is difficult for them to achieve their aims. Compared with Scenario 2, the result of Scenario

Table 11.12 Result of simulation in the existing case

District	East 1	East 2	East 3	East 4	North 1	North 2	North 3	North 4	Total
Return home	4701	6504	1995	1355	6861	1762	417	107	23,723
No return home	0	258	764	1179	53	659	1404	884	5201
Rate of return (%)	100.0	96.2	72.3	53.9	99.2	73.0	22.9	10.8	82.0

Table 11.13 Result of simulation on return home activities in assumed scenarios

Scenario	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Agents trying to return	40,555	49,542	31,564	50,509	40,544	50,828	31,474
Give up returning	11,570	14,731	8702	12,612	11,609	6466	8598
Achieve safe return	23,723	28,346	19,156	30,807	23,811	35,477	19,166
No achieve return	5201	6465	3706	7090	5124	8885	3710
Rate of safe return (%)	82.0	81.4	83.8	81.3	82.3	80.0	83.8
Agents staying	60,075	54,198	66,146	51,111	60,073	44,646	66,132

3 shows less people return home because of enough condition of staying sites. Scenario 4 shows the case that people cannot confirm the safety of their families. There are many people who want to go back home, because they care about their families. In Scenario 5 the result is similar to the case of Scenario 1.

Scenario 6 indicates the worst case, that is, nobody can confirm safety of their families and the condition of staying facilities is bad. The maximum numbers of agents will try to return home as soon as possible in this case. On the contrary, Scenario 7 has the best condition comprehensively. In this case, it is obtained the highest rate of safe return.

The results are summarized as follows:

1. According to the worst scenario, the number of agents that tried to return home became the maximum. However, the rate of agents that could get home is the lowest level. On the other hand, in the scenarios with regard to better conditions of information on safety of the families, the agents that tried to return home became the minimum, while the rate of return home was largest. Thus, agents will have the most appropriate behavior during earthquake occurrence, if there is enough information of the families.
2. Considering Scenario 2 and 3, the difference is remarkable between the results. If staying or waiting facilities have good conditions, more agents stay in downtown area. That is, it is effective to control agents to return home in terms of improvement of staying or waiting facility.

11.5.9 Analysis on Allocation of Temporary Staying Shelters

Figure 11.21 shows the results of scenario 1 from another viewpoint, that is, the agents going home within a possible time for walking exist in each grid. The possible time was considered as 3 h. They have not reached their home yet. The number in each grid indicates agents that remains after beginning of returning home. Those grids locate in 3–5 km from the origin district in downtown. Most of agents want to approach to their residences in the range of 5–10 km from the origin point. They already walked for 3 h so that they need to have a rest in temporary shelters. The number enclosed within a circle means a number of facilities utilized

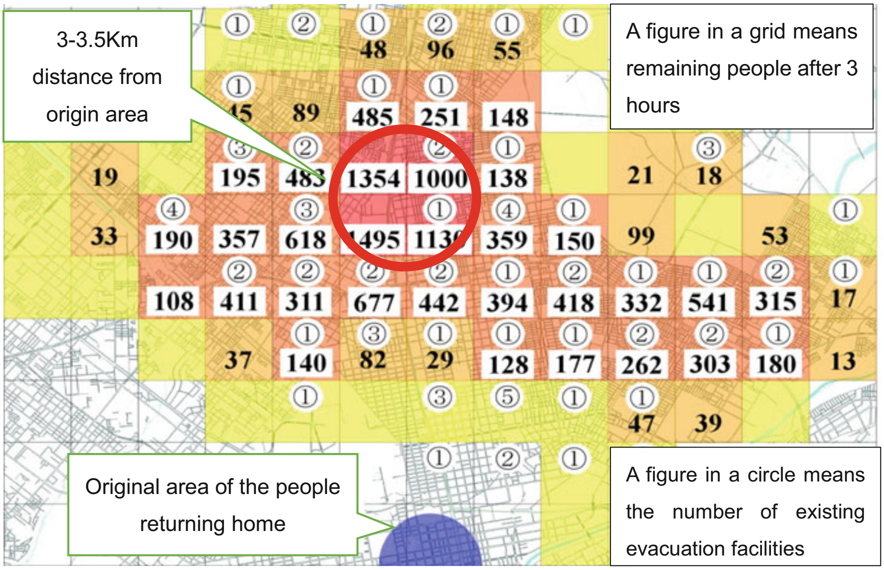

Fig. 11.21 Number of sojourning agents in 3 h after earthquake

for temporary shelters. Agents staying in a grid don't necessarily meet the capacity of the shelters in same grid. Thus, it should be necessary for municipality to adjust and prepare new temporary shelters in the area where those agents must stay.

11.5.10 Results and Consideration

In most of large cities in Japan, many people commute into the center business district (CBD). On the other hand, many people also concentrate there for shopping, enjoying meals and going to hospital. If a huge earthquake suddenly attacks in the city at that time, it causes sudden fear among them and leads to panic Abruptly. Then they intend to go back to home as soon as possible in order to confirm their families' safety and to help their families. Meanwhile, they want to evacuate from there to guard themselves against severe damages by the earthquake. Many evacuees concentrate onto evacuation activities and emergent traffic roads altogether. There happen many obstacles and disturbances along the evacuation roads. We should also reconstruct the behavioral simulation model of returning home for such people.

The study was examined as:

1. The multi-agent simulation model which analyze the behavior of returning home includes three kinds of agents are prepared, namely, the returning agents, the node agents, and the goal agents. Those agents interacted among one another and were evaluated as reaching to the objective points in each district.

2. The limited time enough to reach the objective point was estimated by using MAS. It is difficult for agents to reach the points by the limited time. This means their performances were incompatible with their ideas.
3. It is effective for returning agents to have temporary shelters to go for long hours. It should also be considered that the main evacuation roads are improved as a wider width. This is because in winter, damage will increase more by indirect influences on snow and cold condition.
4. Thus, it should be indispensable to arrange the comprehensive and systematic returning system including not only hardware measures but also software measures.

In the future study, the accurate estimation will possibly be examined due to a combination between multi-agent simulation model and geography information system (GIS) in more detail.

11.6 Conclusion and Remarks

In this study we discussed prediction of human behavior in an unusual term when a huge earthquake occurs. Some experts forecast that a huge earthquake with tsunami will occur somewhere in Japan soon. Therefore, it is important for the disaster prevention governance to build countermeasures of earthquake disaster due to not only hardware but also software, namely, a comprehensive plan. The objective of this study is to grasp the behavioral characteristics of inhabitants during an earthquake and to apply the obtained findings in disaster measures. Specific studies were examined in both cases of the evacuation issues against a tsunami around coastal areas and the return home issues during a huge earthquake in a large city.

Here, a new methodology based on behavior-oriented multi-agent system was developed. First of all, a questionnaire survey was introduced to find the conscious and behavioral characteristics in each generation. In this discussion, seven groups were classified by behavioral identification. The production rules of each agent were constructed by using such different behavioral systems. The inhabitants' behavioral data were used the Person Trip Survey, the data of the supposed town handbook, and so on.

As a result, it comes to the following conclusions on each discussion.

According to the study results on the evacuation issues, the following findings became clear:

1. Through total discussions, it is serious for elderly or disabled people to evacuate for themselves so that the cooperation of family and community is necessary for them.
2. The evacuation time is important to consider in advance. It is also desirable to complete evacuation within 1 h.

3. In cold and snowy areas like Hokkaido, the worse condition will increase the damages of tsunami disaster complexly. So it should be considerable to countermeasure during winter season.

   Subsequently, the findings were obtained by the discussion on return home issue as follows:
4. According to the worst scenario in which information is not enough and temporary staying facilities are also not enough, the number of evacuees is maximum, because most of people in the downtown area anyway eager to go back to their homes.
5. The usual case is similar to the one that the people confirm their family's safety. Namely, the conventional life is based on a reasonable daily behavior.
6. If staying or waiting facilities are secured enough and information is satisfied sufficiently, more people stay in downtown area and panic phenomena do not happen. So it is important for us to manage the information and improve temporary staying facilities in the downtown spot.

Consequently, the appropriate evacuation method is proposed, and then by using such method, the possibility of the evacuation and the return home systems was found in view of the conditions of the sage facilities and the human attributes. Finally, it is hard for a simulation method to recreate the situation during an earthquake, because the verification of simulation is impossible by using specific data. However, when people respond to sudden events like an earthquake, it will come to mind for them almost simple thoughts and activities based on shallow knowledge. So it can be possible to recreate future events certainly, if a questionnaire survey is reliable.

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Finally the author writes down that there was the quotation from the existing paper in *Journal of the EASTS*, the reference described below (Kagaya et al. 2005) about this paper partly.

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Chapter 12
Dynamic Changes in Food Consumption in China: Focusing on the Rice Retail Market

Lily Kiminami, Shinichi Furuzawa, and Akira Kiminami

Abstract Generally, economic growth converts the consumption structure of food due to the difference in the income elasticity of demand for each article of food. In addition to income and price, consumer preference also strongly influences the consumption structure of food. In recent China, with the progress of globalization, there has been a move toward a shift to a sustainable food system in addition to a shift to a modern one. Since structural changes in food consumption and in the retail market are the driving forces of the dynamism of food system, it is significant to understand the current situation and clarify the issues of food system transition for policy-making.

The purpose of this study is to capture the dynamic changes in food consumption in China by focusing on the rice retail market. Specifically, we introduce hedonic approach to analyze the factors of price formation using the information on e-commerce of rice for verifying our two hypotheses. These are "China's rice retail market is in a monopolistic competition characterized by product differentiation" (H1) and "The Meaning-based brands related to the formation of sustainable food market are developing in the rice retail market in China" (H2). In addition, we conduct the survey at retail stores in Shanghai to reinforce our analytical results.

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Finally, we draw policy implication on the strategy for Japanese rice marketing in China based on our empirical study.

Keywords Rice retail market · Brand · China · Food consumption · E-commerce

12.1 Introduction

China's success in increasing agricultural production and in feeding better its growing population in the past three decades has been remarkable. Up to the late 1990s, the principal agricultural policy objective was to increase agricultural production, especially of food grains. Gradually, more attention was given to supporting rural incomes to address the issue of the growing income gap between urban and rural populations. An important change in China's approach to agriculture was the abolition of the long-established agricultural tax, which was effectively implemented by early 2006 (OECD 2013).

In general, economic growth converts the consumption structure of food due to the difference in the income elasticity of demand for each article of food. The proportion of foods such as grain with low-income elasticity in food consumption decreases, and the proportion of foods such as meat and poultry with high-income elasticity in food consumption increases along with income improvement, leading to more high-end food consumption. Moreover, in addition to income and price, consumer preference strongly influences the consumption of food.

In recent years, consumption in China is still expanding, but its trend is changing rapidly. Comprehensive growth is coming to an end, and consumers are more selective about what they spend their money on. In addition, the shift from quantity to quality is significant in food consumption. While sales of food and beverages have remained almost flat, the new trend is that more than half of Chinese consumers are interested in healthy and nutritious foods and 25% of consumers want to buy upgraded rice (McKinsey 2016). Furthermore, with the improvement of Internet access, the popularity of online shopping has increased rapidly. Conventionally, there have been concerns about quality and safety issues in food e-commerce, but EC usage is increasing along with the "improvement of convenience through home delivery services."

On the other hand, although the export of Japanese rice to China has attracted much attention in recent Japan, it is hard to say that the export of rice to China is on the right track.[1] One of the reasons is considered that there is intense competition among different varieties, brands, and price ranges in the Chinese rice market

[1] Although, China is regarded as a strategic export target country for Japanese rice, its export volume in 2019 is about 621 tons. In addition, the Japanese export target for rice is 100,000 tons per year, but the actual result in 2019 is less than 30,000 tons (https://www.maff.go.jp/j/syouan/keikaku/soukatu/kome_ysyutu/kome_yusy)

(Kiminami 2010). In addition, the perception of the Chinese middle class toward buying foreign brands even if they are expensive is declining. Instead of judging the value of a product with the keyword "foreign-affiliated," the trend is to determine the price based on the brand image (Xiang et al. 2015). Therefore, there is a possibility that some Japanese rice exporters and related organizations are unable to keep up with rapid changes in rice consumption in China.

Furthermore, with the progress of globalization, there has been a move toward a shift to a sustainable food system in recent China in addition to a shift to a modern one. Since structural changes in food consumption and in retail market are the driving forces of food system dynamism, it is significant to grasp the current situation and clarify the issues of food system transition for policy-making.

The purpose of this study is to capture the dynamism of food consumption in China by focusing on the rice retail market. The research is designated as follows. First, we will make a literature review on the issues of development of brand theory and agricultural product brand, retail market development in e-commerce, brand analysis on agricultural products and rice in China, and sustainable diets and food market in Sect. 12.2. Next, the analytical framework and hypotheses for achieving the objective of the research as well as the methods for hypothesis verification will be presented based on the above literature review in Sect. 12.3. And in Sect. 12.4, two hypotheses will be verified by introducing hedonic approach and conducting the survey at retail stores in Shanghai. Finally, in Sect. 12.5, we will draw policy implication on the strategy for Japanese rice marketing in China based on the above analytical results.

12.2 Literature Review

12.2.1 Development of Brand Theory and Agricultural Product Brand

The American Marketing Association (AMA) defines a brand as a "name, term, sign, symbol or design, or a combination of them intended to identify the goods and services of one seller or group of sellers and to differentiate them from those of other sellers." However, according to Aoki (2011) and Hampf and Lindberg-Repo (2011), the major themes of brand research so far have changed significantly. In the following, we summarize the changes in brand research with reference to Aoki (2011).

Until the 1980s, brands were seen as a means for sale, and the main interests of research were brand loyalty and brand image. In the 1980s, "brand equity" began to be emphasized along with the accumulation of asset value in the brand as a result of marketing activities. Aaker (1991) defined brand equity as "a set of brand assets and liabilities linked to a brand, its name and symbol, that add to or subtract from the value provided by a product or service to a firm and/or to that firm's customers" and grouped the assets and liabilities on which brand equity consisting of five categories: (1) brand loyalty, (2) name awareness, (3) perceived quality, (4) brand association, and (5) other proprietary brand assets (patents, trademarks, channel relationships, etc.).

Since the mid-1990s, brand research has focused on exploring the essence of strong brands, and Aaker (1996) presented the concept of brand identity as “a unique set of brand associations that the brand strategist aspires to create or maintain. These associations represent what the brand stands for and imply a promise to customers from the organization members.” Therefore, the clarification and sharing of the identity as the “brand should be” are essential conditions for building a strong brand. In that sense, brands are regarded as “the starting point of marketing” (Aoki 2011).

On the other hand, Keller (1993) focuses on the structure of consumer’s brand knowledge as a source of brand equity and develops the theory of customer-based brand equity (CBBE) as a framework of brand building. “Customer-based brand equity” is defined as “the differential effect of brand knowledge on consumer response to the marketing of the brand.” Therefore, in order to build a strong brand, the challenge is how to create a brand knowledge structure that generates desirable consumer responses such as choice. It presents a systematic framework and specific procedures for creating a desirable brand knowledge structure. In addition, Keller (2008) has developed a strategic brand theory using the knowledge in consumer behavior research and presented a brand-building framework called “brand-building blocks.”

Allen et al. (2008) have seen a change in the trend of brand theory since the 2000s. Instead of the traditional “information-based view of branding,” it has shifted to “meaning-based view of branding.” In a new view of branding, brand is a meaning, a means to support people’s life and to give meaning to their life. Aoki (2014) sees information-based and meaning-based view of branding as a complementary relationship.

However, the brand theory based on industrialization cannot be applied to primary products such as agricultural products. As pointed out by Hazumi (2002), the following five requirements are necessary for the brand to be established: a mass production format called industrialization, the abolished status system, an established mass market, the logistics and information networks throughout the country, and the freedom of business. Otherwise, it is called a pre-brand, if a producer or the like gives a mark for identification in situations where these requirements are not met or if it is recognized as a symbol for quality assurance and differentiation from other products. The pre-brand concept here corresponds to the fact that Moore and Reid (2008) called Proto brand for the pre-industrial brand.

On the other hand, quality differences in agricultural products are expressed by differences in transaction prices. In order for prices to accurately convey the quality of products, quality information transmission systems such as product ratings, standards, inspections, certifications, brands, and credits are used for sharing the knowledge about the quality of the goods being traded among trading entities. Shigetomi (2017) has demonstrated that the quality information system that is incorporated into the transactions of Thai rice is determined by the market, socioeconomic, and technical conditions surrounding the trading system.

12.2.2 Retail Market Development and E-Commerce

According to Barney (1986), there are three types of competition: IO (industrial organization) competition, Chamberlinian competition, and Schumpeterian competition, and each has its own competitive strategy. The market where IO competition is assumed is a complete competition market or an imperfect competition market, and it is important for companies to create an oligopolistic state due to barriers to entry. However, the market where Chamberlinian competition is assumed is an exclusive competitive market, and it is important for firms to have management resources that demonstrate their unique strength for differentiation and fierce competition. Furthermore, Schumpeterian competition takes place in a rapidly changing environment where innovation occurs, and it is important for firms to respond flexibly to the environment. In recent years, the change in competition in the rice retail market in China is considered as a change from the IO competition to the Chamberlinian competition, and the importance of management resources of the companies that make up the food system is increasing.

Furthermore, new developments in brand research have occurred along with the development of e-commerce since the 2000s. Currently, many online platform businesses that are rapidly expanding with the development of ICT are one of the representative examples of two-sided market.[2] The economy of scale, the economy of scope, and the network effects (direct and indirect) are easy to work, so the market size is expanding rapidly (METI 2016). Design in the platform business has been discussed from the viewpoints of innovation and competition policy because it affects the environment for creating transactions and interactions between stakeholders as well as the direction of innovation. In particular, China's online platform has gained significant market penetration both domestically and abroad and is currently attracting international attention (OECD 2019).

There are many economic studies on the online market, but the most important studies related to this research are those on competitive strategy and consumer behavior. As Clemons et al. (2002) pointed out, for services with relatively simple and clear descriptions of products, price dispersion exists in the online market, and differentiation strategies are important. Wang et al. (2019) also found in a study on China that differentiated retailers on the online market gain consumer loyalty and have price control.

Changes in the environment of media information are enabling information to be transmitted by individual consumers and creating an environment in which a consumer community is formed (a site where consumers transmit and share information

[2]For a theoretical study on two-sided market, see Rochet and Tirole (2003).

the so-called consumer-generated media (CGM)). Network externalities through interaction between consumers promote the accumulation of consumer experience, knowledge sharing, and product evaluation. Therefore, in the analysis of brand formation in the social commerce environment, research focusing on consumer interaction is important.

In addition to online and offline retailers, there are hybrid-type retailers that are both online and offline. On the other hand, consumers not only use the online market and the offline market in comparison but also take a browse-and-switch action using both. Therefore, the factors that define the superiority of the online market over the offline market are not simple. Shi et al. (2019) have built a theoretical model that shows the relationship between the characteristics of goods and services and consumer's channel choices. Forman et al. (2009) and Nault and Rahman (2019) clarified the impact of factors such as offline transportation costs, online nonuse costs, and online and offline retail prices on consumer's channel choices.

12.2.3 Brand Analysis on Agricultural Products and Rice in China and Japan

In recent years, researches on brand value and quality value of agricultural products both in China and Japan are increasing. Firstly, studies on rice by choice experiments include Zhou et al. (2017), Xu et al. (2018), Nie et al. (2018), De Steur et al. (2013), and Zheng et al. (2018). Zhou et al. (2017) measured consumers' willingness to pay for rice with different ecolabels (green labels, organic labels), geographical indications, and brands (national brands, local brands). It also revealed the attributes of consumers that have an impact on willingness to pay for rice. Nie et al. (2018) conducted a choice experiment on rice with different certifications, traceability, grades, brands, and prices for 607 consumers in nine cities in China. It clarified that consumers pay attention to the certifications from the government.

Secondly, as for the studies on rice by hedonic analysis, Wang et al. (2009) conducted the analysis of 208 types of rice data collected at 18 supermarkets in Haidian District, Beijing, China, and clarified that weight, grade, variety, package, certification, place of origin, and brand of rice determined the price. Furthermore, the production area, official certification, leading brands, and packages have a positive impact on the price. In Li and Yang (2017), using 450 types of rice data collected at 19 supermarkets in Nanjing, it clarified that the physical characteristics of rice (rice varieties, grades, and weights) and packages (materials, transparency, vacuum, expiration date), certification labels (organic, geographical indications, functional indications), brands, and locality indications have different effects on prices. By measuring the hedonic price function of typical brands of Japanese rice, Kiminami et al. (2009a) found that the prices of rice were explained by attributes such as rice varieties, origin, and taste. Furthermore, Kiminami et al. (2009b) showed that the purchase behavior for Japanese rice in China is not from its rareness but from its quality and brand reputation, based on the results of an Internet survey of consumers (1000 people) in Beijing and Shanghai.

Thirdly, although the quality of rice has been strongly influenced by the locality of production and the grade of varieties so far in Japan, rice is being differentiated and branded by various qualities when the distribution has become multilayered today (Fuyuki 2014). Saito (2010) clarified the characteristics of regional brands and pointed out the importance of strategy for brand management. Suzuki and Kiminami (2009) revealed the status of regional collective trademark registration. Takita and Kikuchi (2012) clarified the effects of rice quality, locality, and variety on rice consumption through conjoint analysis. In addition, rice is also differentiated and branded by cultivation method considering biodiversity in Japan. The Ministry of Agriculture, Forestry and Fisheries of Japan made a list of 22 "ecolabeled rice with biodiversity-friendly practice" in 2010. Taie (2012, 2013) clarified the economic characteristics of "living creature mark rice" (the nature of public goods such as environmental quality) and analyzed the price premium from the perspective of product differentiation under monopolistic competition. Oishi (2016) and Tanaka and Oishi (2017) have clarified the factors affecting the price premium of "living creature mark rice" through empirical analysis. Furthermore, they pointed out the importance to cultivate the market by publishing information from producers and sellers and collaborating with those who sympathize and support the concept.

12.2.4 Sustainable Diets and Food Market

Since 2010, there has been an increasing interest in sustainable diets in the area of scientific research (FAO and Biodiversity International 2010),[3] but the following problems have been pointed out, such as the relationship with adjacent social issues are unclear (e.g., fair trade, animal welfare, sustainable agriculture, social acceptability, etc.), there are few policy studies, and it is difficult to uniformly evaluate and discuss dietary habits because eating behavior is easily influenced by culture and individual preference. There can be a variety of transitional routes in sustainable diets. In Bilali et al. (2018), it is pointed out that various strategies need to be implemented in order to move to a sustainable food system, such as a continuous aggregation to improve efficiency, restraining demand for sustainable diets, and alternative food networks for food system transition, and the path of each strategy is discussed.

On the other hand, Garnett and Wilkes (2014) summarized changes in China's food system over the past 35 years in terms of economic growth, food security

[3]Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe, and healthy, while optimizing natural and human resources.

policies, and demographic changes. On that basis, it pointed out that the sustainable food system in China is important to change from three aspects of health, environment, and supply chain. In addition, the international economy, climate change, and resource constraints are the defining factors, and the trends in consumption and policy are driving forces.

Liu et al. (2016) pointed out that it is effective to apply the social practices approach (SPA) that captures problems from both human behavior and social structure in order to correctly understand the problems surrounding sustainable consumption. As the result of a review of sustainable consumption in three areas of food, energy, and mobility in China, it is pointed out that there is a lack of research on the dynamism regarding changes in consumer behavior and changes to sustainable consumption. In particular, in the food sector, although there are many analyses focusing on technical research and individual behavior such as choice experiments, there are few analyzes from other viewpoints.

Furthermore, the Chinese economy is projected to develop a path of sustainable growth by shifting from the investment-driven economy to the consumption- and service-driven economy by 2030 (McKinsey 2013). In the consumption-driven economy, product quality and differentiation will play an increasingly important role. In particular, in the grocery retail market, the role of quality information, including information transmission, certification systems, and labels is becoming more important (Saitone and Sexton 2009).

12.3 Analytical Framework and Methods

12.3.1 Analytical Framework and Hypotheses

Based on the above literature review, for achieving our objective to clarifying the dynamism of food consumption in China by focusing on the rice retail market, this research will be undertaken according to the analytical framework shown in Fig. 12.1, and the following two hypotheses are set for verification. In Fig. 12.1, it is considered that the structure and quality of the rice retail market are determined by the business strategy of the company on the supply side, consumer behavior on the demand side, as well as the interaction of knowledge-technology and institutions-policies. However, we will mainly analyze the competitive strategy and consumer behavior of companies in this research. Specifically, we will analyze the rice retail market focusing on the EC market (two-sided market) and the actual store market from the perspective of brand theory for the following reasons.

Firstly, in consumer-driven economies, consumer behavior strongly defines market dynamism and its development, and analyzing the consumer behavior based on brand theory can add perspectives from different dimensions of economics (the view of the development of product differentiation under monopolistic competition), business administration (the competitive strategies of companies such as product

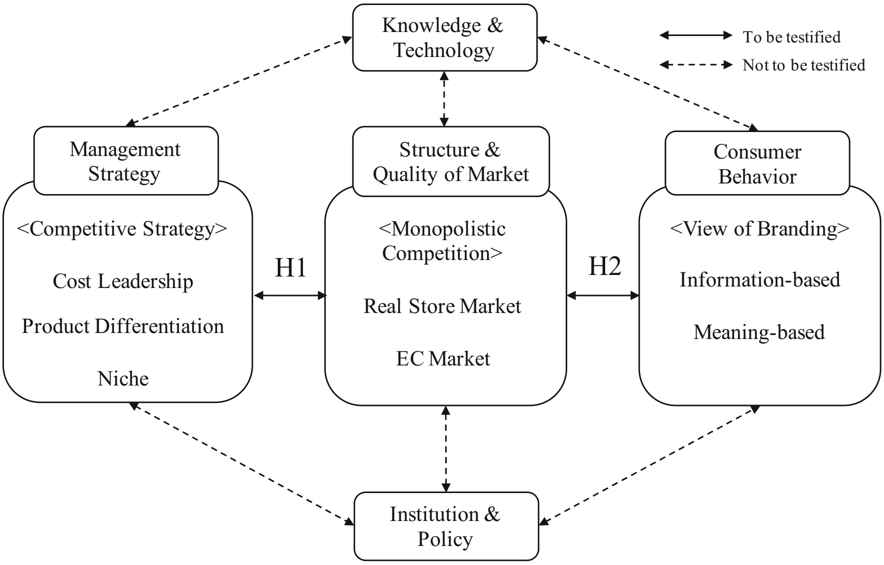


Fig. 12.1 Analytical framework for the dynamism of rice retail market

Table 12.1 Degree of market development

		Consumer's view of brand		
		I: Low (information-based) II: Low (meaning-based)	I: High II: Low	I: High II: High
Production differentiation (consumption diversity)	(Low)	A (low)	–	–
	(Middle)	–	B (middle)	C (middle)
	(High)	–	D (middle)	E (high)

differentiation), and marketing theory (value creation in response to changes in consumer's view of brands).

Secondly, a two-sided market has the impacts of "consumption externalities" and "consumption diversity" on the retail market development. In the platform market, consumption externalities such as network externalities enable the retail market to develop through cumulative feedback, and the company's product differentiation strategy will progress consumption diversity rapidly.

Furthermore, the relationship between the hypothesis set and the degree of market development in this study is explained as follows. Table 12.1 summarizes the degree of market development from the two perspectives of product differentiation in retail market (here, mainly seen as consumption diversity) and consumer's brand view. Hypotheses 1 is related to product differentiation, and hypothesis 2 is related to the view of brand. First, if the degree of product differentiation is low and meaning-based brand view is low, it can be evaluated that the level of market development is low (corresponding to A in the table). In other words, it is a stage to overcome the underdeveloped market in developing countries, and the standardization of products for infrastructure development related to distribution such as transportation and reduction of transaction costs is progressing to some extent, but there is no brand. Next, when the product differentiation is at a middle level but information-based view of brand is high, it can be evaluated that the degree of market development is at a middle level (corresponding to B in the table). At this stage, the modernization of retail market and distribution is progressing, and branded goods begin to be traded in the market. However, the brand at this stage has a strong meaning of presenting quality information and remains at the pre-brand or proto-brand. Finally, when product differentiation is at a high level and both information-based and meaning-based views of brand are high, the degree of market development is evaluated at a high level (corresponding to E in the table). In general, the route from B to E often follows B → C → E or B → D → E.

Hypothesis 1: China's rice retail market is in a monopolistic competition characterized by product differentiation.

Hypothesis 2: The meaning-based brands related to the formation of sustainable food market are developing in the rice retail market in China.

12.3.2 Data and Analytical Methods

In order to clarify our two hypotheses, we measure the hedonic price function of rice using the following function form. A classical least square method is used for the estimation, and robust standard error is used to increase the robustness of the results. In addition, explanatory variables are set in accordance with previous research (such as Wang et al. 2009; Costanigro and McCluskey 2011) for actual stores. However, this research is characterized by adding the variables of sale site and buyer evaluation in the analysis.

Price (unit price) = F (sales method, variety/subspecies, processing method, production area, certification, packaging, sale site, customer evaluation).

The data used for the analysis was based on data collected from Taobao's e-commerce site from December 6 to December 8, 2018. Of the total 1850 products extracted from the "Dami: rice" category (counting as different products even if the same product is priced differently), a total of 748 samples that were successfully saved in pictures during the same period were analyzed.

The variables used are as shown in Table 12.2. Among the physical characteristics, samples with unknown varieties were used as standards for japonica rice, indica rice, and aromatic rice. About half of the production area is Thailand. This is because Thai rice has low entry costs for companies to handle as a product in the online market being standardized as a product in the international market.

There are three sale sites: chaoshi.tmall.com, tmall.com, and taobao.com. Of these, tmall.com and taobao.com have the ability to report buyer ratings to sellers. Therefore, in the following, two estimations of A (not including a customer evaluation with the number of 748 samples) and B (including a customer evaluation

Table 12.2 List of variables and descriptive statistics

Type	Variables	Mean	Min.	Max.	Code	Remarks
Price	Unit price (yuan/kg)	30.59	5.59	380	Numeric value	Log transformation
	Price (yuan)	128.87	2	4188	Numeric value	
Sales method	Weight (kg)	5.61	0.1	125	Numeric value	Log transformation
	Expiration date (months)	14.43	1	24	Numeric value	Log transformation
	Number of bags	1.27	1	10	Numeric value	Log transformation
	Direct from farm 1	0.25	0	1	0–1 dummy	
	Direct from farm 2	0.09	0	1	0–1 dummy	
Variety/subspecies	Japonica rice	0.11	0	1	0–1 dummy	
	Indica rice	0.02	0	1	0–1 dummy	
	Aromatic rice	0.51	0	1	0–1 dummy	
Processing method	Germinated rice	0.12	0	1	0–1 dummy	
	Sprouted rice	0.03	0	1	0–1 dummy	
	Brown rice	0.19	0	1	0–1 dummy	
	Red rice	0.19	0	1	0–1 dummy	
Production area	Thailand	0.48	0	1	0–1 dummy	
	Northeast 3 provinces	0.18	0	1	0–1 dummy	
	Heilongjiang province	0.13	0	1	0–1 dummy	
	Wuchang rice (trademark)	0.01	0	1	0–1 dummy	

(continued)

Table 12.2 (continued)

Type	Variables	Mean	Min.	Max.	Code	Remarks
Certification	HACCP&ISO	0.02	0	1	0–1 dummy	
	Organic	0.06	0	1	0–1 dummy	
	Green food	0.01	0	1	0–1 dummy	
	GI (SAIC)	0.02	0	1	0–1 dummy	
	GI (AQSIQ)	0.02	0	1	0–1 dummy	
	GI (MOA)	0.00	0	1	0–1 dummy	
	Thai government (export)	0.23	0	1	0–1 dummy	
	CCIC export(China)	0.01	0	1	0–1 dummy	
Packaging	Plastic	0.81	0	1	0–1 dummy	
	Vacuum	0.29	0	1	0–1 dummy	
	Transparent	0.28	0	1	0–1 dummy	
Sale site	Tmall supermarket (Chaosi)	0.10	0	1	0–1 dummy	
	Tmall	0.22	0	1	0–1 dummy	
	Taobao, etc.	0.68	0	1	0–1 dummy	
Customer evaluation	Coincidence of explanation	4.81	4.3	5	Numeric value (0–5)	Normalization
	Service attitude	4.81	4.5	5	Numeric value (0–5)	Normalization
	Delivering service	4.80	0.8	5	Numeric value (0–5)	Normalization

Notes: The expiration date is set as 1 month when there is no description (cannot be specified)
The variables “direct from farm 1”and “direct from farm 1” correspond to cases where “farmer” and “self-production” are included in the page title (= 1)
The customer evaluation of the seller is only on sale sites other than “Tmall Supermarket”
Numeric value data is logarithmized or normalized as indicated in the remarks column at the time of estimation
GI is an abbreviation for geographical indication and the official names of the abbreviations in the parentheses are as follows:
SAIC (State Administration for Industry and Commerce)
AQSIQ (General Administration of Quality Supervision, Inspection and Quarantine)
MOA (Ministry of Agriculture)

with the number of 673 samples) are performed. However, the customer's evaluation with respect to the sellers has three items of coincidence of explanation, service attitude, and delivery service.

12.4 Analytical Results

12.4.1 Results from Hedonic Rice Function

Tables 12.3 (estimation A) and 12.4 (estimation B) are the estimation results. The results of the variable selection model, variables with a significance level of 5% or less, will be described.

First, let us take a look at the results of estimation A. As for the sales method, small packaging and freshness are evaluated due to weight (−−−), expiration date (+++), and number of bags (+++) are significant in the results. As for the varieties and processing methods, japonica rice (−−−) and red rice (++) are significant. It is thought that the formation of a market for value-added rice including health consciousness is progressing. However, one of the reasons why the dummy variables for germinated rice and brown rice are not significant is considered to be difficult to discriminate by using product photos alone compared to red rice. As for the production area, dummies are significant for Thailand (+++) and Wuchang (+++) but not for the three provinces of Northeast China and Heilongjiang province. It can be said that only a part of the production areas and brands is functioning effectively.[4] Furthermore, in the certifications, organic (+++), green food (−−−), and Thai government certification (++) are significant. Therefore, a market for the brand of organic rice has been formed in China due to a stricter standard of organic certification than green food certification contributes to price formation which is different from existing research on edible oil (Jiang et al. 2019), and a public certification is also important in the price formation for Thai rice.

In addition, the results of estimation B are almost the same as the results of estimation A, except the dummy for green food (−) certification is not significant and GI (SAIC) (−) is significant. However, since the data for estimation B does not include the sample of Wuchang, the dummy variable is also excluded from the estimation. As for customer's evaluation, delivery service (++) is significant.

Furthermore, the dummy for sale site (+++) in estimation A and B (++) is significant. The reason why the price of rice is higher for online mall markets than for online supermarket in the EC market of China can be explained by the difference

[4]From Sept. 30, 2018, every packet of Wuchang rice on sale at a flagship store on Alibaba's Tmall platform will be tagged with a QR code. By scanning the code using the Alipay app, customers will be able to track shipments and access related information including where it was harvested and the type of seed used. The new system will also cut delivery time (see *Nikkei Asian Review* Sept. 03. 2018 for details).

Table 12.3 Results of estimation A (not including customer evaluation)

	Explained variable = unit price	Full variable model (A-1)		Variable selection model (A-2)	
	Explanatory variables	Coef.	*t*-value	Coef.	*t*-value
	Constant	2.692	23.852***	2.709	34.594***
Sales method	Weight (kg)	−0.277	−10.140***	−0.268	−9.887***
	Expiration date (months)	0.140	6.301***	0.150	7.469***
	Number of bags	0.288	4.807***	0.300	5.221***
	Direct from farm 1	−0.027	−0.398		
	Direct from farm 2	−0.128	−1.484	−0.130	−1.594
Variety/subspecies	Japonica rice	−0.248	−3.262***	−0.255	−3.510***
	Indica rice	0.030	0.224		
	Aromatic rice	−0.012	−0.117		
Processing method	Germinated rice	−0.059	−0.577		
	Sprouted rice	−0.031	−0.244		
	Brown rice	0.079	0.982	0.107	1.715*
	Red rice	0.139	1.762*	0.135	1.993**
Production area	Thailand	0.210	2.138**	0.234	3.647***
	Northeast 3 provinces	−0.012	−0.134		
	Heilongjiang province	0.043	0.493		
	Wuchang rice (trademark)	0.794	2.735***	0.582	2.860***
Certification	HACCP&ISO	0.174	1.399	0.176	1.420
	Organic	0.686	8.388***	0.686	8.527***
	Green food	−0.292	−2.446**	−0.377	−3.907***
	GI (SAIC)	−0.297	−0.972		
	GI (AQSIQ)	0.040	0.220		
	GI (MOA)	0.321	2.301**		
	Thai government (export)	0.131	2.737***	0.125	2.683***
	CCIC export (China)	−0.083	−0.447		

Packaging	Plastic	0.072	0.877		
	Vacuum	0.098	1.939*	0.110	2.255**
	Transparent	−0.111	−2.057**	−0.089	−1.837*
Sale site	Tmall	0.315	3.821***	0.281	4.053***
(Ref. :Tmall Supermarket)	Taobao, etc.	0.207	2.657***	0.166	2.689***
Customer evaluation	Coincidence of explanation	–	–	–	–
	Service attitude	–	–	–	–
	Delivering service	–	–	–	–
	Adjusted *R*-squared	0.457		0.463	
	F-statistic	22.72		38.92	
	Significance *F*	0.000	***	0.000	***
	AIC	−992.5		−1012.1	
	Observations	748		748	

Notes: "*" (10%), "**" (5%), and "***" (1%) indicate statistical significance
Results of robust standard error are used
The variable selection model is the result of variable selection according to the minimization criteria of AIC (Akaike's information criterion)

Table 12.4 Results of estimation B (including customer evaluation)

	Explained variable = unit price	Full variable model (B-1)		Variable selection model (B-2)	
	Explanatory variables	Coef.	*t*-value	Coef.	*t*-value
	Constant	−0.067	−0.045	1.818	3.670***
Sales method	Weight (kg)	−0.272	−9.682***	−0.264	−9.493***
	Expiration date (months)	0.161	5.948***	0.171	7.170***
	Number of bags	0.283	4.652***	0.290	4.978***
	Direct from farm 1	−0.012	−0.174		
	Direct from farm 2	−0.133	−1.541	−0.122	−1.501
Variety/subspecies	Japonica rice	−0.252	−2.889***	−0.251	−2.988***
	Indica rice	0.082	0.474		
	Aromatic rice	−0.008	−0.069		
Processing method	Germinated rice	−0.082	−0.741		
	Sprouted rice	−0.033	−0.238		
	Brown rice	0.060	0.700	0.090	1.426
	Red rice	0.141	1.719*	0.154	2.270**
Production area	Thailand	0.178	1.678*	0.203	2.743***
	Northeast 3 provinces	0.017	0.168		
	Heilongjiang province	−0.016	−0.143		
	Wuchang rice (trademark)	–	–	–	–
Certification	HACCP&ISO	0.146	1.079		
	Organic	0.705	7.445***	0.728	8.147***
	Green food	−0.354	−2.614***		
	GI (SAIC)	−1.449	−7.684***	−0.853	−8.304***
	GI (AQSIQ)	0.560	4.452***		
	GI (MOA)	0.322	2.252**		
	Thai government (export)	0.119	2.392**	0.124	2.589***
	CCIC export (China)	−0.077	−0.409		

Packaging	Plastic	0.036	0.418		
	Vacuum	0.100	1.904*	0.108	2.201**
	Transparent	−0.110	−2.010**	−0.095	−1.942*
Sale site	Tmall	0.108	2.338**	0.117	2.575**
(Ref.:Tmall Supermarket)	Taobao, etc.	–	–	–	–
Customer evaluation	Coincidence of explanation	1.650	0.792		
	Service attitude	0.633	0.291		
	Delivering service	0.797	2.246**	1.068	2.085**
	Adjusted *R*-squared	0.410		0.416	
	F-statistic	16.56		32.94	
	Significance *F*	0.000	***	0.000	***
	AIC	−863.8		−885.4	
	Observations	673		673	

Notes: "*" (10%), "**" (5%), and "***" (1%) indicate statistical significance
Results of robust standard error is used
The variable selection model is the result of variable selection according to minimization criteria of AIC (Akaike's information criterion)

in target consumers and the competitive strategy of stores. In general, there are many consumers in the EC market due to there is no physical restrictions as in actual stores. On the other hand, each company's competitive strategy becomes more important in the EC market due to the competition is more intense than in actual stores. As for the competition strategy on the store side, online supermarket is implementing a cost leadership strategy, and online mall stores are implementing a product differentiation strategy or a niche strategy.[5] As a result, the price of rice on the online mall sites is higher than on the online supermarket site.

From the results of estimations A and B, the rice retail market that evaluates (1) safety, (2) organic premium, (3) added value (including health-oriented), and (4) brand (partial) has been developed in the Chinese rice e-commerce market. This is almost consistent with the results of previous studies. It was also found that network externalities through consumer interactions are functioning to some extent. In the rice retail market for B2C e-commerce in China, product differentiation under monopolistic competition makes management strategies (including marketing) of each company and producer more important. However, it is necessary to improve the rice retail market through reforms in institutions and distribution systems since the following problems are appealed from the analytical results: local brands are not well established, there are strong concerns about safety, and geographical indications and direct marketing are not effective means.

12.4.2 Results from Actual Store Survey

Based on the above analytical results and Kiminami (2010), a rice price survey was conducted in March 2019 for food retailers in Shanghai, China. The retail outlets targeted are "City'super: Shanghai Guojin Center Store," a luxury supermarket located in Pudong New Area, "Lianhua Super Market: Siping Store" for general consumers, and "Lianbuohui: A street for national specialty products" (Fig. 12.2 and Table 12.5). Data on 28 types of Chinese rice and 1 type of Japanese rice were collected. The following characteristics were observed.

Firstly, the price difference between products is large which is up to about 16 times. The minimum price (per 5 kg) is 24.4 yuan, and the maximum price is 390 yuan for Chinese rice. However, the price for Japanese rice (Yumepirika) is 495 yuan which is about 1.3 times of the highest price for Chinese rice. Secondly, there is a great difference in merchandise among stores. The products sold by each store were not sold at other stores, and the price of rice was also very different, with the lowest price of City'super being higher than the highest price of Lianhua

[5]At online supermarket, a large lot of products that are standardized or highly recognized in the market are sold. Therefore, there is the economy of scale at online supermarket. On the other hand, since the stores at online mall market are opened by a plurality of small businesses, it is difficult to greatly increase the sales volume. Therefore, there is a tendency to have high-value-added products and more diversified products at online mall market.

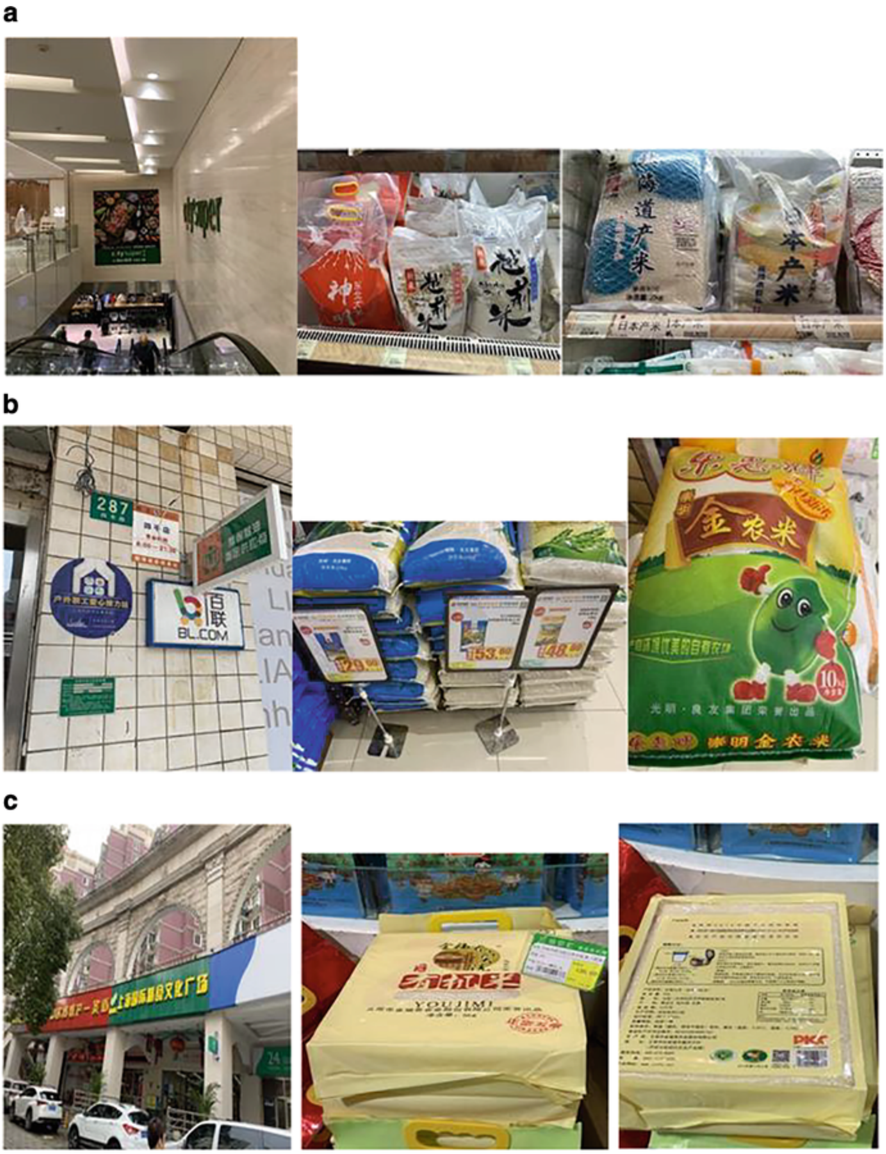


Fig. 12.2 (**a**) City'super Shanghai Guojin Center Store. (**b**) Lianhua Super Market: Siping Store. (**c**) Lianbuohui: A street for national specialty products

Table 12.5 Retail price of rice in Shanghai City (March 2019)

Retail store	Brand	Price (yuan/5 kg)	Producing area	Variety	kg	Certification and PR
City'super Shanghai Guojin Center Store	Echizen rice milk color variety	257.5	Donggang, Liaoning province	MQ	2	Zhangxing Guangmei Agricultural Science and Technology Co., Ltd. (Full ownership of Capital by Japan) Supervision
	Echizen rice Japanese Koshihikari variety	173.3	Changxing, Zhejiang province	KH	4.5	
	Organic light rice	365.0	Jiangsu province	KH	1	Certificate COFCO (China Organic Food Certification Center)
	Brown rice	390.0	Jiangsu province	KH	1	
	Cream queen rice	71.0	Dandong city	MQ	2.5	
	Niigata beauty rice	261.3			4	
	Gu Yizhai Jilin ecological rice	87.0	Changchun, Jilin province		2.5	
	Good fortune rice	195.0			2	
	Double color double aromatic rice	147.5			2	Wuchang, Flower aromatic rice, Black aromatic rice
	Jilin rice	176.0			2.5	
	Natural slow rice	176.0			2.5	No chemical fertilizer, no pesticide
	Shenming northeast rice	69.0			5	
	Liangyun polished rice	175.0			2	
	Liangyun unpolished rice	192.5			2	
	Hokkaido-produced rice	495.0		YP	2	

Lianhua super market: Siping store	Soft aromatic rice	29.9	Yucheng City, Jiangsu province		5	Farm direct harvest/base direct supply
	Chongming golden aromatic rice	24.4	Chongming District, Shanghai		10	Registered cadaster Chongming District, Shanghai
	Guangming Chongming farm rice	26.9	Chongming District, Shanghai		10	
	Dabie Mountain aromatic soft rice	32.5	Ankang City, Anhui province		10	
	Chongming golden farm rice	26.5	Chongming District, Shanghai		10	Guangming Liangyou Group accomplished
	Haifeng high-quality rice	32.8			10	
	High-quality Akitakomachi	36.4			10	
Lianbuohui: A street for national specialty products	Run sheep rice	180.0	Qidihar City, Heilongjiang province		5	China organic product
	Jinfuqiao house courtyard (Wuchang rice treasure organic rice)	120.0	Wuchang City, Heilongjiang province	4–2	5	GI, Wuchang rice, PICC, QR code
	Jinfuqiao house courtyard (Wuchang rice)	98.0	Wuchang City, Heilongjiang province	4–2	5	GI, Wuchang rice, PICC, QRcode
	Jinfuqiao house courtyard	33.0			10	Royal tribute
	Kairu flower aromatic	116.0	Wuchang, city of Harbin, Heilongjiang province		5	Wuchang rice
	Kairu aromatic rice	114.0	Wuchang, city of Harbin, Heilongjiang province		2.5	
	Kairu long grain aromatic	58.0	Wuchang City, Heilongjiang province		5	Northeast rice

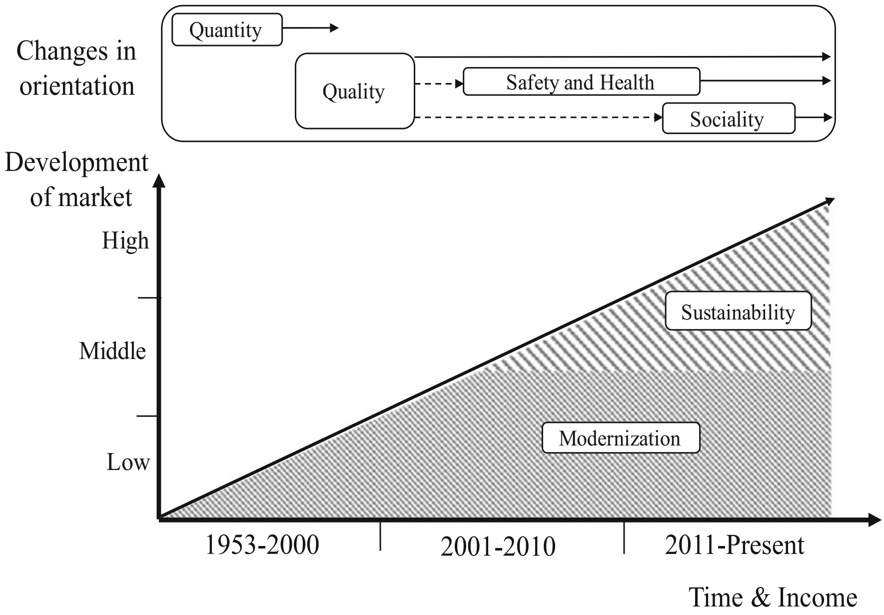
Note: The contents of the abbreviations of the varieties are as follows:
MQ milky queen, *KH* Koshihikari, *YP* Yumepirika, *4-2*: Guoyou rice No. 4 (commonly known as Dao Hua Xiang No. 2)

Super Market. In addition, products in City'super are under 5 kg, while products in Lianhua Super Market are 10 kg. Thus, the layer of customers at both stores is considered to be completely different. Thirdly, there was only one variety of Chinese rice clearly specified by the variety name. On the other hand, Japanese varieties are emphasized by including Koshihikari and milky queen in the product name or by greatly describing them on the package. Fourthly, rice production and distribution companies have multiple products with different qualities and varieties under a single trademark. Also there are products appealed to be produced on directly managed farms. On the other hand, the only recognized regional brand was "Wuchang Dami: rice produced in the area called Wuchang." Fifthly, differentiation by the methods of environment-friendly farming such as organic farming and pesticide-free farming is being carried out. Sixthly, there are products produced locally or involved in production by Japanese company produce. Therefore, in addition to rice exports, Japanese companies and producers are taking part in the Chinese rice market.

It is clear from the above that the consumer's purchasing behavior of rice is greatly influenced by the product attributes in China. However, the large difference in assortment between stores suggests that the store selection of the consumer determines the range of product selection. In addition, consumer needs are diverse; while there are many high-quality and expensive products, there are also many inexpensive and less differentiated products. Therefore, the management strategies (including marketing) of each company/producer are becoming more important along with the meaning-based brand view in which interaction between consumers is considered as being formed in recent China. Therefore, our two hypotheses "China's rice retail market is in a monopolistic competition characterized by product differentiation" (H1) and "the meaning-based brands related to the formation of sustainable food market are developing in the rice retail market in China" (H2) are verified.

12.5 Concluding Remarks and Policy Implication

Finally, based on the abovementioned analytical results in addition with previous researches, the changes in the rice retail market in China can be expressed as shown in Fig. 12.3. The horizontal axis represents changes in time and income, and the vertical axis represents the degree of competition among rice varieties, production areas, and brands. Along with the market mechanism introduced in China's food supply, the competition between producers has been reflected in rice retail market, and the brands on the labeling production area swept retail in the beginning of 2000s. Subsequent to distribution reform (especially the rapid development of retail market), the brands of the production area disappeared in no time and were replaced by the brands representing the variety, quality, and cultivation methods. Also, the popularity of Japonica rice produced in Northeast China has declined since 2005 due to the increased consumer's safety concerns and the emergence of wealthy



	1953-2000	2001-2010	Current
Changes in retail market	Market, Small and medium stores	+Modern supermarket	+EC market, Social commerce
Principles of price formation	Transportation cost	Product differentiation (Vertical)	Product differentiation (vertical+horizontal)
Consumer image	Homogeneity	Low income + High income class	Middle class
Competitive Structure	(Low) Competition	(Middle) Competition among producing areas	(High) Competition among brands
Example of Competition	[Low quality conventional products] Japonica rice Indica rice	[High quality conventional products] Japonica rice (domestic variety) Indica rice (domestic aromatic)	[Domestic products] Brand rice Japanese variety rice Organic rice High value-added rice (Health) [Imports] Japonica rice (Japan) Aromatic rice (Thailand)
Brand	Nothing	Pre-brand	Brand

Fig. 12.3 Dynamism of the rice retail market in China

people (Kiminami 2008). In recent years, with the increase of the middle class, the interest in organically cultivated rice (with certification) and high-value-added rice (brown rice, red rice, Japanese varieties rice, etc.) has increased. At the same time as health consciousness is getting stronger, the interests in environment-friendly farming and in interaction between producers and consumers are also growing. In other words, the development of the rice retail market in China was at a low level (A) before the 2000s but changed to a middle level (B) in the 2000s. From 2011, it has started directly shifting to the stage of high level (E) along with a rapid transition to the meaning-based brand view and consumer interaction. The reason behind the dynamic change is thought to be caused by the rapid development of retail market through cumulative feedback due to the externalities of consumption in the two-sided market and the rise of the middle class in the huge consumption market. Therefore, Chinese food system is in the phase of the transition from a modernization toward both modernization and sustainability.

In order to continuously sell a certain lot of Japanese rice in the Chinese market in the future, it is necessary for Japanese rice producers and distributors to work together to develop a marketing strategy based on appropriate market segmentation and targeting under such circumstances. Specifically, instead of the traditional method of pushing out Japanese rice entirely by the government, firms should actively cooperate with each other to grasp the needs of consumers and build the required brands for Japanese rice through sharing the image and interacting with Chinese consumers.

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Chapter 13
Ecological Migration Policy and Livestock Farm Management

Zhan Jin

Abstract An ecological migration policy has been implemented since 2001 as part of China's Western Development Strategy. This policy aims to allow development in ecologically fragile areas, particularly ethnic minority regions, to cope with poverty, while simultaneously protecting the environment. Researchers from ethnic minorities who reside overseas have asserted that the promotion and implementation of this policy amounts to cultural genocide based on prejudice and discrimination by the Han Chinese leadership against livestock breeding. Because of population growth by the large scale migration of the Han race, over farming, and excessive development, land resources are remarkably degenerating in Inner Mongolia. Till 2004, it is said that 90% of the grassy plain degenerated. In order to restore the destroyed environment, "conservation set-aside grasslands and forests program" came to be carried out over a wide area in China from the 1990s. To the farmers who have difficulty in earning their livelihood, "Ecological Migration Policy" appears as the supporting factor. From the standpoint of the influence on pastoralists' household economies, the structure of income and the expenditure of pastoralists after migration will be clarified. In addition, the simulation of cases of "not emigrating" will be done. By comparing the simulation cases to current cases, analysis on the influence of "Ecological Migration Policy" given to pastoralists' household economies will be clarified. It is important not only for the government but also for private corporations and local communities to enhance their concerns for the environment, and to support "ecological migrants," realizing their contribution for the environment. Supporting the life of pastoralists is a necessary condition for the success of the "Ecological Migration Policy," and that is also the first step for the success of the environmental policies.

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13.1 Introduction

An ecological migration policy has been implemented since 2001 as part of China's Western Development Strategy. This policy aims to allow development in ecologically fragile areas, particularly ethnic minority regions, to cope with poverty, while simultaneously protecting the environment. Researchers from ethnic minorities who reside overseas have asserted that the promotion and implementation of this policy amounts to cultural genocide based on prejudice and discrimination by the Han Chinese leadership against livestock breeding (Yang 2011).

In this context, this paper takes the view that the Chinese communist government is pursuing a consistent policy vis-a-vis ethnic minority. Furthermore, we deem that this policy has not changed with the implementation of China's reform and open door policy or the Western Development Strategy. Therefore, we contend that China's ecological migration policy is an industrial policy that seeks to redistribute scarce resources available for economic development. Consequently, this policy aims to redistribute to the non-agrarian sector land, water, and other resources owned by farmers via deagrarianization, depastoralization, and urbanization. In this manner, one can contend that the low productivity of livestock raising justifies an industrial development policy. We are led to presume that the attribution of "backwardness" to livestock farming simply serves as a shorthand to justify a necessary industrial development policy.

This paper discusses to what extent the objectives of the Western Development Strategy have been realized, with a focus on the ecological migration policy. The policy uses environmental protection as a justification to expropriate the land of farmers engaged in livestock breeding and to relocate them to urban areas to work in secondary and tertiary industries. The resources taken from the livestock herders have been allocated to secondary industries, ensuring elimination of the livestock-raising industry, which highly depends on the ecological environment and competes for land use with secondary industries, which have higher productivity. The ecological migration policy has obvious downsides with respect to the livelihoods of the animal herders, and the implementation of the related compensatory policies is flawed. From the perspective of livestock herders' livelihoods, this paper presents a survey of the former inhabitants of Village B, Sonid Right Banner, Xilin Gol League, in Inner Mongolia to assess the impact of the ecological migration policy on the lives of livestock farmers.

13.2 China's Localized Economic Policies and Ecological Migrants

Shinjilt (2005) categorized Eastern China as an ethnically Chinese area using Chinese characters and Western China as an ethnically non-Chinese area using non-Chinese characters. His article claims that the Western Development Strategy is based on an attitude of Han Chinese superiority. This means that the—according to Chinese social development theory—backward western areas ought to evolve by modeling themselves after the developed areas. However, this view is a bit extreme. Until the 1970s, the areas in Western China received preferential investment under policies that stressed heavy industry and placed weight on the western part of the country. According to Huhbator (2007), many Soviet aid projects in China's first 5-year plan, which began in 1953, were implemented in Western China. Because of economic policies biased toward the western areas, little economic disparity existed between Eastern and Western China until the reform and open door era.

After the reform and open door policy, China, with its large land area and population of one billion, continued to pursue localized economic policies aimed at economic development. However, the focus of construction investment shifted away from Western China and toward Eastern China. Eastern China was emphasized because the coastal areas were more convenient for receiving an influx of foreign capital, the procurement of raw materials, and export of finished goods. The reason, in other words, was locational conditions. This can be explained as an implication of Deng Xiaoping's "getting rich first" theory, which meant to let those who can get rich first. The second part of this theory—the areas that got rich first should help the less developed areas—was later implemented by Jiang Zemin. The Western Development Strategy focused on the acceleration of infrastructure development, preservation and protection of the ecological environment, adjustment and streamlining of the industrial structure, and development of science and technology, education, and sanitation businesses. The strategy intended to rectify the economic disparities between the east and the west. The economic disparities among Eastern, Central, and Western China have indeed narrowed since 2003 (Dai 2010), reflecting the policy goals and impact of the Western Development Strategy.

In China, policy implementation is executed by the central, provincial, city, prefectural, township, and village governments, in that order. The lower levels of government do the actual work and are assessed by their accomplishments. This setup also applies to the Western Development Strategy. However, unlike previous policies, while economic development holds the most important position in the Western Development Strategy, it also has another centerpiece in the protection of the ecological environment. In other words, the central government has ordered the regions to pursue both economic development and environmental protection, including in ecologically fragile areas.

Since 2000, numerous studies have focused on environmental issues in Inner Mongolia and governmental and community efforts to tackle them. The impetus for this research was serious land degradation.[1] In 1996, degraded grassland area constituted 58.3% of the total grassland or 45.9 million ha (Wang 2006). By 2004, this area had increased to approximately 90% of the total (Nemekhjargal 2006). The Grain for Green Project (stop farming and return the land to forests and grassland) was implemented as an environmental policy starting in 2000. In addition, the Grazing for Grass Project (stop grazing and return the land to grassland) started in 2003. Under this Grazing for Grass Project (known as the New Three Grazing policies), grasslands are classified into three levels: grazing cessation, where pastures lie fallow while livestock are raised in barns during grass germination time; grazing rotation, whereby the pasture lands are divided into several sections and take turns lying fallow; and no grazing, where grazing is temporarily prohibited. For farmers having trouble maintaining their livelihoods due to the Grain for Green or Grazing for Grass programs, an ecological migration policy of assisting them by moving them to other areas was instituted (Bato 2007). These programs considered grazing the culprit in land degradation.

Numerous studies have explored the causes of soil degradation, and it has been attributed to population increases from the large-scale migration of Han Chinese (Borjigin 2001; Du 2005; Narenhua 2007); excessive land reclamation, mainly for agriculture (Narenhua 2007; Du 2005); road and factory construction and mining of mineral resources (Nemekhjargal 2006), and so on. Of course, although some studies have explored overgrazing by livestock farming (Oniki and Shuang 2004; Du 2005; Oniki and Gensuo 2006), it is not widely acknowledged that grazing has more of a link to desertification than other industries. At least, nothing has linked the traditional Mongolian nomadic lifestyle to desertification. Regional governments faced the dilemma of simultaneously being responsible for economic development and environmental protection without adequate experience or know-how in those areas. Thus, the implementation of the ecological migration policy aimed to perpetuate industrial production in order to safeguard the "accomplishments" of economic development by avoiding the imposition of limitations on industry but, as a surrogate, enacted environmental "protection" that viewed the livestock breeding industry, which indeed does depend on the environment, as a burden on that environment and putting limitations on it.

Insofar as the Western Development Strategy was a program aimed to reduce the regional economic disparities between the east and the west, its implementation should have at least maintained and, if possible, raised farmers' living standards. The question posed by this is: Can farmers whose only experience is in the livestock business maintain their living standards after they have migrated as part of the implementation of the ecological migration policy? Accordingly, this paper conducted an interview survey of former livestock farmers from Village B, Sonid Right Banner, Xilin Gol League in Inner Mongolia.

[1]The concept of land degradation generally refers to desertification, soil salinization, and desolation (as in the Gobi).

13.3 Overview and Industries in the Survey Area

In the Xilin Gol League, located in the center of the Inner Mongolia Autonomous Region, 97.8% of the land area is grassland. Livestock breeding is the major industry. The number of sheep and goats is 14,861,500 head in total (Inner Mongolia Autonomous Region Statistics Bureau 2007). This figure, along with the number of domesticated animals, is the highest in Inner Mongolia. Within Inner Mongolia, the Xilin Gol League seems to have implemented the ecological migration program the most deliberately and broadly. Therefore, much of the research on ecological migration has been conducted in the Xilin Gol League because it is easy to cite references and draw comparisons in this area. Sonid Right Banner is part of the region known as the north side of the Yinshan Mountains, which is in the western part of the Xilin Gol League. It is situated more than 1000 m above sea level. To the west is the Ulate desert, and to the east are the Hunchindak sands.[2] The north side of the Yinshan Mountains lies to the south, and subsoil made of sand is to the north. With these surroundings, 36.0% of the total land area is semi-wasteland grassland, 60.0% is wasteland, and 4.0% is grassland. Sonid Right Banner's grassland area (including the semi-wasteland grassland and wasteland) covers 21,625 km^2 or 96.8% of its total land area of 22,340 km^2. Of this, 19,212 km^2 or 86.0% is usable grassland. The Hunchindak sands traverse the center of the banner, so the entire banner is situated in an arid wasteland and semi-wasteland area. Annual precipitation is 186 mm, evaporation is 2384 mm, and most of the rain falls during autumn. The average annual temperature is 3.4 °C, annual hours of sunshine are 3232 h, northwest winds move the sands at an average of 5.5 m per second almost daily, and the major weather events are drought, hail, cold wind currents, and sandstorms. As the vegetation primarily comprises dwarf gramineous grass and dwarf bushes (semidesert vegetation), the ecology is fragile to the point of being difficult to restore (Dalintai and Enhe 2006). Administratively, Sonid Right Banner is responsible for three sumu and three towns (57 villages), and it has a total population of 69,000 people.

In this natural environment, livestock farming mainly comprises cattle in the eastern sandy area and sheep and goats in the western semi-wasteland grasslands. At the end of 2005, Sonid Right Banner had 517,600 head of domesticated livestock, placing the area at the 52nd position among the 101 banner areas in Inner Mongolia. Among these, sheep and goats numbered 504,900 head, placing the area at the 41st position among 96 banner areas owning sheep and goats. In other words, the Sonid Right Banner is about average in Inner Mongolia in terms of the scale of its livestock raising. With the implementation of the ecological migration policy, the number of sheep and goats declined by 32.9% in 2005 compared with that in 2004. During the same time period, the per capita annual net income of farmers and livestock herders was 1864 yuan, the lowest in Inner Mongolia. Primary industries, which employed

[2]Sand area is a region covered by sand dunes or a hard or semihard surface. They are not as arid as a desert, and they have more water and vegetation than a desert.

approximately half of the working population, constituted a mere 13.2% of the total production, while secondary industries (principally mining) employed 17.4% of the working population and constituted 58.3% of the total production. The average wage of a nonagricultural worker was 16,662 yuan, placing the area at the 22nd position in Inner Mongolia (Inner Mongolia Autonomous Region Statistics Bureau 2007).[3] We can see that a serious income disparity exists among industries. According to Tian (2011), although the Xilin Gol League is classified as an arid region, it has swamps and waterways and had them stretching back several millennia into the past. As industrial development rapidly progressed from 2000, coal mining increased, and dams and the huge Uragai industrial area were built. The industrial area contains a large ammonia plant, urea plant, and methanol plant. A canal that is 4 m wide and 4 m deep has been constructed between the park and the dam.

Our survey area, Village B in Urigentala Town, is located in the northeastern area of the Sonid Right Banner (Fig. 13.1) and has an area of 35,510 ha. It is 75 km from Saihantala Town, where the banner's administrative offices are located. Since there are no paved roads, it takes approximately 3 h to drive one way by car from the town to the nearest farm house. Village B is located in the same league as the Uragai industrial area, so it is impacted by industrial production. The village's population comprises 93 households with 297 people, of which 136 are male and 161 are female. All these households were engaged in livestock farming before the ecological migration program was implemented. The major occupation was livestock farming, with only a few working outside the village. Per capita net income in 2006 was 1331 yuan, which is below the per capita net income of 1864 yuan for farmers and herders in the Sonid Right Banner in 2005. If income and expenditures decline after the ecological migration, the living standards of the ecological migrants will be even lower than Inner Mongolia's lowest-income farmers and herders. As this paper's survey area is the poorest livestock-raising area in Inner Mongolia, we believed that the ecological migration program would help improve herders' household finances vis-a-vis other regions and that the local community would be more inclined to support the ecological migration program.

The ecological migration program was launched in Sonid Right Banner in 2002. In 2006, Village B was designated as a no-grazing test area, and the ecological migration program was started there at the same time as grazing prohibition. The village's entire land area of 35,510 ha was supposed to be barricaded off from the outside, and grazing was prohibited; however, actually, grassland area owned by 77 of the village's 93 households (or 235 people) was made off-limits to grazing. The remaining 16 households (62 people) were not relocated, so livestock farming continues on at least 6265 ha (17.6%) of the grassland area.[4] Furthermore, 13 of

[3]The information on nonagricultural incomes published in the annual statistics is for workers with formal contracts with companies and does not reflect the incomes of ecological migrants who primarily work in informal sectors.

[4]This figure was derived by dividing the land owned by households that continued to engage in livestock raising by the total land area. The area of grassland that is not off-limits to grazing may be higher if we include land that is jointly held.

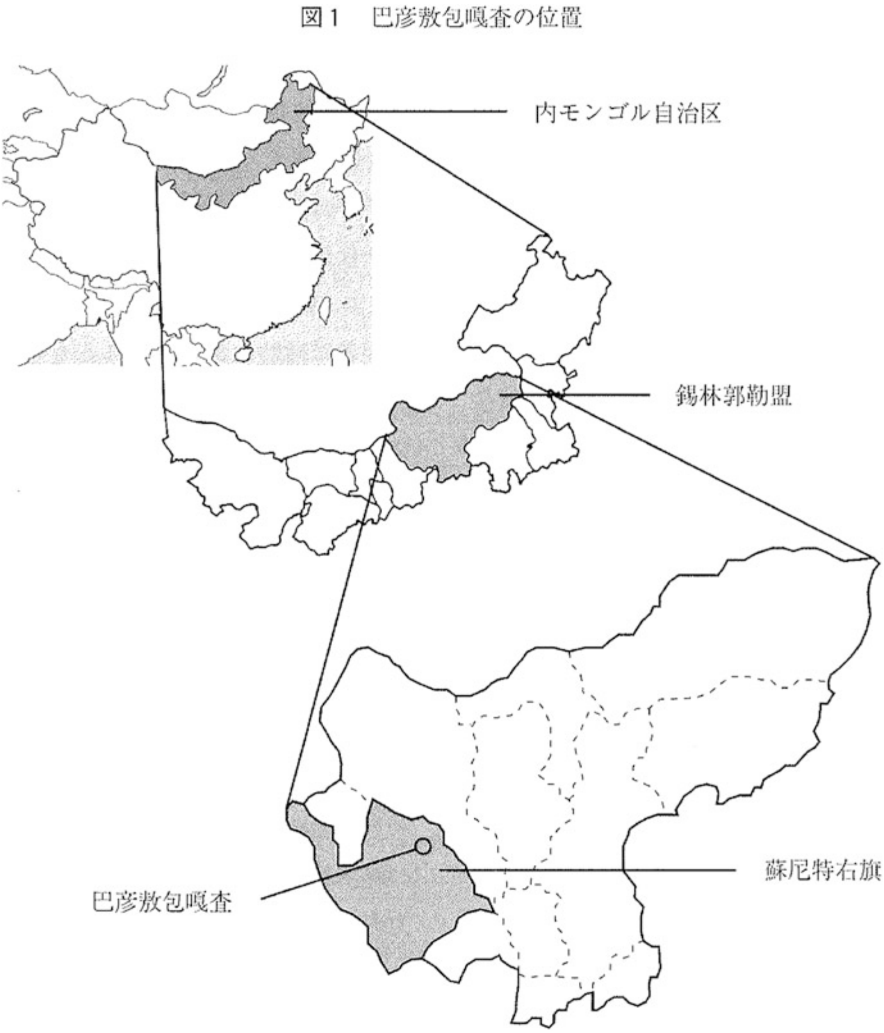

Fig. 13.1 Location of survey area

the 77 households that became ecological migrants moved to other regions, and the village council has information on where they moved. In addition, 27 households of ecological migrants who moved to Saihantala Town were unable to maintain their livelihoods, so they moved again to another area. The village council therefore does not have any information on where they moved or their living conditions. To get an overview of Village B, we conducted interviews with all the 37 households living in Saihantala Town (this paper uses data from a survey conducted in August 2008).

13.4 Description and Implementation Status of the Ecological Migration Program[5]

Village B's no-grazing test period ran for 5 years, from 2006 to 2011. During this period, three major laws and ordinances were adopted to safeguard the lives and maintain the livelihoods of herders. A preferential policy for no-grazing test areas, hereinafter called the preferential policy, was enacted for Village B. It primarily dealt with maintaining livelihoods, providing housing, providing subsidies, and ensuring grassland contract rights. An ordinance concerning pensions for aging herders relocated to urban areas, hereinafter called the pension system, is a pension plan for all ecological migrants in Sonid Right Banner. The system to guarantee a minimum livelihood for farm villages (a system to protect the lives of the low-income residents of farming communities, hereinafter called the minimum guarantee system) is a national program that pays subsidies to poor people.[6] Although these programs are not aimed at ecological migrants, as stated later, the preferential policy uses the minimum guarantee system as one of its financial resources, thereby giving subsidies to ecological migrants. Table 13.1 presents the specific content of the nine articles of the preferential policy and pension system and compares them in terms of their state of implementation.

The system for maintaining the livelihoods and protecting the lives of ecological migrants, on which the nine articles of the preferential policy focus, is set up in accordance with the economic circumstances of the recipients. In general, those who are well-off receive preferential treatment.

First, according to Article 1 of the preferential policy, a person who wants to start a business in Saihantala Town is given a store worth 110,000 yuan (a floor area of 100–120 m^2). Of this amount, the person must contribute 60,000 yuan of their own money, while the government provides 50,000 yuan (this subsidy and the subsidy discussed later are a grant that do not have to be repaid). Of the 37 ecological migrant households that we surveyed, 12 households had started businesses (others who wanted to do so had difficulty raising the funds, so they did not start any businesses), but only 1 household had availed itself of the subsidy system. The subsidy system was not being used because the subsidy is paid only after the business has been started. In other words, the people starting the business are not paid when they need the funds to start it. They are paid after the company or store is set up and in operation. Consequently, preference is given to those who are well-off economically, while those who want to start a business but do not have the financial means face difficulties in taking advantage of the subsidy system.

[5]Data and analysis are based on Jin (2010a).

[6]The minimum guarantee system was originally meant to provide a safety net by giving money to poor people, but ecological migrants are also eligible even if they do not meet some of the conditions. Moreover, the state of implementation and amounts paid vary from province to province. In Sonid Right Banner, there are three standard payment amounts—924 yuan, 600 yuan, and 438 yuan—depending on the eligible person's income.

Table 13.1 "Grazing for Grass" programs for maintenance and protection of livelihoods and their status of implementation

Program	Target	Description[a]	Livestock farmers' opinions[b]
Preferential policies	Persons who want to start a business	Saihantalazhen town provides a store of 100–120 m^2 for a price (60,000 yuan of own funds +50,000 yuan of subsidy money, article 1)	Difficult to utilize
	Families of married couples aged 40 years and under, with at least two people in the workforce	Saihantalazhen town provides a 65 m^2 apartment for a price (5000 yuan of own funds +45,000 yuan of subsidy money, article 2)	The houses are defective Uneasiness about the property deed No employment subsidies
	Married couples aged 40–50 years and basically able to work	Subsidy of 5000 yuan for persons buying a house (article 3)	No employment subsidies
	Married couples aged 50 years or over Persons who are basically unable to work	Eligible for the village's minimum guarantee system Subsidy of 5000 yuan for persons buying a house (article 4)	No complaints
	Poor people who are able to work	Zhurihezhen town provides a free apartment Guarantees employment for at least one person per household (article 5)	Not functioning Poor work conditions
	Persons who have graduated from a vocational or higher-level school or have completed military service Persons who want to start a business in the tertiary sector	Employment subsidies, subsidies for starting a business Loans of up to 20,000 yuan (term of 1 year, article 6)	Employment subsidies not functioning Difficult to get subsidies for starting a business
	Unemployed high school graduates	City unemployment registry, with preference given to those who are working or in the military (article 7)	Poor work conditions
	All households	For ecological migrants Pays a subsidy of 1.24 yuan per mu of grassland For persons still engaged in livestock farming Pays a subsidy of 0.82 yuan per mu of grassland Guarantees grassland usage rights (articles 8 and 9)	Delays and nonfulfillment Amounts are low Actually getting 0.6 yuan Insufficient explanation/insecurity

(continued)

Table 13.1 (continued)

Program	Target	Description[a]	Livestock farmers' opinions[b]
	Persons attending school at the compulsory education level	Exemption from school and textbook fees Pays subsidies for living expenses to students attending boarding schools (article 9)	No complaints
Pension program	Seniors	Eligible to receive a pension at age 61 Amount is the sum of mean income for 2007 plus 1/120 of cumulative premium payments made (including interest) Premium payments made until the age of 55 years Lump sum of 15,000 yuan Premium payments made from the age of 55 years Goes down by 500 yuan each year Persons aged 60 years or over who are unable to pay Pay half of the premiums in a lump sum, with the remainder withheld from the pension Persons in arrears are assessed a late fee of 0.2% per day	Actual eligibility starts at the age of 80 years System's existence not commonly known Almost totally unfulfilled

Source: Compiled by the author

[a]The program descriptions were compiled from the Sonid Right Banner Urigentala Town Village B preferential policy for no-grazing test areas and the Sonid Right Banner ordinance concerning pensions for aging herders relocated to urban areas

[b]Livestock farmers' opinions are the opinions of livestock farmers regarding the status of implementation of the various programs, as compiled from our survey interviews

Article 6 of the preferential policy provides for a system that lends up to 20,000 yuan to those who want to start a business in a tertiary industry but do not have sufficient funds of their own (such loans are for 1 year and must be repaid), so many households have received such loans. A condition for granting such loans is the acquisition of a business permit from the bureau for industry and commerce; however, obtaining a business permit requires a review of the company's name and business content as well as a review of its reserve funds. As in Article 1 of the preferential policy, which was discussed above, these loans are not disbursed until after the company or store is set up and in operation. Therefore, almost all households try to borrow money from their relatives to obtain a business permit, and households that cannot do so have to give up on starting a business.

Article 5 of the preferential policy provides for a system that provides free housing to poor households capable of working and guarantees employment to at least one person per household. Article 7 gives an urban family register to unemployed ecological migrants who have graduated from high school and gives preferential assistance to them in jobs or in military service (in most of China's rural areas, military service is regarded as a type of job). However, most migrants do not really get any job leads; even if they are given jobs, it is usually after a long wait, the pay is lower than what they earned through raising livestock, and the jobs usually have poor working conditions, so life remains hard for these households in cities where prices are high. Poor people in the younger age brackets are especially disgruntled. Furthermore, the program to provide free housing is not being implemented.

Livelihood protection differs depending on the subject. First, two programs are offered to older people who are economically disadvantaged. The first program is a minimum guarantee system for married couples aged 50 years and over who are basically unable to work (Article 4 of the preferential policy). The vague definition of "a person who is basically unable to work" seems to have made those aged 50 years and over who are not working eligible for the minimum guarantee of 438 yuan per year at level 3. The second program is the pension plan. Among these programs, the pension plan is poorly implemented. Although the age for receiving a pension starts at 61 years under these regulations, pension payments only actually start at the age of 80 years and over in Village B. Furthermore, many eligible people aged 80 years and over and their families do not know that this plan exists. In other words, the pension plan is hardly being executed.

No special guarantee program exists for disabled people, who are also economically disadvantaged; thus, households that have disabled members face increasing costs when they relocate to high-cost urban areas. Since production activities and living activities are executed in the same environment in grassland areas, one can engage in production activities while taking care of or nursing a sick person. If one migrates to a city, however, it is impossible to work while taking care of or nursing a sick family member. Therefore, households with sick or disabled family members see their breadwinners' earnings decline when they move to the city.

The content of programs for ecological migrants also differs by the age of those who are eligible, in addition to their economic situation. According to Article 2 of the preferential policies, in Saihantala Town, households in which the husband and wife are aged 40 years or below and that have two or more people capable of working can have their livelihood supported by receiving an apartment of 65 m^2 worth an equivalent of 50,000 yuan. Of this amount, they pay 5000 yuan of their own funds, and the remaining 45,000 yuan is paid through a subsidy. According to Articles 3 and 4 of the preferential policies, households in which the husband and wife are aged 40–50 years and are capable of working and households in which the husband and wife are aged 50 years or over can receive a subsidy of 5000 yuan when they buy a house; however, this subsidy is paid only after their property deed is inspected, in other words, after they have bought the house. Although livestock farmers are supposed to be able to choose whether they will remain in the city or return to the grassland after the no-grazing period is over, these differences in treatment by age bracket suggest that the policy's intent is to "proactively and smoothly relocate young workers to speed up the transition of the industrial structure."

The most popular program and the one for which all ecological migrants are eligible is the one involving grassland contract rights and subsidies. According to Article 8 of the preferential policies, ecological migrants are paid 1.24 yuan for each mu (approx. 666 m^2) of grassland, while those who continue to engage in livestock farming receive a subsidy of 0.82 yuan per mu during the grazing holiday period between April 1 and May 15. The subsidy amounts differ by banner. Village B's 1.24 yuan is on the low side. In addition, the lack of confidence in the implementation of this program is high: the 0.62 yuan being actually paid during grazing holidays to those who continue to engage in livestock raising differs from the promised amount; only approximately half of the promised subsidy is being paid to ecological migrants, and the delayed amounts had not been disbursed as of the time of our survey in August 2008. Furthermore, the subsidy is for the grassland and does not cover losses on prior investments in livestock farming facilities and equipment. Livestock farmers spend a total of 50,000–90,000 yuan to provide the necessary housing (approximately 20,000 yuan), barns (approximately 15,000–50,000 yuan), hay storage structures (approximately 3500 yuan each), tractors (approximately 8800 yuan each), and wind turbines (approximately 4000 yuan each). However, there are no subsidies for the degradation or loss of these facilities. The losses are even higher for households with water storage wells or drinking water tanks.

13.5 How the Ecological Migration Policy Impoverishes Workers

The ecological migration policy implemented as in Table 13.1 impacted the household finances of livestock farmers in various ways. However, not all were poor. Some households actually became more affluent after relocating than they were in their previous lives. Here, we will divide people into those who received preferences and those who were treated unfavorably by the policy and examine the impact of the ecological migration policy on the lives of livestock farmers. Figure 13.2 illustrates how the ecological migration policy works for each group.

First, nonworkers in young age groups, mainly children and pupils in primary and middle school (students), are eligible for subsidies and remain exempt from school and textbook charges. If we consider the subsidies for educational expenses that are not received by other urban dwellers as a form of income, the higher an ecological migrant student's income, the more this becomes a preference. Furthermore, nonworking people in the older age groups did not have any income before they relocated, but they became eligible for the minimum guarantee system and the pension system after relocation. Persons who "have in principle lost their ability to work because they are aged 50 years or over" were able to get an income by relocating; thus, relocation improved the lives of nonworking older people in the

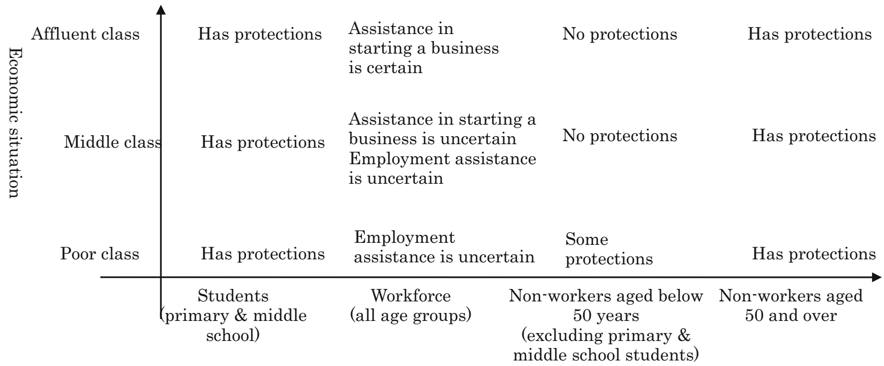

Fig. 13.2 Functions of the ecological migration policy by Target Group. (Source: Compiled by the author based on field surveys)

middle and poor classes in particular to some extent. This is reflected in the opinion, “only old people and children have profited from relocating,” that we heard in our field survey.

Differences exist between those who get job assistance among the students and old people who are being protected. The few who are affluent can readily get assistance in starting a business, but there are vast differences in the type of assistance available for others who want to start a business. These differences are in the amount of assistance given to those taking out loans to start a business in consideration of their repayment ability. Assistance to ecological migrants starting businesses is preferentially given based on considerations of whether it will protect the profits or avoid losses for the public institutions. Furthermore, when livestock farmers who have little education and have not received any job training lose their means of production and migrate to urban areas as unskilled laborers, they have very few job choices, so it is uncertain whether they will receive any employment assistance. Consequently, livestock farmers who have never witnessed unemployment become ecological migrants with high rates of unemployment, so they face both economic and psychological instability. Thus, a huge decline in workers’ incomes, which support their household finances, has impoverished many in the middle class and among the poor people. Except for the destitute poor, who are eligible for the guaranteed minimum, nonworking people in the middle-aged groups, most of whom are disabled, quickly become impoverished by the higher cost of living, and their lives are not protected after they relocate. Overall, the ecological migration policy has created poverty, mainly among those in their 20s through early 50s.

13.6 Direct Impact of Ecological Migration on Household Finances[7]

In 2005, Sonid Right Banner's revenues per capita were 1388 yuan, and expenses per capita were 3553 yuan. Given this financial situation, promoting the ecological migration policy and creating new subsidy policies would pressurize local government finances. Furthermore, according to a survey by the Sonid Right Banner Farming Area Migration Service Center, 2343 livestock farmers in Sonid Right Banner had become ecological migrants by April 2006, of which 1535 were in the workforce. During this same period, while the number of people working in secondary and tertiary industries in the towns (urban areas) was 2539, the number of unemployed was higher at 2679. This number indicates that the implementation of the ecological migration policy caused the unemployment rate in urban areas to skyrocket and that it was extremely difficult for these areas to absorb all the ecological migrants who were capable of working. Let us now look at the direct impact of this on livestock farmers' household finances.

13.6.1 State of Ecological Migrants' Household Finances

Table 13.2 indicates the state of ecological migrants' household finances.

Ecological migrants' incomes can be segregated into three broad categories. The first category is subsidies that comprise no-grazing subsidies and minimum guarantees. This type of income constitutes at least approximately 12% and at most 100% of the total household income, with a mean of approximately 34%.

The second type is income from one's own business or from an employer. Livestock farmers for whom raising livestock is a family business want to start up their own businesses rather than work at a company. Although there are multiple subsidy programs for supporting ecological migrants in starting businesses, they contain restrictions on usage in the form of strict reviews of the applicant's own funds and the like; thus, only 12 households were actually able to start businesses, while the others gave up on trying. Rather than the fact that one-third of the survey participants started businesses, we want to focus on the fact that most households, including those who started businesses, are unable to take advantage of the subsidy system. Because the people starting the business are not given the subsidy until after the business is set up and in operation, they cannot get any funds when they need them the most, which is at the time the business is set up. The subsidy is paid only after the company or store is operating normally. Consequently, this amounts to a preferential policy for the affluent class, while people with tight finances who want to start a business have trouble availing themselves of this

[7] Data and analysis are based on Jin (2010b).

Table 13.2 State of ecological migrants' household finances

No.	No. of household members (persons)	Grassland area (in mu)	Income (in yuan)											% reliance on subsidies
			No-grazing subsidies	No-grazing subsidies per person	Minimum guarantee	Pension	Employment income	Management income	Agricultural income	Livestock farming income	Other income	Total income	Income per capita	
1	3	5836	7237	2412			10,000					17,237	5746	0.42
2	4	6000	7440	1860	2400			7000				16,840	4210	0.58
3	4	3000	3720	930			4000					7720	1930	0.48
4	7	9100	11,284	1612	2400	3600	15,600	18,000	10,000	5600		66,484	9498	0.21
5	3	3000	3720	1240				25,000				28,720	9573	0.13
6	4	3600	4464	1116			10,000			3500		17,964	4491	0.25
7	5	7598	9422	1884	1200		6000	15,000				31,622	6324	0.34
8	2	5000	6200	3100	600						200	7000	3500	0.97
9	4	5057	6271	1568	2400		5000					13,671	3418	0.63
10	4	10,129	12,560	3140	600		8000			4400		25,560	6390	0.51
11	3	3800	4712	1571			29,000	6000				39,712	13,237	0.12
12	5	5710	7080	1416			14,400					21,480	4296	0.33
13	3	2414	2993	998	1200		10,000					14,193	4731	0.30
14	5	7631	9462	1892				15,000		3500		27,962	5592	0.34
15	3	1500	1860	620				30,000				31,860	10,620	0.06
16	4	3298	4090	1022	870		7000					11,960	2990	0.41
17	4	5057	6271	1568			18,000	10,000				34,271	8568	0.18
18	3	5859	7265	2422			18,000			2400		27,665	9222	0.26
19	4	5057	6271	1568	2400		14,000			2000		24,671	6168	0.35
20	4	3280	4067	1017	440		7000	3000				14,507	3627	0.31
21	5	5657	7015	1403			20,400			2400		29,815	5963	0.24
22	4	5149	6385	1596			14,400					20,785	5196	0.31

(continued)

Table 13.2 (continued)

No.	No. of household members (persons)	Grassland area (in mu)	Income (in yuan)											% reliance on subsidies
			No-grazing subsidies	No-grazing subsidies per person	Minimum guarantee	Pension	Employment income	Management income	Agricultural income	Livestock farming income	Other income	Total income	Income per capita	
23	4	7473	9267	2317			10,000			1800		21,067	5267	0.44
24	5	6683	8287	1657	880			15,000				24,167	4833	0.38
25	4	1400	1736	434			16,800			3000		21,536	5384	0.08
26	3	6420	7961	2654	1200		5000					14,161	4720	0.65
27	3	2533	3141	1047			10,000			2400	2000	17,541	5847	0.18
28	3	1460	1810	603				25,000				26,810	8937	0.07
29	4	6683	8287	2072			13,000		2000	3000		26,287	6572	0.32
30	4	5252	6512	1628	1760		10,000			2500		20,772	5193	0.40
31	2	1762	2185	1092	1200		10,800					14,185	7092	0.24
32	2	8766	10,870	5435	600							11,470	5735	1.00
33	4	4279	5306	1326			39,000			1000		45,306	11,326	0.12
34	3	2500	3100	1033			4500	3000		1000		11,600	3867	0.27
35	5	4176	5178	1036			8200			2100		15,478	3096	0.33
36	3	2363	2930	977			12,000					14,930	4977	0.20
37	3	4720	5853	1951	1200		25,200			400		32,653	10,884	0.22

Consumption expenditures (in yuan)										Surplus (in yuan)	
Food (including meals out)	Heating & light	Healthcare	Transportation & communication	Leisure	Clothing	Education	Other	Total expenditures	Expenditures per capita	Total surplus	Surplus per capita
8000	1000	500	900	2000	1000		1000	14,400	4800	2837	946
10,000	1000	3000						14,000	3500	2840	710
3000	1080	600	1800				1200	7680	1920	40	10
24,000	6000	3000	3600				200	36,800	5257	29,684	4241
7000	6980	500	1000	3000	1200	600	6400	26,680	8893	2040	680
3500	1200	7200	2440				960	15,300	3825	2664	666
12,000	2895	7000	1800	300			300	24,295	4859	7327	1465
3000	1500	2000	500					7000	3500	0	0
3000	1000	7200	500		2000	3000		16,700	4175	−3029	−757
5000	2400	800	800	1000	1600		1000	12,600	3150	12,960	3240
8000	2480	300	800		2000	1000	8700	23,280	7760	16,432	5477
14,400	600		5760					20,760	4152	720	144
2000	3480	2000	800		200		1000	9480	3160	4713	1571
9000	5500	10,000	1200		2000	2000	4900	34,600	6920	−6638	−1328
2400	1800		3600				12,400	20,200	6733	11,660	3887
4000	2440		2400				720	9560	2390	2400	600
4000	2680	6000	2400					15,080	3770	19,191	4798
10,800	600	600	2400					14,400	4800	13,265	4422
4000	1320	6000	2400				10,000	23,720	5930	951	238
4000	2280	600	1200				1200	9280	2320	5227	1307
5000	1320	3600	2400				1200	13,520	2704	16,295	3259
4000	1200	700	2400				1440	9740	2435	11,045	2761
4500	2680	1000	600	2000	1500		2000	14,280	3570	6787	1697
8000	3480	1500	1500	2000	1200		4300	21,980	4396	2187	437

(continued)

Table 13.2 (continued)

Consumption expenditures (in yuan)										Surplus (in yuan)	
Food (including meals out)	Heating & light	Healthcare	Transportation & communication	Leisure	Clothing	Education	Other	Total expenditures	Expenditures per capita	Total surplus	Surplus per capita
4000	1200	600	2400				2400	10,600	2650	10,936	2734
5000	2480	500	600		600		1000	10,180	3393	3981	1327
4000	1500	6000	800		600		3000	15,900	5300	1641	547
3000	2400		3600				14,400	23,400	7800	3410	1137
12,000	1200	600	2400				6200	22,400	5600	3887	972
7000	900	6000	800	1000	1800	1000	3000	21,500	5375	−728	−182
3000	2280	3000					500	8780	4390	5405	2702
4000	1000	1000	300				1000	7300	3650	4170	2085
15,000	1200		3600				1200	21,000	5250	24,306	6076
3000	1800		2400				2400	9600	3200	2000	667
5000	1200	800	2400				1200	10,600	2120	4878	976
5000	2380	300	700	1000	2000	1000	1500	13,880	4627	1050	350
8400	1920		1200				1200	12,720	4240	19,933	6644

Source: Calculated by the author based on survey findings. See the text for details on how the calculations were performed
No-grazing subsidy = grassland area × 1.24 yuan
% reliance on subsidies = (no-grazing subsidy + minimum guarantee)/total income

system. Furthermore, starting a business is relatively risky. Businesses started by 6 of the 12 households are in financial difficulties. Although some may regard a 50% success rate as high, from the standpoint of maintaining overall living standards, risky economic activities lead to the impoverishment of ecological migrants or a widening of disparities in living standards, which are not desirable outcomes. The businesses that were successful were those requiring some judgment of technology and market needs, such as precious metal processing, motorcycle repair, and fish retailing, and those that target a general clientele. Meanwhile, the businesses that did not do well included eating and drinking establishments, pool halls, and traditional Mongolian clothing makers. Opening a restaurant or pool hall is relatively easy, so the competition is fierce. Most livestock farmers who became ecological migrants in 2006 were unable to set up stores in the bustling city center, so most of them located stores near their homes. Therefore, most of their customers were fellow ecological migrants from their former locations with little purchasing power. These stores thus served as gathering places for ecological migrants, but this was also a reason that other customers did not come. In the case of the traditional Mongolian clothing maker, customers were mostly Mongolian, with almost no Chinese customers. Since Mongolian attire is not appropriate for work and there are no opportunities to wear it except for weddings and festivities, it seems that when the people became ecological migrants, their need for traditional Mongolian clothing declined. Furthermore, according to the store owners and livestock farmers, ecological migrants in unstable living situations no longer bought expensive Mongolian garb.

In terms of employment, the ecological migrants are poorly educated, and only few have received any job training; thus, only one person who had not been a senior member of the village council was able to get a job as a full-time employee or contract employee. No one else had a formal employment contract. In terms of job type, most of them were working at construction sites or car washes, were delivering beverages, or were working as security guards, sales assistants at independently owned stores, and at other day jobs or jobs with a limited time period. Most were receiving low wages on the order of 500–600 yuan per month and were caught up in labor-management problems. In comparison, although taxicab drivers have relatively stable incomes and a high wage base, ecological migrants have trouble getting this type of job because they have neither the time nor the money to get the necessary driver's license. Furthermore, the written exam for getting a driver's license is in standard Chinese, which most livestock farmers are unable to read or write, so it is nearly impossible for them to get a license.

The third category is income from agriculture and livestock farming. As indicated, 2 of the 37 ecological migrant households had become tenant farmers who earned income by growing potatoes and other vegetables. Furthermore, 16 households had entrusted some of their sheep to friends and relatives when they relocated to the city. In these cases, the method of allocating the earnings derived from the lamb and sheep wool was determined through discussions among the parties involved. In most cases, the ecological migrants were receiving as much as approximately 50% of the revenue, but one ecological migrant with the least income was receiving little of the wool revenue.

Although the livestock farmers had moved to urban areas, they could not be considered as having become acclimated to urban life and successful in changing the way they made a living. Looking at the correlations among the three metrics of no-grazing subsidies per capita, per capita income, and degree of reliance on subsidies, the correlation coefficient for per capita income and reliance on subsidies is −0.54, indicating that per capita income of households relying on subsidies is low. Furthermore, the correlation between no-grazing subsidies per capita and the degree of reliance on subsidies is 0.77, indicating a tendency for families receiving high no-grazing subsidies to be dependent on subsidies. In addition, we categorized these three metrics into three groups—the upper, middle, and lower third—and performed a cross-tabulation among the metrics (Tables 13.3, 13.4 and 13.5). We confirmed a positive correlation between no-grazing subsidies per capita and the degree of reliance on subsidies that was significant at the 10% level. We confirmed a strong negative statistical correlation between per capita income and degree of reliance on subsidies that was significant at the 1% level. In all cases, the analysis indicated no correlation between no-grazing subsidies per capita and per capita income (the correlation coefficient was −0.02). In addition, we got almost the same results when we used no-grazing subsidies per capita instead of per capita subsidies calculated as the sum of no-grazing subsidies plus minimum guarantees. From these findings, we can hypothesize the following (Fig. 13.3). Livestock farmers owning large tracts of grassland are in a favorable position, so they do not need to acquire other means of livelihood. Even after relocating, they receive generous subsidies based on the area of their grassland holdings, so they are able to maintain their livelihoods and thus rely more on subsidies compared with the other livestock farmers. Meanwhile, the livestock farmers who do not own much grassland area were not able to earn enough income from livestock farming alone, so they have

Table 13.3 Relation between no-grazing subsidy per capita and degree of eliance on subsidies

		Reliance on subsidies						Total	
		Top third		Middle third		Bottom third			
No-grazing subsidy per capita	Top third	**7**	58.3%	**4**	33.3%	**1**	8.3%	**12**	100.0%
		58.3%	18.9%	33.3%	10.8%	7.7%	2.7%		32.4%
	Middle third	**3**	25.0%	**3**	25.0%	**6**	50.0%	**12**	100.0%
		25.0%	8.1%	25.0%	8.1%	46.2%	16.2%		32.4%
	Bottom third	**2**	15.4%	**5**	38.5%	**6**	46.2%	**13**	100.0%
		16.7%	5.4%	41.7%	13.5%	46.2%	16.2%		35.1%
	Total	**12**		**12**		**13**		**37**	100.0%
		100.0%	32.4%	100.0%	32.4%	100.0%	35.1%	100.0%	100.0%

Note: χ^2 (Chi-Square) value 7.862, $p = 0.097$

Table 13.4 Relation between degree of reliance on subsidies and per capita income

		Per capita income						Total	
		Top third		Middle third		Bottom third			
Reliance on subsidies	Top third	**1**	8.3%	**4**	33.3%	**7**	58.3%	**12**	100.0%
		8.3%	2.7%	33.3%	10.8%	58.8%	18.9%		32.4%
	Middle third	**2**	16.7%	**4**	33.3%	**6**	50.0%	**12**	100.0%
		16.7%	5.4%	33.3%	10.8%	46.2%	16.2%		32.4%
	Bottom third	**9**	69.2%	**4**	30.8%	**0**	0.0%	**13**	100.0%
		75.0%	24.3%	33.3%	10.8%	0.0%	0.0%		35.1%
	Total	**12**		**12**		**13**		**37**	100.0%
		100.0%	32.4%	100.0%	32.4%	100.0%	35.1%	100.0%	100.0%

Note: χ^2 (Chi-Square) value 15.674, $p = 0.003$

Table 13.5 Relation between no-grazing subsidy per capita and per capita income

		Per capita income						Total	
		Top third		Middle third		Bottom third			
No-grazing subsidy per capita	Top third	**4**	33.3%	**5**	41.7%	**3**	25.0%	**12**	100.0%
		33.3%	10.8%	41.7%	13.5%	23.1%	8.1%		32.4%
	Middle third	**5**	41.7%	**4**	33.3%	**3**	25.0%	**12**	100.0%
		41.7%	13.5%	33.3%	10.8%	23.1%	8.1%		32.4%
	Bottom third	**3**	23.1%	**3**	23.1%	**7**	53.8%	**13**	100.0%
		25.0%	8.1%	25.0%	8.1%	53.8%	18.9%		35.1%
	Total	**12**		**12**		**13**		**37**	100.0%
		100.0%	32.4%	100.0%	32.4%	100.0%	35.1%	100.0%	100.0%

Note: χ^2 (Chi-Square) value 3.336, $p = 0.503$
Yates' continuity correction is usually applied when the expected value is either for a sample size of 40 or less or a 2 × 2 cross-tabulation table, but in this study, we used SPSS 14.0 to automatically make Yates' continuity correction on 2 × 2 cross-tabulation tables for samples of 20 or more. To improve the accuracy of our estimates, we used Fisher's exact test (direct proof) in addition to the χ^2 test and matched the significance levels of the findings with those of our research
Source: Calculated by the author based on the survey findings

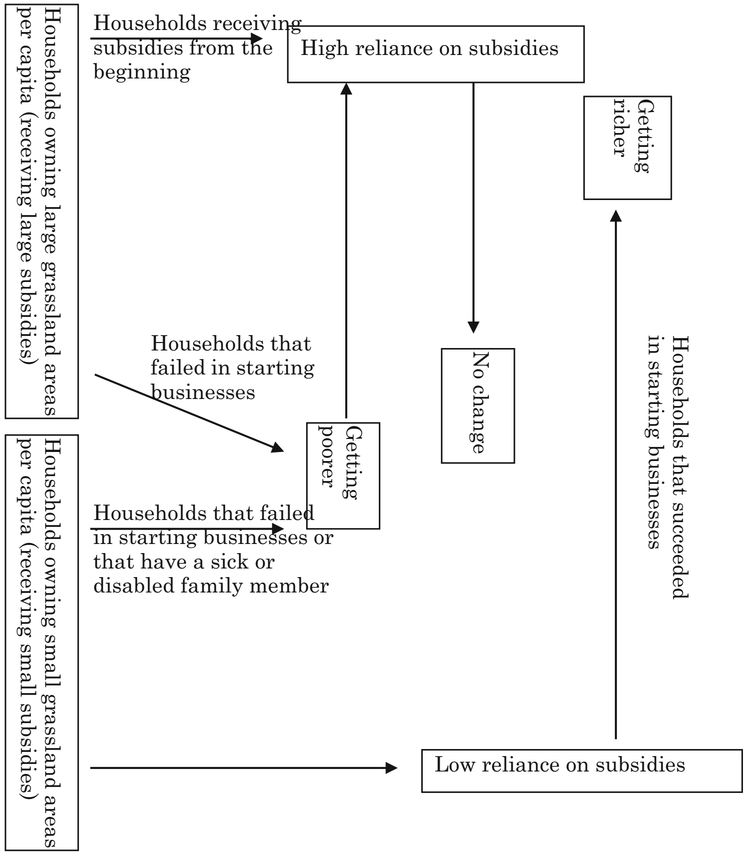

Fig. 13.3 Possible relations among subsidies, income, and degree of reliance on subsidies

prior experience of working in other industries. After migrating, they do not depend on subsidies but succeed in quickly earning an income through their own efforts. Thus, a correlation exists between no-grazing subsidies per capita and reliance on subsidies and between per capita income and reliance on subsidies. Furthermore, a strong tendency exists for households with sick or disabled family members or who fail at starting their own businesses to have dwindling incomes, and as a result, they seem to become dependent on subsidies. Therefore, from a different aspect, a correlation exists between per capita income and reliance on subsidies. Because it is possible for households with both high and low subsidies per capita to become richer or poorer, we did not observe any direct correlation between no-grazing subsidies per capita and per capita income.

With respect to consumption expenditures, we interviewed each household about how much they spent on food, heating and light, medical payments, transportation and communication, leisure activities, clothing, education, and other categories

(Table 13.2). First, we observed stark differences among households with regard to food expenditures. Households that spent a lot on food spent most of that money on eating out, while households with low food expenditures tended to be affected by the number of older people and children (we are using the WHO definition of "older people" as those 60 years of age or older while children are younger than 16 years old) in the family. Further, those who were running restaurants were allotting their family's food expenses to the restaurant, while those who had other people taking care of their sheep were adding those costs to their household food expenses. As for heat and lighting, although there was almost no variation among households in basic amounts used for daily life, major differences existed in winter heating costs, with the higher-income households spending more on heating. Regarding medical payments, these costs were higher for households that had sick, disabled, and older family members. Some correlation was observed in spending on leisure, clothing, and education. Spending on clothing by households that spent more on leisure activities and by households with students was higher than that for other households. As for other expenditures, those who had started businesses included taxes and some operating costs in this category; for those who had not started businesses, such expenses mainly comprised monetary gifts for friends' and relatives' weddings, childbirth, and other life events. Finally, looking at the surplus left over after deducting expenditures from income,[8] the value was negative for three households. This indicates that these households are dipping into their savings to live. Furthermore, several households had surpluses of 0 or close to 0, indicating that they would be unable to deal with unforeseen expenses.

13.6.2 Estimated Impact on Household Finances While Continuing to Engage in Livestock Farming

Considering the breakdown of the household finances of livestock farmers who continued to engage in livestock farming, we estimated what ecological migrants' household finances would look like if they were still engaged in raising livestock. The findings are given in Table 13.6.

Livestock farmers' incomes basically comprise the following three items. The first item is revenue earned from raising ewes and nanny goats for breeding purposes (called basic ewes) and selling the lambs born every year. The number of basic ewes is about the same as the number of head of sheep being raised (hereinafter called sheep). The sheep population turns over every 4–5 years. Livestock prices rose in 2008, so lambs were being sold at approximately 400–450 yuan per head, almost double the 2006 level (as of 2008, the price of a lamb was approximately 12.4 yuan per kg). The second item is revenue from selling sheep wool and cashmere. One kg

[8]Here, surplus means income less basic consumption expenditures. Although some amounts may be allocable to savings, it is not savings.

Table 13.6 Estimates of household finances in the case where livestock farming continues

No.	Sheep (head)	Income (in yuan)				Production costs (in yuan)				
		Subsidies	Wool, etc.	Lambs	Total income	Feed costs during fallow period	Veterinary costs	Hay production costs	Hay purchasing costs	Depreciation
1	61	3618	2097	26,140	31,856	3040	243	912	9119	3000
2	63	3720	2156	26,875	32,751	3125	250	938	9375	3000
3	31	1860	1078	13,438	16,376	1563	125	469	4688	2500
4	95	5642	3270	40,760	49,673	4740	379	1422	14,219	3000
5	31	1860	1078	13,438	16,376	1563	125	469	4688	2500
6	38	2232	1294	16,125	19,651	1875	150	563	5625	2500
7	79	4711	2731	34,033	41,474	3957	317	1187	11,872	3000
8	52	3100	1797	22,396	27,293	2604	208	781	7813	3000
9	53	3135	1817	22,651	27,604	2634	211	790	7902	3000
10	106	6280	3640	45,369	55,290	5276	422	1583	15,827	3000
11	40	2356	1366	17,021	20,742	1979	158	594	5938	2500
12	59	3540	2052	25,576	31,168	2974	238	892	8922	3000
13	25	1497	868	10,813	13,177	1257	101	377	3772	2500
14	79	4731	2742	34,181	41,654	3974	318	1192	11,923	3000
15	16	930	539	6719	8188	781	63	234	2344	2500
16	34	2045	1185	14,772	18,002	1718	137	515	5153	2500
17	53	3135	1817	22,651	27,604	2634	211	790	7902	3000
18	61	3633	2106	26,243	31,982	3052	244	915	9155	3000
19	53	3135	1817	22,651	27,604	2634	211	790	7902	3000
20	34	2034	1179	14,692	17,904	1708	137	513	5125	2500
21	59	3507	2033	25,339	30,879	2946	236	884	8839	3000
22	54	3192	1850	23,063	28,106	2682	215	805	8045	3000

23	78	4633	2686	33,473	40,792	3892	311	1168	11,677	3000
24	70	4143	2402	29,934	36,479	3481	278	1044	10,442	3000
25	15	868	503	6271	7642	729	58	219	2188	2500
26	67	3980	2307	28,756	35,044	3344	268	1003	10,031	3000
27	26	1570	910	11,346	13,826	1319	106	396	3958	2500
28	15	905	525	6540	7969	760	61	228	2281	2500
29	70	4143	2402	29,934	36,479	3481	278	1044	10,442	3000
30	55	3256	1887	23,525	28,668	2735	219	821	8206	3000
31	18	1092	633	7892	9618	918	73	275	2753	2500
32	91	5435	3150	39,264	47,850	4566	365	1370	13,697	3000
33	45	2653	1538	19,166	23,357	2229	178	669	6686	2500
34	26	1550	898	11,198	13,646	1302	104	391	3906	2500
35	44	2589	1501	18,705	22,795	2175	174	653	6525	2500
36	25	1465	849	10,584	12,899	1231	98	369	3692	2500
37	49	2926	1696	21,142	25,764	2458	197	738	7375	2500

(continued)

Table 13.6 (continued)

Net income (in yuan)		Net income per capita (in yuan)		Basic consumption expenditures (in yuan)	Education	Health care	Surplus (in yuan)		Surplus per capita (in yuan)	
If producing hay	If purchasing hay	If producing hay	If purchasing hay	If producing hay	If purchasing hay	If producing hay	If purchasing hay			
24,661	16,455	8220	5485	5100		500	19,061	10,855	6354	3618
25,439	17,001	6360	4250	4700		3000	17,739	9301	4435	2325
11,719	7501	2930	1875	5400		600	5719	1501	1430	375
40,132	27,335	5733	3905	10,500		3000	26,632	13,835	3805	1976
11,719	7501	3906	2500	3700	600	500	6919	2701	2306	900
14,563	9501	3641	2375	5400		7200	1963	−3099	491	−775
33,013	22,328	6603	4466	6400		7000	19,613	8928	3923	1786
20,699	13,668	10,349	6834	2000		2000	16,699	9668	8349	4834
20,969	13,858	5242	3464	4700	3000	7200	6069	−1042	1517	−261
45,009	30,765	11,252	7691	5400		800	38,809	24,565	9702	6141
15,511	10,167	5170	3389	4400	1000	300	9811	4467	3270	1489
24,064	16,035	4813	3207	7100			16,964	8935	3393	1787
8942	5547	2981	1849	3700		2000	3242	−153	1081	−51
33,169	22,438	6634	4488	5700	2000	10,000	15,469	4738	3094	948
4610	2500	1537	833	4400			210	−1900	70	−633
13,132	8494	3283	2124	5400			7732	3094	1933	774
20,969	13,858	5242	3464	6800		6000	8169	1058	2042	264
24,770	16,531	8257	5510	5100		600	19,070	10,831	6357	3610
20,969	13,858	5242	3464	6100		6000	8869	1758	2217	439
13,047	8434	3262	2109	5400		600	7047	2434	1762	609
23,813	15,858	4763	3172	6400		3600	13,813	5858	2763	1172
21,405	14,164	5351	3541	5400		700	15,305	8064	3826	2016
32,420	21,912	8105	5478	5400		1000	26,020	15,512	6505	3878

28,676	19,278	5735	3856	5700		1500	21,476	12,078	4295	2416
4136	2167	1034	542	4700		600	−1164	−3133	−291	−783
27,429	18,401	9143	6134	3700		500	23,229	14,201	7743	4734
9506	5944	3169	1981	4400		6000	−894	−4456	−298	−1485
4420	2367	1473	789	4400			20	−2033	7	−678
28,676	19,278	7169	4820	4700		600	23,376	13,978	5844	3495
21,893	14,508	5473	3627	5400	1000	6000	9493	2108	2373	527
5852	3374	2926	1687	3400		3000	−548	−3026	-274	−1513
38,549	26,222	19,275	13,111	2700		1000	34,849	22,522	17,425	11,261
17,782	11,764	4445	2941	6800			10,982	4964	2745	1241
9349	5834	3116	1945	4400			4949	1434	1650	478
17,293	11,421	3459	2284	7100		800	9393	3521	1879	704
8700	5377	2900	1792	3,700	1000	300	3700	377	1233	126
19,872	13,234	6624	4411	4400			15,472	8834	5157	2945

Source: Calculated by the author based on the survey findings. See the text for details on how the calculations were made

Notes:

No. of sheep = Grassland area/96

Amount of subsidy = Grassland area × 0.62 yuan

Wool, etc. = Number of sheep head × 35 yuan (in the simulation, the ratio of sheep and goats was set at 50:50)

Lamb = Number of sheep head × 430 yuan

Feed costs during fallow period = Sheep head x 50 yuan

Grazing holiday feed costs = number of head × 50 yuan

Veterinary costs = Number of sheep head × 4 yuan

Hay production costs = number of sheep head × 15 yuan

Hay purchasing costs = Number of sheep head × 150 yuan of wool can be sheared from each sheep, and the market price per kg is 4–6 yuan. Furthermore, 0.3 kg of cashmere can be sheared from each goat, with a market price of 210 yuan per kg. The third item is subsidies of 0.62 yuan per mu of grassland paid during the grazing holiday period from April 1 to May 15. Therefore, if we just divide the area of the pastures owned by a livestock farmer by the area needed per head being raised, we can roughly estimate the farmer's overall income.

There are two major types of production expenses. One comprises expenses for feed and veterinary care for the sheep, and the other is expenses for barns, hay storage facilities, machinery, and other fixed assets.

Sheep are given feed during the 45-day fallow period and winter. The fallow period overlaps with the sheep breeding period, so the sheep are often fed corn and processed feed, in addition to hay. The cost of feeding one sheep during the fallow period is 45–55 yuan, which is about the same as the subsidy for the fallow period. During winter, each sheep consumes approximately 140 kg of hay, which the farmers procure in various ways.[9] If all of it is purchased, the hay costs 0.8–1.0 yuan per kg, including shipping costs, so the cost of feeding each sheep is less than 150 yuan. If the hay is produced on the farm itself, the cost includes the price of seeds (20–25 yuan per mu), electricity for watering equipment and the like (0.78 yuan per kWh), the price of fertilizer (110–270 yuan per bag of nitrogenous fertilizer), and light diesel fuel costs for farm equipment (1300 per barrel or 9.6 yuan per kg). Adding these up, the cost of producing 1 kg of hay comes to 0.08–0.10 yuan or 11.0–15.0 yuan to feed each sheep. Besides feed costs, there are also annual veterinary charges of 3–4 yuan per sheep for vaccinations and the like.

Our calculations with respect to fixed assets are as follows. First, although barns come in many sizes, they cost 15,000–50,000 each. Wooden barns are the cheapest, costing 3.5–4.0 yuan per pole, and are said to have a useful life of 10 years, including repairs (if there are no major disasters). A concrete barn costs 17–18 yuan per pole, more than four times that of a wooden barn, but it has a life span more than four times as long. Thus, there is little difference when depreciating the structure over its life. Besides barns, farmers also need to make basic investments totaling 16,000–20,000 yuan for hay silos (approximately 3500 yuan each), tractors (approximately 8800 yuan each), wind turbines (approximately 4000 yuan each), and other equipment. The useful lives vary depending on the size of the barn and how often the equipment is used. Based on our survey findings, we set depreciation at 2500 yuan per year for households with less than 50 head of sheep and 3000 yuan per year for households with 50 or more head of sheep. Although the actual numbers vary by household and this is not necessarily accurate, we use general

[9]For this paper, we ran simulations for both cases of producing all hay on the farm, which costs the least, and of purchasing all hay, which costs the most. In actuality, however, farmers will produce some hay on their own and buy the rest, depending on the size of their grassland area, how many people are working there, and the growing conditions for the grass. Furthermore, a few of the farmers employ temporary live-in workers at 50 yuan per day. In other words, the means of acquiring hay vary from household to household and from year to year, so we are unable to use a uniform method.

levels based on the average derived from our survey of livestock farmers (including the recollections of those who relocated).

Furthermore, there are 5 households of 93 households in Village B who own wells. The installation price is 48,000–100,000 yuan with a pump. Some of these installation costs are covered by subsidies. There are those who made water storage wells for 5000 yuan each, but this is rare. Because the two types of wells are not regarded as necessities but as luxuries for mere convenience, we omitted investment in wells from the following simulation of household finances.

The output of the simulation was per capita net income of 1034–19,275 yuan with a mean of 5452 yuan for farms producing their own hay and per capita net income of 542–13,111 yuan with a mean of 3612 yuan for farms that buy hay. Among consumption expenditures, electricity is generated in-house, fuel is dried livestock manure, and water from the well is free. Items that need to be purchased include rice, noodles, tea, seasonings, alcoholic beverages, and clothing. Furthermore, there are additional expenses for motorcycles, which are the mode of transportation for workers, and mobile phones, which are the means of communication. Consumption expenses do not include any money used for leisure activities or to improve convenience.

13.6.3 Comparison Between the Simulation and Actual Circumstances

Table 13.7 compares post-relocation per capita income and per capita surplus with the results of our simulation. First, in the estimates for the hay producers, who had low production costs and high net incomes, after they relocated, the per capita income of 7 households (18.9% of the total) more than doubled while that of 12 households (32.4% of the total) was less than twice as high as before. In other words, income rose for 51.4% of the households as a result of relocating. After relocation, 2 households (5.4%) saw their per capita incomes decrease by more than half, while 16 households (43.2%) saw their per capita incomes decrease by less than half. Therefore, income declined for 48.6% of the households as a result of relocation. However, per capita surplus more than doubled for 7 households (18.9%) and less than doubled for 6 households (16.2%), so surplus rose for 35.1% of households as a result of relocation. Surplus was reduced to less than half for 20 households (54.1%) and declined by less than half for 4 households (10.8%), so per capita surplus declined for 64.9% of households as a result of relocation.

For the hay-purchasing scenario, which has high production costs and low net incomes, the per capita income of 13 households (35.1%) more than doubled after relocation, while it less than doubled for 17 households (46.0%), so 81.1% of households got higher incomes by relocating. At the same time, per capita income declined by more than half for 1 household (2.7%) and declined by less than half for 6 households (16.2%), so 18.9% of households saw their incomes decline as

Table 13.7 Comparison of post-ecological migration incomes/surpluses and estimates of what they would have been if the farmers had not relocated

No.	Per capita income		Per capita surplus	
	Comparison with when hay is produced	Comparison with when hay is purchased	Comparison with when hay is produced	Comparison with when hay is purchased
1	−	+	−	−
2	−	−	−	−
3	−	+	−	−
4	+	++	+	++
5	++	++	−	−
6	+	+	+	++
7	−	+	−	−
8	−	−	−	−
9	−	−	−	−
10	−	−	−	−
11	++	++	+	++
12	−	+	−	−
13	+	++	+	++
14	−	+	−	−
15	++	++	++	++
16	−	+	−	−
17	+	++	++	++
18	+	+	−	+
19	+	+	−	−
20	+	+	−	++
21	+	+	+	++
22	−	+	−	+
23	−	−	−	−
24	−	+	−	−
25	++	++	++	++
26	−	−	−	−
27	+	++	++	++
28	++	++	++	++
29	−	+	−	−
30	−	+	−	−
31	++	++	++	++
32	−	−	−	−
33	++	++	++	++

(continued)

Table 13.7 (continued)

No.	Per capita income		Per capita surplus	
	Comparison with when hay is produced	Comparison with when hay is purchased	Comparison with when hay is produced	Comparison with when hay is purchased
34	+	+	−	+
35	−	+	−	+
36	+	++	−	++
37	+	++	+	++

Source: Calculated by the author based on the findings of Tables 13.1 and 13.2
Notes:
"− −" means that actual income and surplus declined at least twice as much as the estimated amounts
"−" means that actual income and surplus declined up to twice as much as the estimated amounts
"+" means that actual income and surplus increased less than twice as much as the estimated amounts
"++" means that actual income and surplus increased more than twice as much as the estimated amounts

a result of relocation. Furthermore, the per capita surplus more than doubled for 15 households (40.5%) and less than doubled for 4 households (10.8%), so 51.3% of households had higher surpluses if they relocated. Per capita surplus declined by more than half for 13 households (35.2%) and declined by less than half for 5 households (13.5%), so 48.7% of households had a lower surplus by relocating.

These estimates show that relocation led to more than half of households receiving higher per capita incomes. This is not only because income levels are higher in urban areas than in rural areas but also because cash revenues are higher in urban areas because their monetary economies are well developed. However, because prices in urban areas are high, higher incomes do not necessarily translate into higher living standards. Our estimates show that surpluses would decline for 64.9% and 48.7% of households and that 54.1% and 35.2% of those households would see their surplus decrease to less than half, which is a serious deterioration in living standards. We can therefore surmise that impoverishment is a quite common outcome of relocation.

Table 13.8 is a summary of the changes in living standards by perception after relocation. Our survey findings show that relocation led to the perceptions of higher living standards for 6 households (16.2%), to no change in living standards for 15 households (40.5%), and to lower living standards for 16 households (43.3%). Our survey findings show that relocation led to higher income levels in urban areas and an increase or decrease in one's income. However, more than 40% of households considered themselves poorer after relocation, which is consistent with the output of our simulation and which supports the above findings.

The current mean per capita income and surplus are highest for households with perceived improved living standards, but if these households had not relocated, their per capita income and surplus would be lower than those of other households.

Table 13.8 Mean household financial indicators by perception of changes in post-migration living standards

Change in post-migration living standards	Current situation (yuan/person)		Producing hay (yuan/person)		Buying hay (yuan/person)		Dependence on subsidies	Grassland area (mu/person)	Veterinary costs (yuan/person)
	Income	Surplus	Net income	Surplus	Net income	Surplus			
Improved (6 households, 16.2%)	8569	2525	2901	1084	1783	−34	0.15	795	1750
No change (15 households, 40.5%)	5668	2137	6666	4900	4434	2668	0.43	1587	1623
Worsened (16 households, 43.3%)	5786	1207	5464	3132	3637	1305	0.33	1299	3887

Source: Calculated by the author based on survey findings
Note: Dependence on subsidies = (no-grazing subsidies + minimum guarantee)/total income

Because these households have less usable grassland area, they cannot have many sheep. Therefore, they had experience working in secondary and tertiary industries before the ecological migration policy was enforced, and they also had the desire to start their own businesses. As a result, after relocating, it was easier for them to adapt to the urban lifestyle, they succeeded in starting up businesses with the new business subsidies and other government assistance, and they tended to be the least reliant on subsidies for income.

Households that felt their living standard was unchanged after relocating owned the largest areas of usable grassland, so they were receiving higher subsidies than the other households. Because they enjoyed the most advantageous conditions for livestock farming before relocating, they tended to exclusively engage in livestock farming, had no desire to branch out into other industries, and had never received any job training. After relocating, they were maintaining their previous standard of living by relying on subsidies, but they had a high possibility of becoming poorer in the absence of public assistance.

Households whose standard of living deteriorated after relocating had slightly smaller grassland areas before relocation than did the households whose living standards were unchanged, so they received less subsidy money. However, their post-relocation per capita incomes were about the same as those whose living standards were unchanged. Compared with other households, this group had the lowest per capita surpluses because higher expenditures had lowered their standard of living. With respect to expenditures, first, for the costs of starting a business, 6 of 16 households whose standard of living had declined had started a business that failed, thus the decline in their standard of living. Next, 5 of the 37 households had a sick or disabled family member, and the standard of living of 4 of them had declined. When they were living on the grassland, production activities and living activities happened in the same place, so they could work while taking care of a sick or disabled family member. In the city, however, such caregiving required labor, and they did not receive any pay for that. Those households whose standard of living declined tended to have the highest healthcare expenses of all the households, and this was probably impacting their household finances. The above findings are consistent with the scheme outlined in Fig. 13.3 and thus strongly support this hypothesis.

13.6.4 Problems with the Ecological Migration Policy

In our field survey, 56.7% of the subjects do not consider themselves to have a lower standard of living after relocating. However, these subjects constituted only 37 of the 77 livestock farming households that became ecological migrants, and we were unable to find out what happened to the remaining 40 households. For instance, even if we assume that living standards had not declined for all of the 13 households that relocated a second time to other areas, it is a fact that at least the 27 households whose whereabouts were unknown were unable to make a living in

Saihantala Town. When we add them to the 16 households with a lower standard of living in our survey, this means that the standard of living declined for 43 households (55.8% of the 77 households that relocated). There seem to be two major problems with the ecological migration policy, causing it to destabilize the lives of so many livestock farmers.

The first concerns how the policy was formulated. As a whole, the ecological migration policy is supporting the economically advantaged, and although it protects some of the weak, it does nothing for those in the middle class. Support that is easy for the economically advantaged to obtain works to further strengthen their financial situations, thus widening the economic disparities between this group and the other groups. Also, here, it is easy for the economically advantaged to obtain work to further strengthen their financial situation, thus widening the economic disparities between those who do not know the lingua franca and are poorly educated, have been taken away from their accustomed living environment, receive almost no support, and are living as unskilled laborers in a market economy. Having to compete with city dwellers for job opportunities is very likely to force them into poverty. In other words, when the ecological migration policy was formulated, no consideration was given to their language problems or to problems that would crop up because they belong to an ethnic minority with its own customs. Also, in terms of protecting the weak, which should be the most important point, the policy merely classifies those being affected into age groups and offers protections only to older people and students. This categorization thus protects some who are affluent and do not need public assistance, while disqualifying some of the sick and the disabled, who need public assistance, from eligibility. As a result, the terms of the ecological migration policy lack fairness and are not suitable for protecting the weak and maintaining their livelihoods.

Second is the problem of policy execution. It seems that various efforts were made to induce livestock farmers to relocate before the ecological migration policy was implemented. First, all the households said that the number of times they received house calls from the village's Communist Party chapter or leaders of the women's association had gone up, and the reason for these visits was mainly to publicize the policy. Publicizing a policy has traditionally entailed clearly telling people about both the advantages and disadvantages, yet these visits did not discuss any disadvantages for livestock farmers but only overemphasized the potential for starting a business or getting a job, the insurance and pension eligibility requirements, and subsidy amounts. After relocating, the ecological migrants found that their living situations had deteriorated beyond imagination as a result of delayed subsidy payments and the nonfulfillment of some of the preferential policies. In response to this situation, the livestock farmers who had become ecological migrants said that the terms of the promises made when the policy was being publicized, the promises made when they were relocating, and the conditions that were actually provided were getting worse, in that order. In particular, they singled out a lack of administrative capability in regard to ensuring job opportunities, which is the most critical element for a stable livelihood.

Because Village B was a no-grazing test area, relocation of only part of a household was not permitted. Rather, the entire household had to decide whether to move or not. Also, households that continued grazing were not fined for owning too many livestock but were subject to strict limits on their herd size. Because a policy that lacked flexibility was being enforced, the livestock farmers ended up taking on more risks.

13.7 Conclusion

Through a field survey, this paper has clarified that the implementation of the ecological migration policy worsened the living standards of the majority of livestock farmers because their household financial situations deteriorated. Policy implementation is not simply the dutiful accomplishment of a mission. Adequate consideration needs to be given to the reasonableness of the policy, whether it can be properly executed, and the burden it places on citizens. The ecological migration policy has, through various subsidies and other forms of assistance, not only lead to the misallocation of natural resources, but it has also diminished the so-called economic welfare as a result of major shortcomings with regard to the fair distribution of income. Improvements need to be made in the content and execution of what the ecological migration policy is doing to maintain the livelihoods and protect the living standards of those who have relocated. With respect to the ecological migration policy, there first should be a broadening of the scope of livelihood protections to include those who are economically disadvantaged due to illness and disabilities. Doing this will serve to protect the human rights as well as other social rights of the sick and disabled, and it will work toward maintaining the living standards of households with family members in these groups. Because gainful employment is essential to maintaining a household's livelihood, the creation of employment opportunities for which migrants are qualified could stabilize migrants' household incomes. Furthermore, when enforcing the ecological migration policy, both environmental policy and the ecological migration policy must be premised on the passage of legislation that provides for employment contracts and ensures fulfillment of their terms.

The ecological migration policy affects both the household finances and the social lives of livestock farmers. Ecological migrants who have relocated to urban areas to attain a modern urban lifestyle and improve their living standards by getting jobs in secondary and tertiary industries face many obstacles. These include high living expenses for things they previously did not have to pay for such as water, electricity, gas, and their staple food, meat, as well as job instability, income uncertainty caused by the nonpayment of wages, the loss of their grassland culture, separation from friends and family, and the lack of language skills to communicate their discomfort or dissatisfaction. In other words, even if most people can overcome economic poverty, they are still suffering greatly from psychological deprivation.

Because the ecological migration policy was adopted as a supplementary measure for environmental policy, it should accomplish the recovery of grasslands by prohibiting grazing. State Grasslands Administration Bureau (2008) reported that the mean hay production per square meter in Village B's grassland area is 35.2 g, which is 51% higher than that in similar areas that are not under the Grazing for Grass policy (surveyed on June 19, 2008). However, in the field survey conducted by the author in August of the same year, the livestock farmers said that despite plentiful precipitation over the previous 3 years, the pastures had not recovered. Although the no-grazing policy is meant to restore grasslands, large-scale mining and industrial production continue near the village. No one has raised the question of how much of a negative impact these activities are having on grassland recovery. Environmental protection and recovery involve some pain for society in the form of lower production and consumption and changes in lifestyle, but it is not right that livestock farmers should bear all of this pain. Justifying industrial development policies by contending that livestock breeding is "backward" and denigrating minority cultures based on prejudice and discrimination is counterproductive and in the end a threat to social stability.

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Chapter 14
Assessment of Policies on Environmental Impacts of Socioeconomic Activities: A Case Study of Kasumigaura Basin, Japan

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Abstract As environmental problems, such as global warming and ozone layer depletion, have a significant influence on various ecosystems, it is imperative to examine this relationship in depth. This is especially true for specific ecosystems, such as lakes, and the environmental problems affecting them. In this study, we propose a synthesized environment management policy, such as the control of water and air pollutant emissions, using a computer simulation. We considered both the ecological system in and around Lake Kasumigaura in Japan and the related socioeconomic changes in the catchment areas of the lake during a certain period. The pollutants measured in this study are total nitrogen, total phosphorus, and chemical oxygen—taken as water pollutants—as well as carbon dioxide, sulfur oxide, and nitrogen oxides, taken as greenhouse effect gases and air pollutants. This study targeted the simulation period between 1999 and 2007, which was when some of the research and development projects for new air pollution abatement and water quality improvement technologies started in this basin. The objectives of this research were to identify policy considerations for effectively reducing air and water pollutants in the basin without new technology and the kind of impact these policy considerations will have and to uncover how environmental load reduction technologies should be designed. The results show that governments should take advantage of the immediate effect of the capital reduction subsidy and prioritize budget allocations to reduce air pollutants in the earlier years of the target period. The government should then install domestic wastewater facilities such as

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sewage systems to reduce water pollutant emissions. The results also show that more economically efficient water pollutant-reduction technologies are required, especially those that transform pollutant emissions to single molecular form. The results of this research can contribute to the validity evaluation of research and development projects that have been implemented in this basin thus far.

Keywords Comprehensive evaluation · Computer simulation · Simultaneous control · Air and water pollutants · Socioeconomic activities

14.1 Introduction

Lake Kasumigaura, located in the southeastern part of Ibaraki Prefecture in Japan (Fig. 14.1), has played a key role in the basin's socioeconomic activities. However, the deterioration of the basin's water quality has been observed since around 1970, and today, it is negatively affecting the residents of this area. Comparing the air pollution problem in Japan before and after the 1980s shows that the pollution became more severe due to emissions—not from any particular source of pollutants as with Japan's historical environmental pollution incidents but from all socioeconomic activities. Today, the pollutants are wide ranging with many interrelated issues. This includes indirect effects on the human body, such as those caused by sulfur oxide (SOx) and nitrogen oxide (NOx), and on the environment, such as through global warming caused by carbon dioxide (CO_2). Therefore, it is necessary to control several pollutants simultaneously. Regarding air pollution and water environments like lakes and marshes, acid rain is one of the main concerns. Acid rain is caused by SOx and NOx, which are products of socioeconomic activities, and flows into lakes, marshes, and rivers, posing fatal danger to the creatures inhabiting the areas to the point of possible extinction. Thus, while measuring the environmental problems faced by lakes and marshes, it is necessary to

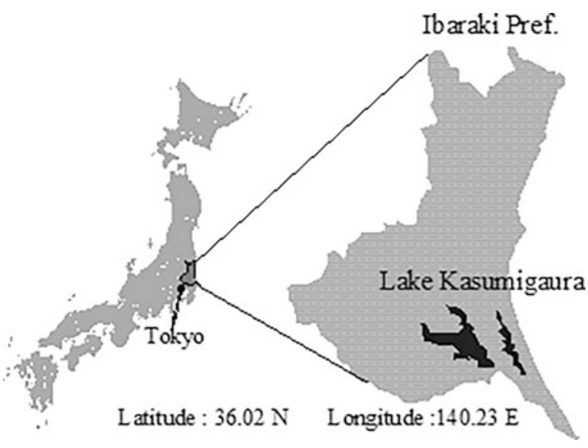

Fig. 14.1 Location of Lake Kasumigaura

consider not only the control of water pollutants but also the control of several other related environmental hazards, such as air pollutants and the resulting problems (Ballatore 2003).

Baumol and Oates (1988) analyzed the political aspects of environmental problems. The necessity of controlling socioeconomic activities—an important aspect of solving environmental problems and the formation of policy—was analyzed by Oka (1997). Numerous papers and books analyze the economic policy aimed at reducing greenhouse gases and air pollutants, especially at the macroeconomic level (e.g., Wei et al. 2011; Sumner et al. 2011; Galinato and Yoder 2010). Mizunoya and Higano (2000, 2001) clarified the static and dynamic effect of the environmental tax policy with a simulation analysis by combining socioeconomic activities and environmental movement into one model. Regarding policy on improving water quality in a closed water resource, Takagi et al. (2002) investigated the economic evaluation of policy for improving water quality and the allotment to reductions of pollutant emissions by using the computable general equilibrium model and by considering economic entities and the dynamics of pollutants. Yang et al. (2015) constructed socioeconomic and ecosystem models using social scientific methods with a focus on social activities and water pollution problems. In these studies, the interdependent relationship between socioeconomic activities and pollutant emissions in the basin is modeled linearly, based on an extended input-output analysis method; the simulations in these studies provided a socially acceptable pollution inflow and optimum policy. However, few existing studies have focused on the simultaneous emission control of air pollutants and water pollutants based on existing economic policies. In this research, we selected Lake Kasumigaura—which plays a significant role in the daily activities of residents in Ibaraki Prefecture—as the research area. The simulation period was between 1999 and 2007, a period when some of the R&D projects for new air pollution abatement and water quality improvement technologies were started in this basin. We constructed a simulation model that includes the emission structure, the flow of air and water pollutants within the basin of Lake Kasumigaura, the socioeconomic activities of the basin's municipalities, and the related environmental economic policy. We also conducted a simulation-based optimization exercise to propose a comprehensive and optimal environmental policy for lakes and marshes, considering both air and water pollution. Through the simulation, we aim to identify an effective policy for the reduction of air and water pollutants in the basin of Lake Kasumigaura without using new technologies, determine the impact the policy would have, and ascertain how the technologies that reduce environmental load should be designed.

14.2 Research Methodology

14.2.1 Outline of the Research Methodology

First, we constructed the study's simulation models, in which we considered the dynamics of air and water pollutants within the basin, the socioeconomic activities, and the comprehensive regional environmental policy. This model is constructed based on the input-output analysis model originally developed by Leontief to study the relationship between economic sectors (Leontief 1941, 1986). Second, we set the upper limitation on air pollutants emitted by socioeconomic activities within the basin, the amount of water pollutants flowing into Lake Kasumigaura, and the total budget amount from Ibaraki Prefecture. Third, a simulation-based optimization exercise was conducted with the maximization of gross regional product (GRP) in the simulation period, considering the social discount rate. Finally, based on the results, we analyzed the optimal level of economic activities of the basin, the optimal budget allocation of Ibaraki Prefecture, and the proposed nature of the environmental technologies. The model is an integration of three sub-models: (1) the water pollutant dynamics model, (2) the air pollutant emission model, and (3) the socioeconomic activity model. Figure 14.2 shows the relationships between these sub-models. The model also includes many alternative policy measures that are likely to be implemented (see Table 14.5 for specific policy content). With setting upper limits on the amounts of air pollutant emissions and water pollutant inflow, the model endogenously clarifies the policy implementation program, that is, which policy, when, and in which region the environment should be improved within the basin. At the same time, the model enables us to evaluate the effects of the program.

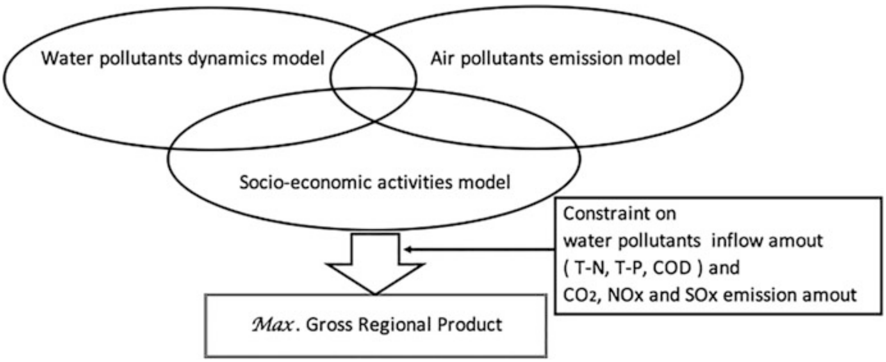

Fig. 14.2 The relationship between sub-models

14.2.2 Modeling Framework

The municipalities within the target basin are the same as those designated by Project for Water Environment Renovation by the Science and Technology Promotion Foundation of Ibaraki of Lake Kasumigaura (2001). Targeted rivers consist of 17 major rivers that flow into Lake Kasumigaura, including two direct discharges, assuming that all small rivers within the basin join any of the major rivers (Table 14.1). The municipality index in Table 14.1 is numbered from upstream- to downstream-located municipalities.

The environmental loads controlled in this study include three air pollutants and three water pollutants. The air pollutants are CO_2, a greenhouse gas, as well as NOx and SOx, which cause acid rain. The water pollutants are T-N (total nitrogen), T-P (total phosphorus), and COD (chemical oxygen demand). We divide the industries under study into five sectors (Table 14.2), while households and the government are categorized as the model's final demand sector. Air pollutants are generated through the production activities of industries and the consumption activities of the final demand sector. We assumed a linear relationship between the product of each sector and the amount of pollutants emitted. We also considered three sources of water pollutants: (1) production-related sources, such as industries shown in Table 14.2, (2) household-related sources, and (3) nonpoint land use-related sources. For household-related sources, the household wastewater disposal system was divided into six categories, as shown in Table 14.3. Here, we assumed that the population of sewage plant users increases but never decreases. Moreover, the number of treatment septic tank and night soil septic tank users does not increase because the production of both systems was ceased due to the self-regulation of septic tank manufacturers since 1999. Land use, which is a nonpoint source, was divided into five categories as shown in Table 14.4. Other land uses include a fallow field and latent residential land, shown in Table 14.5.

The "comprehensive and optimal environmental policy" considered here is a regional environmental economic policy aimed at controlling the emission of air and water pollutants. The policy entity is Ibaraki Prefecture and Table 14.5 shows the concrete contents of the policy. Figure 14.3 shows the budget flow throughout the implementation of the policy. The prefectural government pays subsidies directly to the agricultural sector to promote the fallowing of fields and to production-related sources (with the exception of the agricultural sector) to reduce working capital and adjust production. Moreover, the construction of sewage systems—including rural community sewage systems—is done using a subsidy from the prefectural government as well as revenue transferred from their own general accounts and local bonds. Furthermore, a combined treatment septic tank is installed by each household by means of supplementing the subsidy received from the prefectural government and municipalities.

The data used in the simulation is from 1999 and we simulate the model for a 9-year period: 1999–2007. Regarding the input coefficient matrix, we calculated it from the 1995 input-output table for Ibaraki Prefecture (Ibaraki Prefectural

Table 14.1 Classification of target areas

River index (index i in the model)	River name	Municipality index (index j in the model)	Municipality name
1	Sakura River	1	Iwase town
		2	Yamato village
		3	Makabe town
		4	Akeno town
		5	Kyowa town
		6	Shimodate city
		7	Shimotsuma city
		8	Tsukuba city
		9	Niihari village
		10	Tsuchiura city
2	Seimei River	11	Miho village
3	Koise River	12	Chiyoda town
4	Sonobe River	13	Yasato town
		14	Ishioka city
		15	Tamari village
5	Kajinashi River	16	Tamatsukuri town
6	Ono River	17	Kukizaki town
		18	Ushiku city
		19	Ryugasaki city
		20	Ami town
		21	Edosaki town
		22	Sakuragawa village
7	Ichinose River	23	Kasumigaura town
8	Shin-Tone River	24	Tone town
		25	Kawachi town
		26	Shin-tone town
		27	Azuma town
9	Hokota River	28	Asahi village
10	Tomoe River	29	Iwama town
		30	Minori town
		31	Ibaraki town
		32	Ogawa town
		33	Hokota town
11	Yamada River	34	Kitaura town
12	(Direct Discharge into the lake)	35	Taiyo village
13	Gantsu River	36	Asou town
14	(Direct Discharge into the lake)	37	Kashima city
15	Yogoshi River	38	Ushibori town
16	Maekawa River	39	Itako town
17	Hitachi-Tone River	40	Hasaki town
		41	Kamisu town

Table 14.2 Classification of production-related pollutant sources

Index	Industry name
1	Agriculture (upland cropping, rice cropping)
2	Livestock (dairy farming, beef farming, pig farming)
3	Fisheries (eel farming)
4	Manufacturing industry
5	Other industries

Table 14.3 Classification of household-related (wastewater) sources

Index	Facility name
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

Table 14.4 Classification of land use-related (nonpoint) pollutant sources

Index	Land use name
1	Upland field
2	Rice field
3	Mountain forest
4	City area
5	Other land use

Table 14.5 Policies to improve environmental quality in the Kasumigaura basin

Pollutant emission source	Counter measure
Industry	I. Subsidy for industries to reduce working capital so as to adjust production
Household	II. Subsidy for the municipalities to install sewage systems and rural community sewage systems
	III. Subsidy for the municipalities to promote installation of combined treatment septic tanks
Nonpoint (land use)	IV. Subsidy for rice cropping farmers to purchase the rice seed-planting machine having the function of precise fertilization (subsidizing rate is 5.6% of the purchase price)
	V. Subsidy for rice cropping farmers to use less-elution types of fertilizers (subsidization rate is 15% of the purchase price)
	VI. Subsidy to promote field fallowing (conversion of rice or paddy fields into fallow fields)

Government 1995), as there is no table for 1999. The simulation is conducted for five cases, setting the upper limit for both the amount of air pollutants emitted and water pollutants flowing into Lake Kasumigaura for each year of the simulation period. Table 14.6 shows the amounts of pollutants used as the limitation for each simulation. The upper limit of the total budget that Ibaraki Prefecture expends on the policy is set at 20 billion yen per year. This value was obtained from Hirose and Higano (1999). The simulation was conducted using a computer and LINGO software for operations research released by Lindo Systems.

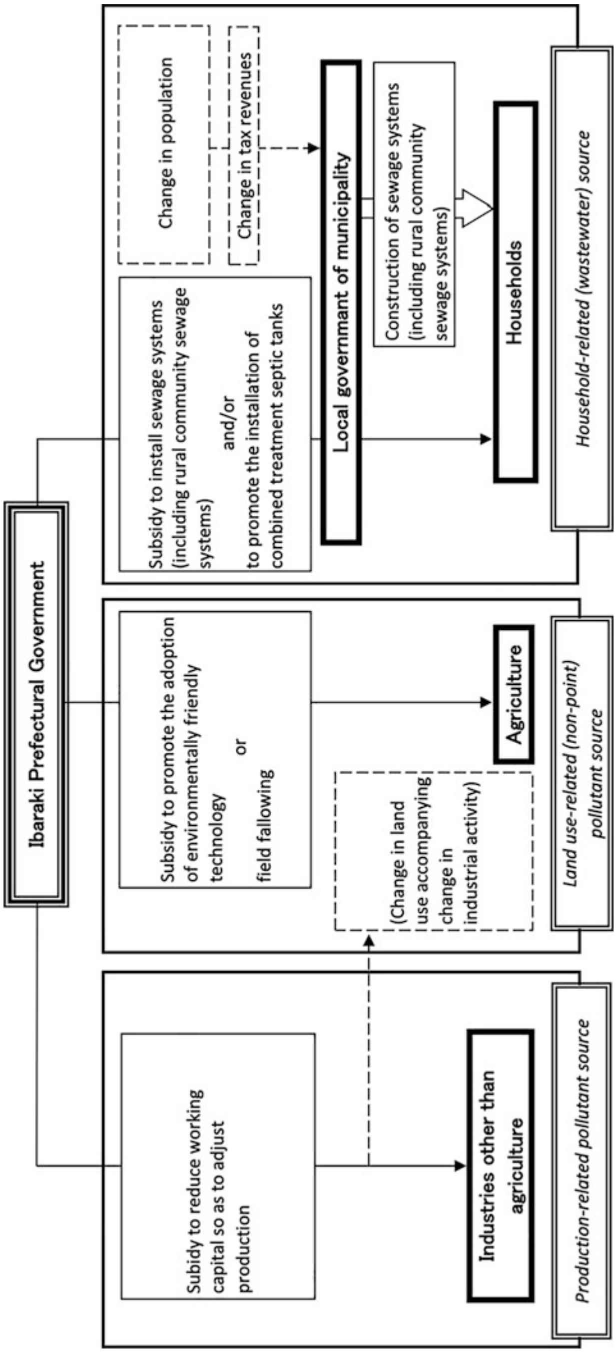

Fig. 14.3 Flow of budget by implementation of policy

Table 14.6 Simulation case setting

Case name	Emission reduction rate in 2007 (compared with emissions in 1999)	T-N	T-P	COD	CO_2	NOx	SOx
		Emission constraint in 2007 (t)	Emission constraint in 2007 (t)	Emission constraint in 2007 (t)	Emission constraint in 2007 (t)	Emission constraint in 2007 (t)	Emission constraint in 2007 (t)
Case 0	0%	4427	278	10,532	31,950,235	88,514	31,237
Case 10	10%	3984	251	9478	28,755,212	79,663	28,113
Case 20	20%	3541	223	8425	25,560,188	70,811	24,989
Case 30	30%	3099	195	7372	22,365,165	61,960	21,866
Case 35	35%	2878	181	6846	20,767,653	57,534	20,304

14.3 Simulation Model

This simulation model consists of more than 45 equations. Because of restrictions on the number of pages, only important model equations are shown in this paper.

14.3.1 Water Pollutants Dynamics Model

The Total Load of Pollutants Flowing into the Lake

In this model, the water pollutants in the lake are defined as the sum of those that flow through the rivers from sewage treatment plants, fisheries, and rainfall onto the surface of the lake. Thus:

$$Q^{hp}(t) = \sum_i RQ_i^{hp}(t) + QF^{hp}(t) + \sum_d QD_d^{hp}(t) + QR^{hp}(t) \tag{14.1}$$

in which:

$Q^{hp}(t)$ is the total load of pollutants p in block h of the lake at time t (en.)*.
$RQ_i^{hp}(t)$ is the load of pollutants p in block h of the river i at time t (en.)
$QF^{hp}(t)$ is the load of pollutants p by fisheries in block h at time t (en.)
$QD_d^{hp}(t)$ is the load of pollutants p in block h by sewage plant d at time t (en.)
$QR^{hp}(t)$ is the load of pollutants p by rainfall in block h at time t (ex.)*.
*(en.) indicates an endogenous variable and (ex.) indicates an exogenous variable in the equations.

Pollutant Load in the Sub-Basins of Each River per Municipality

Water pollutants, which are assumed to be generated by socioeconomic activities, flow into the lake through the rivers. Thus:

$$RQ_i^{hp}(t) = \sum_j RQM_i^{hp}(t) + \sum_j r_{ij}^{hp}(t) + \sum_j QR_{ij}^{hp}(t) + \sum_j QD_d^{ijp}(t), \tag{14.2}$$

in which:

$RQM_{ij}^{hp}(t)$ is the pollutants p transported to municipality j from the upstream of river i that flow into block h of the lake at time t (en.)
$\gamma_{ij}^{hp}(t)$ is the pollutants p emitted by socioeconomic activities in municipality j in the sub-basin of river i that flows in block h (en.)
$QR_{ij}^{hp}(t)$ is the pollutants p by rainfall in municipality j in the sub-basin of river i that flows into block h (ex.)

$QD_d^{ijp}(t)$ is the pollutants p discharged by the sewage plant d in municipality j of the sub-basin of river i (en.)

Pollutants Emitted by Socioeconomic Activities

The total pollutants emitted by socioeconomic activities in the sub-basin comprise pollutants from households, nonpoint sources, and point sources. Thus:

$$r_{ij}^{hp}(t) = QZ_{ij}^{hp}(t) + QL_{ij}^{hp}(t) + QX_{ij}^{hp}(t), \tag{14.3}$$

in which:

$QZ_{ij}^{hp}(t)$ is the pollutants p (excluding those through sewage) loaded by households in municipality j of river i that flows into block h at time t (en.)

$QL_{ij}^{hp}(t)$ is the pollutants p emitted by nonpoint sources in municipality j of river i that flows into block h (en.)

$QX_{ij}^{hp}(t)$ is the pollutants p emitted by socioeconomic activities (excluding those by fisheries) in municipality j of river i that flows into block h (en.)

Pollutants from Household Wastewater in Each Municipality

$$QZ_{ij}^{hp}(t) = \sum_k E^{pk} \cdot Z_{ij}^k(t), \tag{14.4}$$

in which:

E^{pk} is the emission coefficient of pollutants p from household wastewater treatment facility k ($k \neq 1$) (ex.)

$Z_{ij}^k(t)$ is the population that uses household wastewater treatment facility k in municipality j and discharge pollutants into river i (en.)

Load of Pollutants from Nonpoint Sources

$$QL_{ij}^{hp}(t) = G^{pl} \cdot L_{ij}^l(t), \tag{14.5}$$

in which:

G^{pl} is the coefficient of pollutants p emitted through land use l (ex.)

$L_{ij}^l(t)$ is the area of land use l in municipality j that emits pollutants into river i (en.)

Load of Pollutants from Industrial Activities

$$QX_{ij}^{hp}(t) = P^{pm} \cdot X_{ij}^{m}(t), \tag{14.6}$$

in which:

P^{pm} is the coefficient of pollutants p emitted by industry m (ex.)

$X_{ij}^{m}(t)$ is the production of industry m in municipality j that emits pollutants into river i (en.)

14.3.2 Air Pollutant Emission Model

The total of air pollutant emissions due to socioeconomic activities is the sum of emissions from the industries and the final demand sector.

$$AZ_g(t) = AP_g^m \cdot \sum_i \sum_j \sum_m X_{ij}^m(t) + AP_g^C \cdot C(t), \tag{14.7}$$

in which:

$AZ_g(t)$ is the emission amount of air pollutants g in Kasumigaura basin in term t (en.)

AP_g^m is the coefficient of pollutants g emitted by industry m (ex.)

AP_g^C is the coefficient of pollutants g emitted by final demand (ex.)

14.3.3 Socioeconomic Activity Model

The measures for the treatment of household wastewater include the provision of sewage services, rural community sewage services, and the installation of combined treatment septic tanks. These measures are mainly implemented by local governments.

Equipment for Sewage and Rural Community Sewage Services

An increase in the population that uses a sewage system or a rural community sewage system is dependent on the construction investment:

$$\Delta z_{ij}^{k}(t) \leq \Gamma_{ij}^{k} \cdot i_{ij}^{k}(t) \tag{14.8}$$

in which:

$\Delta z_{ij}^{k}(t)$ is the change in population of municipality h that use sewage system ($k = 1$) and rural community sewage system ($k = 2$) in municipality j of river i that flows into block h at time t (en.)

Γ_{ij}^{k} is the reciprocal of the necessary construction investment per person that uses the sewage and rural community sewage services in municipality j of river i that flows into block h (ex.)

$i_{ij}^{k}(t)$ is the construction investment in municipality j of river i for sewage system ($k = 1$) and rural community sewage system ($k = 2$; en.)

Sewage Systems and Rural Community Sewage Systems

The investment for the construction of a sewage system and a rural sewage system is determined by the construction allotment of the municipality and subsidies that are provided by the prefectural and central governments. Thus:

$$i_{ij}^{k}(t) = \left(\frac{1}{1 - M_{ij}^{k}}\right) cc_{ij}^{k}(t) \tag{14.9}$$

in which:

M_{ij}^{k} is the subsidization rate by the prefectural and central governments (ex.)

$cc_{ij}^{k}(t)$ is the construction allotment in municipality j of river i ($k = 1$, sewage system; $k = 2$, rural community sewage system; en.)

Maintenance Costs of the Sewage System

The maintenance costs of the sewage system and the rural community sewage system are covered by the users and municipality. Thus:

$$mc_{ij}^{k}(t) = v_{ij}^{k} z_{ij}^{k}(t) = N_{ij}^{k} z_{ij}^{k}(t) + g_{ij}^{k}(t) \tag{14.10}$$

in which:

$mc_{ij}^{k}(t)$ is the total maintenance cost of facility k ($k = 1$, sewage system; $k = 2$, rural community sewage system) in municipality j of river i (en.)

v_{ij}^{k} is the maintenance cost per user of k in municipality j of river i (ex.)

N_{ij}^{k} is the user charge per user of k in municipality j of river i (ex.)

$g_{ij}^{k}(t)$ is the transfer from the general account of municipality j of river i to cover maintenance costs of k (ex.)

Subsidization for the Installation of Combined Treatment Septic Tanks

The installation of a combined treatment septic tank ($k = 3$) is subsidized by the municipality, the central government, and the prefectural government. Thus:

$$\delta \, \Delta z_{ij}^{3}(t) = \left(\frac{1}{1 - M_{ij}^{3}} \right) b_{ij}^{3}(t) \tag{14.11}$$

in which:

δ is the installation cost of combined treatment septic tank per person (ex.)

$b_{ij}^{3}(t)$ is the amount of funds transferred from the general account of municipality j of river i for the installation of a combined treatment septic tank (en.)

Budget Constraints

Subsidization by the municipality for the construction of a sewage system ($k = 1$), a rural community sewage system ($k = 2$), and the installation of a combined treatment septic tank ($k = 3$) is covered by a special account, which includes a specific portion of the municipality's general account and the household wastewater treatment subsidy granted by the prefectural government. Thus:

$$b_{ij}^{1}(t) + b_{ij}^{2}(t) + b_{ij}^{3}(t) + g_{ij}^{1}(t) + g_{ij}^{2}(t) \leq \omega_{ij} R_{ij}(t) + s_{ij}^{1}(t) \tag{14.12}$$

in which:

ω_{ij} is the transfer of the special account for household wastewater treatment to the general account of municipality j in the sub-basin of river i (ex.)

$R_{ij}(t)$ is the budget of municipality j in the sub-basin of river i (en.)

$s_{ij}^{1}(t)$ is the subsidy for household wastewater measures in municipality j in the sub-basin of river i which is granted by the prefectural government to the special account of the municipality (en.)

Fallow Field Promotion Policy

The conversion of fields and rice fields to fallow fields (categorized as "other land use") is subsidized by the prefectural government. Thus:

$$L_{ij}^{l5}(t) \geq \lambda^{l} s_{ij}^{l}(t) \tag{14.13}$$

in which:

λ^{l} is the reciprocal of the subsidy for one unit conversion of land use l to land use of other purposes (index $= 5$; ex.)

$s_{ij}^{l}(t)$ is the subsidy given by the prefectural government for the conversion of land use l ($l = 1$, field; $l = 2$, rice field) to land use for other purposes in municipality j of river i (en.)

Production Function and Curtailment

Production is dependent on the accumulated capital. The prefectural government restricts the production of fields ($m = 1$) and rice fields ($m = 2$) through the fallow field promotion policy. The production of other industries ($m = 3$ to $m = 8$) is restricted by leaving capital idle and subsidizing for loss due to the idle capital. The productivity of fields and rice fields is also dependent on the area of cultivated land. Thus:

$$X_{ij}^{m}(t) \leq \alpha^{m} \cdot k_{ij}^{m}(t) \quad (\text{for } m = 1) \tag{14.14}$$

$$X_{ij}^{m}(t) \leq \alpha^{m} \left\{ k_{ij}^{m}(t) - s_{ij}^{m}(t) \right\} \quad (\text{for } m = 2\text{–}5) \tag{14.15}$$

in which:

α^{m} is the ratio of capital to output in industry m (ex.)

$s_{ij}^{m}(t)$ is the subsidy given by the prefectural government to reduce capital stock in municipality j of river i (en.)

$$X_{ij}^{m}(t) \leq \beta^{m} L_{ij}^{l} \tag{14.16}$$

β^{m} is the ratio of cultivated land to output in industry m ($m = 1$, field; $m = 2$, rice field) (ex.)

Capital Stock Accumulation

$$k_{ij}^{mP}(t+1) = k_{ij}^{mP}(t) + i_{ij}^{mP}(t) - d^{m} k_{ij}^{mP}(t) \tag{14.17}$$

in which:

$k_{ij}^{mP}(t)$ is the capital of industry m available in municipality j of river i at time t (en.)

$i_{ij}^{mP}(t)$ is the investment for industry m in municipality j of river i at time t (en.)

d^{m} is the depreciation rate of industry m (ex.)

Total Budget of the Prefecture for the Countermeasures

It is assumed that the prefectural government spends approximately 20 billion yen on implementing 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. Thus:

$$
\begin{aligned}
y(t) \geq \sum_j S_{ij}^1(t) + \sum_j \sum_m S_{ij}^m(t) + \sum_j \sum_l S_{ij}^l(t) + \sum_i \sum_j S_{ij}(t) \\
+ \sum_i \sum_j SU_{ij}(t),
\end{aligned}
\tag{14.18}
$$

in which:

$y(t)$ is the total budget spent by the prefectural government for implementing the countermeasures (ex.)

$S_{ij}(t)$ is the subsidy for the rice cropping farmer in municipality j of river i to purchase the rice seed-planting machine having a fertilization function (en.)

$SU_{ij}(t)$ is the subsidy for the rice cropping farmer in municipality j of river i to use less-elution types of fertilizers at time t (en.)

Flow Balance in the Commodity Market

The total products of each industry are decided by the balance between supply and demand. Thus:

$$
X(t) \geq Ax(t) + C(t) + i^m(t) + B^s \left\{ i^1(t) + i^2(t) \right\} + B^c \left\{ \delta \Delta Z^3(t) \right\} + e(t),
\tag{14.19}
$$

in which:

$X(t)$ is the column vector of the mth element in the total product of industry m in the basin (en.)

A is the input-output coefficient matrix (ex.)

$i^m(t)$ is the column vector of the mth element of the total investment in industry m (en.)

B^s is the column vector of the ith coefficient of the induced production in industry i through the construction of sewage and rural community sewage systems (ex.)

$i^k(t)$ is the total investment for the construction of sewage system ($k = 1$) and rural community sewage ($k = 2$) (en.)

B^c is the column vector of the ith coefficient of the induced production in industry i through the construction of a combined treatment septic tank (ex.)

$\delta \Delta z^3(t)$ is the total investment for the installation of a combined treatment septic tank (superscript index = 3; en.)

$e(t)$ is the column vector of net export (en.)

Gross Regional Product

We consider the GRP of the basin as an index that reflects the level of all socioeconomic activities. We also consider it as a potential function in which the maximization of the function simulates the driving force of the economy and market mechanism. Thus:

$$\mathrm{GRP}(t) = V \cdot X(t), \tag{14.20}$$

in which:

V is the row vector of gross value added (ex.)

14.3.4 Constraints on the Amount of Air Pollutant Emissions and Water Pollutant Inflow

We set constraints on the amount of air pollutant emissions and water pollutants flowing into Lake Kasumigaura for each year.

$$AZ_g^*(t) \geq AZ_g, \tag{14.21}$$

$$Q^{p*}(t) \geq \sum_h Q^{hp}(t), \tag{14.22}$$

in which:

$AZ_g^*(t)$ is the restriction on the emission of air pollutants in term t (*ex.*)

$Q^{p*}(t)$ is the restriction on the flow of water pollutants into Lake Kasumigaura in term t (ex.)

14.3.5 Objective Function

The market mechanism and driving force of the economy are simulated by the nonlinear maximization of the gross regional products in the basin. This is done considering the structural constraints of socioeconomic activities, the emission and the transportation of water pollutants, the water demand and supply as well as its recycling in the basin, and the upper and lower constraints of the water level in the lake, among other factors. Thus:

$$\max \sum_{t=1} \frac{1}{(1+\rho)^{(t-1)}} \mathrm{GRP}(t) \tag{14.23}$$

in which:

ρ is the social discount rate (= 0.05).

14.4 Simulation Results

14.4.1 Changes in the Objective Function

The value of the objective function remained steady around 34 trillion yen when pollutants are reduced by 0% to 20%. When we set the reduction rate at 30%, the objective function decreased to around 33.2 trillion yen (Fig. 14.4). This value is approximately 800 billion yen less than that of Case 0, the baseline case. In the simulation, we obtained feasible solutions when the reduction rate was below 30%. However, we did not obtain feasible solution when the reduction rate is more than 30%. We conducted a simulation by setting the initial total expenditure budget amount at more than 20 billion yen but did not obtain a feasible solution. These results indicate that, in those years, a 30% reduction was the maximum achievable level when using pollutant-reduction/abatement technologies. Therefore, to find a way out of the deadlock, the development and introduction of more advanced technologies for pollutant reduction was essential. Ibaraki Prefecture conducted a project involving the development of new technologies for the purification of Lake Kasumigaura through the Collaboration of Regional Entities for the Advancement of Technological Excellence (CREATE) from FY1997 until FY2002. Moreover, they also conducted a "development program of biomass recycling in Kasumigaura" for 3 years starting in FY2002 as a city area program by the Ministry of Education, Culture, Sports, Science and Technology. This program was aimed at cleaning up and recycling organic waste from and around Lake Kasumigaura. These programs were significant for the abovementioned tasks.

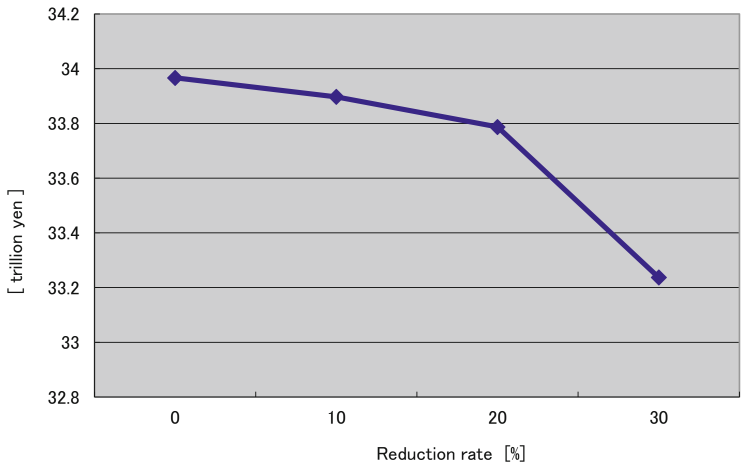

Fig. 14.4 Change in the objective value

14.4.2 Changes in Emission Amounts of Air Pollutants and Water Pollutants Flowing into Lake Kasumigaura

Figures 14.5, 14.6 and 14.7 shows changes in the amount of each water pollutant flowing into Lake Kasumigaura, while Figs. 14.8, 14.9 and 14.10 show emission amounts of each air pollutant in the basin area. The amount of each water pollutant shows a decreasing pattern with each year in both Case 20 and Case 30. Remarkably, T-P and COD were less than the constraint value (shown in Table 14.6) in every case, while the amount of T-N was the same as the constraint value in every case. For

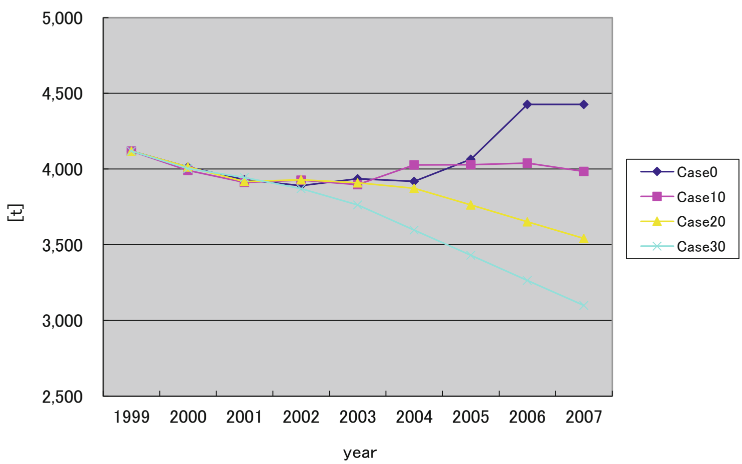

Fig. 14.5 Changes in T-N emission amounts

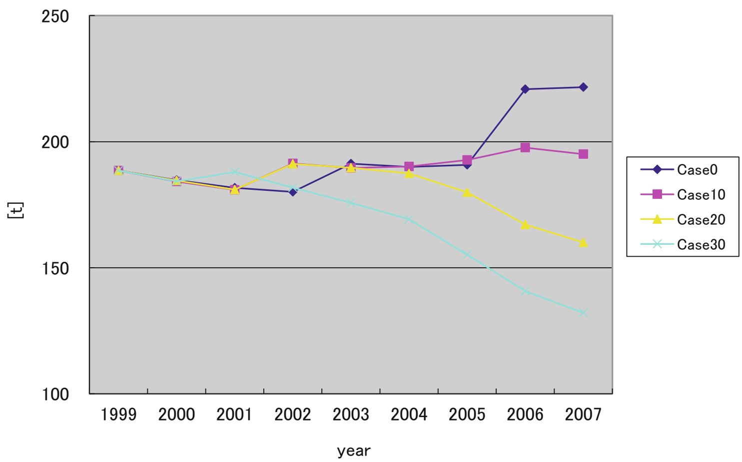

Fig. 14.6 Changes in T-P emission amounts

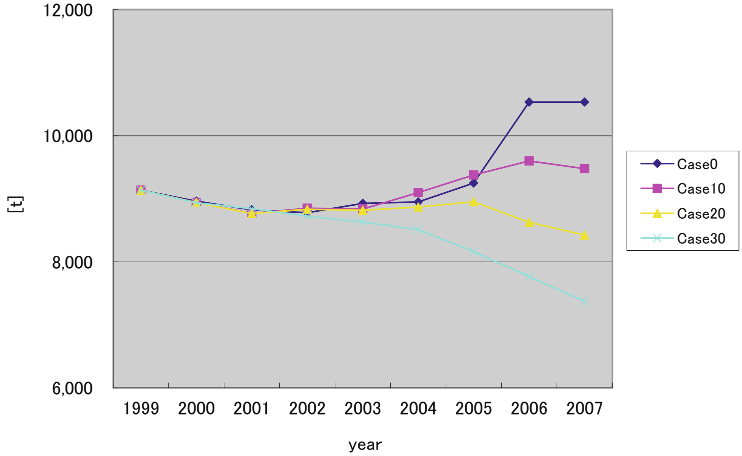

Fig. 14.7 Changes in COD emission amounts

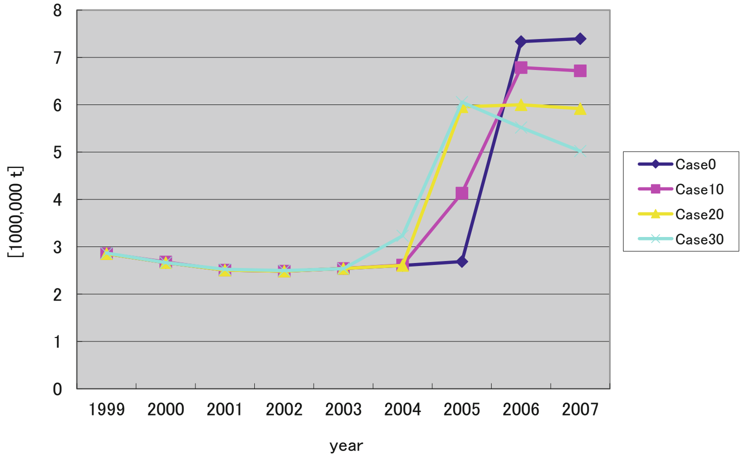

Fig. 14.8 Changes in CO_2 emission amounts

example, the value of T-P was 132 t while the constraint value in Case 30 for 2007 was 195 t. Likewise, the value of COD was 7372 t while the constraint in Case 30 for 2007 was 7372 t. In contrast, the changes in the amount of air pollutants indicate a contrasting pattern. The amount of air pollutants decreased significantly at the beginning of the simulation period, especially in the first year, and then increased until they reached the constraint value in the middle of the simulation period. These indicate that it is difficult to simultaneously control the amounts of water and air pollutants by maximizing economic activity scale, and it is therefore effective to try to reduce air pollutants in the earlier and water pollutants in the later phase of the simulation period. Considering changes in air pollutant emissions, the value of SOx

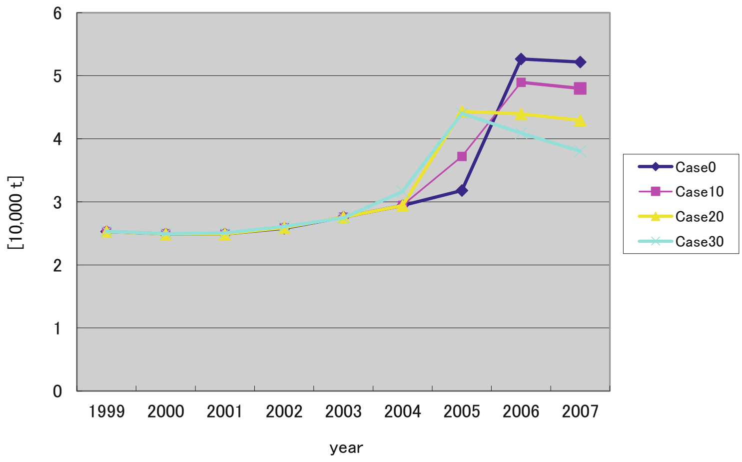

Fig. 14.9 Changes in NOx emission amounts

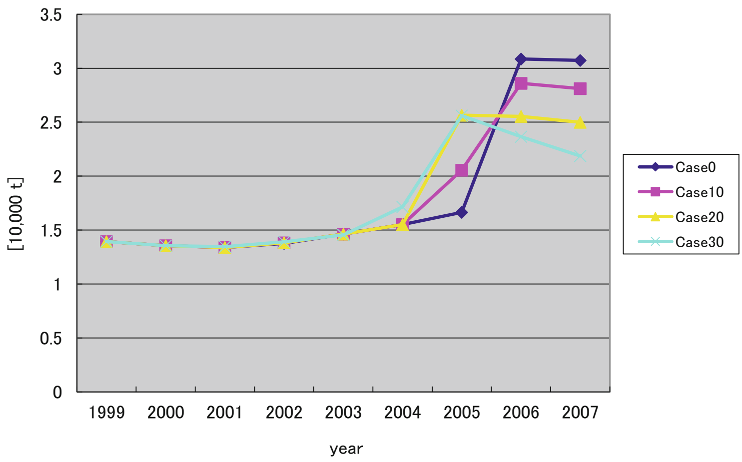

Fig. 14.10 Changes in SOx emission amounts

emission in the last year of every case was the same as the constraint value (e.g., in Case 30 for 2007, the value was the same as the constraint value), whereas the results of CO_2 and NOx were below the constraint value. Specifically, CO_2 was far below the constraint value. For example, the value of the constraint on CO_2 emission is 22 million t in Case 30 for the final year, while the result value was five million t. Likewise, the value of constraint on the emission of NOx in 2007 is 62,000 t, and the result value was 38,000 t, with a difference of 24,000 t.

Mizunoya et al. (2007) clarified that nitrogen is the most crucial water pollutant in terms of reduction. According to the results of the simulation, technologies in those used water resources as the destination of surplus nitrogen from socioeconomic activities, resulting in excessive load to the area. Considering this situation, technological developments to help discharge nitrogen to non-water resources were required. Ideally, technologies that make pollutants harmless to the environment and release them into the atmosphere, such as those that convert nitrate nitrogen into molecular nitrogen, were favored.

14.4.3 Changes in Accumulative Budget Distribution and Budget Expenditure on Each Policy

Figures 14.11, 14.12, 14.13 and 14.14 show the changes in budget expenditure on each policy during the years. In every case, a large portion of the budget is expended on treatment measures against production-related sources. This is because of the time required to observe the effects of the subsidy. The subsidy expenditure to install a sewage system and a rural community sewage system, which is a measure against household-related sources, is tied to the commencement and completion of the installation service. This means there is a time lag on the appearance of the

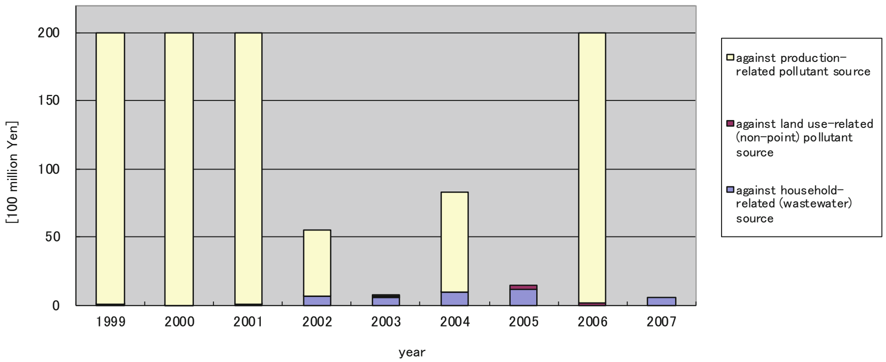

Fig. 14.11 Accumulative budget distribution on each policy (Case 0)

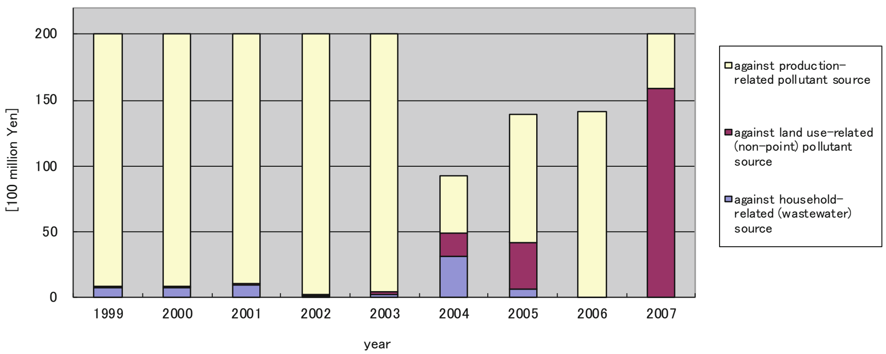

Fig. 14.12 Accumulative budget distribution on each policy (Case 10)

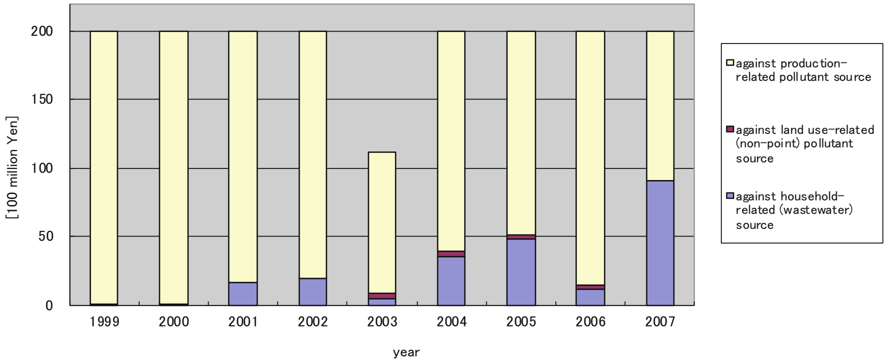

Fig. 14.13 Accumulative budget distribution on each policy (Case 20)

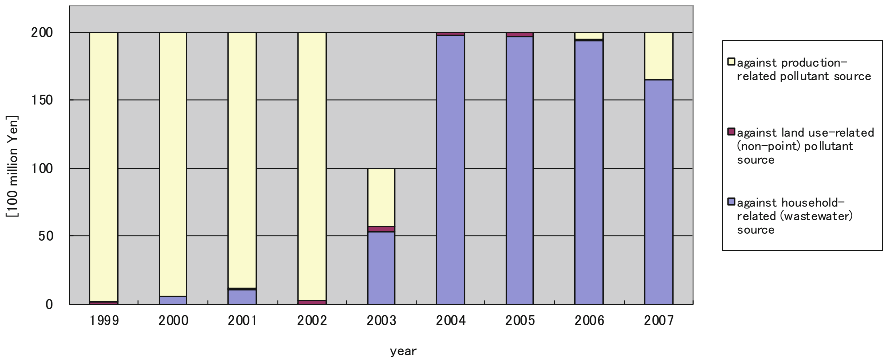

Fig. 14.14 Accumulative budget distribution on each policy (Case 30)

reduction effect. Conversely, the subsidy for reducing working capital to adjust production, which is a measure against production-related sources, directly controls production activities. Therefore, the budget works at once for reducing pollutant emission. Since production activities are the main sources of air pollutants, air pollutants were considerably decreased at the beginning of the simulation period.

Up to Case 20, the accumulative budget allocation for measures against production- and household-related sources increased along with the reduction rate (Fig. 14.15). However, in Case 30, expenses for measures against production-related sources decreased considerably, and expenses for measures against household-related sources increased significantly, compared with Case 20. Household-related sources can be considered as the main sources of water pollutants, while production-related sources can be considered as main sources of air pollutants. Considering these, the results show that the marginal cost for the reduction of water pollutants becomes drastically high at some point. For example, expenses for measures against household-related sources were 6.6 billion yen, 23 billion yen, and 82.4 billion yen in Case 10, Case 20, and Case 30, respectively. To increase the reduction rate

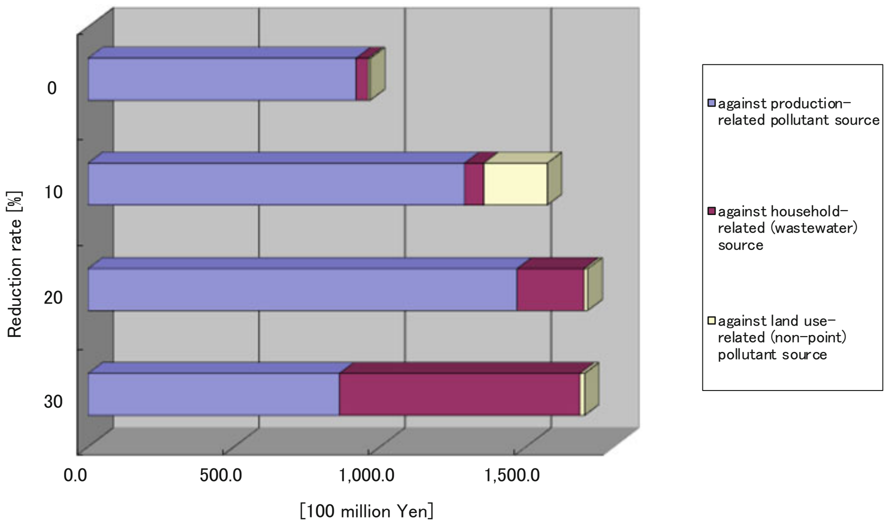

Fig. 14.15 Accumulative budget distribution on each policy

of water pollutant inflow by the same amount again, 16.4 billion yen is required in Cases 10–20 and 59.4 billion yen in Cases 20–30, an increase of 3.6 times. Interestingly, fisheries in every municipality received subsidies to reduce working capital, while other industries in every municipality did not necessarily receive a subsidy. This is because the emission coefficients of both air and water pollutants for fisheries are very high. It is well known that the emission coefficient of water pollutants is high because of hatchery fish diets. Meanwhile, the emission coefficient of air pollutants, through the high consumption of heavy oil by fishery boats, has not been considered a big problem. However, these simulation results show that fisheries also play a pivotal role in the reduction of air pollutants.

Figure 14.16 shows the total accumulative budget expended from Ibaraki Prefecture to each municipality for 9 simulated years in Case 30. According to the result, a larger portion of the budget was distributed to municipalities no. 29 (Iwama Town), 20 (Ami Town), and 1 (Ishioka City) during the 9 years. In Iwama Town, the budget was spent mostly on measures against household-related sources of pollutants. This is because, although the financial scale for this town is large, the potential demand for the installation of sewerage facilities was very high, as existing ones were not well equipped. In Ami Town, the budget was spent mostly on measures against production-related sources. The Ono River basin where Ami Town lies is turning into a satellite town for commuters going to Tokyo. Although the population growth rate of Ami Town is the highest among the study areas, there are only a few large sources of tax revenue, resulting in a small financial scale per capita and poor progress on the installation of the sewage systems. Plants and business-related industries in Ami Town received large subsidies to reduce working capital because they have especially large production levels. In Iwase Town, the budget was

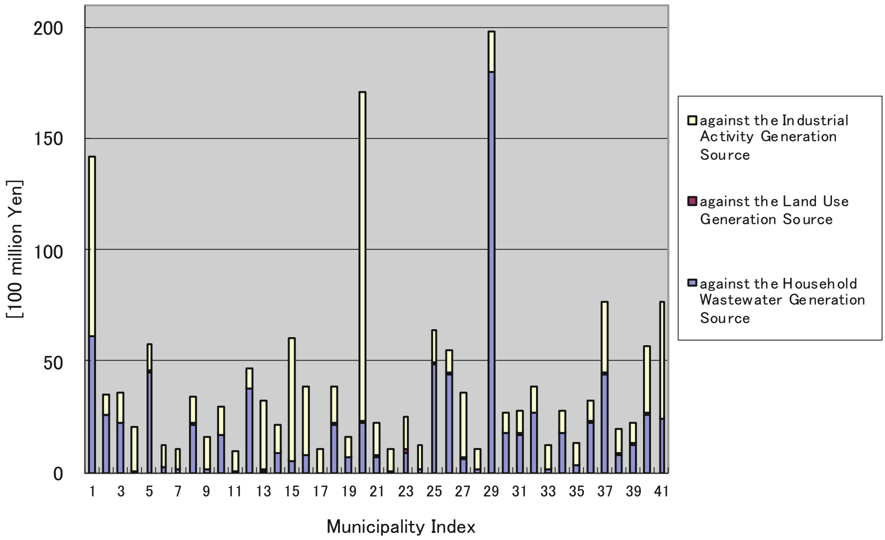

Fig. 14.16 Total accumulative budget expended to each municipality

distributed almost equally toward expenses on measures against production- and household-related sources. Iwase Town is located upstream of Sakura River, whose basin is the largest with a thriving dairy farming industry. The rural community sewage system is comparatively well equipped; however, the sewage system is not performing well for the size of the financial scale. It is conceivable that the high potential demand for the installation of sewage systems is the reason for expenses on measures against household-related sources.

14.5 Conclusion and Suggestion

This study finds that if the prefectural government had introduced the environmental policy listed in Table 14.5 to the Kasumigaura basin efficiently, emissions of air and water pollutants into Lake Kasumigaura could have been reduced by 30% between 1999 and 2007 compared with 1999. In the future, to reduce air and water pollutants while maximizing economic activity and taking advantage of the immediate effect of the capital reduction subsidy, the prefectural government should prioritize budget allocations to reduce air pollutants in the earlier years of the target period.

Afterward, in the later years of that target period, the government should take measures to reduce water pollutant emissions by installing domestic wastewater facilities such as sewage systems. Moreover, because the marginal cost of water pollutant reduction increases significantly as the reduction rate increases, water pollutant-reduction technologies that are more economically efficient will be required. Particularly, it is desirable to develop a technology that emits pollutants in single molecular form, without exerting any load on water bodies or the atmosphere. Our study also revealed the problematic environmental load of the fishery industry. Although the problem of increasing load on water bodies by the fishery industry, especially the aquaculture industry, has been recognized, there has been little recognition of the load on the atmosphere by fishing vessels. In the future, it is desirable to develop ships with low air pollutant emissions through technologies such as hybridization of power.

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Chapter 15
Industrial Agglomeration Due to High-Speed Railway Investment: A Monopolistic Competition Model Impact Assessment

Takaaki Okuda

Abstract In this study, we developed a monopolistic competition model to analyze the impact of a high-speed railway on the economy of the Chubu region of Japan. Normally, in monopolistic competition models, it is assumed that the elasticity of substitution is constant. In our model, however, it is assumed that the elasticity of substitution differs between goods produced in the region and composite goods. Two types of transaction costs are considered: logistics service costs and information service costs. Impact analysis using this model produced the following findings. If a Maglev high-speed train line is opened between Tokyo and Nagoya, the Chubu region will experience growth in automotive industries and other processing and assembly industries. On the other hand, the Kanto region will experience growth in service industries. If the Maglev train line is extended to Osaka, the Chubu region will see growth in processing and assembly industries and the Kinki region will see growth in basic material industries and consumer goods industries. In the latter case, the Kanto region will again experience growth in service industries.

Keywords Industrial agglomeration · High-speed railway · Monopolistic competition model · Impact analysis · Maglev line

15.1 Introduction

In 2011, the Japanese government decided to invest in a new high-speed railway line connecting Tokyo and Osaka. A superconducting magnetic levitation railway is planned for this line. Although the existing line runs at 270 km/h, the new line is designed to run at 500 km/h. The travel time between Tokyo and Osaka will improve

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from 2 h and 30 min to 67 min when this line opens. In other words, three major metropolitan regions in Japan (Tokyo, Nagoya, and Osaka metropolitan regions) will become one huge metropolitan region.

In the fight against global warming, European countries are investing in intercity high-speed railways. Asian countries are also planning to have intercity high-speed rails to continue economic growth. The Japanese government was the first in the world to invest in high-speed railways by connecting Tokyo and Osaka. It has also invested in high-speed railway networks all over Japan. Since then, technology improvements have constantly increased the speed of Japanese intercity railways. In this context, investing in a superconducting magnetic levitation (maglev) line is an attempt to further enhance the service level of intercity railways in Japan.

The new line will greatly shorten the travel time in the three metropolitan regions. The metropolitan regions already have larger markets than other regions and provide a wide variety of goods and services. These features have led to high company productivity and became driving forces that attracted many people to metropolitan regions. Under these circumstances, opening the new line will make the three metropolitan regions as one large metropolitan region, which is expected to further increase the productivity and attractiveness of the three metropolitan regions.

In this study, we developed a quantitative model to analyze the effect of the opening of the new maglev line on the regional economy in Japan and on the productivity and attractiveness of the three metropolitan regions. In Sect. 15.2, we summarize conventional related research. In Sect. 15.3, we summarize the impact of the new maglev line. In Sect. 15.4, we describe a monopolistic competition model for evaluating the influence of the new maglev line. In Sect. 15.5, we describe a method for calibrating this model. In Sect. 15.6, we present the analysis of the effects of the new maglev line using this model.

15.2 Related Research

15.2.1 Regional Econometric Models

Many economic models have been developed to analyze the impact of intercity transportation investments, such as high-speed rails, on regional economies. In Japan, for example, Amano and Fujita (1968) developed a regional econometric model based on an interregional input-output analysis and endogenous interregional trade coefficients. This model was used to evaluate the economic effects of a high-speed rail project and a strait-crossing project in Japan. The Economic Research Institute's (1968) regional economic model for nine regions in Japan was developed by Fukuchi et al. This model has been used by the National Land Agency of Japan to evaluate high-speed rail and highway networks and in the Japanese national comprehensive development plan. Okuda and Hayashi (1995) proposed a multiregional general equilibrium model introduced from a probabilistic approach, which cleared the effects of motorway improvement in Japan.

15.2.2 Computable General Equilibrium Models

In the late 1990s, computable general equilibrium models, which emphasized consistency with general equilibrium theory, began to be used in the evaluation of transportation projects (See National Land Agency in Japan (1998,1999)). These project evaluations were performed by a cost-benefit analysis, and the computable general equilibrium model was used for the benefit evaluation (See Okuda (2006)). The Railway Bureau of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (2000) has used this computable general equilibrium model to analyze the economic effects of the maglev line that connects Tokyo and Osaka. In academics, Koike et al. (2000) analyzed the economic effects of the maglev line using a computable general equilibrium model. In this model, the technical coefficient of the production function is defined as a function of passenger traffic. However, large-scale projects are expected to have a significant impact on urban agglomeration. Therefore, whether this relationship holds even after the implementation of the project has become a major issue.

15.2.3 Monopolistic Competition Models

In the 2000s, monopolistic competition models that considered transportation costs in the monopolistic competition theory were used to evaluate transportation projects. In Europe, in particular, Broecker (2002) developed the CGEurope model based on a monopolistic competition model. The Trans-European Network-Transport (TEN-T) was evaluated using this model. However, there is no transportation project in TEN-T that brings three major metropolitan regions closer to one metropolitan region in a way similar to the maglev line. Therefore, an evaluation method that fully considers the characteristics of the maglev line is required. In addition to the evaluation of transportation projects, many empirical analyses using monopolistic competition models have been conducted. For example, Redding and Venables (2004) clarified the relationship between a monopolistic competition model and a gravity model. Regional wage differences are also analyzed by this model. Stelder (2006) and Au and Henderson (2006) used Redding and Venables' (2004) description to develop models in the grid level or models developed in China.

15.2.4 Position of This Research

A great deal of research has analyzed the economic effects of intercity high-speed rails. However, as explained in Sect. 15.2.3, the maglev line is a transportation project that brings three metropolitan regions closer in terms of the transportation time and makes them as one metropolitan region. For this reason, the maglev line may significantly change the urban agglomeration of the three metropolitan regions. To explicitly define the mechanism of urban agglomeration in metropolitan regions, monopolistic competition models determine that increasing returns to scale is more desirable than applied general equilibrium models that assume constant returns to scale. Therefore, developing a monopolistic competition model that considers transportation costs in the monopolistic competition theory is desirable. However, there are many challenges in evaluating the maglev line using a monopolistic competition model. In monopolistic competition models, transportation costs mainly include costs required for logistics. However, when the maglev line opens, the three major metropolitan regions will approach one metropolitan region. As a result, services provided in each metropolitan region may be provided between the metropolitan regions. Therefore, a major issue will be how to handle such service transactions.

15.3 Impact of the Linear Chuo Shinkansen

15.3.1 Changes in Traffic Time

The travel time between Tokyo, Nagoya, and Osaka was gradually shortened by the opening of the Shinkansen line and the improvement of the railway system. However, the opening of the maglev line will further shorten the travel time. As shown in Fig. 15.1, the travel time between Tokyo and Nagoya is currently 1 h and 40 min, but it will be 40 min after the opening of the maglev line. Moreover, the travel time between Tokyo and Osaka is currently 2 h and 30 min, but it will be reduced to 67 min. Hachioji (52 min), Tsukuba (63 min), Chiba (41 min), and other cities in the Tokyo metropolitan region can be accessed in approximately 1 h from Tokyo by the intercity rail. Under these circumstances, when the maglev line opens, Nagoya and Osaka will be located within the Tokyo metropolitan region in terms of travel time.

15.3.2 Changes in Service Input

Comparing the interregional transactions in the interregional input-output table, transactions within the same metropolitan region show larger values than transactions between different metropolitan regions. This tendency is particularly notice-

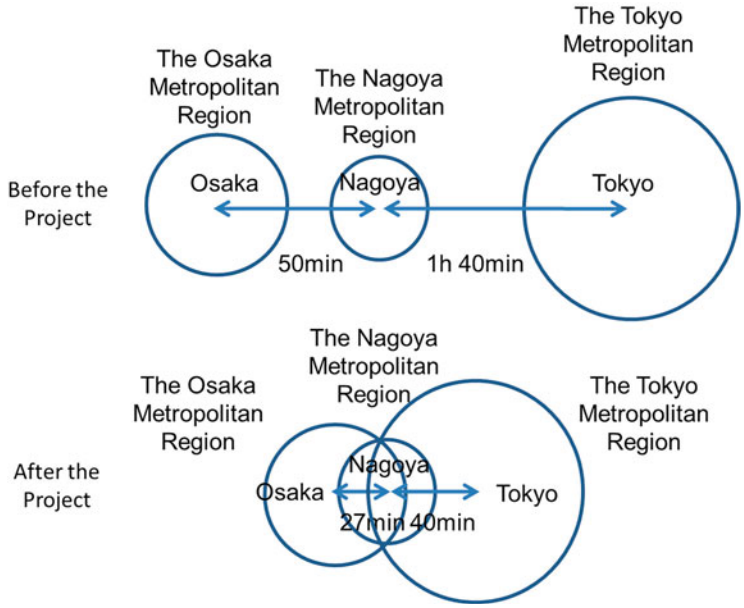

Fig. 15.1 Changes in travel time with the high-speed rail for the Tokyo, Nagoya, and Osaka metropolitan regions

able in service transactions, which often involve the movement of people. For example, buyers of the service may move to the seller of the service, or conversely, the seller of the service may move to the buyer of the service. Furthermore, to provide a service, a branch office may be set up, and a person who provides the service may belong to the office. In the case of product transactions in the same metropolitan region, products and services are combined and sold, instead of selling only products. That is, product transactions are often combined with information services, such as introducing products that are matched to the needs of customers or in combination with aftersales services.

15.3.3 Love of Variety and Productivity

There are many products and services in a metropolitan region. This diversity allows companies in a metropolitan region to produce more efficiently. High productivity in a metropolitan region can attract more companies to the metropolitan region. When the maglev line opens, the Tokyo, Nagoya, and Osaka metropolitan regions will approach one huge metropolitan region. New products and services targeting this new market may appear. As a result, the types of products and services will increase, so companies will be able to produce even more efficiently and the productivity of the three metropolitan regions will be further improved.

15.4 Monopolistic Competition Model

15.4.1 Basic Concept

In this study, we will develop a monopolistic competition model that takes into account different substitutions between intergroup and intragroup of goods and services as pointed out by Matsuyama (1994). For this purpose, let us assume a utility function and a production function, as shown in Fig. 15.2. In the normal monopolistic competition model, the elasticity of substitution between goods and services produced in all regions is assumed to be constant. In this model, the elasticity of substitution between goods and services produced in one region is different from that between composite goods produced in each region. By taking into account the different elasticities of substitution in the two levels, the mechanism of concentration and decentralization of companies can be expressed.

In normal monopolistic competition models, only the transportation cost is considered as the transaction cost. This study is explicitly divided into two transaction costs, namely, logistics service costs and information service costs. Assuming the iceberg transport cost, the consumer's price of an industrial product produced in a region can be defined as follows:

$$P_X(r,s,i) = P(r,i)\,\tau_F(r,s,i)\,\tau_C(r,s,i) \tag{15.1}$$

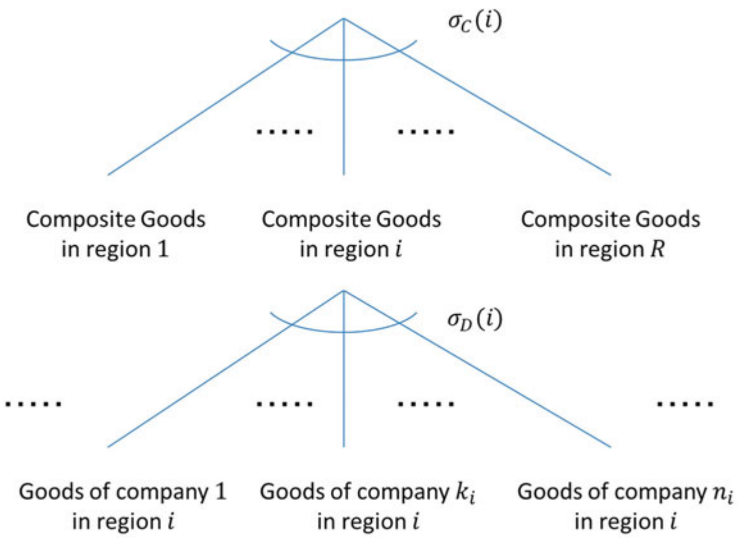

Fig. 15.2 Elasticity of substitution between goods and services

where $P_x(r, i)$ is the producer price of a good i in region r, $\tau_F(r, s, i)$ is the coefficient of the logistics service costs from region s, and $\tau_c(r, s, i)$ is the coefficient of the information service costs from region s.

It is assumed that many companies are producing in each region. The transportation costs of all companies in the same region are given by Eq. (15.1).

15.4.2 Final Demand Sector

Differentiated goods and services are assumed in the monopolistic competition theory. The final demand sector in each region has the following utility functions considering the love of variety:

$$U(s) = \prod_i C(s, i)^{\alpha_c(s,i)} \tag{15.2}$$

$$C(s, i) = \left\{ \sum_r D(r, s, i)^{\frac{\sigma_C(i)-1}{\sigma_C(i)}} \right\}^{\frac{\sigma_C(i)}{\sigma_C(i)-1}} \tag{15.3}$$

$$D(r, s, i) = \left\{ \sum_{k=1}^{N(r,i)} X(r, s, i, k)^{\frac{\sigma_D(i)-1}{\sigma_D(i)}} \right\}^{\frac{\sigma_D(i)}{\sigma_D(i)-1}} \tag{15.4}$$

where $U(s)$ is the utility in region s, $C(s, i)$ is the consumption of composite goods i in region s, $D(r, s, i)$ is the consumption in region s of composite goods i produced in region r, $N(r, i)$ is the number of goods i produced in region r (number of firms), $X(r, s, i, k)$ is the consumption in region r of goods i produced in region r, $\alpha_c(s, i)$ are the parameters of a Cobb-Douglas-type utility function, and $\sigma_c(i)$, $\sigma_s(i)$ is the elasticity of substitution on goods i.

The goods and services produced in each region are combined by the CES-type function in Eq. (15.4) at the bottom level. In addition, the composite goods are combined by the CES-type function in Eq. (15.3) at the middle level, and the composite goods are combined by the Cobb-Douglas-type function in Eq. (15.2) at the top level. Assuming that goods and services produced in each region are symmetric, the price of goods and services is constant in each region.

Then, by solving the utility maximization problem under budget constraints, the expenditure $E(r, s, i)$ evaluated in the producer prices of industry i is as shown in Appendix 1.

15.4.3 Production Sector

Based on the monopolistic competition theory, firms produce differentiated goods and services. Moreover, all goods and services produced in each region are symmetric. The following equations are the production functions of a firm producing in region r:

$$Q\left(s,j\right)+Q_0\left(s,j\right)=F(s,j)^{\alpha_F(s,j)}\prod_i C(s,i,j)^{\alpha_C(s,i,j)} \tag{15.5}$$

$$F\left(s,j\right)=\left\{\alpha_L(s,j)^{\frac{1}{\sigma_F(i)}}L\left(s,j\right)^{\frac{\sigma_F(i)-1}{\sigma_F(i)}}+\alpha_K\left(s,j\right)^{\frac{1}{\sigma_F(i)}}K\left(s,j\right)^{\frac{\sigma_F(i)-1}{\sigma_F(i)}}\right\}^{\frac{\sigma_F(i)}{\sigma_F(i)-1}} \tag{15.6}$$

$$C\left(s,i,j\right)=\left\{\sum_r D(r,s,i,j)^{\frac{\sigma_C(i)-1}{\sigma_C(i)}}\right\}^{\frac{\sigma_C(i)}{\sigma_C(i)-1}} \tag{15.7}$$

$$D\left(r,s,i,j\right)=\left\{\sum_{k=1}^{N(r,i)} X(r,s,i,j,k)^{\frac{\sigma_D(i)-1}{\sigma_D(i)}}\right\}^{\frac{\sigma_D(i)}{\sigma_D(i)-1}} \tag{15.8}$$

where $Q(s,j)$ is the production of goods and services in industry j (symmetry); $Q_0(s,j)$ is the fixed production; $F(s,i)$ is the value-added input; $C(s,i,j)$ is the input of composite goods and services in industry I; $L(s,j)$ is the labor input; $K(s,j)$ is the capital input; $D(r,s,i,j)$ is the input of composite goods of industry i produced in region r; $N(r,i)$ is the number of goods and services (number of firms); $X(r,s,i,j,k)$ is the input of goods k of industry i in region r; $\alpha_F(s,i)$, $\alpha_c(s,i)$ are the parameters of the Cobb-Douglas-type function; $\alpha_L(s,i)$, $\alpha_K(s,i)$ are the parameters of the CES-type function; and $\sigma_F(i)$, $\sigma_c(i)$, $\sigma_D(i)$ is the elasticity of substitution.

Goods and services produced in each region are combined by the CES-type functions in Eq. (15.8) at the bottom level, and the composite goods are combined by the CES-type functions in Eq. (15.7) at the middle level. In addition, labor and capital are combined by the CES-type functions in Eq. (15.6), and these composite goods are all combined by the Cobb-Douglas-type function in Eq. (15.5) at the top level.

Fixed production is required to consider the fixed cost of the firm. If the cost minimization problem is solved under this production function, then the expenditure is evaluated by the producer price, as shown in Appendix 2.

Furthermore, the profit of this firm can be defined as follows.

$$\Pi\left(s,j\right)=P\left(s,j\right)Q\left(s,j\right)-P_{\mathrm{A}}\left\{Q\left(s,j\right)+Q_0\left(s,j\right)\right\} \tag{15.9}$$

If there is a large number of firms, the price elasticity of the demand for the firm is $\varepsilon=\sigma_{\mathrm{D}}(j)$. As a result, the following pricing rule can be obtained from the profit maximization problem:

$$P\,(s,\,j)=\frac{\sigma_{\mathrm{D}}(j)}{\sigma_{\mathrm{D}}(j)-1}P_{\mathrm{A}}\,(s,\,j) \tag{15.10}$$

That is, the price marks up the marginal cost. Moreover, if the firms are in a monopolistic competition market, then the firm profit will be zero. Production will be constant as follows:

$$Q\,(s,\,j)=\{\sigma_{\mathrm{D}}(j)-1\}\,Q_{\mathrm{o}}\,(s,\,j) \tag{15.11}$$

15.4.4 Factor Markets

The following equation is obtained from the supply and demand conditions in the labor and capital markets:

$$L_0(s)=\sum_j N\,(s,\,j)\,L\,(s,\,j) \tag{15.12}$$

$$\sum_s K_0(s)=\sum_s\sum_j N\,(s,\,j)\,K\,(s,\,j) \tag{15.13}$$

where $L_0(r,i)$ is the labor endowment and $K_0(r,i)$ is the capital endowment.

The labor and capital prices can be obtained from Eqs. (15.12) and (15.13). Then, the income of region s is as follows:

$$Y(s)=P_L(s)L_0(s)+P_K K_0(s) \tag{15.14}$$

15.4.5 Number of Firms

The revenues of industry i in region r are equal to the sum of the expenditure for the intermediate demand of the production sector and the expenditure of the final demand sector. That is:

$$R\,(r,i)=\sum_s\sum_j E\,(r,s,i,j)+\sum_s E\,(r,s,i) \tag{15.15}$$

where:

$$R\,(r,i)=N\,(r,i)\,P\,(r,i)\,Q\,(r,i) \tag{15.16}$$

Therefore, the number of firms is solved from Eq. (15.16).

15.5 Parameter Estimation

15.5.1 Interregional Input-Output Table

The parameter estimation of the model proposed in Sect. 15.4 was performed by using the interregional input-output table (2005) estimated by the Ministry of Economy, Trade and Industry. The interregional input-output table divides Japan into nine regions (Fig. 15.3). However, the Okinawa region is smaller than the other regions, so it was included in the Kyushu region. The interregional input-output table divides industries into 48 industries. In this study, the eight industries shown in Table 15.1 were used for the industrial classification, which takes into account the characteristics of the interregional transactions.

15.5.2 Estimation of Logistics Service Cost

To calibrate the model described in Sect. 15.4, the logistics and information service costs were estimated. First, traffic time, tolls, and driving costs were calculated for

Table 15.1 Classification and consolidation of industries in Japan

8 Combined industries	53 Industries
Agriculture, forestry, and fishery industry	Agriculture, forestry, fishery
Basic material industry	Mining, chemical products, petroleum and coal products, plastic and rubber products, ceramic stone and clay products, steel and steel products, non-steel metals and products, other metal products
Processing assembly industry	General machinery, electric equipment, transportation equipment, precision machinery
Lifestyle-related industry	Food, drinks, and tobacco; textiles; lumber and wooden products; furniture; pulp and paper products; publishing and printing; other manufactured products
Construction and public supply industry	Construction, electricity, gas, and thermal energy supply; water supply; waste collection
Commerce industry	Wholesale and retail trade, transportation
Wide-area service industry	Financial service and insurance, telecommunications and broadcasting, education, scientific research, advertising and market research, goods rental and leasing, other business service, other amusement and recreation services, drinking and eating places, accommodation, other personal services
Local service industry	Real estate, public services, medical and health service, other nonprofit organizations

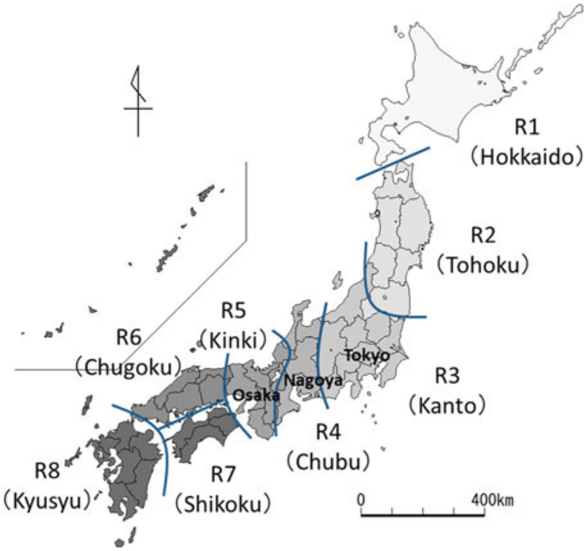

Fig. 15.3 Regional classifications

each of the 47 prefectures from the road network for expressways and national highways. Second, the generalized transportation costs were estimated from the manual of the cost-benefit analysis on road investments in Japan (See Guideline for road investment evaluation committee (1989)). Third, the logistics service costs were calculated from the multiplication of the generalized transportation cost and the interregional transactions obtained from the interregional input-output table. Lastly, the logistics service costs were adjusted to correspond to the inputs from the transportation sector of the input-output table.

15.5.3 Estimation of Information Service Costs

From Appendices 1 and 2, the interregional transaction value $M(r, s, i)$ can be calculated as follows:

$$M(r, s, i) = \sum_j E(r, s, i, j) + E(r, s, i) = A(r, i)\, B(s, i)\, N(r, i)^{\alpha(i)} \exp\left\{-\beta(i) t\left(r, s\right)\right\} \tag{15.17}$$

where

$$A(r, i) = P(r, i)^{1-\sigma_C(i)} \tag{15.18}$$

$$B(s, i) = \sum_j P_C(s, i, j)^{\sigma_C(i)} N(s, j)\, C(s, i, j) + P_C(s, i)^{\sigma_C(i)} C(s, i) \tag{15.19}$$

$$\alpha(i) = \frac{1 - \sigma_C(i)}{1 - \sigma_D(i)} \tag{15.20}$$

$$\tau(r, s, i)^{1-\sigma_D(i)} = \exp\left\{-\beta(i)t\Big(r, s\Big)\right\} \tag{15.21}$$

In addition, the following equation is obtained by taking the logarithm of Eq. (15.17):

$$\ln M\,(r, s, i) = \alpha(i) \ln N\,(r, i) - \beta(i)t\,(r, s) + \ln A\,(r, i) + \ln B\,(s, i) \tag{15.22}$$

Therefore, Eq. (15.22) was used for the parameter estimation.

The interregional transaction value can now be obtained from the interregional input-output table. For the travel costs $\tau_c(r, s)$, we used the generalized transportation costs, which were calculated from the passenger transport network of aviation, railways, and roads. Because firm production is constant in Eq. (15.11), the production obtained from the interregional input-output table is used as a proxy index for the number of firms.

The third term $\ln A(r, i)$ on the right side of Eq. (15.11) was estimated as the dummy variable of the production region in the multiple regression. Similarly, the fourth term $\ln B(r, i)$ on the right side of Eq. (15.11) was estimated as the dummy variable of the consumption region in the multiple regression.

15.5.4 Estimation Results

Tables 15.2 and 15.3 show the results of the parameter estimation. As regards the adjusted coefficient of determination, the highest value is 0.9749 for the agriculture, forestry, and fishery industry, followed by basic material industry at 0.9779, processing and assembly industry at 0.9769, lifestyle-related industry at 0.9778, and industry at 0.9783. Moreover, the smallest value is 0.7712 for local service industry, followed by construction and utility service industry at 0.8570, and wide-area service industry at 0.9256. However, all categories show generally good values, and reasonable estimation results were obtained.

Values were estimated for the coefficients of each variable. First, the coefficient of the generalized transportation cost is the lowest for the processing and assembly industry at 0.008 and commerce industry at 0.018. There is fairly widespread interregional trade in these industries. Furthermore, there is no significant difference among the agriculture, forestry, and fishery industry, basic material industry, and lifestyle-related industry, with values 0.029, 0.024, and 0.022, respectively. Conversely, the construction and utilities industry has the largest coefficient at 0.064, followed by local service industry at 0.037 and wide-area service industry at 0.034. In these industries, interregional transactions are sharply reduced as transportation costs increase. Compared with the agriculture, forestry, and fisheries industry and manufacturing industry, other industries have fewer regional interregional

Table 15.2 Parameter estimation results (1)

	Agriculture, forestry, and fishery industry	Basic material industry	Processing and assembly industry	Lifestyle-related industry
	Coefficient ($t-v.$)	Coefficient ($t-v.$)	Coefficient ($t-v.$)	Coefficient ($t-v.$)
Travel cost	0.029 (7.6)	0.024 (10.1)	0.008 (5.1)	0.022 (11.3)
Number of firms	0.96 (48.1)	0.97 (82.6)	0.93 (116.6)	0.98 (105.5)
Prod. in R1	0.55 (2.6)	– (–)	– (–)	0.28 (2.3)
Prod. in R2	0.59 (2.9)	– (–)	– (–)	– (–)
Prod. in R4	−0.57 (−2.9)	– (–)	−0.23 (−2.1)	– (–)
Prod. in R5	−0.62 (−3.1)	– (–)	– (–)	– (–)
Prod. in R6	– (–)	– (–)	– (–)	– (–)
Prod. in R7	– (–)	– (–)	−0.17 (−1.7)	– (–)
Prod. in R8	– (–)	– (–)	−0.30 (−3.0)	– (–)
Cons. in R1	−1.56 (−6.1)	−2.23 (−10.8)	−2.59 (−19.3)	−2.17 (−14.5)
Cons. in R2	−1.12 (−4.5)	−1.50 (−7.4)	−1.88 (−14.3)	−1.96 (−13.5)
Cons. in R4	−1.51 (−6.0)	−1.15 (−5.8)	−1.01 (−7.7)	−1.51 (−10.4)
Cons. in R5	−0.76 (−3.0)	−1.08 (−5.4)	−1.25 (−9.7)	−1.05 (−7.2)
Cons. in R6	−1.89 (−7.7)	−1.66 (−8.4)	−1.94 (−15.1)	−2.11 (−14.6)
Cons. in R7	−2.53 (−10.3)	−2.61 (−13.1)	−2.87 (−22.1)	−2.79 (−19.3)
Cons. in R8	−1.58 (−6.5)	−1.43 (−7.2)	−1.42 (−10.9)	−1.60 (−11.1)
Constant	– (–)	– (–)	– (–)	– (–)
R	0.9993	0.9996	0.9999	0.9998
R^2	0.9986	0.9993	0.9997	0.9996
Adjusted R^2	0.9749	0.9779	0.9769	0.9778

transactions and more transactions from neighboring areas where transportation costs are low.

The coefficient of the number of firms (logarithmic value) is 0.96 for the agriculture, forestry, and fishery industry, 0.97 for the basic material industry, 0.93 for the processing and assembly industry, 0.98 for the lifestyle-related industry, and 0.96 for the commerce industry. From Eq. (15.20), in these industries, the elasticity of substitution between regions is larger than the elasticity of substitution within a region. Thus, the agglomeration effect is relatively small in these industries. Furthermore, the coefficient of the number of firms (logarithmic value) exceeds 1:1.77 for the local service industry, 1.68 for the construction and utility industry, and 1.49 for the wide-area service industry. From Eq. (15.20), the elasticity of substitution between regions is larger than the elasticity of substitution within a region. Thus, the agglomeration effect is greater in these industries.

As mentioned above, local service, construction and utility service, and wide-area service industries are likely to cause regional concentration because their agglomeration effects are greater than those of other industries. Furthermore, the transportation cost coefficient for these industries has a large value, which prevents

Table 15.3 Parameter estimation results (2)

	Construction and public supply industry	Commerce industry	Wide-area service industry	Local service industry
	Coefficient ($t-v.$)	Coefficient ($t-v.$)	Coefficient ($t-v.$)	Coefficient ($t-v.$)
Travel cost	0.064 (7.8)	0.018 (9.5)	0.034 (8.6)	0.037 (4.7)
Number of firms	1.68 (8.4)	0.96 (103.7)	1.49 (18.8)	1.77 (8.4)
Prod. in R1	−1.02 (−2.0)	– (−)	– (−)	0.87 (1.8)
Prod. in R2	−1.38 (−3.0)	– (−)	−1.10 (−4.9)	– (−)
Prod. in R4	– (−)	– (−)	−1.41 (−6.1)	−1.98 (−4.5)
Prod. in R5	– (−)	– (−)	−0.85 (−3.5)	– (−)
Prod. in R6	– (−)	– (−)	−0.60 (−2.6)	– (−)
Prod. in R7	– (−)	– (−)	– (−)	– (−)
Prod. in R8	– (−)	– (−)	−0.66 (−3.0)	– (−)
Cons. in R1	−2.62 (−4.6)	−2.44 (−15.5)	−2.14 (−7.7)	−3.70 (−6.3)
Cons. in R2	−2.77 (−4.9)	−1.67 (−10.8)	−1.98 (−7.2)	−2.72 (−4.8)
Cons. in R4	−4.16 (−7.5)	−1.06 (−6.8)	−1.83 (−6.6)	−1.94 (−3.4)
Cons. in R5	−3.72 (−6.7)	−0.97 (−6.3)	−1.20 (−4.3)	−1.43 (−2.5)
Cons. in R6	−3.84 (−7.0)	−1.53 (−10.0)	−1.97 (−7.2)	−2.61 (−4.6)
Cons. in R7	−5.72 (−10.4)	−2.45 (−15.9)	−2.93 (−10.8)	−4.05 (−7.1)
Cons. in R8	−3.22 (−5.9)	−1.45 (−9.5)	−1.81 (−6.7)	−1.89 (−3.4)
Constant	−11.62 (−3.6)	– (−)	−9.26 (−6.8)	−16.56 (−4.7)
R	0.9411	0.9998	0.9719	0.9039
R^2	0.8856	0.9996	0.9445	0.8170
Adjusted R^2	0.8570	0.9783	0.9256	0.7712

regional concentration. However, if transportation investment significantly reduces transportation costs, then these industries could cause regional concentration.

15.6 Quantitative Analysis of the Maglev Line from Tokyo to Osaka

15.6.1 Case Setting

Using the monopolistic competition model developed in this study, we conducted an impact analysis on the opening of the maglev line from Tokyo to Osaka. We set two cases for the opening of the maglev line. In the first case, the maglev line between Tokyo and Nagoya will reduce the travel time from the current 1 h and 40 min to 40 min. In the second case, the maglev line between Tokyo and Osaka will reduce the travel time from 2 h and 30 min to 67 min.

15.6.2 Maglev Line Between Tokyo and Nagoya

Figure 15.4 shows how the production in each industry changes when the maglev line will open between Tokyo and Nagoya. In this figure, the opening of the maglev line will increase the production of the processing and assembly industry and the basic material industry in R4 (Chubu). Moreover, commercial production increases along with these changes. The processing and assembly industry that produces automobiles and automobile parts and the basic material industry that supplies them are both located in R4 (Chubu). These industrial clusters related to automobiles have resulted in a high production level of automobiles.

In addition, when the maglev line will open, it will be easier to input many services from R3 (Kanto), which will further increase productivity and production. Furthermore, in R3 (Kanto), the opening of the maglev line will increase the production of the wide-area service and local service industries. These service industries are concentrated in R3 (Kanto). The service industry realizes high productivity through these industrial clusters. In addition, the opening of the maglev line will further expand the service market, which is expected to further increase the service production in R3 (Kanto).

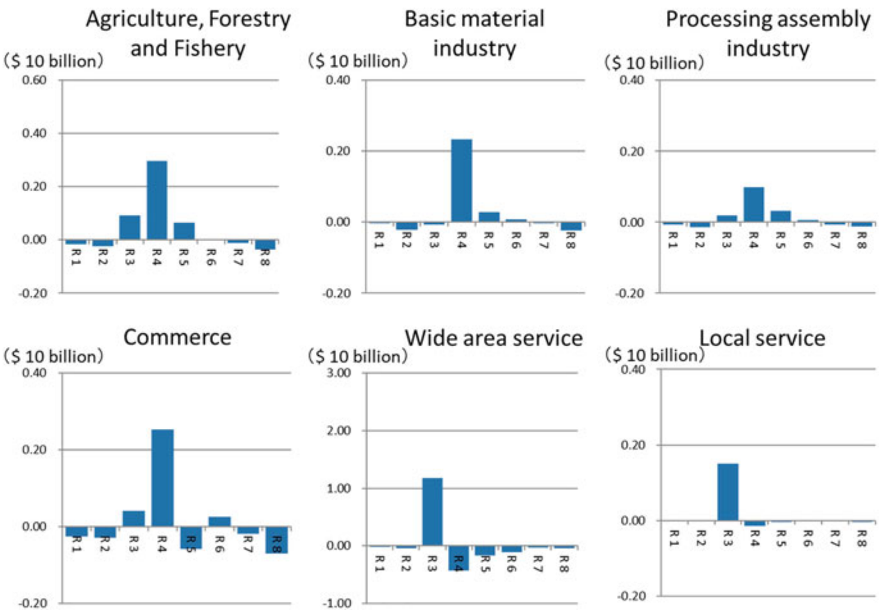

Fig. 15.4 Production change caused by the opening of the maglev line from Tokyo to Nagoya

15.6.3 Maglev Line Between Tokyo and Osaka

Figure 15.5 shows how the production of each industry will change when the maglev line will open between Tokyo and Osaka. According to the figure, the opening of the maglev line will increase production in the machining and assembly industry in R3 (Chubu). In R5 (Kinki), production will increase in basic material and lifestyle-related industries. In R3 (Chubu) and R5 (Kinki), commercial production will increase with the increase in manufacturing production. In R3 (Chubu), there is a high concentration of processing and assembly industries, and in R5 (Kinki), there are basic material and lifestyle-related industries. When the maglev line will open, it will be easier to input services produced in R3 (Kanto). This will increase the productivity of the manufacturing industries in R4 (Chubu) and R5 (Kinki) and will therefore increase their production.

In R3 (Kanto), the opening of the maglev line will increase the production of wide-area service and local service industries. The opening of the maglev line from Tokyo and Osaka will expand the service market. Thus, the service production in R3 (Kanto) will increase. Meanwhile, in R4 (Chubu), the opening of the maglev line will reduce the production of the wide-area service and local service industries. In R5 (Kinki), the production of the wide-area service industry will decrease, and the production of the local service industry will increase.

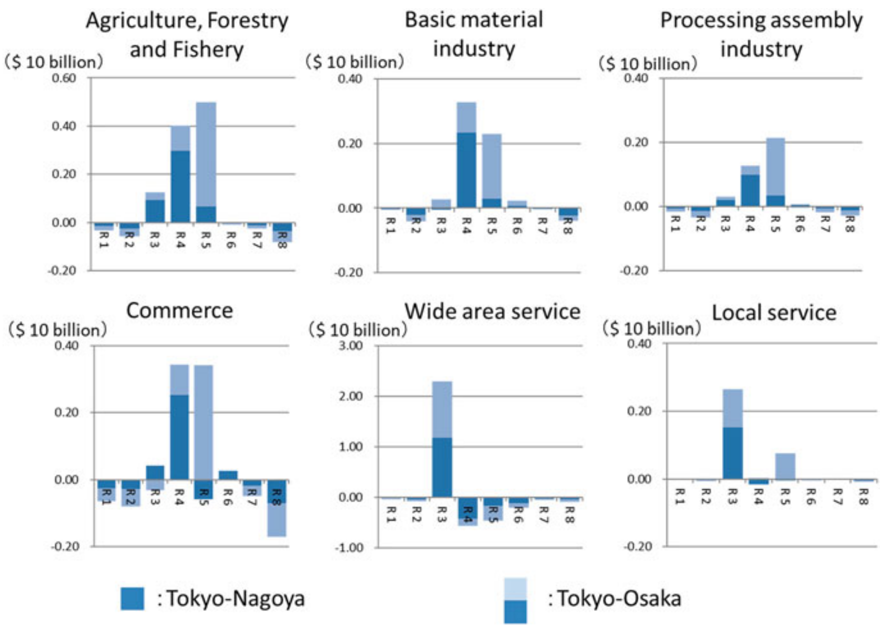

Fig. 15.5 Production change caused by the opening of the maglev line from Tokyo to Osaka

15.7 Conclusion

In this study, we developed a monopolistic competition model to analyze the impact of the maglev line between Tokyo and Osaka on the regional economy. Normally, in a monopolistic competition model, the elasticity of substitution of the differentiated goods is constant, but in the monopolistic competition model proposed in this study, the elasticity of substitution is different between goods produced in a region and composite goods between regions. In this monopolistic competition model, two transaction costs are considered, namely, logistics service costs and information service costs.

We also proposed a method for estimating the parameters of this monopolistic competition model using the interregional input-output table of Japan. The parameter estimation results show that, for the agriculture, forestry, and fishery industry, manufacturing industry (basic material industry, processing and assembly industry, lifestyle-related industry), and commerce, the elasticity of substitution between regions is smaller than the elasticity of substitution within a region. Clearly, these industries tended to be dispersed. Meanwhile, for wide-area service, local service, and construction and utility service industries, the elasticity of substitution between regions is larger than the elasticity of substitution within a region, and these industries tend to be concentrated. However, transportation costs should be kept low for interregional transactions of these industries. Therefore, the transportation costs do not cause a phenomenon that concentrates in a specific region. In the future, if transportation costs decrease due to transportation investments, it may be possible to concentrate in specific regions.

Using the impact analysis results with the monopolistic competition model, the following findings were obtained. If the maglev line is opened between Tokyo and Nagoya, R4 (Chubu) is likely to increase production in the automotive industry and other processing and assembly industries and in the basic material industry that supplies materials to the automotive industry. In R3 (Kanto), the production of service industries is likely to increase. If the maglev line is opened between Tokyo and Osaka, the production will likely increase in the processing and assembly industry in R4 (Chubu) and in the basic material and lifestyle-related industries in R5 (Kinki). In R3 (Kanto), the production of service industries is likely to increase.

Appendix 1: Expenditure of the Final Demand Sector

Assuming that differentiated goods produced in each region are symmetric, the price of the goods will be constant in the region. The utility maximization problem is solved under the budget constraint, and the consumption of the goods produced in a region is as follows:

$$C\,(s,i) = \alpha_C\,(s,i)\,\frac{Y(s)}{P_C\,(s,i)} \tag{15.23}$$

$$D\,(r,s,i) = \left(\frac{P_D\,(r,s,i)}{P_C\,(s,i)}\right)^{-\sigma_C(i)} C\,(s,i) \tag{15.24}$$

$$X\,(r,s,i,k) = \left(\frac{P_X\,(r,s,i)}{P_D\,(r,s,i)}\right)^{-\sigma_D(i)} D\,(r,s,i) \tag{15.25}$$

where:

$$P_C\,(s,i) = \left\{\sum_r P_D(r,s,i)^{1-\sigma_C(i)}\right\}^{\frac{1}{1-\sigma_C(i)}} \tag{15.26}$$

$$P_D\,(r,s,i) = \left\{\sum_{k=1}^{N(r,i)} P_X(r,s,i)^{1-\sigma_D(i)}\right\}^{\frac{1}{1-\sigma_D(i)}} \tag{15.27}$$

where $Y(s)$ is the income in region s, $P_C(s,i)$ is the consumer's price of composite goods i in region s, $P_D(r,s,i)$ is the producer price in region s of composite goods i in region r, and $P_X(r,s,i)$ is the producer price in region s of differentiated goods of industry i in region r.

Equations (15.27) and (15.25) are as follows:

$$P_D\,(r,s,i) = N(r,i)^{\frac{1}{1-\sigma_D(i)}}\,P_X\,(r,s,i) \tag{15.28}$$

$$X\,(r,s,i,k) = X\,(r,s,i) = N(r,i)^{\frac{\sigma_D(i)}{1-\sigma_D(i)}}\,D\,(r,s,i) \tag{15.29}$$

Then, the expenditure of composite goods in a region is as follows:

$$E\,(r,s,i) = N\,(r,i)\,P_X\,(r,s,i)\,X\,(r,s,i) \tag{15.30}$$

Furthermore, when Eqs. (15.29), (15.24), (15.28), and (15.23) are substituted to Eq. (15.30), the following equation is obtained:

$$E\,(r,s,i) = N(r,i)^{\frac{1-\sigma_C(i)}{1-\sigma_D(i)}}\,\tau(r,s,i)^{1-\sigma_C(i)}\,P(r,i)^{1-\sigma_C(i)}\,P_C(s,i)^{\sigma_C(i)}\,C\,(s,i) \tag{15.31}$$

Appendix 2: Expenditures in the Production Sector

In the same way as in the final demand sector, the cost minimization problem can be solved under the production function, so that the inputs of the production sector are as follows:

$$F(s,j) = \frac{\alpha_F(s,j)\,P_A(s,j)\,Q(s,j)}{P_F(s,j)} \tag{15.32}$$

$$L(s,j) = \alpha_L(s,j)\left(\frac{P_L(s)}{P_F(s,j)}\right)^{-\sigma_F(j)} F(s,j) \tag{15.33}$$

$$K(s,j) = \alpha_K(s,j)\left(\frac{P_K}{P_F(s,j)}\right)^{-\sigma_F(j)} F(s,j) \tag{15.34}$$

$$C(s,i,j) = \frac{\alpha_C(s,i,j)\,P_A(s,j)\,Q(s,j)}{P_C(s,i,j)} \tag{15.35}$$

$$D(r,s,i,j) = \left(\frac{P_D(r,s,i,j)}{P_C(s,i,j)}\right)^{-\sigma_D(i)} C(s,i,j) \tag{15.36}$$

$$X(r,s,i,j,k) = \left(\frac{P_X(r,s,i)}{P_D(r,s,i,j)}\right)^{-\sigma_Z(i)} D(r,s,i,j) \tag{15.37}$$

where:

$$P_A(s,j) = \left(\frac{P_F(s,j)}{\alpha_F(s,j)}\right)^{\alpha_F(s,j)} \prod_i \left(\frac{P_C(s,i,j)}{\alpha_C(s,i,j)}\right)^{\alpha_C(s,j)} \tag{15.38}$$

$$P_F(s,j) = \left\{\alpha_L(s,j)\,P_L\Big(s,j\Big)^{1-\sigma_F(i)} + \alpha_K\Big(s,j\Big)P_K\Big(s,j\Big)^{1-\sigma_F(i)}\right\}^{\frac{1}{1-\sigma_F(i)}} \tag{15.39}$$

$$P_C(s,i,j) = \left\{\sum_r P_D(r,s,i,j)^{1-\sigma_C(i)}\right\}^{\frac{1}{1-\sigma_C(i)}} \tag{15.40}$$

$$P_D(r,s,i,j) = \left\{\sum_{k=1}^{N(r,i)} P_X(r,s,i)^{1-\sigma_D(i)}\right\}^{\frac{1}{1-\sigma_D(i)}} \tag{15.41}$$

where $P_A(s,j)$ is the producer price of differentiated goods of industry j in region s, $P_F(s,j)$ is the price of value-added goods of industry j in region s, $P_C(s,i,j)$ is the consumer price of composite goods of industry j in region s, and $P_D(r,s,i,j)$ is the consumer price in region r of differentiated goods of industry j in region s.

Equations (15.41) and (15.37) are as follows:

$$P_D(r,s,i,j) = N(r,i)^{\frac{1}{1-\sigma_D(i)}} P_X(r,s,i) \tag{15.42}$$

$$X(r,s,i,j,k) = X(r,s,i,j) = N(r,i)^{\frac{\sigma_D(i)}{1-\sigma_D(i)}} D(r,s,i,j) \tag{15.43}$$

Then, the expenditure on the industry is as follows:

$$E(r,s,i,j) = N(r,i)\, P_X(r,s,i)\, N(s,j)\, X(r,s,i,j) \tag{15.44}$$

Furthermore, by substituting Eqs. (15.43), (15.36), (15.42), and (15.23) into Eq. (15.44), the following equation is obtained:

$$E(r,s,i,j) = N(r,i)^{\frac{1-\sigma_C(i)}{1-\sigma_D(i)}} \tau(r,s,i)^{1-\sigma_C(i)} P(r,i)^{1-\sigma_C(i)} P_C(s,i,j)^{\sigma_C(i)} N(s,j)\, C(s,i,j) \tag{15.45}$$

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Chapter 16
Performance Rankings of Asia-Pacific Supercities by Means of Data Envelopment Analysis

Soushi Suzuki, Karima Kourtit, and Peter Nijkamp

Abstract Over the past decades, the Asia-Pacific Rim has exhibited an unprecedented high degree of economic and geographic dynamics. Clearly, cities in this region display heterogeneity in terms of economic performance, technological innovativeness, environmental conditions and cultural recognition and interaction. It is, therefore, interesting to develop an efficiency ranking of the multidimensional performance of these large cities. The first aim of this chapter is now to undertake a multifaceted performance ranking of large cities in the Asia-Pacific region by using a DEA (data envelopment analysis). A second aim of the present chapter is to perform a sensitivity analysis on the type of DEA employed, so as to test the robustness of the base ranking obtained from a standard DEA. A third aim of the chapter is to present a performance improvement projection based on the original DEA model and our new projection model for inefficient cities. These three aims of the research will be empirically addressed by using a comprehensive data set on seven quantitative main indicators regarding economic performance, technological innovativeness, environmental conditions and cultural recognition and interaction for 13 Asia-Pacific supercities.

Keywords Asia-Pacific supercities · Efficiency ranking · DEA (data envelopment analysis) · DFM (distance friction minimization) model

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16.1 Introduction

Our planet is increasingly showing the signs of an urbanized geographical settlement structure. This *New Urban World* (see Kourtit 2014, 2015) marks a historical breakthrough compared to previous settlement patterns: rurality as a dominant geographical characteristic of our world is replaced by urbanity. This historical mega-trend manifests itself most clearly in the share of people in a country or region that resides in a city or urban (or metropolitan) area. This urbanization rate has shown a rapid rise in the past two centuries; it rose from 10 to 15% in the pre-Napoleonic time to over 50% worldwide, with an urbanization degree of about 70 to 80% in most OECD countries. And for the time being, there is no foreseeable standstill to this mega-trend. Various projections indicate that by the middle of this century the urbanization rate on our planet will have increased to over 75%.

This drastic change in the geography of our world is not just a neutral spatial redistribution of people. It is the consequence of major socioeconomic, technological, logistic, climatological, political and institutional changes in our world, in which the economies of agglomeration have become a powerful force for a rise in geographic density, proximity and connectivity (see Nijkamp 2016). In this context, urban agglomerations have become the engines of economic, technological, political and social power. Consequently, cities are not passive actors in a dynamic and open world geography. Instead, the awareness is rapidly growing that major agglomerations—especially megacities with more than 10 mln inhabitants—become the new 'control and command centres' of our world (Sassen 1991). Such large urban areas become contemporaneous influential magnets for economic activity, in combination with their creative, cognitive and innovative ability. Their historically centripetal and centrifugal impact is now extended from their traditional hinterlands to a worldwide scale in a globalizing economy.

The consequence of the above sketched development is that cities have turned into active players in the global geography of our world, with the inevitable result that they will have to maintain or expand their position. In tandem with the worldwide globalization trend, urban agglomerations have nowadays a permanent drive to perform better, so as to increase their global recognition or their place on the worldwide economic performance ladder. Indeed, cities have become performance-driven agents which are involved—directly or indirectly—in a global competition in terms of recognition or achievement. We call this trend here the 'search for supercities', viz. the ambition of urban agglomerations in our world to perform better than others.

The measurement of urban performance calls for an appropriate methodological approach, in which the output-input ratio of cities will be interpreted as a performance measure (in economics usually called efficiency or productivity). The assessment of urban output achievement and urban input efforts is, however, fraught with many operational problems. In the past decades, a very effective instrument has been developed and employed, called data envelopment analysis (DEA), which is able to confront a multidimensional set of outputs with a multidimensional set of inputs (see Charnes et al. 1978; Suzuki and Nijkamp 2017). DEA has become an important performance method. This approach will be adopted here, be it in various adjusted forms.

The main aim of the chapter is now to test the robustness of DEA results—applied to the performance of various Asia-Pacific cities (13 in total)—against variations in the number of outputs, the number of inputs, the number of actors and the type of DEA used. In the present chapter, a very detailed and extensive database on Asia-Pacific cities will be used, with a view to explore whether changes in the database or in the methodological base will lead to a change in the performance ranking of the Asia-Pacific cities investigated.

The chapter is organized as follows. After this introductory section, we will offer in Sect. 16.2 a concise sketch of urban dynamics in the Asia-Pacific region, while we will also introduce DEA as a methodological instrument to perform a sensitivity analysis on the efficiency ranking of the 13 Asia-Pacific cities under consideration. Next, Sect. 16.3 will be devoted to a more detailed description of the urban database used, which originates from the so-called GPCI data system provided by the Mori Memorial Foundation in Japan. The core of the analysis is formed by Sect. 16.4, which contains a description of the various sensitivity analyses to be carried out on the data and on the methods. In Sect. 16.5, we present an efficiency improvement projection based on original DEA model and our new model for inefficient cities. The final section provides all results from the sensitivity analyses and interprets these findings and offers conclusions and prospects for further research.

16.2 Data Envelopment Analysis as a Tool for Tracing Asia-Pacific Supercities

The Asia-Pacific Rim has over the past decades shown an unprecedented multi-faceted dynamics. From a largely underdeveloped region after WWII, it has turned into one of the main vibrant heartlands of the global economy. The initially selective set of the previous 'Asian tigers' in the 1980s has gradually been extended towards a modern competitive region with powerful mega-economies such as China and India. This development has deeply impacted the world economy and the economic geography of our world.

The dynamics of the Asia-Pacific area is also reflected in the growth of urban agglomerations in this region. The rise of megacities (e.g. Tokyo, Beijing, Shanghai, Singapore) is a clear sign of the underlying far-reaching economic, social, political and demographic transformations of the countries involved. All such cities are increasingly becoming economic and technological powerhouses with a worldwide impact. At the same time, they are involved in a fierce competition so as to be recognized as a high-performing supercity, in terms of economic performance, technological innovativeness, environmental conditions and cultural recognition and interaction. Through smart specialization and creative development, they try to climb as high as possible on the global competitiveness ladder. Despite a foreseen population decline in various countries (e.g. China, Japan), it turns out that their megacities are still rising (to the detriment of rural areas).

As mentioned in the introduction of this chapter, DEA has become an established scientific analysis instrument to assess the compound performance of agents (including cities), by estimating the generalized efficiency of these agents (i.e. cities) through the calculation of combined output and input achievements. Various introductions into DEA and applications to urban efficiency rankings can be found in Borger and Kerstens (1996), Worthington and Dollery (2000), Afonso and Fernandes (2006), Suzuki et al. (2008), Nijkamp and Suzuki (2009), Kourtit et al. (2013) and Suzuki and Nijkamp (2017). This large number of applied studies shows that an operational analysis of urban efficiency in a competitive environment is an important but also intriguing research topic on the regional science literature.

We will apply in the present study DEA as a tool to arrive at a ranking of various Asia-Pacific cities (13 in total). We will perform a sensitivity analysis on the database for these Asia-Pacific cities, along various relevant dimensions of completeness and accuracy of the information. In addition, we will use two types of DEA methodology, namely, the Charnes, Cooper and Rhodes approach (usually abbreviated as the CCR model) and the slack-based measure (SBM) model, by employing both models for a so-called super-efficiency DEA method. The basic CCR model was originally developed by Charnes et al. (1978). Over the past decades, a wide range of adjustments and revisions has been implemented, so as to cope with weak elements, limitations or specific needs of DEA model applications. A specific feeble element of a standard CCR model is that all efficient actors have an identical score, equal to 1.0.

An interesting new endeavour was developed by Anderson and Petersen (1993) who developed the super-efficiency (SE hereafter) model based on the initial CCR model so as to arrive at a complete ranking of all efficient decision-making units (DMUs) (even though they have all an efficiency score equal to 1.0). The efficiency scores from an SE model are then obtained by eliminating the data on the DMU to be evaluated from the solution set to examine its relative effect. These values are then used to rank the initial efficient DMUs, and consequently, efficient DMUs may then obtain an efficiency score above 1.0, while the scores of all inefficient DMUs remain identical and below 1.0.

We will also use here an adjusted version of a standard DEA model, namely, a slack-based measure (SBM) model which was developed by Tone (2001). The main distinction between the standard CCR model and the SBM model is related to the use of a radial-type model and non-radial-type model, respectively. A shortcoming of a radial model is the neglect of slacks in computing the efficiency score. Consequently, the radial-type model may bias and overestimate the efficiency score. In contrast, the non-radial-type models including the SBM model deal with a slack directory. Hence, an SBM model can mitigate the overestimating problem. The SBM model was also developed as an SE-type model (see Tone 2002). We will use in our analysis both the CCR input- and the SBM input-type model based on an SE model.

Based on a performance measurement results, we can identify inefficient cities, and these cities may need some effort for their performance improvement. Therefore, we present an efficiency improvement projection based on CCR, SBM and our original model, namely, distance friction minimization (DFM) model (more detail, see Suzuki et al. (2010) and Suzuki and Nijkamp (2017)). CCR model has only focused on a uniform input reduction or a uniform output augmentation function in the improvement projections. SBM model is representative for the class of non-radial models, which focus only on the presence or absence of slacks in input-output space. This model generally assume an equality for each weight related to input and output items, so that a characteristic feature for each input-output item for each DMU is that it does not take into account an efficiency improvement projection. Our DFM model can evaluate the relative importance of each item with reference to the value of each input. The same holds for each output, where optimum weights of one output item provide a measure of the relative contribution of one output item to the overall value or efficiency score. These values show not only which items contribute to the performance of DMUs but also to what extent they do so. In other words, it is possible to express and quantify the distance frictions (or, alternatively, the potential increases) in improvement projections. A cornerstone of the DFM model is that it focuses on the features of an actor and capitalizes the actor's strength; in other words, it develops the actor's strength in its improvement. Then, we compare these projection results and present a several alternative improvement projection for inefficient cities.

In the next section, we will first introduce the GPCI database and the selection of the 13 Asia-Pacific cities, followed by a sensitivity experiment of various types of DEA models.

16.3 The Database and Analytical Framework for the Asia-Pacific Cities

For a systematic operational comparison of Asia-Pacific cities' performance outcomes, our empirical approach uses a unique and extensive data set on measurable indicators for the cities under consideration, viz. the Global Power City Index (GPCI), produced by the Institute for Urban Strategies and organized by the Mori Memorial Foundation (2016) in Tokyo. We will use here very recent data for the year 2016, which offer a great potential for a comparative benchmark analysis for the Asia-Pacific large cities. The GPCI database will thus be used here as a strategic tool to evaluate and to rank the comprehensive strategic power determinants of 13 major cities in this region, in terms of their strengths and their weaknesses.

The GPCI database is a multi-annual worldwide data system on large cities, in which the comprehensive performance scores and rankings of these global cities are based on six main assessment categories, namely, *economy*, *research and development*, *cultural interaction*, *livability*, *environment* and *accessibility*. Each of these main indicator classes is subdivided into a set of appropriate and measurable sub-indicators, so that finally a strictly consistent and carefully tested database on approx. 70 sub-indicators related to many world cities (40 in total) is created. The 70 indicators break down into 59 indicators based on statistics or numerical data and 11 indicators using original questionnaires, some of which combine the score of the questionnaire with numerical data. Acquisition of data is as follows:

1. Statistical materials (59 indicators).
   (a) Whenever possible, official statistics are used as main sources of data.
   (b) Quantitative data not derived from official statistics is taken from source such as academic research papers or other forms of publication which are clearly sourced.
2. Original questionnaires (11 indicators).
   (a) Questionnaires for residents and workers aimed at those living and/or working in a target city.
   (b) Questionnaires of experts aimed at those with experiences living in and/or visiting multiple target cities.

This database is published annually since 2009. The 13 Asia-Pacific cities used in our analysis are taken from this database. All further details are available in the above-mentioned GPCI report.

In our presentation we refer now to the 'score by indicator' data sets in the GPCI report. Most of these indicator data are converted into a standardized indicator value, falling in between 100 and 0, so that the data can be evaluated according to a uniform standard measurement. The highest performance of an indicator receives a score equal to 100 and the poorest a score of 0. However, since a higher value for cost indicators (such as for risk and CO_2 emission) necessarily means essentially a low assessment score, the value assignment scale was converted for these indicators (i.e. the highest score of a cost item is 0 and the lowest score is 100).

We will now use for our benchmark analysis a selected set of relevant input and output data of the GPCI-2016 study for a set of 13 large Asia-Pacific cities to evaluate and compare their economic performance, technological innovativeness, environmental conditions and cultural interaction efficiency. The DMUs (decision-making units or cities) used in our comprehensive analysis are listed in Table 16.1.

As shown in Table 16.1, we have selected as relevant DMUs the available set of 13 Asia-Pacific cities from the GPCI system. For our comparative performance analysis of the cities under consideration, we consider as evaluation criteria the following: economic performance, technological innovativeness, environmental conditions and cultural recognition and interaction. Based on this viewpoint, we will select and introduce now three relevant input and two relevant output items as follows:

Input (I):

- (I1) Total employees (EMP, hereafter)
- (I2) Research and development (R&D) expenditures (R&D, hereafter)

Table 16.1 List of DMUs

No	DMUs
1	Bangkok
2	Beijing
3	Fukuoka
4	Hong Kong
5	Kuala Lumpur
6	Mumbai
7	Osaka
8	Seoul
9	Shanghai
10	Singapore
11	Sydney
12	Taipei
13	Tokyo

Table 16.2 Indicators of cultural recognition and interaction

Indicator type	Indicator
Cultural resources	Environment of creative activities
	Number of World Heritage Sites (within 100 km area)
	Opportunities of cultural, historical and traditional interaction
Facilities for visitors	Number of theatres and concert halls
	Number of museums
	Number of stadiums
Attractiveness to visitors	Number of guest rooms of luxury hotels
	Number of hotels
	Level of satisfaction for shopping
	Level of satisfaction for dining
Volume of interaction	Number of foreign residents
	Number of visitors from abroad
	Number of international students

- (I3) Cultural interaction (the score of this item was calculated by adding up the indicator scores in Table 16.2) (CI, hereafter)

Output (O):

- (O1) GDP
- (O2) Environment (the score of this item was calculated by adding up the indicator scores in Table 16.3) (ENV, hereafter)

Indicators using original questionnaires are 'environment of creative activities', 'opportunities of cultural', 'level of satisfaction for shopping' and 'level of satisfaction for dining' in Table 16.2. All other indicators are based on statistical materials.

Regarding the number of DMUs, input and output items, Dyson et al. (2001) suggested a 'rule of thumb' that to achieve a reasonable level of discrimination,

Table 16.3 Indicator of environment

Indicator
CO_2 emissions
Density of suspended particulate matter (SPM)
Density of sulphur dioxide (SO_2), density of nitrogen dioxide (NO_2)

the practitioner needs a number of DMUs to be at least 2× (number of input items × number of output items). For example, in case of three inputs and two outputs like as this study, a number of DMUs of at least 12 is needed. In this study, we can acquire data in Asia-Pacific cities no more than 13 DMUs, and then we have to carefully select a number of inputs and outputs. This is a reason why only 3 inputs and 2 outputs in 13 cities, total of only 78 of data, are used.

Furthermore, this study only used 2016 data set, but a main aim of this study is to show a robustness of the performance ranking of cities. The time series trend of the performance ranking of cities may still be expected in the future research topics.

16.4 Sensitivity Analysis for DEA Applications

16.4.1 A Sensitivity Analysis Matrix

As mentioned above, one of the main challenges of the present study is to perform a robustness analysis on the application of DEA to 13 Asia-Pacific cities. We will undertake this robustness analysis in two steps, viz. (A) a sensitivity analysis on several methodological variants of a DEA and (B) a sensitivity analysis on the number of input items and output items and on the number of DMUs (or cities).

(A) *Sensitivity of DEA Regarding Methodological Features*

In this part of the study, we will address the impact of shifts in methodological approaches to a DEA. We will pay particular attention to the following sensitivity experiments, using two types of super-efficient (SE) DEA models:

- A1: SE-CCR (a sensitivity test on the effect of an SE-CCR model for the city rankings).
- A2: SE-SBM (a sensitivity test on the impact of an SE-SBM model on the city rankings).

(B) *Sensitivity of DEA for Shifts in Information Base*

We will now successively undertake the following experiments on the sensitivity of DEA results in relation to variations on the information side of the DEA used:

- B1: Input elimination (the change in DEA outcomes as a consequence of a change in the number of input items in the DEA).

- B2: Output elimination (the change in DEA results as a consequence of a change in the number of output items in the DEA).
- B3: Efficient DMU elimination (the change in DEA results as a consequence of a change in the number of DMUs in the DEA; this holds only for efficient DMUs). Clearly, if we eliminate inefficient DMUs from the DMU set, the efficiency scores for the DMUs will not change. Conversely, if we eliminate any efficient DMU, the efficiency scores will certainly change to a greater or lesser extent.

It should be noted that the above-mentioned sensitivity analyses described at A and B can be performed separately, but they can also be performed in various combinations of A and B, as is illustrated in the following integral sensitivity matrix (see Table 16.4).

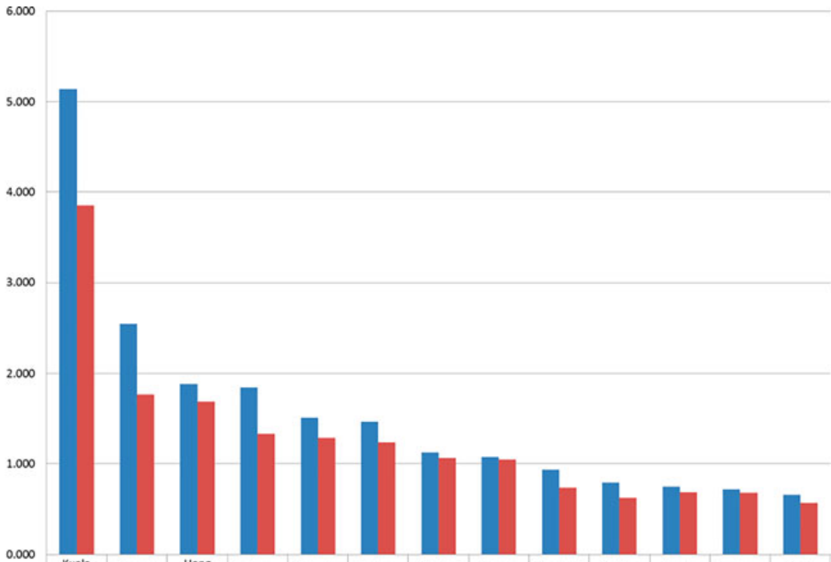
Table 16.4 A sensitivity analysis matrix for DEA

A: Methodological sensitivity B: Information sensitivity	A1: Super efficiency (SE)-CCR	A2: Super efficiency (SE)-SBM
B1:3I (input)-2O (output)-13DMUs	SE-CCR-3I-2O-13DMUs	SE-SBM-3I-2O-13DMUs
2I (with elimination on CI)-2O-13DMUs	SE-CCR-2I(eli CI)-2O	SE-SBM-2I (eli CI)-2O
2I (with elimination on R&D)-2O-13DMUs	SE-CCR-2I(eli R&D)-2O	SE-SBM-2I (eli R&D)-2O
1I (with elimination on CI and R&D)-2O-13DMUs	SE-CCR-1I(eli CI and R&D)-2O	SE-SBM-1I(eli CI and R&D)-2O
B2: 3I-1O (with elimination on GDP)-13DMUs	SE-CCR-3I-1O (eli GDP)	SE-SBM-3I-1O(eli GDP)
3I-1O (with elimination on ENV)-13DMUs	SE-CCR-3I-1O (eli ENV)	SE-SBM-3I-1O (eli ENV)
B3:3I (input)-2O (output)-12DMUs (with elimination on Bangkok)	SE-CCR-eli BAN	SE-SBM-eli BAN
3I (input)-2O (output)-12DMUs (with elimination on Fukuoka)	SE-CCR-eli FUK	SE-SBM-eli FUK
3I (input)-2O (output)-12DMUs (with elimination on Hong Kong)	SE-CCR-eli HON	SE-SBM-eli HON
3I (input)-2O (output)-12DMUs (with elimination on Kuala Lumpur)	SE-CCR-eli KUA	SE-SBM-eli KUA
3I (input)-2O (output)-12DMUs (with elimination on Mumbai)	SE-CCR-eli MUM	SE-SBM-eli MUM
3I (input)-2O (output)-12DMUs (with elimination on Sydney)	SE-CCR-eli SYD	SE-SBM-eli SYD
3I (input)-2O (output)-12DMUs (with elimination on Taipei)	SE-CCR-eli TAI	SE-SBM-eli TAI
3I (input)-2O (output)-12DMUs (with elimination on Tokyo)	SE-CCR-eli TOK	SE-SBM-eli TOK

16.4.2 Results of Sensitivity Analysis in SE-CCR and SE-SBM Models

The efficiency evaluation result for the 13 Asia-Pacific cities based, respectively, on the SE-CCR model and the SE-SBM model using the above-mentioned 3 input-2 output database is presented in Fig. 16.1. The rankings for both types of models appear to be entirely identical. Also the pattern of efficient and inefficient cities among these 13 cities is entirely robust. From Fig. 16.1, it can also be seen that Kuala Lumpur, Bangkok, Hong Kong, Sydney, Fukuoka, Tokyo, Mumbai and Taipei are regarded as super-efficient cities. In contrast, Shanghai, Beijing, Osaka, Singapore and Seoul are evaluated as inefficient or less efficient cities. These cities may need an additional boost and an extra effort for improving their performance.

It also can be seen that the rank orders for the pairs of SE-CCR-3I-2O-13DMUs and SE-SBM-3I-2O-13DMUs offer completely identical results. These results demonstrate a robustness of performance rankings of the Asia-Pacific supercities from the viewpoint of a methodological sensitivity. The result for these two cases may be used as a comparative benchmark for our sensitivity analysis.



	Kuala Lumpur	Bangkok	Hong Kong	Sydney	Fukuoka	Tokyo	Mumbai	Taipei	Shanghai	Beijing	Osaka	Singapore	Seoul
SE-CCR-3I-2O-13DMUs	5.140	2.541	1.884	1.846	1.509	1.467	1.126	1.075	0.940	0.793	0.746	0.718	0.659
SE-SBM-3I-2O-13DMUs	3.852	1.767	1.691	1.332	1.287	1.239	1.064	1.049	0.740	0.625	0.690	0.682	0.570

Fig. 16.1 Efficiency scores based on the SE-CCR and SE-SBM model

16.4.3 Results of Sensitivity Analysis on Information Variation

Sensitivity Analysis for Input and Output Item Elimination

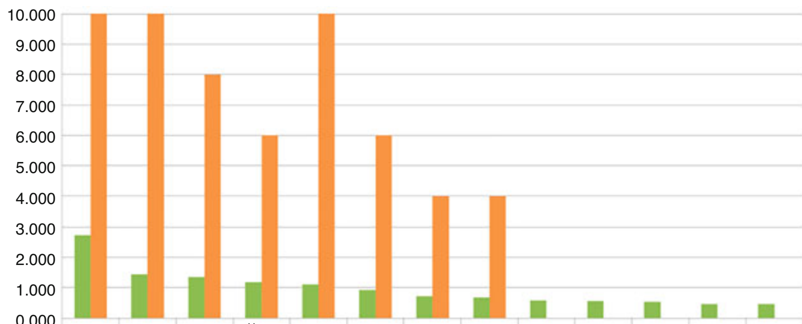
We will now carry out a sensitivity analysis on a change in the number of input and output items. The efficiency scores of the combination of A1 and A2 with B1 and B2 in Table 16.4 are shown in Fig. 16.2.

From Fig. 16.2, we notice that Kuala Lumpur and Bangkok are relatively high-scoring supercities, but their efficiency score in the case of 2I (eli R&D)-2O and 1I (eli CI and R&D)-2O appears to decrease significantly. Especially, Bangkok was even assessed in these cases as an inefficient city. In contrast, the results from Fukuoka and Sydney appear to yield stable and robust scores. From these findings, we can also compute the average scores and the number of times a city is considered to be a super-efficient DMU (i.e. number of times with a score above 1.0), as shown in Fig. 16.3.

If we compare Fig. 16.3 (as a comparative target), we observe that Sydney ranks on the second place, while the number of times it qualifies as an SE city is even 10. In contrast, Bangkok and Hong Kong have a lower rank, viz. the third and fourth place, while the number of times as an SE is also lower, viz. 8 and 6, respectively. We also notice that the rank order for inefficient cities is also significantly changing; especially, Beijing appears to shift downwards dramatically to the 13th position.

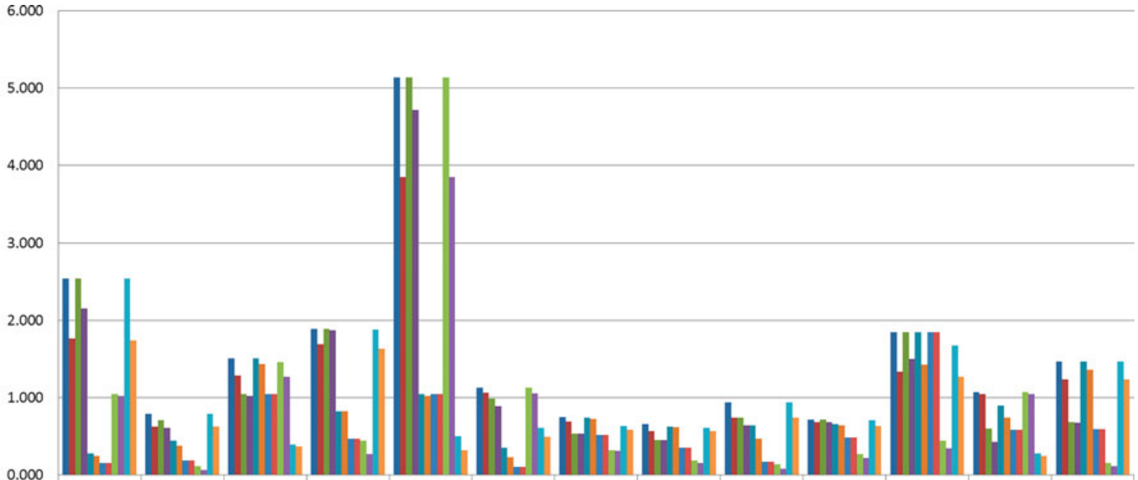
Sensitivity Analysis for Efficient DMU Elimination Case

We will now also carry out a sensitivity analysis on the efficient DMU elimination case. The efficiency scores of the combination of A1 and A2 with B3 in Table 16.4 are shown in Fig. 16.4.



	Kuala Lumpur	Sydney	Bangkok	Hong Kong	Fukuoka	Tokyo	Taipei	Mumbai	Singapore	Osaka	Shanghai	Seoul	Beijing
Ave Score	2.736	1.436	1.350	1.180	1.115	0.922	0.717	0.679	0.575	0.571	0.534	0.468	0.460
Number of times as SE	10	10	8	6	10	6	4	4	0	0	0	0	0

Fig. 16.2 Average score and number of times as a super-efficient DMU in the information elimination case



	Bangkok	Beijing	Fukuoka	Hong Kong	Kuala Lumpur	Mumbai	Osaka	Seoul	Shanghai	Singapore	Sydney	Taipei	Tokyo
SE-CCR-3I-2O	2.541	0.793	1.509	1.884	5.140	1.126	0.746	0.659	0.940	0.718	1.846	1.075	1.467
SE-SBM-3I-2O	1.767	0.625	1.287	1.691	3.852	1.064	0.690	0.570	0.740	0.682	1.332	1.049	1.239
SE-CCR-2I(Eli-CI)-2O	2.541	0.706	1.044	1.884	5.140	0.986	0.534	0.454	0.742	0.713	1.846	0.598	0.686
SE-SBM-2I(Eli-CI)-2O	2.150	0.609	1.022	1.874	4.721	0.892	0.532	0.454	0.638	0.687	1.498	0.424	0.677
SE-CCR-2I(Eli-R&D)-2O	0.282	0.448	1.509	0.824	1.049	0.357	0.739	0.626	0.642	0.659	1.846	0.896	1.467
SE-SBM-2I(Eli-R&D)-2O	0.249	0.380	1.431	0.821	1.025	0.232	0.726	0.622	0.465	0.642	1.423	0.745	1.358
SE-CCR-1I(Eli-CI, R&D)-2O	0.158	0.186	1.044	0.472	1.049	0.103	0.520	0.350	0.172	0.483	1.846	0.587	0.597
SE-SBM-1I(Eli-CI, R&D)-2O	0.158	0.186	1.044	0.472	1.049	0.103	0.520	0.350	0.172	0.483	1.846	0.587	0.597
SE-CCR-3I-1O(Eli-GDP)	1.046	0.111	1.462	0.445	5.140	1.126	0.319	0.191	0.142	0.268	0.448	1.075	0.157
SE-SBM-3I-1O(Eli-GDP)	1.018	0.062	1.267	0.275	3.852	1.053	0.311	0.153	0.079	0.221	0.349	1.049	0.112
SE-CCR-3I-1O(Eli-Env)	2.541	0.793	0.398	1.876	0.499	0.611	0.632	0.613	0.940	0.709	1.675	0.279	1.467
SE-SBM-3I-1O(Eli-Env)	1.743	0.625	0.367	1.634	0.320	0.493	0.584	0.570	0.740	0.637	1.272	0.245	1.239

Fig. 16.3 Sensitivity analysis results of a change in the number of input and output items

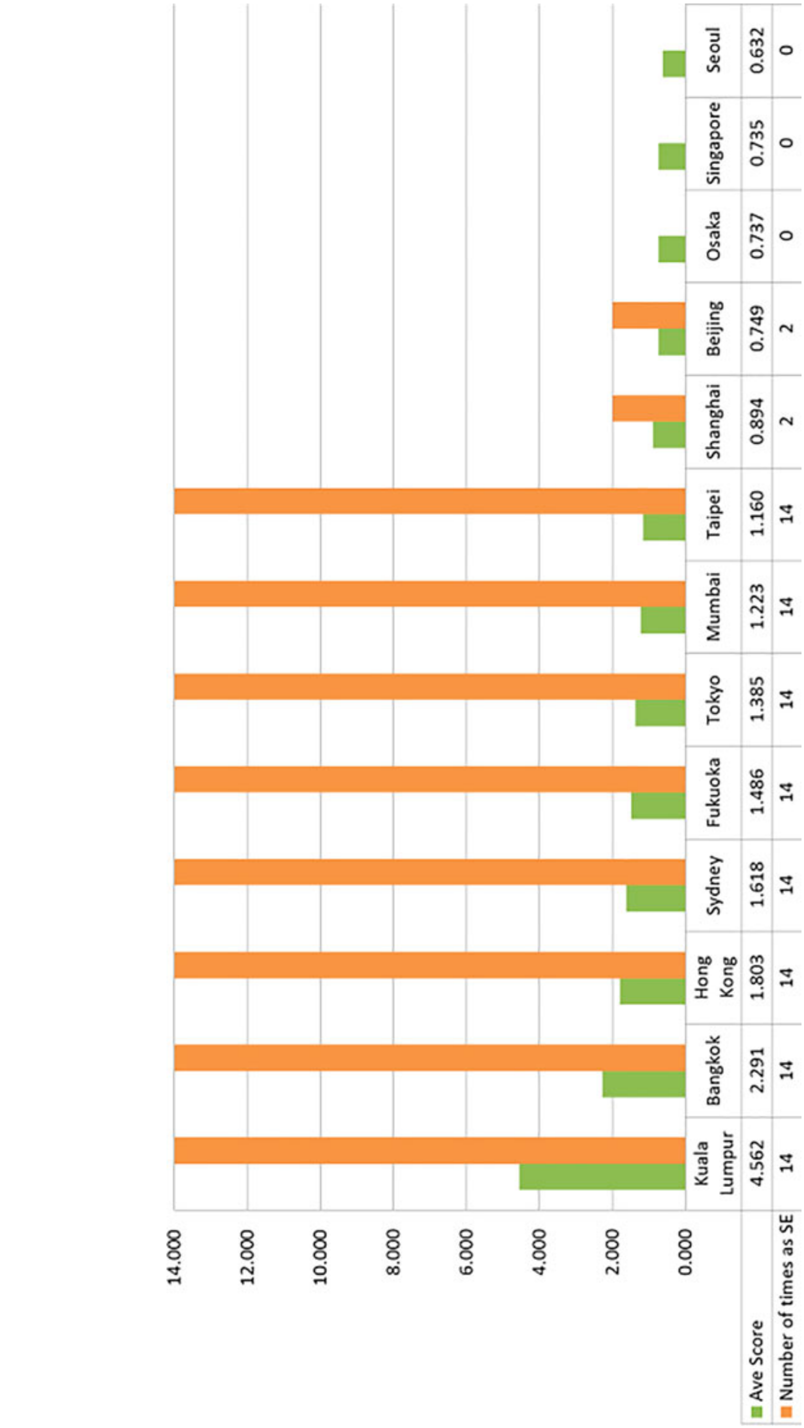


Fig. 16.4 Average score and number of times as super-efficient DMU in a DMU elimination case

In Fig. 16.4, we notice that the results were not dramatically changing. If we compute the average scores and the number of times a city is a super-efficient DMU (i.e. number of times above score 1.0, as shown in Fig. 16.5), we find interesting absolute shifts but still similar patterns.

If we compare Fig. 16.5 with Fig. 16.1 (as a comparative benchmark), then we notice that all rank orders of scores in Fig. 16.1 and Fig. 16.5 offer completely the same results.

We also notice that Shanghai and Beijing are two times evaluated as a super-efficient city. From Fig. 16.4, it can be seen that these results are both showing up for the case with the elimination of Hong Kong. This result suggests that cities in China may have similar characteristics and thus may likely have a great influence on each other.

16.4.4 Standard Deviations of the DEA Score, Optimum Weights for Input and Output Items

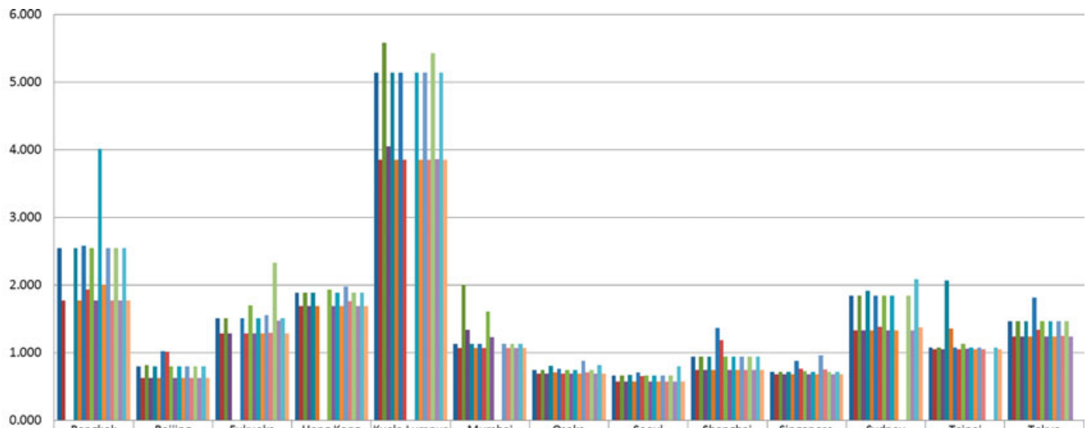
As mentioned above section, Chinese city may have similar characteristics. We especially focused on this matter, and we will analyse and consider a reason from a viewpoint of average and standard deviations of the DEA score and optimum weights for input and output items.

Average and standard deviations of the DEA score are presented in Fig. 16.6.

If we compare Fig. 16.6 with Fig. 16.1 (as a comparative benchmark), we notice that the rank order for Hong Kong and Beijing are significantly changing; Hong Kong appears to shift downwards from 3th to 4th position; especially Beijing appears to shift downwards dramatically from 10th to 12th position. We also notice that these cities scored a large SD than their similar rank cities (Hong Kong, 0.555; Beijing, 0.246); thus performance score of these cities may vary widely and be volatile.

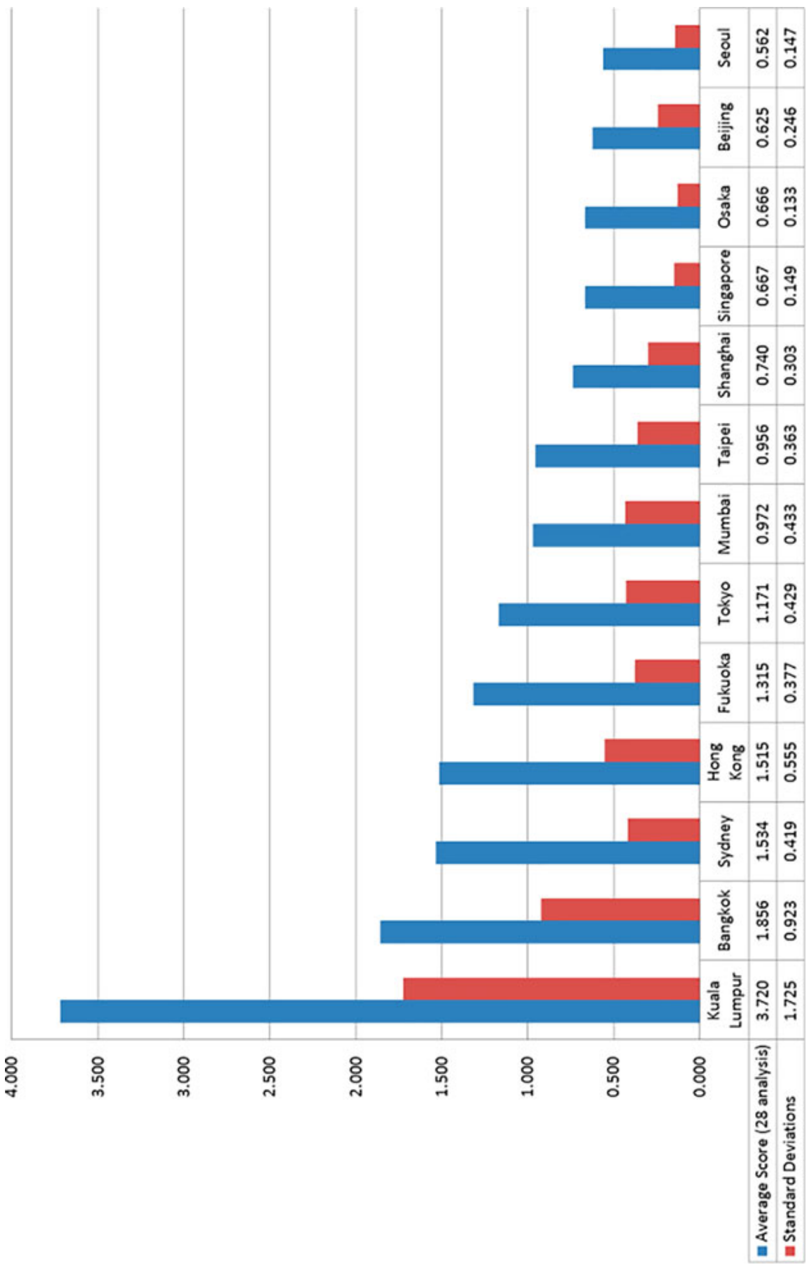
Next, optimum weight is the set of most favourable weights for each DMU, so that we can find the relative importance of each indicator with reference to the value of each input and output items for each DMU. These values show not only which items contribute to the performance of DMU but also to what extent they do so. Optimum weights for input and output items for each city are presented in Figs. 16.7 and 16.8.

From Figs. 16.7 and 16.8, it can be seen that, for instance, Hong Kong obtains a weight for employees equal to 0.492 and for R&D equal to 0.508 in its inputs, while it obtains for GDP a weight of 1.856 and for environment 0.028 in its output. It also can be seen that Shanghai obtains a weight for R&D equal to 0.090 and for cultural interaction equal to 0.910 in its inputs, while it obtains for GDP a weight of 0.940 in its output, and Beijing obtains a weight for R&D equal to 0.813 and for cultural interaction equal to 0.187 in its inputs, while it obtains for GDP a weight of 0.793 in its output.



	Bangkok	Beijing	Fukuoka	Hong Kong	Kuala Lumpur	Mumbai	Osaka	Seoul	Shanghai	Singapore	Sydney	Taipei	Tokyo
SE-CCR-3I-2O-13DMUs	2.541	0.793	1.509	1.884	5.140	1.126	0.746	0.659	0.940	0.718	1.846	1.075	1.467
SE-SBM-3I-2O-13DMUs	1.767	0.625	1.287	1.691	3.852	1.064	0.690	0.570	0.740	0.682	1.332	1.049	1.239
SE-CCR-eli-BAN		0.813	1.509	1.884	5.581	2.003	0.746	0.659	0.940	0.718	1.846	1.075	1.467
SE-SBM-eli-BAN		0.625	1.287	1.691	4.046	1.334	0.690	0.570	0.740	0.682	1.332	1.049	1.239
SE-CCR-eli-FUK	2.541	0.793		1.884	5.140	1.126	0.807	0.669	0.940	0.720	1.911	2.069	1.467
SE-SBM-eli-FUK	1.767	0.625		1.691	3.852	1.064	0.711	0.570	0.740	0.682	1.332	1.356	1.239
SE-CCR-eli-HON	2.582	1.021	1.509		5.140	1.126	0.757	0.708	1.362	0.882	1.846	1.075	1.818
SE-SBM-eli-HON	1.930	1.011	1.287		3.852	1.064	0.691	0.654	1.180	0.764	1.386	1.049	1.334
SE-CCR-eli-KUA	2.541	0.793	1.695	1.930		1.609	0.746	0.659	0.940	0.722	1.846	1.132	1.467
SE-SBM-eli-KUA	1.768	0.625	1.287	1.691		1.228	0.690	0.570	0.740	0.684	1.333	1.062	1.239
SE-CCR-eli-MUM	4.016	0.793	1.509	1.884	5.140		0.746	0.659	0.940	0.718	1.846	1.075	1.467
SE-SBM-eli-MUM	2.005	0.625	1.287	1.691	3.852		0.690	0.570	0.740	0.682	1.332	1.049	1.239
SE-CCR-eli-SYD	2.541	0.793	1.550	1.977	5.140	1.126	0.882	0.659	0.940	0.960		1.075	1.467
SE-SBM-eli-SYD	1.767	0.625	1.293	1.765	3.852	1.064	0.705	0.570	0.740	0.753		1.049	1.243
SE-CCR-eli-TAI	2.541	0.793	2.327	1.884	5.424	1.126	0.746	0.659	0.940	0.718	1.846		1.467
SE-SBM-eli-TAI	1.767	0.625	1.471	1.691	3.861	1.064	0.690	0.570	0.740	0.682	1.332		1.239
SE-CCR-eli-TOK	2.541	0.793	1.509	1.884	5.140	1.126	0.811	0.799	0.942	0.718	2.083	1.075	
SE-SBM-eli-TOK	1.767	0.625	1.287	1.691	3.852	1.064	0.690	0.570	0.740	0.682	1.375	1.049	

Fig. 16.5 Sensitivity analysis results for efficient DMUs eliminated

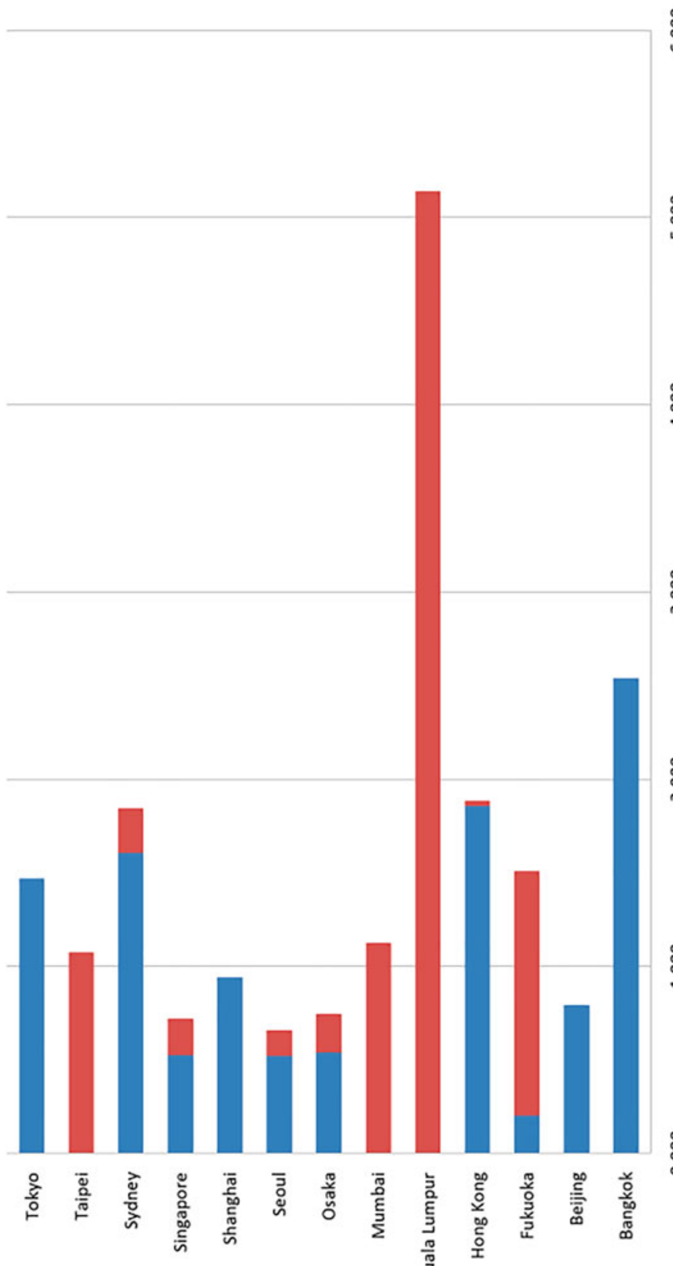


	Kuala Lumpur	Bangkok	Sydney	Hong Kong	Fukuoka	Tokyo	Mumbai	Taipei	Shanghai	Singapore	Osaka	Beijing	Seoul
Average Score (28 analysis)	3.720	1.856	1.534	1.515	1.315	1.171	0.972	0.956	0.740	0.667	0.666	0.625	0.562
Standard Deviations	1.725	0.923	0.419	0.555	0.377	0.429	0.433	0.363	0.303	0.149	0.133	0.246	0.147

Fig. 16.6 Average and standard deviations of the DEA score

	Bangkok	Beijing	Fukuoka	Hong Kong	Kuala Lumpur	Mumbai	Osaka	Seoul	Shanghai	Singapore	Sydney	Taipei	Tokyo
VX(1) Employees	0.309	0.000	0.649	0.492	0.556	0.000	0.316	0.000	0.000	0.399	1.000	0.000	0.000
VX(2) R&D	0.691	0.813	0.000	0.508	0.444	0.800	0.179	0.201	0.090	0.283	0.000	0.492	0.000
VX(3) Cultural Interaction	0.000	0.187	0.351	0.000	0.000	0.200	0.505	0.799	0.910	0.318	0.000	0.508	1.000

Fig. 16.7 Optimum weights for input items



	Bangkok	Beijing	Fukuoka	Hong Kong	Kuala Lumpur	Mumbai	Osaka	Seoul	Shanghai	Singapore	Sydney	Taipei	Tokyo
UY(1) GDP	2.541	0.793	0.203	1.856	0.000	0.000	0.540	0.521	0.940	0.526	1.605	0.000	1.467
UY(2) Environment	0.000	0.000	1.306	0.028	5.140	1.126	0.206	0.138	0.000	0.193	0.241	1.075	0.000

Fig. 16.8 Optimum weights for output items

From these finding, we notice that Chinese cities reveal features similar to optimum weights; especially, these cities have a commonality feature that has forte at R&D in input items and at GDP in output item and has weakness at environment in output item. This is thought to be the cause of why Shanghai and Beijing are two times evaluated as a super-efficient city, showing up for the case with the elimination of Hong Kong. Especially, Beijing shows more similar feature than Shanghai with Hong Kong, because the R&D score of Beijing has more weight than Shanghai, like Hong Kong. This is thought to be the cause of wide variation and volatility for Beijing. And as we mentioned above, these cities have a commonality feature that has weakness at environment in output item than other cities, and then this is thought to be the cause of low robustness for Chinese cities. It requires attention to these characteristic features in evaluation.

16.5 Efficiency Improvement Projection

16.5.1 Outline of the Distance Friction Minimization (DFM) Approach

We first give a brief description of the normal DFM approach. The standard Charnes et al. (1978) model (abbreviated hereafter as the CCR-I (input) model) for a given DMU_j ($j = 1, \cdots, J$) to be evaluated in any trial k (where k ranges over $1, 2 \ \ldots, J$) may be represented as the following fractional programming (FP_k) problem (for a full description, see Suzuki and Nijkamp 2017):

$$
\begin{aligned}
&(\text{FP}_k) \quad \max_{v,u} \ \theta = \frac{\sum_s u_s y_{sk}}{\sum_m v_m x_{mk}}, \\
&\text{s.t.} \ \frac{\sum_s u_s y_{sj}}{\sum_m v_m x_{mj}} \le 1 \quad (j = 1, \cdots, J), \\
&v_m \ge 0, \quad u_s \ge 0,
\end{aligned}
\tag{16.1}
$$

where θ represents an objective variable 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 often called an input-oriented CCR model, while its reciprocal (i.e. an interchange of the numerator and denominator in the objective function (16.1) with a specification as a minimization problem under an appropriate adjustment of the constraints) is usually known as an output-oriented CCR model. Model (16.1) is obviously a fractional programming model, which may be solved stepwise by first assigning an arbitrary value to the denominator in (16.1) and next maximizing the numerator (see also Suzuki et al. 2010).

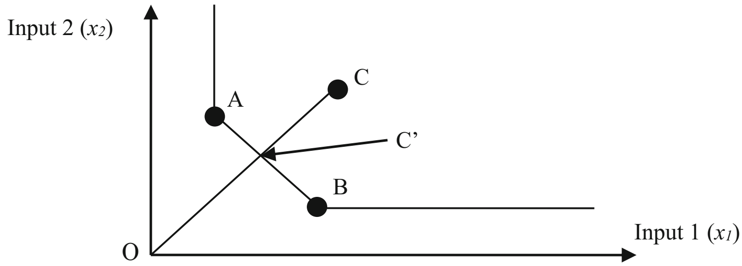


Fig. 16.9 Illustration of the original DEA projection in input space

The improvement projection $\left(\hat{x}_k, \hat{y}_k\right)$ can now be defined in (16.2) and (16.3) as:

$$\hat{x}_k = \theta^* x_k - s^{-*}; \tag{16.2}$$

$$\hat{y}_k = y_k + s^{+*} \tag{16.3}$$

These equations indicate that the efficiency of (x_k, y_k) for DMU_k can be improved if the input values are reduced radially by the ratio θ^* and the input excesses s^{-*} are eliminated (see Fig. 16.9). It should be noted that the original DEA models presented in the literature have focused on a uniform input reduction or on a uniform output increase in the efficiency improvement projections, as shown in Fig. 16.1 ($\theta^* = \text{OC}'/\text{OC}$).

The (v^*, u^*) values obtained as an optimal solution for formula (16.1) result in a set of optimal weights for DMU_k. Hence, (v^*, u^*) is the set of the most favourable weights for DMU_k, measured on a ratio scale. Thus, $v_m{}^*$ is the optimal weight for 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 output item s. These values show not only which items contribute to the performance of DMU_k but also the extent to which they do so. In other words, it is possible to express the distance frictions (or alternatively, the potential increases) in improvement projections.

Next, we use next the optimal weights $u_s{}^*$ and $v_m{}^*$ from (16.1) and then describe the efficiency improvement projection model (see also Suzuki et al. 2010). In this approach, a generalized distance indicator is employed to assist a DMU to improve its efficiency by a movement towards the efficiency frontier surface. Of course, the direction of the efficiency improvement depends on the input-output data characteristics of the DMU. It is now appropriate to define the projection functions for the minimization of distance by using a Euclidean distance in weighted space. As mentioned earlier, a suitable form of multidimensional projection function 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. This 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 might address both an input reduction and output increase. Here, we will only briefly sketch the various steps (for more details, we refer to Suzuki and Nijkamp 2017).

First, the distance functions Fr^x and Fr^y are specified by means of (16.4) and (16.5), which are defined by the Euclidean distance. Next, the following MOQP is solved by using d_{mk}^x (a reduction of distance for x_{mk}) and d_{sk}^y (an increase of distance for y_{sk}) as variables:

$$\min Fr^x = \sqrt{\sum_m \left(v_m^* x_{mk} - v_m^* d_{mk}^x\right)^2}, \tag{16.4}$$

$$\min Fr^y = \sqrt{\sum_s \left(u_s^* y_{sk} - u_s^* d_{sk}^y\right)^2}, \tag{16.5}$$

$$\text{s.t. } \sum\nolimits_m v_m^* \left(x_{mk} - d_{mk}^x\right) = \frac{2\theta^*}{1+\theta^*}, \tag{16.6}$$

$$\sum\nolimits_s u_s^* \left(y_{sk} + d_{sk}^y\right) = \frac{2\theta^*}{1+\theta^*}, \tag{16.7}$$

$$x_{mk} - d_{mk}^x \geq 0, \tag{16.8}$$

$$d_{mk}^x \geq 0, \tag{16.9}$$

$$d_{sk}^y \geq 0, \tag{16.10}$$

where x_{mk} is the amount of input item m for any arbitrary inefficient DMU_k, while y_{sk} is the amount of output item s for any arbitrary inefficient DMU_k. The constraint functions (16.6) and (16.7) 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 sides contribute according to their initial levels 1 and θ^*, 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 targets and the output augmentation targets with the following expressions:

Input reduction target:

$$\sum\nolimits_m v_m^* \left(x_{mk} - d_{mk}^x\right) = 1 - \left(1 - \theta^*\right) \times \frac{1}{(1+\theta^*)} = \frac{2\theta^*}{1+\theta^*}, \tag{16.11}$$

Output augmentation target:

$$\sum\nolimits_s u_s^* \left(y_{sk} + d_{sk}^y\right) = \theta^* + \left(1 - \theta^*\right) \times \frac{\theta^*}{(1+\theta^*)} = \frac{2\theta^*}{1+\theta^*}. \tag{16.12}$$

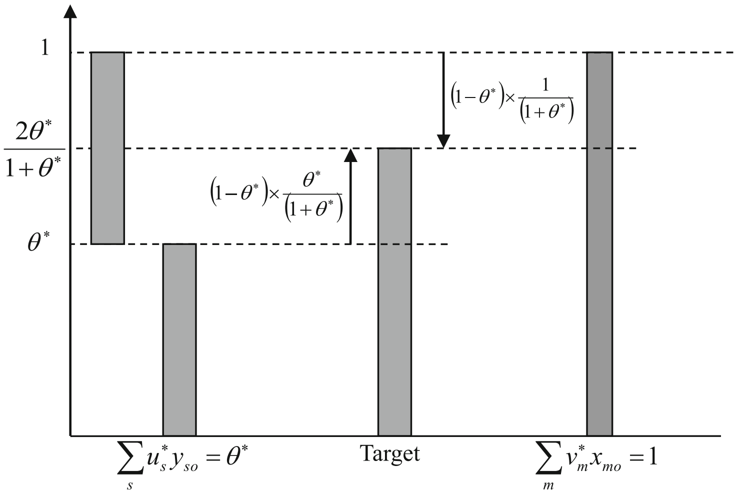


Fig. 16.10 The DFM model with an illustration of the relative contribution of inputs and outputs to closing the efficiency gap

An illustration of this approach is given in Fig. 16.10.

It is now possible to determine each optimal distance d_{mk}^{x*} and d_{sk}^{y*} by using the MOQP model (16.4)–(16.10). The distance minimization solution for an inefficient DMU_k can be expressed by means of formulas (16.13) and (16.14):

$$x_{mk}^* = x_{mk} - d_{mk}^{x*}; \tag{16.13}$$

$$y_{sk}^* = y_{sk} + d_{sk}^{y*}. \tag{16.14}$$

By means of the DFM model described above, it is possible to present a new efficiency improvement solution based on the standard CCR projection. This means an increase in new promising options for efficiency improvement strategies 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. 16.11).

16.5.2 *Efficiency Improvement Projection Based on CCR, SBM and DFM model*

Based on performance measurement results, we can identify inefficient cities, and these cities (Beijing, Osaka, Seoul, Shanghai and Singapore) may need some effort for their performance improvement. An efficiency improvement projection based

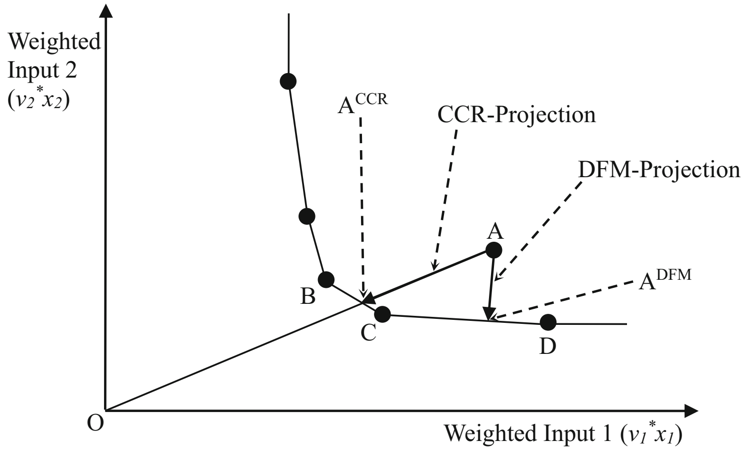


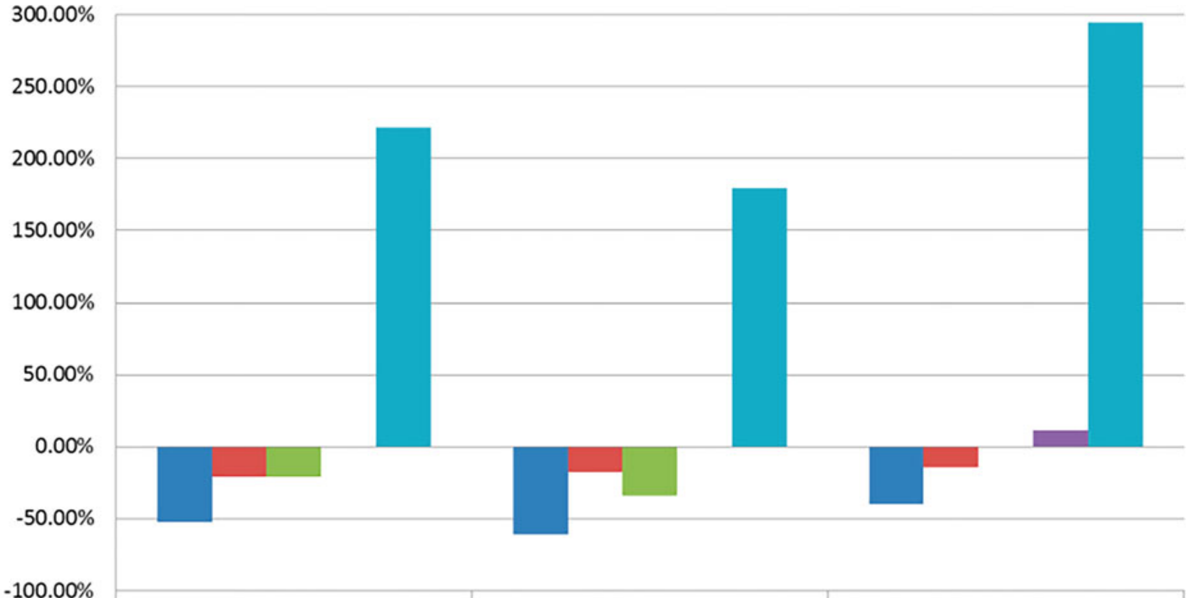
Fig. 16.11 Degree of improvement of the DFM and the CCR projection in weighted input space

on CCR, SBM and DFM model is presented in Figs. 16.12, 16.13, 16.14, 16.15 and 16.16.

In Figs. 16.12, 16.13, 16.14, 16.15 and 16.16, it appears that the ratios of change in the DFM projection are smaller than those in the CCR and SBM projection, as was expected. In Figs. 16.12, 16.13, 16.14, 16.15 and 16.16, this particularly applies to Osaka, Seoul and Singapore which are non-slack-type cities (Slack are zero). 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 Seoul in Fig. 16.14 should reduce the R&D and cultural interaction by 34.10% and its employees by 35.81% in order to become efficient. The SBM projection shows that Seoul in Fig. 16.11 should reduce the employees by 25.90%, the R&D by 82.97% and cultural interaction by 20.12%, and an increase in the environment of 9.90% is required to become efficient. On the other hand, DFM results show that a reduction in cultural interaction of 25.71% and an increase in the GDP of 25.98% are required to become efficient. Apart from the practicality of such a solution, the DFM model shows clearly that a different and a perhaps more efficient solution is available than the standard CCR and SBM projection to reach the efficiency frontier.

We also notice that projection results of Beijing (Fig. 16.12) and Shanghai (Fig. 16.15) show that they clearly need a serious effort and improvement for environment.

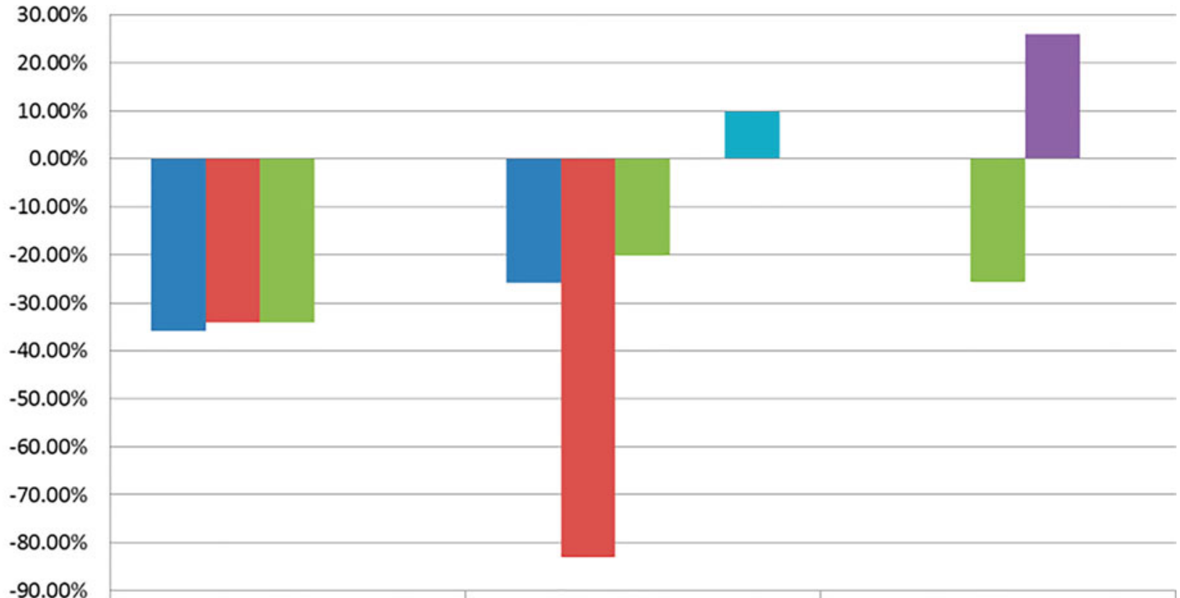


	CCR	SBM	DFM
(I)Employees	-52.37%	-60.64%	-39.94%
(I)R&D	-20.71%	-17.58%	-14.16%
(I)Cultural Interaction	-20.71%	-34.25%	-0.21%
(O)GDP	0.00%	0.00%	11.55%
(O)Environment	221.84%	179.43%	294.51%

Fig. 16.12 Efficiency improvement projection results of the CCR, SBM and DFM model (Beijing)

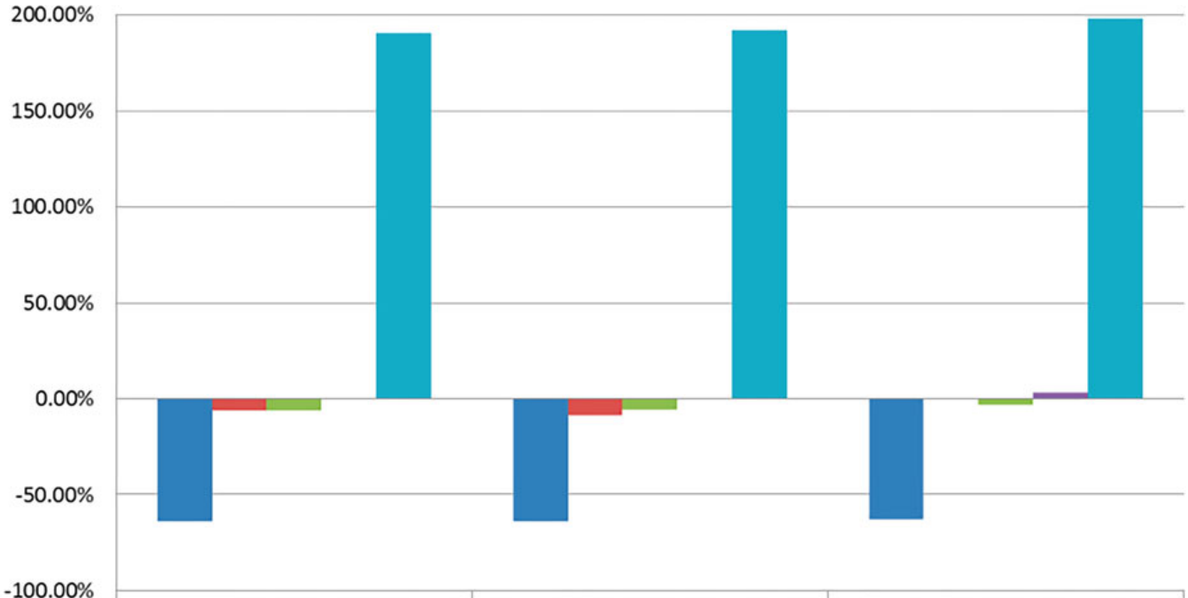
	CCR	SBM	DFM
(I)Employees	-25.39%	0.00%	-15.25%
(I)R&D	-25.39%	-66.18%	-4.51%
(I)Cultural Interaction	-25.39%	-26.84%	-17.65%
(O)GDP	0.00%	0.00%	17.96%
(O)Environment	0.00%	0.00%	5.57%

Fig. 16.13 Efficiency improvement projection results of the CCR, SBM and DFM model (Osaka)



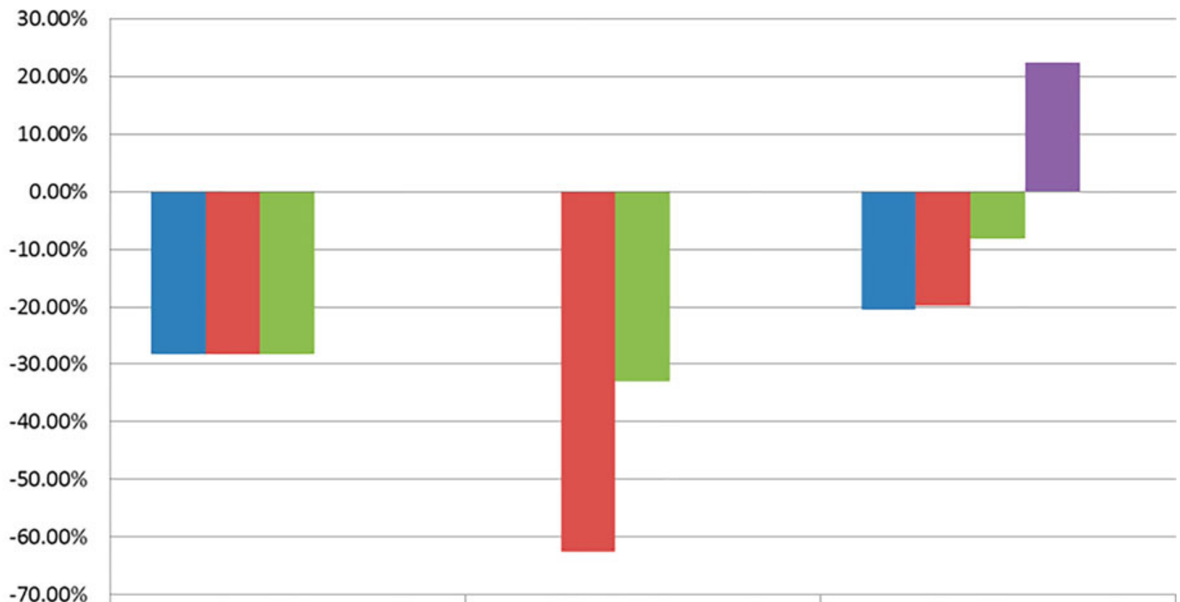
	CCR	SBM	DFM
(I)Employees	-35.81%	-25.90%	0.00%
(I)R&D	-34.10%	-82.97%	0.00%
(I)Cultural Interaction	-34.10%	-20.12%	-25.71%
(O)GDP	0.00%	0.00%	25.98%
(O)Environment	0.00%	9.90%	0.00%

Fig. 16.14 Efficiency improvement projection results of the CCR, SBM and DFM model (Seoul)



	CCR	SBM	DFM
(I)Employees	-63.63%	-63.57%	-62.58%
(I)R&D	-6.04%	-8.76%	0.00%
(I)Cultural Interaction	-6.04%	-5.77%	-3.42%
(O)GDP	0.00%	0.00%	3.11%
(O)Environment	190.38%	191.93%	197.64%

Fig. 16.15 Efficiency improvement projection results of the CCR, SBM and DFM model (Shanghai)



	CCR	SBM	DFM
(I)Employees	-28.15%	0.00%	-20.48%
(I)R&D	-28.15%	-62.60%	-19.79%
(I)Cultural Interaction	-28.15%	-32.90%	-8.21%
(O)GDP	0.00%	0.00%	22.38%
(O)Environment	0.00%	0.00%	0.00%

Fig. 16.16 Efficiency improvement projection results of the CCR, SBM and DFM model (Singapore)

16.6 Conclusions and Lessons

DEA is a quantitative method for assessing the efficiency of economic agents, such as cities. It has found various applications in a variety urban benchmark studies. It is an important question whether different DEA methods and different DEA information levels lead to different results.

In this chapter, we have tested the robustness of DEA results—applied to the performance of various Asia-Pacific cities (13 in total)—against variations in the number of outputs, the number of inputs, the number of actors and the type of DEA model used.

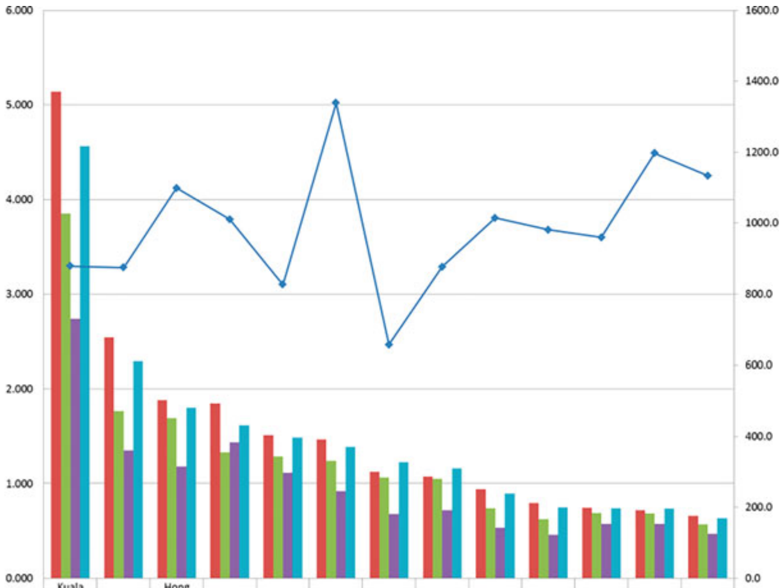
From our efficiency evaluation results for 13 Asia-Pacific cities based on the SE-CCR model and the SE-SBM model using a 3 input-2 output information base, Kuala Lumpur, Bangkok, Hong Kong, Sydney, Fukuoka, Tokyo, Mumbai and Taipei may be regarded as super-efficient cities. In contrast, Shanghai, Beijing, Osaka, Singapore and Seoul are regarded as inefficient cities.

Most comparative studies including the GPCI-2016 scores are based on an aggregate (weighted or unweighted) average of a set of background factors that have been translated into operational indicators. The approach adopted in the present study has focused attention much more on the efficiency and productivity of Asia-Pacific cities, using a comparative data set. The research presented in the present study has offered interesting insights into the benchmark position of Asia-Pacific cities, based on an extensive data set. Our findings reveal striking differences compared to standard ranking and benchmarking procedures (GPCI-2016), as shown in Fig. 16.17.

In conclusion, our method to calculate at unambiguous DEA ranking results provides promising findings leading to further research on urban performance analysis.

In our empirical analysis, we carried out a sensitivity analysis in two steps, viz. (A) a methodological comparison and (B) a sensitivity check on the number of input items and output items and the number of DMUs. From these results, it appeared that significant changes in efficiency scores may occur in the case of shifts in the number of input and output items. From these findings, we may draw the conclusion that if an important item (either input or output) is eliminated, then the efficiency score of all cities may change significantly. The research lesson from this experiment is that we need to carefully select the input and output items in any DEA benchmark analysis.

It seems a logical lesson from our analysis not to be dependent on a few selective input or output criteria in a comparative DEA but to go for a comprehensive database. This multidimensional information system may next be reduced by means of multivariate statistical techniques (e.g. principal component analysis), so that a more stable and orthogonal database may be created that is more robust vis-à-vis changes in the underlying multidimensional database.



	Kuala Lumpur	Bangkok	Hong Kong	Sydney	Fukuoka	Tokyo	Mumbai	Taipei	Shanghai	Beijing	Osaka	Singapore	Seoul
SE-CCR-3I-2O	5.140	2.541	1.884	1.846	1.509	1.467	1.126	1.075	0.940	0.793	0.746	0.718	0.659
SE-SBM-3I-2O	3.852	1.767	1.691	1.332	1.287	1.239	1.064	1.049	0.740	0.625	0.690	0.682	0.570
Ave Score (eli I,O items)	2.736	1.350	1.180	1.436	1.115	0.922	0.679	0.717	0.534	0.460	0.571	0.575	0.468
Ave Score (eli DMUs)	4.562	2.291	1.803	1.618	1.486	1.385	1.223	1.160	0.894	0.749	0.737	0.735	0.632
GPCI-2016	878.7	874.3	1098.5	1009.9	826.4	1338.5	657.3	876.3	1014.4	981.0	959.1	1197.0	1133.3

Fig. 16.17 Score comparison between GPCI-2016 and DEA results

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Chapter 17
Chinese Internal Migration and Income Disparity in 1980s and 1990s - A Two-area (Urban and Rural), Two-sector (Formal and Informal) Model Based on An Extended Gravity Formula

Masakatsu Suzuki

Abstract This paper aims to quantitatively analyze the relationship between interregional / intraregional population migration and regional income disparity in China in the 1980s and 1990s using econometric methods.

In this paper I divided China into the developed coastal, the retarded inland, and middle regions. These regions were divided into urban and rural areas and then divided into formal and informal sectors.

Based on this regional classification, I created a time series data set for the period from 1978 to 2001. And then, a “two-region (urban and rural), two-sector (formal and informal) econometric model” was built, and various simulations performed. This is the most detailed model for a developing country.

Inter-provincial migration and urbanization trends are important factors when discussing the development of Chinese economy, trends in interregional disparities, and inland region development. However, there are scarce of statistical information, empirical analysis, and econometric studies on the scale and pattern of internal population migration, the amounts of remittances by migrant workers to their hometowns. Therefore, this paper quantitatively clarifies these factors, including regional disparities.

Keywords Chinese economy · Econometric analysis · Population migration · Income disparity · Formal-informal sector · Extended gravity formula

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17.1 Introduction

This paper aims to divide China into three regions, developed coastal region, retarded inland region, and middle region, and it is to analyze the relationship between population migration from poor areas to developed areas and regional disparities. For this purpose, I built a "three regions (coastal, middle, and inland), two areas (urban and rural), and two sectors (formal and informal) econometric model" and performed some simulations.

In China, population migration according to regional disparities was increasing rapidly. In the period of "Great Leap Forward (Dayuejin; from 1958 to 1960)," 20 million persons flowed into the urban area. And, two problems occurred in the urban area: (1) bad harvests from 1959 caused food difficulties, (2) job scarcity according to urban construction reduction. Therefore, Chinese government, "People's Republic of China Hukou Registration Regulation (Hukou Dengji Tiaoli; 1962)" has restricted population migration and restrained the urban population to 20%.

On the other hand, surplus labor had increased rapidly in rural area by productivity improvements and population growth. Furthermore, the migration restrictions have been eased by the collapse of the People's commune (Renmin Gongshe) since 1980s, foreign direct investment (FDI) were concentrated in the coastal region in the 1990s, and the regional disparities had expanded. Thus, the need for unskilled labor in urban area had led to a rapid increase in the migration of poor farmers to urban area.

Intraregional/interregional population migration is important for searching the development of Chinese economy, trends of regional disparities, and the possibility of inland region development. However, there are scarce of statistical information, fact finding, and quantitative analysis on the scale of migration, the outflow and inflow area, the actual situation of remittances of migrant workers, and the effect of reducing regional disparities.

Therefore, I performed time series estimation of formal and informal sector productivity of urban and rural areas as basic work. Next, I subdivided population migration into 36 patterns (30 patterns of interregional migration, 6 patterns of intraregional migration; see Fig. 17.1). Furthermore, I introduced the educational level of urban and rural areas (illiterate and semi-illiterate, primary school, junior high school, senior high school, and university) as important explanatory variables for the population migration functions and the labor productivity functions. In the Harris-Todaro formulation, formal sector employment and unemployment exist in urban area, and migration from rural to urban area occurs at the unemployment rate and the ratio of formal sector wages and rural wages. In reality, the idle labor force in urban area is not completely unemployed, and they are pooled in informal sector that are less productive. I corrected that point and built the most detailed population migration econometric model in developing countries.

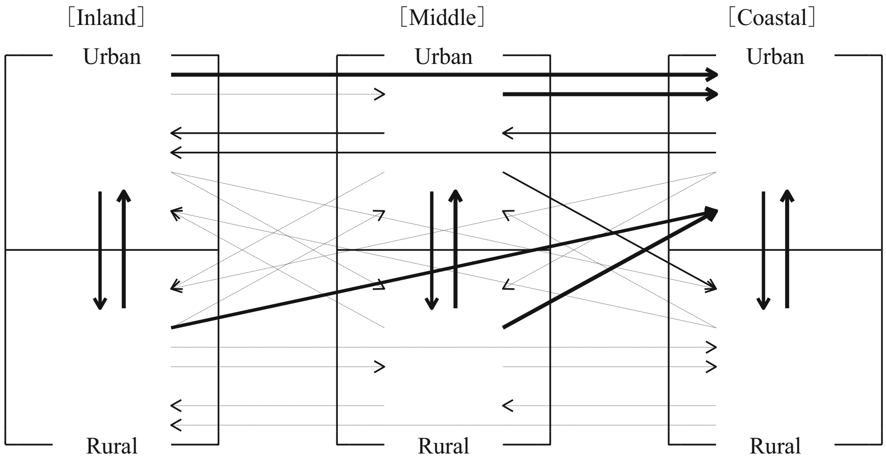


Fig. 17.1 Population migration
Notes: The arrows are drawn in four patterns, from dotted lines to extremely bold lines. The dotted lines indicate small-scale migrations (less than 10,000 persons per year), and the extremely bold lines indicate large-scale migrations (several hundred thousand persons per year). In addition, the bold lines (6 extremely bold lines and 4 bold lines; total 10) are endogenous variables in this model in Sect. 17.4
Source: Created by the author

The structure of the model I explained in this paper, which I mentioned the details of the theoretical process, such as data creation in another paper (Suzuki 2007).[1] The model was built based on time-series data from 1978 to 2001 (24 years, 1990 price); I used this model to perform various simulations to quantitatively analyze the impact of (1) deregulation of population migration, (2) changes in education levels, (3) promotion of foreign direct investment, (4) "China Western Development (Xibu Dakaifa)" on Chinese economy.

This paper is an expands version based on previous studies (Suzuki and Fukuchi 2004).

17.2 Definition of Regional Division and Population Migration

17.2.1 Regional Division and China Western Development

Chinese administrative divisions are divided into coastal, middle, and inland regions. The coastal region has 12 Provinces, Direct-administered Municipalities,

[1] In this paper, I used the data created by Suzuki (2007). I estimated labor productivity and capital stock for each sector, and used Chinese official statistics for the other data. 217 variables area used in this paper.

and Autonomous Regions (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan), the middle region has 9 provinces and Autonomous Regions (Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan), and the inland region has 10 provinces, Direct-administrated Municipalities and Autonomous Regions (Sichuan, Chongqing, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang).

The China Western Development is a policy to develop the inland region where economic development has been delayed and reducing regional disparities: (1) infrastructure development, (2) ecosystem protection, (3) education, science, and technology promotion. The target areas are the inland region, Guangxi, and Inner Mongolia (12 provinces, Direct-administrated Municipalities and Autonomous Regions), the total area was 71% and the population was only 29% of China (1990s). In this region, infrastructure development was delayed, the regional GDP was 17% of China, and there were many state-owned enterprises that were large but low productivity. Therefore, Chinese government bankrupted 5335 state-owned enterprises in the 5 years to 2001, and the number of unemployed and layoff workers in the urban area reached 48 million persons. Therefor, I performed a simulation on the China Western Development in Sect. 17.4.

In this paper, as mentioned above, I divided China into three regions (coastal, middle, and inland) and two areas (urban and rural), based on Chinese official statistics. Furthermore, I divided each area into two sectors (formal and informal), and analyzed in detail the effects of rural surplus labor and migrant workers into income disparities.

17.2.2 Formal and Informal Sector Definition

Fukuchi (1998) surveys the literature and definitions of informal sector, but the actual situation varies from country to country. Furthermore, the definition is multidimensional: technical, economic, management, legal, and social. In this paper, the areas (urban and rural) are divided into two sectors (formal and informal) with reference to Chinese official statistics.

17.2.3 Definition of Urban Formal and Urban Informal Sector

In Chinese official statistics, the urban labor force are classified into 10 categories: (1) state-owned units; (2) urban collective-owned units; (3) cooperative units; (4) joint ownership units; (5) limited liability corporations; (6) share-holding corporations ltd.; (7) private enterprises; (8) units with funds from Hong Kong, Macao, and Taiwan; (9) foreign funded units; (10) self-employed individuals. But the total values ((1) to (10)) and the urban labor forces have a large statistical error. Therefore, I assumed this statistical error as (11) unemployed persons according to the reform of state-owned enterprise, potential unemployed in the enterprise, and migrant workers. And I defined (10) self-employed individuals and (11) statistical error as urban informal sector and (1) to (9) as urban formal sector, referring to Kojima (1996a), Setherman (1976), Song (2003), Meng (2001), and field surveys by the author.[2]

17.2.4 Definition of Rural Formal and Rural Informal Sector

In Chinese official statistics, the rural labor force is classified into three categories: (1) township and village enterprises, (2) private enterprises, and (3) self-employed individuals. But the total values ((1) to (3)) and rural labor force have large statistical error as with in urban area. Therefore, I assumed this statistical error as (4) farmer (including surplus labor force). And I defined (3) self-employed individuals and (4) farmers as rural informal sector and (1) township and village enterprises and (2) private enterprises as rural formal sector.

17.2.5 The Actual Situation of the Informal Sector in China

According to Wang et al. (2000), an empirical study of rural-urban population migration in the Northeast China is as follows: (1) there is a wage gap of about 30% between urban and rural area, which is causing strong urbanization; (2) wage distribution is high in the formal sector, but overlaps; (3) in the case of blue-color, the labor market is continuous in both formal and informal sectors; (4) in the case of white-color, the educational level is decisive, and the anti-Todaro model is supported, because there is a high barrier to migrate to the formal sector.

In this way, employment in the urban formal sector and the urban informal sector has both a fluid part and a non-fluid part, and it is difficult to describe in a single way. However, educational level is an important determinant of the speed of population migration and employment status. In this paper, based on these points, I introduced educational variables of the population migration functions, the labor productivity functions, and the labor force functions. Furthermore, I tried to describe the labor market in the formal and informal sectors that are not necessarily integrated but connected.

According to the estimate of this paper, first, in the urban labor force is 239.40 million persons, the urban informal labor force is 112.89 million persons, and the informal ratio is 47.15% (2001). According to Todaro (1994), the informal

[2]The results of the field survey by the author were considered: Institute of Population Research, Sichuan University (Director, Prof. He Jingxi, 2000), South China University of Technology (Guangdong, 2003), Guangdong Provincial Bureau of Statistics (2003).

ratio (slum population ratio) is 26–79% (26–67% in Asia) in large cities in developing countries.

Next, in terms of productivity, urban formal sector is 18,924 yuan/person, urban informal sector is 8381 yuan/person, rural formal sector is 6227 yuan/person, and rural informal sector is 2885 yuan/person (2001). As a result, I found the following: (A) there was more than double disparity between urban informal and urban formal sectors, and the labor market was divided; (B) the productivity of urban informal sector was 34.6% higher than that of rural formal sector, which indicates greater incentives for urbanization.

17.2.6 Population Migration

In order to classify population migration in detail, I divided it into 36 patterns: 6 population outflow areas (coastal urban, middle urban, inland urban, coastal rural, middle rural, and inland rural area) and 6 population inflow areas (same as population outflow areas) (see Fig. 17.1).

Kojima (1996b) divided China into (A) urban areas, (B) densely populated areas, and (C) rural areas, further discussing Chinese main population migration patterns before and after "Third Front Construction period (Sanxian Jianshe; 1964–1975)" in three periods. Population migration patterns were changing dramatically: (1) from (A) and (B) to (C) in the 1950s, (2) from (A) to (C) in the year 1961 to 1976, (3) from (B) and (C) to (A) after 1985. In this paper, I analyzed the population migration after 1981 in detail with the Chinese Population Census in the years 1987, 1990, 1995, and 2000 (1987 and 1995 are 1% sampling survey).

17.3 Model Structure

Three regions (coastal, middle, and inland), two areas (urban and rural), and two sectors (formal and informal) econometric model including population migration (94 functions; 10 population migration functions, 12 labor productivity functions, 12 labor force functions, 60 definition functions, observation period 1981–2001, 1990 price, 217 variables).

Regarding regional disparities in China, Lyons (1991) shows that both production and consumption decreased from the 1950s to the 1970s (Great Leap Forward period, Third Front Construction period, Cultural Revolution period (Wenhua Dageming; 1966–1977)). However, since 1978, both production and consumption have begun to increase rapidly. The analysis period in this paper is the period after the regional disparity began to expand.

17.3.1 Population Migration Functions

Table 17.1 shows the population migration functions. In the theoretical study by Fukuchi (2000, 2003), population migration is determined by multiplying population gravity and the logarithm of income ratio ((Y_j) income of population inflow area/(Y_i) income of population outflow area). As a result of the aggregation, the number of population migration per year is determined by (1) the logarithm of national income geometric average and homeland income, (2) the other special factors.[3]

In this paper, I selected 10 large number of migration patterns 36 migration patterns and treated them as endogenous. These are (1) from coastal urban area to coastal rural area, (2) from coastal rural area to coastal urban area, (3) from middle urban area to coastal urban area, (4) from middle urban area to middle rural area, (5) from middle rural area to coastal urban area, (6) from middle rural area to middle urban area, (7) from inland urban area to coastal urban area, (8) from inland urban area to inland rural area, (9) from inland rural area to coastal urban area, (10) from inland rural area to inland urban area (see Table 17.1). In particular, the equations (3) and (7), I adopted a saturation equation of the population inflow area, because the number of in-migration has been increased rapidly since 1990. The other 26 patterns were treated as exogenous variables, because (1) small numbers of migrants, (2) intraregional migration unrelated to population change (6 patterns; from coastal urban area to coastal urban area, etc.). In the following, I describe the most important population migration functions (2 equations (17.1), (17.2)) and describe 10 equations in Table 17.1. In this paper, the functions are estimated before one or more period, avoiding simultaneous functions in consideration of economies of scale.

There is a survey of Greenwood and Hunt (2003) about population migration functions, which summarizes the development of improved gravity formula by many scholars. Fukuchi (2000) derives "Extended Gravity Formula" from micro-foundations. This assumption was also used in Suzuki and Fukuchi (2003, 2004), and in this model, the same assumptions were extended to China. Ohnishi and Mao (2001) has built a population migration model with nine functions according to dividing urban and rural areas. In this model, farmers were assumed to migrate from rural area to urban area according to the income disparity, which is corrected for the unemployment rate according to the Todaro model (the observation period is from 1981 to 1991). The model in this paper, the urban-rural model further divides into formal and informal sectors.

[3]The population migration (N_{ij}) between the outflow area (i) and the inflow area (j) is determined by (1) setting the distance as 1, and (2) multiplying the gravity variable ((N_i)(N_j)/(N)) normalized by the population and the income inequality ratio (Log (Y_j/Y_i)) (i, j, and Y denote population outflow area, population inflow area, and per capita income, respectively) (Fukuchi 2000).

Table 17.1 Population migration functions

Explanatory variable	(1) 1U-1R		(2) 1R-1U		(3) 2U-1U		(4) 2U-2R		(5) 2R-1U	
Constant term	80.23	(5.60)	64.62	(17.35)	−10.07	(−12.01)	331.8	(4.80)	−0.7443	(−0.30)
Extend gravity			2.623E−04	(1.07)	5.81E−04	(2.10)	6.249E−03	(1.48)	1.561E−04	(1.30)
High education rate	−340.0	(−5.02)	−265.6	(−13.87)	40.57	(2.60)	1808	(10.60)	12.09	(1.17)
	166.4	(5.08)	513.8	(39.54)	−32.21	(−3.24)	−1894	(−7.14)	−36.32	(−3.21)
Capital stock					1.035	(3.06)				
FDI or export					1.073E−02	(2.07)				
			2.860	(2.18)						
Labor force, savings, social consumption, etc.	25.60	(1.27)					15.60	(1.37)	3.121	(1.38)
	19.29	(1.02)	10.92	(1.57)	0.347	(1.17)				
Outflow or inflow stock			65,725	(3.75)	−290.1	(−1.24)	58,840	(3.52)	11,068	(2.84)
	−110,232	(−7.72)	−7099	(−10.26)	78.27	(3.02)	−1,269,105	(−4.69)	16,211	(123.51)
Township and village enterprises	0.2977	(2.06)								
R^2/D-W	0.9973	2.17	0.9999	1.54	0.9978	1.74	0.9967	1.37	0.9999	1.11

Explanatory variable	(6) 2R-2U		(7) 3U-1U		(8) 3U-3R		(9) 3R-1U		(10) 3R-3U	
Constant term	44.07	(1.47)	−10.56	(−26.77)	638.1	(3.89)	−0.9792	(−0.66)	447.3	(2.81)
Extend gravity	6.951E−03	(4.11)	2.267E−03	(5.72)			1.704E−04	(1.21)	1.318E−02	(1.61)
High education rate	427.9	(4.42)	62.37	(8.63)	−521.2	(−3.95)	13.37	(2.39)		
	−267.8	(−1.86)	−29.88	(−9.56)	−886.9	(−3.77)	−33.88	(−4.91)		
Productivity									−628.5	(−3.41)
									30.57	(1.04)
FDI or export	45.99	(2.15)	0.4074	(1.70)					230.3	(3.04)
Labor force, savings, social consumption, etc.	22.61	(1.04)	1.232	(1.57)	64.83	(1.39)	9.444	(4.86)	70.11	(2.35)
	23.71	(1.62)	0.4614	(1.79)	102.7	(1.46)			77.56	(1.50)
Outflow or inflow stock	82,763	(1.04)	−1166	(−5.98)	5884	(1.39)			−50,394	(−2.92)
	−18,245	(−3.63)	456.1	(4.50)			12,327	(85.69)	312,840	(2.44)
Township and village enterprises					162.4	(1.79)				
R^2/DW	0.9966	2.23	0.9995	1.92	0.9816	0.86	0.9999	1.21	0.9859	1.64

Note 1: (X), R^2, and DW denote *t* value, determination coefficients after the correction of degree of freedom, and Durbin-Watson coefficient, respectively. Hereafter are common in each table (Tables 17.2 and 17.3)

Note 2: The upper part of the explanatory variable shows (*i*) population outflow area, and the lower part of it shows (*j*) population inflow area

Source: Calculated by the author

(3) Population Migration from Middle Urban Area to Coastal Urban Area

LOG**((2U-1U)/(1UPOPU)*(–1))/(1－*(2U-1U)/(1UPOPU)*(–1)))
=－10.07+5.805E-04**((1UPOPU)*(–1)**(2UPOPU)*(–1)/*(4JINKO)*(–1))
(－12.01)(2.10)
LOG((*1UCGDP*)(–1)/(*2UCGDP*)(–1))
－32.21*((*1USENI*)(–2)+(*1UUNIV*)(–2))/(*1UPOPU*)(–2)
(－3.24)
+40.57*((*2USENI*)(–2)+(*2UUNIV*)(–2))/(*2UPOPU*)(–2)
(2.60)
+78.27*(*1U-1U*)(–2)/(*1UPOPU*)(–2)
(3.02)
－290.1*((*1U-2U*)(–2)+(*1R-2U*)(–2)+(*3U-2U*)(–2)+(*3R-2U*)(–2)
(－1.24)
+(*2U-2U*)(–2))/(*2UPOPU*)(–2)
+1.073E-02*(*1SUMFI*)(–1)/(*2SUMFI*)(–2)
(2.07)
+0.3470*(*1UCGOO*)(–2)/(*2UCGOO*)(–2)
(1.17)
+1.035*(*1USTOK*)(–2)/(*2USTOK*)(–2)
(3.06)
RB^2=0.9978, RA^2=0.9928, SE=0.0626, DW=1.74, AVE=－5.60

(17.1)

(7) Population Migration from Inland Urban Area to Coastal Urban Area

LOG*((*3U-1U*)/(*1UPOPU*)(–1))/(1－(*3U-1U*)/(*1UPOPU*)(–1)))
=－10.56＋2.267E-03*((*1UPOPU*)(–1)*(*3UPOPU*)(–1)/(*4JINKO*)(–1))
(－26.77) (5.72)
LOG((*1UCGDP*)(–1)/(*3UCGDP*)(–1)
－29.88*((*1USENI*)(–2)+(*1UUNIV*)(–2))/(*1UPOPU*)(–2)
(－9.56)
+62.37*((*3USENI*)(–2)+(*3UUNIV*)(–2))/(*3UPOPU*)(–2)
(8.63)
+456.1*(*1U-1U*)(–1)/(*1UPOPU*)(–1)
(4.50)
－1,166*((*1U-3U*)(–1)+(*1R-3U*)(–1)+(*2U-3U*)(–1)+(*2R-3U*)(–1)
(－5.98)
+(*3U-3U*)(–1))/(*3UPOPU*)(–1)
+0.4074*(*1SUMFI*)(–1)/(*1UFKIJ*)(–1)+0.4614*(*1UCGOO*)(–3)/(*3UCGOO*)(–3)
(1.70) (1.79)
+1.232*(*3UFKIJ*)(–3)/(*3UPOPU*)(–3)
(1.57)
RB^2=0.9995, RA^2=0.9982, SE=0.0304, DW=1.92, AVE=－6.4 (17.2)

Note 1: RB^2, RA^2, SE, DW, and AVE denote determination coefficients before and after the correction for degree of freedom, estimated standard deviation of equation error, Durbin-Watson coefficient, and average of the explained variable, respectively

Note 2: In this paper, the three regions are distinguished by the numbers before the variables: 1 means coastal region, 2 means middle region, 3 means inland region, and 4 means China

Source: Calculated by the author

17.3.2 Labor Productivity Functions

Table 17.2 shows the labor productivity functions of urban formal and urban informal, and of rural formal and rural informal. As mentioned above, informal sector has unclear business form, and it is difficult to define a clear production function. In this paper, I explained labor productivity and labor force by functions, and defined the productivity of each sector (formal GDP and informal GDP) by multiplying labor productivity and labor force.

I used the sign condition of the explanatory variables as follows: higher-level education variables (senior high school and university) were positive and lower-level education variables (illiterate and semi-illiterate, and primary school) were negative; furthermore, population inflow variables (population outflow variables) were positive (negative).

Urban Labor Productivity

In urban labor productivity, foreign-owned enterprises accounted for about 50% of total exports value, and the increasing of foreign direct investment was an important factor supporting exports (1990s). In this paper, I selected capital stock, trade value, foreign direct investment, and consumer goods as important explanatory variables of the urban labor productivity functions.

Rural Labor Productivity

According to Esaki (2000), the expansion of regional disparities between coastal rural area and inland rural area were according to the difference in the development of township and village enterprises (Xiangzhen Qiye). Furthermore, in coastal rural area, the income from township and village enterprises is larger than agricultural income; on the other hand, in inland rural area, agricultural income is more important than income from township and village enterprises. In this paper, I selected the following variables as important explanatory variables of the rural labor productivity functions: township and village enterprise (production value, export value, etc.), capital stock, agricultural production value, and production conditions (electricity consumed, total power of agricultural machinery, consumption of chemical fertilizer, etc.).

Table 17.2 Labor productivity functions

Formal sector	(11) 1UFSEI		(12) 2UFSEI		(13) 3UFSEI		(17) 1RFSEI		(18) 2RFSEI		(19) 3RFSEI	
Constant term	1325	(0.29)	2885	(0.49)	−5975	(−3.50)	4432	(2.47)	857.4	(1.24)	245.8	(1.58)
High education rate	225,251	(7.73)	17,337	(1.73)	43,348	(3.79)	5780	(3.18)	3706	(2.84)	5221	(4.70)
Low education rate	−14,096	(−1.86)	−16,038	(−1.83)	−1944	(−1.54)	−0.1325	(−1.78)	−567	(−2.97)		
Capital stock	403	(1.88)	739	(3.42)	280	(1.56)			2188	(2.38)	2204	(4.78)
Productivity			7821	(1.36)								
Consumption							0.2767	(2.86)				
Township and village enterprises exports							104.9	(1.98)				
Labor force	10,939	(2.56)										
Inflow from urban	75,325	(1.34)	2,108,885	(1.98)	699,359	(2.46)					163,789	(3.33)
Outflow							409,750	(2.81)	263,717	(3.79)		
R^2/DW	0.9973	1.70	0.9963	2.17	0.9932	1.03	0.9972	1.08	0.9850	1.70	0.9893	1.05

Informal sector	(14) 1UISEI		(15) 2UISEI		(16) 3UISEI		(20) 1RISEI		(21) 2RISEI		(22) 3RISEI	
Constant term	−10,919	(−1.89)	−12,499	(−2.22)	−6504	(−2.54)	36,018	(5.19)	−2315	(−1.47)	−11,657	(−1.62)
High education rate	10,628	(3.83)	27,542	(6.59)			24,909	(2.54)	18,079	(5.90)	−67,358	(−1.04)
Low education rate	−35,983	(−7.14)	−7843	(−1.62)	3959	(1.22)	−29,221	(−4.87)	4209	(1.24)	19,492	(1.47)
Capital stock	439,803	(30.35)	111,256	(10.89)	41,722	(11.93)	7543	(1.72)			1351	(1.40)
FDI					−7086	(−1.67)						
Export					−476	(−1.10)						
Labor force									3689	(2.95)	21,523	(3.41)
Power usage									254,937	(1.30)		
							6433	(1.00)				
Inflow from urban	1,595,902	(4.31)	1,046,761	(4.30)	161,341	(4.60)					148.1	(1.79)
Inflow form rural			724,278	(3.88)								
Outflow							−5,850,757	(−3.55)	−150,037	(−1.00)	−786,931	(−1.64)
R^2/DW	0.9940	1.42	0.9967	1.19	0.9916	1.29	0.9414	2.61	0.9561	1.81	0.9358	1.83

Note: The upper table shows the formal sector of each region, and the lower table shows the informal sector of each region
Source: Calculated by the author

In the following, I describe the labor productivity functions of coastal region (4 equations) and 12 labor productivity functions in Table 17.2.

(11) Coastal Urban Formal Sector Labor Productivity

$$
\begin{aligned}
(\mathit{1UFSEI}) = {} & 1325 - 14{,}096*((\mathit{1UILLI})(-1)+(\mathit{1UELEM})(-1)+(\mathit{1UJUNI})(-1))/(\mathit{1UPOPU})(-1) \\
& (0.29) \quad (-1.86) \\
& +225{,}251*(\mathit{1UUNIV})(-1)/(\mathit{1UPOPU})(-1) \\
& (7.73) \\
& +403.2*((\mathit{1UFSTO})(-1)+(\mathit{1SUMFI})(-1))/(\mathit{1UINDU})(-1) \\
& (1.88) \\
& +10{,}939*(\mathit{1KENSE})(-1)/(\mathit{1UKIJI})(-1) \\
& (2.56) \\
& +75{,}325*((\mathit{2U\text{-}1U})(-1)+(\mathit{3U\text{-}1U})(-1)+(\mathit{1U\text{-}1U}))/(\mathit{1UPOPU})(-1) \\
& (1.34) \\
& RB^2=0.9973,\ RA^2=0.9928,\ S=424.32,\ DW=1.70,\ AVE=10{,}715.83
\end{aligned}
\tag{17.3}
$$

(14) Coastal Urban Informal Sector Labor Productivity

$$
\begin{aligned}
(\mathit{1UISEI}) = {} & -10{,}919 - 35{,}983*((\mathit{1UILLI})(-1)+(\mathit{1UELEM})(-1)+(\mathit{1UJUNI})(-1)) \\
& (-1.89) \quad (-7.14) \\
& /(\mathit{1UPOPU})(-1)+10{,}628*(\mathit{1USENI})(-1)/(\mathit{1UPOPU})(-1) \\
& \qquad (3.83) \\
& +439{,}803*(\mathit{1UISTO})(-1)/(\mathit{1STOCK})(-1) \\
& (30.35) \\
& +1{,}595{,}902*((\mathit{1R\text{-}1U})(-1)+(\mathit{2R\text{-}1U})(-1)+(\mathit{1U\text{-}1U})(-1))/(\mathit{1UPOPU})(-1) \\
& (4.31) \\
& RB^2=0.9940,\ RA^2=0.9849,\ S=253.96,\ DW=1.42,\ AVE=4393.67
\end{aligned}
\tag{17.4}
$$

(17) Coastal Rural Formal Sector Labor Productivity

$$
\begin{aligned}
(\mathit{1RFSEI}) = {} & 4432 - 0.1325*((\mathit{1RILLI})(-1)+(\mathit{1RELEM})(-1)) \\
& (2.47) \quad (-1.78) \\
& +5780*((\mathit{1RJUNI})(-1)+(\mathit{1RSENI})(-1))/(\mathit{1RPOPU})(-1) \\
& (3.18) \\
& +104.9*(\mathit{1GEXPO})(-1)/(\mathit{1GOTIN})(-1)+0.2767*(\mathit{1RGOOS})(-1) \\
& (1.98) \qquad (2.86) \\
& +409{,}750*((\mathit{1U\text{-}1R})(-1)+(\mathit{2U\text{-}1R})(-1)+(\mathit{3U\text{-}1R})(-1))/(\mathit{1RPOPU})(-1) \\
& (2.81) \\
& RB^2=0.9972,\ RA^2=0.9924,\ S=79.95,\ DW=1.08,\ AVE=4829.92
\end{aligned}
\tag{17.5}
$$

(20) Coastal Rural Informal Sector Labor Productivity

$$
\begin{aligned}
(\mathit{1RISEI}) = {} & \underset{(5.19)}{36{,}018} - \underset{(-4.87)}{29{,}221} * ((\mathit{1RILLI})(-1) + (\mathit{1RELEM})(-1))/(\mathit{1RPOPU})(-1) \\
& + \underset{(2.54)}{24{,}909} * ((\mathit{1RJUNI})(-1) + (\mathit{1RSENI})(-1))/(\mathit{1RPOPU})(-1) \\
& + \underset{(1.72)}{7543} * ((\mathit{1RISTO})(-1)/(\mathit{1RIKIJ})(-1) + \underset{(1.00)}{6{,}433} * (\mathit{1ELECT})(-1)/(\mathit{1RPOPU})(-1) \\
& - \underset{(-3.55)}{5{,}850{,}757} * ((\mathit{1R\text{-}1U})(-1) + (\mathit{1R\text{-}2R})(-1))/(\mathit{1RPOPU})(-1)
\end{aligned}
$$

$RB^2=0.9414$, $RA^2=0.8499$, $S=201.69$, $DW=21.61$, $AVE=2767.10$ (17.6)

Note: RB^2, RA^2, SE, DW, and AVE denote determination coefficients before and after the correction for degree of freedom, estimated standard deviation of equation error, Durbin-Watson coefficient, and average of the explained variable, respectively

Source: Calculated by the author

The Number of Labor Force Functions

Table 17.3 shows the labor force functions of urban formal and urban informal, and for rural formal and rural informal. I treated these variables as endogenous, in consideration of the population migration patterns (see Fig. 17.1) and the productivity gap. I treated sign condition in the same way as the productivity functions: the higher-level educational variables (the lower-level educational variables) were positive (negative), and population inflow variables (population outflow variables) were positive (negative).

In addition, in Chinese official statistics, the unemployment are defined as registered urban unemployment. Therefore, I considered that the unemployment originates from the urban formal sector and are absorbed to the urban informal sector.

In the following, I describe the labor force functions of inland region (4 equations) and 12 labor force functions in Table 17.3.

(25) Inland Urban Formal Sector Labor Force

$$
\begin{aligned}
(\mathit{3RFKIJ}) = {} & \underset{(-1.39)}{-293.7} + \underset{(4.21)}{8168} * ((\mathit{3USENI})(-1) + (\mathit{3UUNIV})(-1))/(\mathit{3UPOPU}) \\
& + \underset{(1.68)}{237.8} * (\mathit{3UFSEI})(-1)/(\mathit{3UCGDP})(-2) + \underset{(5.02)}{277.5} * (\mathit{3UINCO})(-1)/(\mathit{3RINCO})(-2) \\
& - \underset{(-9.98)}{62{,}536} * ((\mathit{3U\text{-}1U})(-1) + (\mathit{3U\text{-}2U})(-1))/(\mathit{3UPOPU})
\end{aligned}
$$

$RB^2=0.9392$, $RA^2=0.8538$, $S=63.09$, $DW=1.91$, $AVE=2452.64$ (17.7)

Table 17.3 Labor force function

Formal sector	(23) 1UFKIJ		(24) 2UFKIJ		(25) 3UFKIJ		(29) 1RFKIJ		(30) 2RFKIJ		(31) 3RFKIJ	
Constant term	−38,259	(−6.43)	−8441	(−2.26)	−293.7	(−1.39)	38,674	(3.82)	31,022	(5.64)	1377	(0.60)
High education rate	188,773	(6.74)	21,899	(2.37)	8168	(4.21)	52,626	(3.07)	5501	(1.09)		
Low education rate							−42,147	(−2.85)	−41,785	(−6.23)	13,300	(2.80)
FDI	26,643	(4.78)										
Own sector productivity			233.3	(1.03)	237.8	(1.68)			478.8	(1.17)	496.3	(1.34)
Other sector productivity							−4626	(−1.59)	−3478	(−1.91)	−2119	(−1.34)
Labor force	9186	(6.59)	2791	(2.70)								
Urban consumption, savings	953.4	(1.79)	132.7	(1.23)	277.5	(5.02)						
	12,037	(2.91)										
Number of township and village enterprises							12,948	(3.04)				
Inflow from urban			206,841	(1.39)					−623,511	(−6.73)		
Outflow			−92,902	(−2.92)	−62,536	(−9.98)	−4,692,525	(−2.28)			−210,640	(−2.36)
R^2/DW	0.9142	2.54	0.9101	1.74	0.9392	1.91	0.9766	1.27	0.9864	2.14	0.9559	2.14

(continued)

Table 17.3 (continued)

Informal sector	(26) 1UIKIJ		(27) 2UIKIJ		(28) 3UIKIJ		(32) 1RIKIJ		(33) 2RIKIJ		(34) 3RIKIJ	
Constant term	−16,983	(−2.32)	5889	(1.05)	−1640	(−0.88)	168,895	(5.11)	−90,992	(−3.34)	−53,673	(−5.47)
High education rate			16,549	(1.33)			13,892	(4.67)	−1489	(−1.27)		
							−13,359*D6	(−3.71)				
Low education rate	19,993	(3.52)	−20,398	(−2.96)	9152	(4.50)			131,383	(3.57)	82,764	(7.00)
Capital stock											10,950	(5.55)
FDI					−4440	(−2.70)						
Own sector productivity	1982	(2.85)	608	(1.98)								
Other sector productivity			−10,234	(−1.73)	−6110	(−8.85)					−942.6	(−1.27)
Labor force	−7944	(−1.93)										
Inflow from urban	103,410	(7.66)	2,087,283	(2.15)	145,727	(5.38)			5,775,900	(3.51)		
Inflow from rural	382,961	(1.20)										
Outflow							−5944	(−4.70)	−4,500,554	(−3.31)	4.404E-02	(14.35)
							7002*D6	(2.96)			1337	(11.97)
Time, dummy	−525.2	(−2.79)			111.6*D3	(1.83)	−162,973	(−2.81)				
	3122*D1	(2.79)			453.4*D4	(4.70)						
	476.4*D2	(4.61)			229.7*D5	(2.42)						
R^2/DW	0.9800	1.72	0.9624	1.27	0.9920	1.35	0.9757	2.21	0.9253	1.33	0.9647	2.38

Note 1: The upper table shows the formal sector of each region, and the lower table shows the informal sector of each region
Note 2: DX is a dummy variable, D1 is 4–6 period, D2 is 21–24 period, D3 is 4–7 period, D4 is 21 period, D5 is 13 period, and D6 is 13–24 period
Source: Calculated by the author

(28) Inland Urban Informal Sector Labor Force

$$
\begin{array}{l}
(\mathit{3UIKIJ}) = -1640 + 9152*((\mathit{3RILLI})(-1) + (\mathit{3RELEM})(-1) + (\mathit{3RJUNI})(-1))/(\mathit{3RPOPU})(-1) \\
\qquad (-0.88)\quad (4.50) \\
\qquad +145{,}727*((\mathit{1U\text{-}3U})(-1) + (\mathit{1R\text{-}3U})(-1) + (\mathit{2U\text{-}3U})(-1) + (\mathit{2R\text{-}3U})(-1) + (\mathit{3R\text{-}3U})(-1) \\
\qquad (5.38) \\
\qquad +(\mathit{3U\text{-}3U})(-1))/(\mathit{3UPOPU})(-1) - 4440*(\mathit{3SUMFI})(-1)/(\mathit{4SUMFI})(-2) \\
\qquad\qquad\qquad\qquad\qquad\qquad (-2.70) \\
\qquad -6110*((\mathit{3KINDU})(-1) + (\mathit{3CINDU})(-1))/(\mathit{3INDUS})(-1) \\
\qquad (-8.85) \\
\qquad +111.6*(\mathit{D\text{-}4}) + 453.4*(\mathit{D\text{-}5}) + 229.7*(\mathit{D\text{-}6}) \\
\qquad (1.83)\qquad (4.70)\qquad (2.42) \\
RB^2=0.9920,\ RA^2=0.9755,\ S=84.40,\ DW=1.35,\ AVE=678.30
\end{array}
\tag{17.8}
$$

(31) Inland Rural Formal Sector Labor Force

$$
\begin{array}{l}
(\mathit{3RFKIJ}) = 1377 + 13{,}300*((\mathit{3RILLI})(-1) + (\mathit{3RELEM})(-1))/(\mathit{3RPOPU})(-1) \\
\qquad (0.60)\quad (2.80) \\
\qquad +496.3*(\mathit{3RFSEI})(-2)/(\mathit{3RISEI})(-1) - 2119*(\mathit{3UISEI})(-2)/(\mathit{3RISEI})(-1) \\
\qquad (1.34)\qquad\qquad\qquad\qquad (-1.34) \\
\qquad -210{,}640*((\mathit{3R\text{-}1U})(-1) + (\mathit{3R\text{-}3U})(-1))/(\mathit{3RPOPU})(-1) \\
\qquad (-2.36) \\
RB^2=0.9559,\ RA^2=0.8928,\ S=145.88,\ DW=2.14,\ AVE=1429.51
\end{array}
\tag{17.9}
$$

(34) Inland Rural Informal Sector Labor Force

$$
\begin{array}{l}
(\mathit{3RIKIJ}) = -53{,}673 + 82{,}764*((\mathit{3RILLI})(-1) + (\mathit{3RELEM})(-1) + (\mathit{3RJUNI})(-1)) \\
\qquad (-5.47)\quad (7.00) \\
\qquad /(\mathit{3RPOPU})(-1) - 942.6*(\mathit{3UISEI})(-2)/(\mathit{3RISEI})(-2) \\
\qquad\qquad\qquad (-1.27) \\
\qquad +10{,}950*(\mathit{3RISTO})(-2)/(\mathit{3RSTOK})(-1) + 4.404E\text{-}02*(\mathit{3R\text{-}3U})(-1)/(\mathit{3RPOPU})(-1) \\
\qquad (5.55)\qquad\qquad\qquad\qquad (14.35) \\
\qquad +1337*((\mathit{3R\text{-}1U})(-1) + (\mathit{3R\text{-}2U})(-1) + (\mathit{3R\text{-}3U})(-1))/(\mathit{3RPOPU})(-1) \\
\qquad (11.97) \\
RB^2=0.9647,\ RA^2=0.9080,\ S=240.65,\ DW=2.38,\ AVE=9582.22
\end{array}
\tag{17.10}
$$

Note: RB^2, RA^2, SE, DW, and AVE denote determination coefficients before and after the correction for degree of freedom, estimated standard deviation of equation error, Durbin-Watson coefficient, and average of the explained variable, respectively

Source: Calculated by the author

17.3.3 Regional Definition Formula

Equations (17.12) and (17.13) are definitions of the urban population and rural population in each area. These are determined by the population in the previous period, the number of natural increases, the number of social increase (decrease) by population migration, and errors. Furthermore, Eq. (17.11), sum the urban and rural populations to determine the population of each region.

Eqs. (17.14), (17.15), (17.16), and (17.17) multiply each sector productivity and labor force to determine each sector GDP (four sectors: urban formal and urban informal sector GDP, and rural formal and rural informal sector GDP).

Eqs. (17.18) and (17.19) sum up each area's formal GDP and informal GDP to determine each region's urban GDP and rural GDP (two areas).

Furthermore, Eq. (17.20) sum the urban GDP and rural GDP to determine the three-region's GDP (coastal, middle, and inland region).

Finally, the sum of the three-region's GDP (coastal, middle, and inland region) is China's GDP (see Appendix 1: Model Structure).

(1) Population (coastal, middle, and inland region)

$$(iiiJINKO) = (iiiUPOPU) + (iiiRPOPU) \tag{17.11}$$

(2) Urban population (coastal, middle, and inland region)

$$\begin{aligned}(iiiUPOPU) = (iiiUPOPU)\,(-1)^{*}(1 + (iiiNATUR)/1000) + (\text{Inflow}) \\ - (\text{Outflow}) + (iiiUGOSA)\end{aligned} \tag{17.12}$$

(3) Rural population (coastal, middle, and inland region)

$$\begin{aligned}(iiiRPOPU) = (iiiRPOPU)\,(-1)^{*}(1 + (iiiNATUR)/1000) + (\text{Inflow}) \\ - (\text{Outflow}) + (iiiRGOSA)\end{aligned} \tag{17.13}$$

(4) Urban formal GDP (coastal, middle, and inland region)

$$(iiiUFGDP) = (iiiUFSEI)^{*}(iiiUFKIJ)/10{,}000 \tag{17.14}$$

(5) Urban informal GDP (coastal, middle, and inland region)

$$(iiiUIGDP) = (iiiUISEI)^{*}(iiiUIKIJ)/10{,}000 \tag{17.15}$$

(6) Rural formal GDP (coastal, middle, and inland region)

$$(iiiRFGDP) = (iiiRFSEI)^{*}(iiiRFKIJ)/10{,}000 \tag{17.16}$$

(7) Rural informal GDP (coastal, middle, and inland region)

$$(iiiRIGDP) = (iiiRISEI)^{*}(iiiRIKIJ)/10{,}000 \quad (17.17)$$

(8) Urban GDP (coastal, middle, and inland region)

$$(iiiU\text{-}GDP) = (iiiUFGDP) + (iiiUIGDP) \quad (17.18)$$

(9) Rural GDP (coastal, middle, and inland region)

$$(iiiR\text{-}GDP) = (iiiRFGDP) + (iiiRIGDP) \quad (17.19)$$

(10) GDP (coastal, middle, and inland region)

$$(iiiGDP) = (iiiU\text{-}GDP) + (iiiR\text{-}GDP) \quad (17.20)$$

(11) Urban GDP per capita (coastal, middle, and inland region)

$$(iiiUCGDP) = (iiiU\text{-}GDP) \,/\, (iiiUPOPU)^{*}\ 10{,}000 \quad (17.21)$$

(12) Rural GDP per capita (coastal, middle, and inland region)

$$(iiiRUGDP) = (iiiR\text{-}GDP) \,/\, (iiiRPOPU)^{*}10{,}000 \quad (17.22)$$

(13) GDP per capita (coastal, middle, and inland region)

$$(iiiPCGDP) = (iiiGDP)/(iiiJINKO)^{*}10{,}000 \quad (17.23)$$

Note: (iii) means common to the three regions (coastal, middle, and inland), and the variables are common to each region

17.4 Final Test and Simulation

17.4.1 Final Test Results

I performed the final test for the observation period (1981–2001). Table 17.4 shows the values of MAPEs (mean absolute percentage error) for the last 5 years (1997-2001). Most of the MAPEs (85.1% of 94 variables) were fairly well controlled, being less than 5%. The results of the final test confirmed that the model was useful, and I performed the following simulations.

Table 17.4 Final test and simulation results

Region/variable	Final value (2001)	MAPE (%)	Deviation rate of each simulation				
			Case A (%)	Case B (%)	Case C (%)	Case D (%)	Case E (%)
1. Population migration							
1U-1R	73.92	1.19	0.25	5.09	−0.81	0.85	4.67
1R-1U	170.81	0.30	−0.70	−5.88	2.66	−1.73	−5.24
2U-1U	560.68	11.98	−27.44	−82.07	−2.33	−51.89	−81.04
2U-2R	110.72	1.97	4.65	15.38	2.78	5.64	14.02
2R-1U	121.30	0.32	0.83	6.98	1.51	2.22	6.20
2R-2U	153.05	1.42	5.01	15.09	4.34	13.78	13.31
3U-1U	200.85	6.04	6.27	−56.21	18.53	1.22	−55.87
3U-3R	67.16	1.89	−1.20	1.02	−22.14	0.07	−0.56
3R-1U	67.41	0.27	0.22	0.46	0.99	0.77	−1.73
3R-3U	109.50	2.29	−0.15	50.43	−6.00	−1.09	76.07
2. Coastal region							
JINKO	53, 463.95	0.26	−0.63	−4.21	−1.92	−1.63	−3.69
UPOPU	24, 672.92	0.60	−1.38	−9.65	−1.25	−3.56	−8.58
RPOPU	28, 791.03	0.00	0.00	0.45	−2.50	0.02	0.43
UFKIJ	6317.44	3.13	−0.48	−37.31	1.28	−0.75	−37.88
UIKIJ	4606.05	4.14	−2.89	21.93	9.17	−2.04	20.52
RFKIJ	7572.75	3.70	1.41	15.87	−21.32	3.08	14.84
RIKIJ	12, 114.75	1.63	−2.20	−21.70	13.90	−5.35	−20.04
GDP	31, 438.66	1.53	−0.17	−6.33	−8.81	1.03	−7.68
U-GDP	21, 514.73	2.11	−1.36	−21.61	5.21	−1.09	−22.65
R-GDP	9923.92	2.48	2.37	26.81	−39.23	5.64	24.23
PCGDP	5880.34	1.69	0.46	−2.20	−7.02	2.70	−4.14
UCGDP	8719.97	2.12	0.02	−13.23	6.55	2.56	−15.39
RCGDP	3446.88	2.48	2.36	26.24	−37.67	5.62	23.69
UFGDP	16, 020.31	2.60	−1.02	−38.45	2.20	−1.37	−39.08
UIGDP	5494.41	4.37	−2.35	27.48	14.00	−0.29	24.57
UFSEI	25, 358.84	2.29	−0.53	−1.81	0.90	−0.62	−1.93
UISEI	11, 928.68	1.74	0.55	4.55	4.42	1.77	3.35
RFGDP	5755.93	3.53	1.41	16.17	−20.44	3.10	15.12
RIGDP	4167.99	4.86	3.67	41.50	−65.20	9.14	36.53
RFSEI	7600.85	0.22	0.00	0.25	1.11	0.01	0.24
RISEI	3440.42	4.49	6.00	80.72	−69.44	15.31	70.77
3. Middle region							
JINKO	43, 518.30	0.30	0.92	3.87	−1.83	2.14	3.36
UPOPU	14, 956.09	1.18	3.53	11.94	0.19	8.20	10.71
RPOPU	28, 562.21	0.12	−0.46	−0.35	−2.89	−1.02	−0.57
UFKIJ	4184.27	6.02	11.48	35.04	0.80	27.55	32.60

(continued)

Table 17.4 (continued)

Region/variable	Final value (2001)	MAPE (%)	Deviation rate of each simulation Case A (%)	Case B (%)	Case C (%)	Case D (%)	Case E (%)
UIKIJ	4246.57	8.43	4.58	5.57	2.12	12.83	7.35
RFKIJ	4077.00	3.97	−6.82	−10.27	−20.73	−18.31	−11.94
RIKIJ	12, 449.58	2.20	−1.89	−6.21	13.87	−16.11	−5.91
GDP	13, 633.69	1.76	2.88	7.20	2.51	3.81	6.59
U-GDP	8162.75	1.80	6.92	16.30	2.15	17.53	15.85
R-GDP	5470.93	3.82	−2.87	−6.38	3.05	−16.64	−6.58
PCGDP	3132.86	1.73	1.93	3.20	4.43	1.63	3.13
UCGDP	5457.81	1.38	3.27	3.89	1.95	8.62	4.63
RCGDP	1915.44	3.80	−2.42	−6.04	6.12	−15.78	−6.05
UFGDP	5240.90	2.87	7.84	24.13	−0.27	18.80	21.67
UIGDP	2921.85	7.68	5.22	2.25	6.51	15.24	5.06
UFSEI	12, 525.23	3.06	−3.26	−8.07	−1.06	−6.86	−8.24
UISEI	6880.48	2.66	0.61	−3.14	4.29	2.13	−2.13
RFGDP	2047.05	4.72	−4.55	−6.51	−16.18	−14.06	−7.64
RIGDP	3423.87	5.96	−1.91	−6.30	14.55	−18.18	−5.98
RFSEI	5020.98	1.40	2.42	4.18	5.74	5.20	4.87
RISEI	2750.19	4.68	−0.01	−0.09	0.60	−2.47	−0.07
4. Inland region							
JINKO	43, 518.30	0.05	−0.24	2.03	−2.58	−0.21	1.77
UPOPU	14, 956.09	0.22	−0.36	9.71	−1.88	−0.75	10.54
RPOPU	28, 562.21	0.08	−0.20	−1.00	−2.86	0.00	−1.70
UFKIJ	4184.27	3.94	−1.41	23.82	−8.14	−9.41	23.33
UIKIJ	4246.57	4.27	0.57	−1.23	1.26	2.42	5.76
RFKIJ	4077.00	5.66	0.23	−11.15	7.54	0.43	−35.36
RIKIJ	12, 449.58	3.85	−2.25	−56.23	−7.88	1.54	−83.35
GDP	13, 633.69	3.59	−2.03	−14.62	−9.84	−1.61	−2.20
U-GDP	8162.75	2.25	−0.20	10.01	−4.02	−5.01	13.10
R-GDP	5470.93	8.44	−4.47	−47.13	−17.51	2.86	−22.55
PCGDP	3132.86	3.57	−1.79	−16.32	−7.44	−1.40	−3.90
UCGDP	5457.81	2.16	0.16	0.26	−2.18	−4.28	2.32
RCGDP	1915.44	8.42	−4.28	−46.60	−15.07	2.86	−21.21
UFGDP	5240.90	3.47	−0.62	12.67	−5.70	−8.03	12.46
UIGDP	2921.85	3.43	0.92	2.87	0.47	3.07	14.83
UFSEI	12, 525.23	2.39	0.80	−9.00	2.65	1.52	−8.81
UISEI	6880.48	2.72	0.34	4.16	−0.77	0.63	8.57
RFGDP	2047.05	6.88	−0.24	−5.97	2.80	0.84	−25.89
RIGDP	3423.87	10.08	−5.64	−58.55	−23.14	3.42	−21.63
RFSEI	5020.98	2.04	−0.48	5.83	−4.41	0.41	14.65
RISEI	2750.19	6.10	−3.46	−5.29	−16.56	1.84	370.82

(continued)

Table 17.4 (continued)

Region/variable	Final value (2001)	MAPE (%)	Deviation rate of each simulation Case A (%)	Case B (%)	Case C (%)	Case D (%)	Case E (%)
5. China							
JINKO	125, 472.03	0.00	0.00	0.00	−2.04	0.00	0.00
UPOPU	47, 701.58	0.04	0.35	0.39	−0.90	0.59	0.82
RPOPU	77, 770.45	0.02	−0.21	−0.22	−2.74	−3.66	−0.49
UFKIJ	12, 884.27	3.93	3.26	−2.51	−0.61	6.84	−3.54
UIKIJ	11, 432.92	5.24	0.63	10.62	4.77	4.49	12.35
RFKIJ	13, 663.14	3.31	−1.20	4.08	−16.89	−3.68	−0.39
RIKIJ	35, 131.41	1.25	−2.10	−26.60	7.34	−7.08	−33.67
GDP	52, 608.94	0.71	0.35	−4.01	−6.02	1.37	−3.19
U-GDP	33, 965.18	1.38	0.75	−8.51	3.31	2.88	−8.96
R-GDP	18, 643.75	1.84	−0.35	4.18	−23.04	−1.38	7.11
PCGDP	4192.88	0.71	0.35	−4.02	−4.06	1.37	−3.20
UCGDP	7120.34	1.38	0.39	−8.87	4.26	2.27	−9.71
RCGDP	2397.28	1.85	−0.13	4.42	−20.87	−1.01	7.64
UFGDP	24, 382.76	1.85	0.94	−18.45	0.65	2.11	−19.39
UIGDP	9582.41	5.25	0.28	16.79	10.07	4.85	17.60
UFSEI	18, 924.44	2.70	−2.24	−16.35	1.28	−4.42	−16.43
UISEI	8381.42	0.71	−0.34	5.57	5.06	0.34	4.67
RFGDP	8508.47	3.44	−0.15	8.87	−17.49	−1.21	6.32
RIGDP	10, 135.28	4.49	−0.51	0.24	−27.70	−1.52	7.75
RFSEI	6227.31	0.27	1.06	4.60	−0.71	2.57	6.74
RISEI	2884.96	3.57	1.62	36.57	−32.64	5.99	62.45

Note: Main variables are listed of each region (coastal, middle, inland region, and China) (see Appendix 2: Variable Table)
Source: Calculated by the author

17.4.2 Simulations

In China, "Chinese Economic Reform (Gaige Kaifang; 1978)" had brought in huge amounts of foreign capital, and the coastal region had achieved high economic growth. On the other hand, there was little inflow of foreign capital to the middle and inland regions, which expanded the regional disparity. Furthermore, population migration, which affects the reduction of income disparity, was legally regulated in China.

In this section, I consider (1) population migration, (2) educational level, (3) China Western Development, and analyze the impact of each factor on the three regional economies (coastal, middle, and inland) and Chinese economic development. Therefore, I performed the following simulations during the observation period (from 1981 to 2001).

1. Case A: Rural educational-level improvement

   During the observation period, in the middle rural and inland rural areas, illiterate and semi-illiterate and primary school population is decreased by 100,000 persons, and junior high school and senior high school population is increased by 100,000 persons.
2. Case B: Increase in foreign direct investment in middle and inland regions

   During the observation period, the amount of foreign direct investment is reduced by 10% in the coastal region. And 67% of the decrease of the coastal region is added to the middle region, and 33% of that is added to the inland region.[4]
3. Case C: Natural growth rate decrease

   During the observation period, the natural increase rate of each region is multiplied by 0.9 (10% decrease).
4. Case D: Promotion of deregulation of population migration

   Multiplying the coefficient of income ratio variable of the population migration functions by 1.1 (10% increase; increased population migration speed).
5. Case E: The China Western Development

   Case A and case B are performed simultaneously.

The observations in these simulations are as follows:

1. Case A: Population migration from middle rural and inland rural area to coastal urban area (0.8%, 0.2%) and population migration from middle rural area to middle urban area (6%) are increased. Higher education in rural area does not necessarily lead to economic growth in rural area, because the highly educated labor force migrates to urban area. However, economic growth was observed in coastal rural GDP (2%) and middle urban GDP and China urban GDP (6%, 0.7%).
2. Case B: The increase in foreign direct investment in middle urban and inland urban areas has expanded employment opportunities in these areas. As a result, population migration from middle urban and inland urban areas to coastal urban area has decreased significantly (−82%, −56%), and population migration from middle rural area to middle urban area and from inland rural area to inland urban area has increased significantly (15%, 50%).

   Economic growth was observed in middle and inland urban areas, and an increase in foreign direct investment in middle and inland urban areas was found to be beneficial in reducing regional disparities.
3. Case C: The decrease of the natural growth rate, the regional disparities tend to increase, except for the intraregional disparities in the middle region. As a result, a population control policy have a negative impact on reducing regional disparities (especially inland region).

[4] The total foreign direct investment in each region during the observation period was as follows: coastal/middle/inland ≒ 85:10:5.

4. Case D: The deregulation of population migration has led to a slight increase in population migration from middle rural and inland rural areas to coastal urban area (2%, 0.7%), from middle rural area to middle urban area (13%), and from inland urban area to coastal urban area (1%). This is influenced by the fact that migration to urban area (especially to coastal urban area) requires skilled labor with a high level of education.
5. Case E: In the China Western Development, middle urban and inland urban area economy has grown (15%, 13%). As a result, population migration from middle urban and inland urban areas to coastal urban area has drastically decreased (−81%, −55%). And population migration has increased from middle rural area to middle urban area and from inland rural area to inland urban area (13%, 76%). It was observed that intraregional disparities in coastal area and interregional disparities in urban area (costal urban, middle urban, and inland urban areas) have decreased. As a result, it was found that the China Western Development would lead to reduction of regional disparities.

17.5 Conclusion

The main observations of the simulations with this model are as follows:

I estimated detailed time series data (from 1978 to 2001) of three regions (coastal, middle, and inland), two areas (urban and rural), and two sectors (formal and informal) in China, and built simultaneous equation model (94 equations), performed the final test. Although a lot of new estimated data were used in this model, MAPEs showed good results.

As a result of the China Western Development simulation, that is the improvement of educational level in the middle and inland regions and the redistribution of foreign direct investment from the coastal region, economic growth was observed in middle and inland urban areas and coastal rural area. This is because (1) the improvement of educational level promotes the outflow of highly educated skilled labor from rural area, it does not lead to economic growth in rural area, (2) the assumption that foreign direct investment inflows only urban area. In coastal urban area, the inflow of foreign direct investment decreases, population migration from other areas (middle urban area, etc.) drastically decreases, and economic growth stagnates. On the other hand, in coastal rural area, brain drain stops, and the economy grows. As a result, intraregional disparities (between urban and rural areas) in coastal region was significantly reduced, but it does not necessarily lead to reducing regional disparities. From the result of this simulation, it was judged that economic policies other than these two economic policies are necessary for full-scale economic growth of the middle and inland regions.

Because of the lack of government budget, this simulation does not assume policies that would stimulate demand in middle and inland rural areas. However, as many scholars have pointed out, government-led infrastructure development and stimulating demand in rural area are important.[5]

In building this model, the author's field survey at the Guangdong Provincial Bureau of Statistics (February, 2003) revealed the following facts; (1) The 2000 Population Census introduced the latest statistical methods, but it had an error of 10% of the total population; (2) The National Bureau of Statistics, People's Republic of China divided this error into rural areas throughout China; (3) These are the reasons for the dramatic increase in population migration from urban to rural areas in the 2000 Population Census. Finally, it should be noted that the author was infected with "SARS" during this field survey.

The results of a separate study by the author are as follows. I had built an econometric model of China that divided the county's 31 Provinces, Direct-administered Municipalities, and Autonomous Regions into 2 areas (urban and rural) (Suzuki 2009). This models was based on the following the author's field surveys: Kunming (Yunnan 2005), Guilin, Yongfu (Guangxi 2005, 2007), Beijing (2006, 2007), Xi'an (Shaanxi 2007), Zhengzhou, Luoyang, Kaifeng (Henan 2007), Hangzhou, and Shaoxing (Zhejiang 2007). These field surveys were considered the regional coverage: (1) coastal, middle, and inland regions, (2) Provinces, Direct-administered Municipalities, and Autonomous Regions, (3) urban and rural areas. Furthermore, these field surveys were funded by the Grant-in-Aid for Scientific Research (C) (3300 thousand yen, from 2005 to 2006).

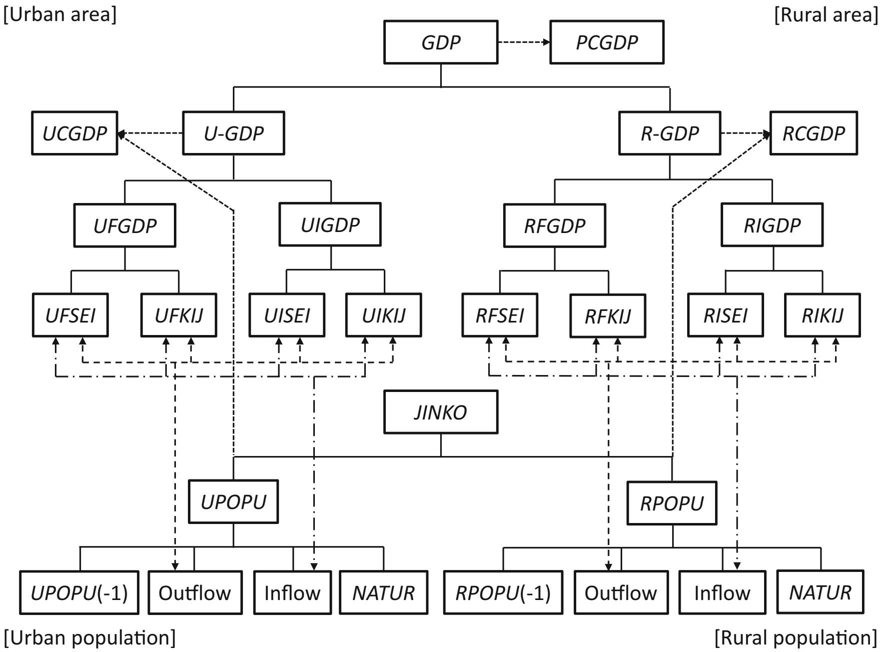
The characteristics of this models is as follows: (1) two areas model (urban and rural); (2) an extended gravity formula was used for the population migration functions between urban and rural areas; (3) the educational level variables were considered as explanatory variables of the population migration functions; (4) a long-term forecasting model (the MAPEs of this model is as low as about 3%, and a long-term forecast of about 15 years is possible).

The various simulation results with this model are as follows: (A) Increasing foreign direct investment in urban and rural areas tends to expand the per capita income disparity between the two areas. In order to achieve economic growth without expanding the income disparity between two areas, the growth of foreign direct investment in rural area needs to be higher than that in urban area. (B) In the long term, the educational level in rural area needs to be improved. (C) Furthermore, the plan to quadruple GDP growth in the year 2020 (compared to in the year 2000 level) is not achievable. The most important factor for achieving this plan is the increase in rural incomes (Suzuki 2009). Chinese government has indicated a policy that per capita income of farmers in the year 2020 twice as much of 2008 (October, 2008).

[5]The China Western Development is "the share of government budget investment in fixed asset investment is 4.2% (1998)" (Kato 2000). Therefore, a large-scale government investment cannot be expected by a serious shortage of financial resources. Therefore, in the simulations in this paper, I considered only the reorganization of foreign direct investment and did not consider the increase in government investment.

Furthermore, I have been conducting the following field surveys in China since 2009: Jinan, Qingdao, Yantai, Zibo, Taian (Shandong; 2009), Shenyang, Dalian (Liaoning; 2010), Changchun, Tonghua (Jilin; 2010), Harbin (Heilongjiang; 2010), Hefei, Huangshan, Xuancheng (Anhui; 2011), Hangzhou, Shaoxing (Zhejiang; 2011), Wuhan, Huanggang, Jingzhou, Yichang, Xiangyang (Hubei; 2012), Hangzhou, Hangzhou, Shaoxing, Huzhou (Zhejiang; 2016), Longyan, Fuzhou, Quanzhou, Zhangzhou (Fujian; 2017), Nanjing, Suzhou, Wuxi, Yangzhou, Zhenjiang (Jiangsu; 2018), and Shanghai (2018). Based on the results of my field surveys, I would like to make Chinese internal population migration and income disparity after 2000 as my future tasks.

Appendix 1: Model Structure



Note: See Appendix 2: Variable Table
Source: Created by the author

Appendix 2: Variable Table

No.	Name	Explanation	Unit
1	*1R-1U*	From coastal rural to coastal urban	10,000 persons
2	*1R-3U*	From coastal urban to inland urban	10,000 persons
3	*1U-1R*	From coastal urban to coastal rural	10,000 persons
4	*1U-1U*	From coastal urban to coastal urban	10,000 persons
5	*1U-2U*	From coastal urban to middle urban	10,000 persons
6	*1U-3U*	From coastal urban to inland urban	10,000 persons
7	*2R-1U*	From middle rural to coastal urban	10,000 persons
8	*2R-2U*	From middle rural to middle urban	10,000 persons
9	*2R-3U*	From middle rural to inlan urban	10,000 persons
10	*2U-1R*	From middle urban to coastal rural	10,000 persons
11	*2U-1U*	Form middle uraban to coastal urban	10,000 persons
12	*2U-2R*	From middle ruban to middle rural	10,000 persons
13	*2U-2U*	From middle urban to middle urban	10,000 persons
14	*2U-3U*	From middle urban to inland urban	10,000 persons
15	*3R-1U*	Form inland rural to coastal urban	10,000 persons
16	*3R-2U*	From inland rural to middle urban	10,000 persons
17	*3R-3U*	From inland rural to inland urban	10,000 persons
18	*3U-1R*	From inland urban to coastal rural	10,000 persons
19	*3U-1U*	From inland urban to coastal urban	10,000 persons
20	*3U-2U*	Form inland urban to middle urban	10,000 persons
21	*3U-3R*	From inland urban to inland rural	10,000 persons
22	*3U-3U*	Form inland urban to inland urban	10,000 persons
23	*CINDU*	Collective-owned units	10,000 units
24	*ELECT*	Electricity consumed in rural areas	Billion kwh
25	*FINVE*	Foreign direct investment	100 million yuan
26	*GDP*	GDP	100 million yuan
27	*GEXPO*	Export value (Township and Village Enterprises)	Billion yuan
28	*GOTIN*	Township and Village Enterprises	10,000 units
29	*INDUS*	Number of enterprises	10,000 units
30	*Inflow*	Total inflow population	10,000 persons
31	*JINKO*	Population	10,000 persons
32	*KENSE*	Total Investment in Construction	Billion yuan
33	*KINDU*	State-owned units	10,000 units
34	*NATUR*	Natural growth rate	‰
35	*Outflow*	Total outflow population	10,000 persons
36	*PCGDP*	GDP per capita	Yuan
37	*RCGDP*	Rural GDP per capita	Yuan
38	*RELEM*	Rural primary school	10,000 persons
39	*RFGDP*	Rural formal GDP	100 million yuan
40	*RFKIJ*	Rural formal labor fprce	10,000 persons

(continued)

No.	Name	Explanation	Unit
41	*RFSEI*	Rural formal productivity	Yuan
42	*R-GDP*	Rural GDP	100 million yuan
43	*RGOOS*	Total retail sales of consumer goods in rural	Billion yuan
44	*RGOSA*	Rural population error	10,000 persons
45	*RIGDP*	Rural informal GDP	100 million yuan
46	*RIKIJ*	Rural informal labor force	10,000 persons
47	*RILLI*	Rural illiterate and semi-illiterate	10,000 persons
48	*RINCO*	Per capita annual net income of rural households	Yuan
49	*RISEI*	Rural informal productivity	Yuan
50	*RISTO*	Rural informal capital stock	Billion yuan
51	*RJUNI*	Rural junior high school	10,000 persons
52	*RPOPU*	Rural population	10,000 persons
53	*RSENI*	Rural senior high school	10,000 persons
54	*RSTOK*	Rural capital stock	Billion yuan
55	*STOCK*	Capital stock	Billion yuan
56	*SUMFI*	Foeign capital stock	100 million yuan
57	*UCGDP*	Urban GDP per capita	Yuan
58	*UCGOO*	Urban total retail sales of consumer goods	100 million yuan
59	*UELEM*	Urban primary school	10,000 persons
60	*UFGDP*	Urban formal GDP	Billion yuan
61	*UFKIJ*	Urban formal labor force	10,000 persons
62	*UFSEI*	Urban formal productivity	Yuan
63	*UFSTO*	Urban formal capital stock	Billion yuan
64	*U-GDP*	Urban GDP	100 million yuan
65	*UGOSA*	Urban population error	10,000 persons
66	*UIGDP*	Urban informal GDP	100 million yuan
67	*UIKIJ*	Urban informal labor force	10,000 persons
68	*UILLI*	Urban illiterate and semi-illiterate	10,000 persons
69	*UINCO*	Per capita annual disposable income of urban households	Yuan
70	*UINDU*	Number of enterprises in urban	10,000 units
71	*UISEI*	Urban informal productivity	Yuan
72	*UISTO*	Urban informal capital stock	Billion yuan
73	*UJUNI*	Urban junior higr school	10,000 persons
74	*UKIJI*	Urban labor force	10,000 persons
75	*UPOPU*	Urban population	10,000 persons
76	*USENI*	Urban senior high school	10,000 persons
77	*UUNIV*	Urban univercity	10,000 persons

Note 1: This table shows the variables listed in this paper, but 217 variables are used in this model (see Suzuki (2007))
Note 2: The units are used in this paper according to the Chinese official statistics ("China Statistical Yearbook", etc.)
Source: Created by the author

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Chapter 18
Output and Profit Effects of Backward Integration Through Joint Projects: A Successive Cournot Oligopoly Model of the Real Estate Industry

Tohru Wako

Abstract The Japanese real estate industry is characterized as vertically related under a successive oligopoly in which landowners and real estate agents are upstream and downstream businesses, respectively. This chapter proposes that supply increases through backward integration and that the output effect is smaller when each of the several downstream businesses integrates backward with plural upstream businesses than when one-to-one integrations are contemplated. In turn, we demonstrate that each (additional) backward integration generally increases profits for the merged entity, whereas profits for the remaining independent businesses decrease with successive integrations. Therefore, incentives exist for the excluded businesses to integrate to recover their lost profits. When all such inadvertent integrations occur, an alternative strategy still prevails for joint enterprises that cannot go back to the original state of nonintegration: a strategy to form one-to-one backward integrations by establishing more downstream sections.

Keywords Successive oligopolies · Residential lots · One-to-one · One-to-many · Backward integrations · Joint enterprises · Extra downstream sections

This chapter is largely based on the Japanese version of the paper Wako (1997) that was published in *Studies in Regional Science.*

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18.1 Introduction

Although the supply of housing land in Japan gradually decreased during the 1980s and 1990s, it has recently remained steady at one-third or lower of its peak in 1973.[1] In the real estate industry in the past, independent projects seeking profits from the resale of land for housing purchased from landowners were in the mainstream. However, the days of pursuing a profit margin are long gone, given the collapse of the bubble economy in the early 1990s. In recent years, as the acquisition of real estate in metropolitan areas is not necessarily easy, real estate agents have a strong tendency to participate in urban redevelopment projects to increase the profitability of land, which is generated from the accumulation of economic resources (Ministry of Land, Infrastructure, Transport and Tourism 2006). Importantly, downstream real estate agents have reached the stage of coordinating every phase of joint projects with upstream landowners to offer high-value-added services.

For each housing land development project, a core real estate agent instead of partner landowners often makes plans when negotiating an agreement, investing, or financing; the Japanese real estate industry has developed to include, through backward integration via joint projects, production of input for housing land that was supplied conventionally by landowners. For example, in land readjustment projects designed to effectively supply land for housing, each core real estate agent sells reserved land for its joint enterprise to help defray the expenses incurred when operating projects, thus acting as the enterprise's business agent. In this case, similar to upstream landowners, a downstream real estate agent is both a joint owner and joint manager of the joint enterprise (Ishihara and Takatsuji 1993).

Regarding the operation of joint projects, the upstream production section of each enterprise can be regarded as belonging to both a core real estate agent and member landowners. Accordingly, joint projects convert market transactions into intra-enterprise transactions, i.e., transactions of partitioned housing land between independent landowners and a real estate agent are replaced by transactions between upstream and downstream sections of the joint enterprise (Miyamoto 1991). In other words, real estate agents achieve backward integration by combining the two-stage production (distribution) process of a single type of product—residential lots—in which all of the products in the upstream process are used as intermediate (final) products in the downstream process.

Therefore, unlike usual oligopolistic manufacturing industries, products in an upstream process are rarely observed to be partly wholesaled to other processors

[1] Approximately 40% of Japan's land for housing is supplied by land readjustment projects. Private developers have similar market shares as those projects, and the rest is from the public sector and other sources. The public sector has also engaged in land readjustment projects on several occasions, and the private sector is likely to supply approximately 70% of the land for housing, enabling suppliers to be classified into two types, namely, private and public. We consider private developers as real estate agents in a broad sense because they usually possess their real estate development sections.

in external markets or to be used as inputs for other types of products within the enterprise when conducting a joint project to supply residential lots.[2]

Moving on to the theory, the vertical integration of successive monopolists (with fixed production coefficients) has long been known to provide merging monopolists with greater profits and their customers with greater outputs at lower prices.[3] Greenhut and Ohta (1979) demonstrated that when vertical integration of successive oligopolists is mutually profitable, industry output increases and product prices decrease. Although substitutions among production factors can exist in many industries, GO investigated the vertical integration of oligopolists subject to fixed input proportions. Additionally, in real estate industries, invariant coefficient technology applies to the relationship between preparing the ground for housing and partitioning a tract of housing land for sale. Moreover, land as an input to residential lots cannot be substituted by any other inputs.

Following the preceding study of GO, Hamilton and Lee (1986) developed their model of a vertical merger by introducing the possibility of entry into the intermediate inputs market. In addition, McGuire and Staelin (1983) Bonanno and Vickers (1988), and Lin (1988) focused on a specific type of vertical integration—the relationship between manufacturers and retailers/distributers—by using a two-stage Bertrand (1883) duopoly model with differentiated goods. By defining the relationship between each retailer and manufacturer as captive and exclusive, they seek the equilibrium vertical structures with the property of sub-game perfectness and their implications for corporate strategies; for example, they have all established the superiority of closed over open systems of distribution. In a related vein, Wako and Ohta (2005) presented a model of the "semi-open" distribution systems under a successive Cournot oligopoly in which producers manage both open and closed channels and provided a theoretical basis for a multichannel management policy.

In what follows, after the application of the GO model to the real estate industry in Sect. 18.2, Sect. 18.3 of this chapter shows that supply increases with backward integration, and the output effect is smaller when each of several real estate agents integrates backward with plural landowners than it is when one-to-one integrations are contemplated. Further, Sect. 18.4 demonstrates that economic welfare tends to increase with backward integration, but the effect of backward integration on joint profits and social surplus is not definitive in general. However, each (additional) backward integration generally increases joint profits for the merged. In sharp contrast, the profits for the remaining independent businesses and industry profits are shown to decrease with successive backward integrations. Therefore, incentives exist for the excluded businesses to integrate to recover their lost profits. The chapter nevertheless stresses that when all such inadvertent integrations occur, an alternative

[2]Note that only the reserved land belonging to joint enterprises need not be sold via the two-stage production process of a single type of product, since the enterprises aim at allotting all of the revenues from reserved land sales for only their business operations.

[3]Refer to Tirole (1988) and Perry (1989) for an explanation of vertical integration, McGee and Bassett (1976) for the backward integration by a monopolist into an upstream competitive stage, and Milgrom and Roberts (1992) for the cost of vertical integration.

strategy still exists for joint enterprises that cannot go back to the original state of nonintegration; we show that the proposed strategy is to form one-to-one backward integrations by establishing more downstream sections.

18.2 Real Estate Industries Formed by Independent Upstream-Downstream Oligopolists[4]

First, consider two vertically related activities in the real estate industry. Let the upstream stage involve the combined operation of partitioning a tract of housing land and wholesaling by n independent landowners to m independent real estate agents (retailers). Conceive of each residential lot resold by the m downstream real estate agents as homogeneous and equal areas of land. The total residential land lots for resale q_{L}, which are in fixed proportion to homogeneous inputs of ground for housing lots q_{b} in area, are received in the form of partitioned land lots from the upstream landowners. Assuming that the landowners are the developers for partitioning a tract of housing land, for simplicity, we have:

$$q_{\mathrm{L}} = \alpha q_{\mathrm{b}}, \tag{18.1}$$

where α stands for the constant coefficient of the partitioning (or production).

Next, let market demand q_{L} for the residential lots as the final product be a uniquely decreasing function of the retail price p_{L}, given by:

$$\begin{aligned} p_{\mathrm{L}} &= f\left(q_{\mathrm{L}}\right) \quad \left(f' < 0\right) \\ &= f\left(\alpha q_{\mathrm{b}}\right), \quad \text{via} \quad (18.1) \end{aligned} \tag{18.2}$$

Market demand q_{L} must be equated with the industry supply by "m" real estate agents. This requirement establishes:

$$q_{\mathrm{L}} = \sum_{i=1}^{m} q_{\mathrm{L}i}, \tag{18.3}$$

where $q_{\mathrm{L}i}$ stands for the ith real estate agent's supply.

Profits for the ith real estate agent π_i^d are then given by:

$$\begin{aligned} \pi_i^{\mathrm{d}} &= p_{\mathrm{L}} q_{\mathrm{L}i} - p_{\mathrm{b}}^{\mathrm{w}} q_{\mathrm{b}i} \\ &= \left(\alpha f - p_{\mathrm{b}}^{\mathrm{w}}\right) q_{\mathrm{b}i} \end{aligned} \quad (i = 1, 2, \ldots, m), \tag{18.4}$$

[4]Other costs (such as taxes) are disregarded in this chapter without loss of generality.

where $p_{\mathrm{b}}^{\mathrm{w}}$ stands for the wholesale price for a residential lot purchased by the ith real estate agent[5] and the superscripts d and w indicate "downstream" and "wholesale," respectively.

Assume that both the upstream landowners and the downstream real estate agents are Cournot (1897) quantity-taking oligopolists as sellers in their respective markets and that, in the wholesale market, the upstream sellers are price-givers and leaders of the downstream buyers who—as followers—are price-takers. The first-order profit maximization conditions for the real estate agents require:

$$\frac{\partial \pi_i^{\mathrm{d}}}{\partial q_{\mathrm{b}i}} = 0, \quad \therefore \alpha \left(f + f' \alpha q_{\mathrm{b}i} \right) = p_{\mathrm{b}}^{\mathrm{w}} \quad (i = 1, 2, \ldots, m), \tag{18.5}$$

where $p_{\mathrm{b}}^{\mathrm{w}}$ is a parameter invariant to changes in the quantity purchased by the individual retailer.

Thus, Eq. (18.5) depicts the individual real estate agent's demand for partitioned residential lots $q_{\mathrm{b}i}$ at the market wholesale price $p_{\mathrm{b}}^{\mathrm{w}}$. Derived market demand for residential lots simply involves summing (18.5) for all $i = 1, 2, \ldots, m$. The aggregation establishes:

$$\alpha \left(mf + \sum_{i=1}^{m} f' \alpha q_{\mathrm{b}i} \right) = m p_{\mathrm{b}}^{\mathrm{w}},$$

$$\alpha \left(f + \frac{1}{m} \sum_{i=1}^{m} f' \alpha q_{\mathrm{b}i} \right) = p_{\mathrm{b}}^{\mathrm{w}}. \tag{18.6}$$

As market demand q_{b} must equate with the market supply by "n" upstream landowners, we also obtain:

$$q_{\mathrm{b}} = \sum_{j=1}^{n} q_{\mathrm{b}j}, \tag{18.7}$$

where $q_{\mathrm{b}j}$ stands for the jth landowner's supply of residential lots. The aggregate upstream supply depends on the profits:

$$\pi_j^{\mathrm{u}} = p_{\mathrm{b}}^{\mathrm{w}} q_{\mathrm{b}j} - c_j q_{\mathrm{b}j} \quad (j = 1, \ldots, n), \tag{18.8}$$

where c_j is a constant unit (marginal) cost of production and superscript u indicates "upstream." Without loss of generality, for simplicity, we conceive of two-

[5] We assume the structure of the residential land market to be successively oligopolistic, aiming to analyze the economic effects of backward integration under a relatively simple framework. By contrast, even though supposing that the input market structure is bilaterally oligopolistic will provide no equilibrium solutions, it is more realistic.

stage industry, with residential land developing and wholesaling belonging to the upstream stage and in turn distributing the partitioned residential lots to consumers serving as the downstream stage.

Profit maximization by the upstream landowners (as Cournot oligopolists) simply requires:

$$\frac{\partial \pi_j^{\mathrm{u}}}{\partial q_{\mathrm{b}j}} = 0,$$

$$\therefore\ \alpha\left(g + \frac{1}{m} f'' \alpha^2 q_{\mathrm{b}} q_{\mathrm{b}j} + \frac{m+1}{m} f' \alpha q_{\mathrm{b}j}\right) = c_j \quad (j = 1, 2, \ldots, n), \tag{18.9}$$

where $g = f + (1/m) f' \alpha q_{\mathrm{b}}$, which henceforth is called the correspondent to f. Note further that (18.9) is based on the profit-maximizing conditions for downstream real estate agents; in effect, Eq. (18.5) is contained in (18.9). Summing (18.9) over all js then establishes:

$$\alpha\left(g + \frac{1}{mn} f'' \alpha^2 q_{\mathrm{b}}^2 + \frac{m+1}{mn} f' \alpha q_{\mathrm{b}}\right) = \frac{1}{n} \sum_{j=1}^{n} c_j \tag{18.10}$$

The equilibrium output of partitioned residential lots is determined uniquely by (18.10), provided that c_js are known and f is well-behaved.[6] Therefore, Eq. (18.10) has established the equilibrium conditions for two vertically related activities under a successive Cournot oligopoly.

18.3 Backward Integrations of Successive Oligopolists by Means of Joint Projects

GO showed that industry supply increases when some firms in the related stages of production integrate vertically. However, their investigation was limiting in the sense that vertical integrations under consideration are achieved by l horizontally independent upstream firms and l corresponding downstream firms.

We look into this matter closely by including backward integrations of a single real estate agent with multiple landowners: this chapter shows whether the output effect is smaller or larger when each of several downstream real estate agents integrates backward with plural upstream landowners than it is when one-to-one integrations are contemplated. Suppose that l backward integrations are achieved by

[6]By well-behaved f, we mean a twice continuously differentiable function that, in addition, yields a monotonically decreasing function with respect to $q_{\mathrm{b}i}$ on the left-hand side of (18.10). The second-order conditions for profit maximization for each upstream landowner can be satisfied if f is relatively less convex.

l_k/k ($k = 1, 2, \ldots, N$) enterprise(s), each of which, in turn, is involved in k individual joint project(s) conducted by a core real estate agent and k partner landowner(s).

Here, note that $\sum_{k=1}^{N} l_k = l \leq m \leq n$. In view of the empirical observations that show that real estate agents (or joint enterprises) are mostly fewer than landowners, we can generalize the GO model to include the output effect of one-to-many backward integrations.

First, profits for joint enterprise i can be defined as[7]:

$$\pi_i^{\mathrm{du}} = p_{\mathrm{L}} q_{\mathrm{L}i} - \sum_{j=1}^{k} c_{ij} q_{\mathrm{b}ij} = f\alpha \sum_{j=1}^{k} q_{\mathrm{b}ij} - \sum_{j=1}^{k} c_{ij} q_{\mathrm{b}ij} \left(i = 1, \ldots, \sum_{k=1}^{1} \frac{l_k}{k}, \ldots, \sum_{k=1}^{2} \frac{l_k}{k}, \ldots, \sum_{k=1}^{N} \frac{l_k}{k} \right), \tag{18.11}$$

where c_{ij} and superscript du denote the marginal cost for joint project j of enterprise i and "downstream and upstream integration," respectively.[8] Problems concerning the distribution of profits within the joint enterprise are not addressed. The first-order profit maximization conditions for joint project j of enterprise i is then:

$$\frac{\partial \pi_i^{du}}{\partial q_{bij}} = 0,$$

$$\therefore \alpha \left(f + f' \alpha q_{\mathrm{b}i} \right) = c_{ij} \quad \left(q_{\mathrm{b}i} = \sum_{j=1}^{k} q_{\mathrm{b}ij} \right) \left(i = 1, 2, \ldots, \sum_{k=1}^{N} \frac{l_k}{k}; \;\; j = 1, 2, \ldots, k \right), \tag{18.12}$$

where the c_{ij}s are independent of and conceived to be lower than the $p_{\mathrm{b}}^{\mathrm{w}}$ of Eq. (18.5). Except for this specification, (18.5) is equivalent to (18.12).

The marginal revenues provided on the left-hand side of (18.5) and (18.12) are the same for each of the downstream real estate agents regardless of whether or not they integrate backward with an upstream landowner or landowners. Because each joint enterprise achieves k ($k = 1, 2, \ldots, N$) backward integrations, summing (18.12) over $j = 1, \ldots, k$ in turn yields:

$$k\alpha \left(f + f' \alpha q_{\mathrm{b}i} \right) = \sum_{j=1}^{k} c_{ij}. \tag{18.13}$$

[7]Profits for joint project j of enterprise i, π_{ij}, can be defined as $\pi_{ij}{}^{du} = f\alpha q_{bij} c_{ij} q_{bij}$.

[8]Vertical integration per se may reduce costs of production, cs. In addition, economies of scale may operate to reduce the cs because integration increases output. We assume away all of these possibilities and concentrate our attention on the economies of integration that are related directly to market structures.

Moreover, the profit-maximizing condition for the $(m-\sum_{k=1}^{N} l_k/k)$ nonintegrated real estate agents remains as given by (18.5) for these $i = \sum_{k=1}^{N}(l_k/k) + 1, \ldots, m$ agents. These $(m - \sum_{k=1}^{N} l_k/k)$ real estate agents can be conceived for simplicity to purchase their residential lots from the $(n - l)$ independent oligopolistic landowners. Therefore, aggregating (18.13) and (18.5), respectively, over $i = 1, \ldots, \sum_{k=1}^{N}(l_k/k)$ and $i = \sum_{k=1}^{N}(l_k/k) + 1, \ldots, m$ establishes:

$$\alpha\left\{l_1 f + f'\alpha\sum_{i=1}^{l_1} q_{\mathrm{b}i}\right\} + \sum_{r=2}^{N}\alpha\left\{\frac{l_r}{r} rf + rf'\alpha\sum_{i=\lambda+1}^{\mu} q_{\mathrm{b}i}\right\} = \sum_{i=1}^{l_1} c_{i1} + \sum_{r=2}^{N}\sum_{i=\lambda+1}^{\mu}\sum_{j=1}^{r} c_{ij} \quad \left(\lambda = \sum_{k=1}^{r-1}\frac{l_k}{k};\;\; \mu = \sum_{k=1}^{r}\frac{l_k}{k}\right), \tag{18.14}$$

$$\alpha\left\{(m-\varphi) f + f'\alpha\sum_{i=\varphi+1}^{m} q_{\mathrm{b}i}\right\} = (m-\varphi)\, p_{\mathrm{b}}^{\mathrm{w}} \quad \left(\varphi = \sum_{k=1}^{N}\frac{l_k}{k}\right) \tag{18.15}$$

These two equations, respectively, provide the aggregated residential lots supplied by $\sum_{k=1}^{N}(l_k/k)$ integrated and $(m - \sum_{k=1}^{N} l_k/k)$ nonintegrated downstream real estate agents.

Note in particular that Eq. (18.15) represents the derived market demand for the residential lots from the perspective of the $(n - l)$ nonintegrated upstream landowners. Profit maximization by these wholesalers involves:

$$\alpha\left\{g^* + \tfrac{1}{m-\varphi} f''\alpha^2\left(\sum_{i=\varphi+1}^{m} q_{\mathrm{b}i}\right) q_{\mathrm{b}j} + \tfrac{m-\varphi+1}{m-\varphi} f'\alpha q_{\mathrm{b}j}\right\} = c_j \left(j = \sum_{k=1}^{N}(l_k) + 1, \ldots, n\right), \tag{18.16}$$

where $g^* = f + \{1/(m-\varphi)\} f'\alpha\sum_{i=\varphi+1}^{m} q_{bi}$.

As profit maximization by the l vertically integrated joint projects is already given by (18.12), it follows that to derive the counterpart to (18.10), we simply have to sum (18.16) over $j = \sum_{k=1}^{N}(l_k) + 1, \ldots, n$ to obtain:

$$\alpha\left\{g^* + \tfrac{1}{(n-\psi)(m-\varphi)} f''\alpha^2\left(\sum_{i=\varphi+1}^{m} q_{\mathrm{b}i}\right)\sum_{j=\psi+1}^{n} q_{\mathrm{b}j} + \tfrac{m-\varphi+1}{(n-\psi)(m-\varphi)} f'\alpha\sum_{j=\psi+1}^{n} q_{\mathrm{b}j}\right\} = \tfrac{1}{n-\psi}\sum_{j=\psi+1}^{n} c_j \left(\psi = \sum_{k=1}^{N} l_k\right) \tag{18.17}$$

Market equilibrium requires the following additional equations:

$$\sum_{j=\psi+1}^{n} q_{\mathrm{b}j} = \sum_{i=\varphi+1}^{m} q_{\mathrm{b}i} \tag{18.18}$$

$$q_{\mathrm{b}} = \sum_{j=\psi+1}^{n} q_{\mathrm{b}j} + \sum_{i=1}^{\varphi} q_{\mathrm{b}i} \tag{18.19}$$

These equation systems, together with (18.14), (18.15), and (18.17), can be solved simultaneously for the five endogenous variables q_{b}, $\sum_{j=\psi+1}^{n} q_{\mathrm{b}j}$, $\sum_{i=\varphi+1}^{m} q_{\mathrm{b}i}$, $\sum_{i=1}^{\varphi} q_{\mathrm{b}i}$, and $p_{\mathrm{b}}^{\mathrm{w}}$, where the derived equilibrium wholesale price must exceed the marginal costs (c_{ij}) for the joint projects (or the upstream landowners).

A significant conclusion derives from the requirement that $p_{\mathrm{b}}{}^{\mathrm{w}} > c_{ij}$. Combining (18.14) and (18.15) toward this end, we obtain:

$$\alpha\left(mf + f'\alpha q_{\mathrm{b}}\right) = \sum_{i=1}^{l_1} c_{i1} + \sum_{r=2}^{N}\sum_{i=\lambda+1}^{N}\sum_{j=1}^{r} c_{ij} - \sum_{r=2}^{N}\sum_{i=\lambda+1}^{\mu}\sum_{j=1}^{r-1} c_{ij} + \left(m - l_1 - \sum_{k=2}^{N}\frac{l_k}{k}\right) p_{\mathrm{b}}^{\mathrm{w}},$$

$$\alpha g = p_{\mathrm{b}}^{\mathrm{w}} - \frac{1}{m}\left[\left(l_1 p_{\mathrm{b}}^{\mathrm{w}} - \sum_{i=1}^{l_1} c_{i1}\right) + \left[\sum_{k=2}^{N}\frac{l_k}{k} p_{\mathrm{b}}^{\mathrm{w}} - \left\{\sum_{r=2}^{N}\sum_{i=\lambda+1}^{\mu}\left(\sum_{j=1}^{r} c_{ij} - \sum_{j=1}^{r-1} c_{ij}\right)\right\}\right]\right] < p_{\mathrm{b}}^{\mathrm{w}}. \tag{18.20}$$

Note that setting $k = N = 1$ and $c_{ij} = c_j$ in these equations from (18.11) to (18.20) leads immediately to the relationship derived by GO, given by:

$$\alpha g = p_{\mathrm{b}}^{\mathrm{w}} - \frac{1}{m}\left(l p_{\mathrm{b}}^{\mathrm{w}} - \sum_{i=1}^{l} c_j\right) < p_{\mathrm{b}}^{\mathrm{w}}. \tag{18.21}$$

In contrast, if no vertical integration has taken place at all, Eq. (18.6) applies and is repeated subsequently for convenience as:

$$\alpha g = p_{\mathrm{b}}^{\mathrm{w}}. \tag{18.22}$$

The identity of the left-hand sides of (18.21) and (18.22), as well as the condition (pursuant to fn. (18.6)) that they are decreasing functions of q_{b}, is each previously established. However, the middle part of (18.21) is less than the right-hand side of (18.22). Therefore, the equilibrium result q_{b} is unambiguously greater under the conditions of (18.21) than that which underscores (18.22).

Furthermore, the second term in the middle part of (18.20) is less than the counterpart of (18.21), given by:

$$\left[\left(l_1 p_{\mathrm{b}}^{\mathrm{w}} - \sum_{i=1}^{l_1} c_{i1}\right) + \left[\sum_{k=2}^{N} \frac{l_k}{k} p_{\mathrm{b}}^{\mathrm{w}} - \left\{\sum_{r=2}^{N} \sum_{i=\lambda+1}^{\mu} \left(\sum_{j=1}^{r} c_{ij} - \sum_{j=1}^{r-1} c_{ij}\right)\right\}\right]\right] < \left(l p_{\mathrm{b}}^{\mathrm{w}} - \sum_{i=1}^{l} c_j\right). \tag{18.23}$$

Hence, inequality (18.23) indicates that the middle part of (18.20) is greater than the counterpart of (18.21). Therefore, by the same line of the previous argument, equilibrium result q_{b} is smaller under the conditions of (18.20) than that which underscores (18.21). In conclusion, the output effect is smaller when each of several downstream real estate agents integrates backward with plural upstream landowners through joint projects than it is when one-to-one integrations are contemplated.

18.4 Comparison of Profits and Welfare Based on Transaction Patterns Concerning Vertical Integrations

The previous section showed that the output effect is smaller when each of several real estate agents integrates backward with plural landowners than it is when one-to-one integrations of a downstream and an upstream business are contemplated. Therefore, the result is a greater output effect provided that we can convert one-to-many backward integrations into one-to-one backward integrations for a given number of landowners.

First, Sect. 18.4 compares the effects of backward integration on outputs, profits, and welfare based on structural transaction patterns between real estate agents and landowners. Vertical integration requires profit incentives among the merging businesses. However, such a merger does not require greater industry profits. Rather, additional mergers are feasible if they increase the profits of merging businesses at the expense of previously merged or remaining independent businesses. Although economic welfare tends to increase with backward integration, the effect of backward integration on joint profits and social surpluses is not definitive in general.

To evaluate the previous statement, assume $\alpha = 1$, $c_{ij} = c$, and $f(q) = a - q$, and let $m = 2$, $n = 3$ in the first case, and $m = n = 3$ in the second case subsequently examined. We summarize the analysis in Tables 18.1 and 18.2, which provides a comparison of the effects of backward integrations on outputs, profits, and welfare when $m = 2$ and $n = 3$ and when $m = n = 3$, respectively. Here l stands for the number of integrations, i for a number assigned to each joint enterprise, p_{L} for the retail prices of a residential lot, q_{L} for industry supply, CS for consumer surplus,

$\sum\pi$ for total industry profits, and SS ($\equiv CS + \sum\pi$) for social surplus. Additionally, π^{d} and π^{u} indicate the individual profits for a real estate agent and a landowner, respectively. Further, $\pi_i{}^{\mathrm{du}}$ denotes the profits for the merged businesses. The figures depicted in the second column from the left of the tables show the structural patterns of transactions, where the solid lines (dotted lines) indicate backward integrations (market transactions between independent downstream and upstream businesses).

Next, vertical integration can be readily shown to increase the profits of the initial merged businesses (when l goes from 0 to 1 or from 0 to 2). Additional backward integration also brings about a further increase in the joint profits for the merged (when l goes from 1 to 2). Incentive exists accordingly for the backward integration. For example, profits for a joint enterprise $\pi_i{}^{\mathrm{du}}$ in patterns (II) and (III) that reach a maximum value of 0.1836 $(a-c)^2$ when $l = 2$ in pattern (III) exceed the counterpart total profits for the remaining independent downstream and upstream businesses $\pi^{\mathrm{d}} + \pi_{\mathrm{u}}$ and $\pi^{\mathrm{d}} + \sum\pi_{\mathrm{u}}$, respectively, in pattern (I). In contrast, however, profits for the remaining independent businesses, and the industry profit $\sum\pi$ as well, can be shown to decrease during the process. Specifically, profits for the remaining independent businesses ($\sum\pi - \pi_i{}^{\mathrm{du}}$) in (II) and (III) fall below the counterparts $\pi^{\mathrm{d}} + \sum\pi_{\mathrm{u}}$ and $\pi^{\mathrm{d}} + \pi_{\mathrm{u}}$ in (I), respectively. Note that the profits for an independent real estate agent π^{d} when $l = 2$ is almost one-half that when $l = 1$.

Nevertheless, even if enterprise 1 (enterprise 2) in pattern (IV) starts on joint project(s) after enterprise 2 (enterprise 1), the joint profit $\pi_i{}^{\mathrm{du}}$ (= 0.1111 $(a-c)^2$) exceeds the counterpart profits $\pi^{\mathrm{d}} + \pi_{\mathrm{u}}$ in pattern (III) ($\pi^{\mathrm{d}} + \sum\pi_{\mathrm{u}}$ in pattern (II)). In other words, incentives exist for the initially excluded businesses to integrate vertically to recover their lost profits.

In fact, the final stage when $l = 3$ (in pattern (IV)) is characterized by lower total industry profit $\sum\pi$ than that which prevailed initially when no backward integration occurred at all, that is, when $l = 0$. In particular, the profits for enterprise i ($i = 1, 2$) $\pi_i{}^{\mathrm{du}}$ (= 0.1111 $(a-c)^2$) in pattern (IV) fall short of the counterpart profits $\pi_i{}^{\mathrm{du}}$ (= 0.1600 $(a-c)^2$) in pattern (II) and $\pi_i{}^{\mathrm{du}}$ (= 0.1836 $(a-c)^2$) in pattern (III), respectively. Merged businesses now find the original state to be a better one.[9]

If all such inadvertent integrations have occurred, the chapter nevertheless stresses that an alternative strategy still exists for the joint enterprise that cannot go back to the original state of nonintegration.[10] We show that the proposed strategy is to form one-to-one backward integrations by establishing more downstream sections, by allowing $m = 3$ (in pattern (V)): this strategy enables the profit for enterprise 2 $\pi_i{}^{\mathrm{du}}$ (= 0.1250 $(a-c)^2$) in (V) to be greater than the counterpart profit $\pi_i{}^{\mathrm{du}}$ (= 0.1111 $(a-c)^2$) in (IV).

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[9]Refer to Perry (1978) for the case in which a downstream monopsonist purchases inputs from not only a partially integrated upstream production sector but also from the remaining independent suppliers and Ordover et al. (1990) for the integration-deterring strategies by an initially integrated firm involved in the two-stage process of production under a successive duopoly with price-setting.

[10]The integrations as a subject of our inquiry are not long-term integrations, as observed in the petroleum-processing industry. Therefore, structural patterns of integrations can turn variable and reversible to some extent whenever a joint project was completed or another project is started.

Table 18.1 Profit and welfare effects of backward integrations when $m = 2$, $n = 3$

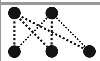
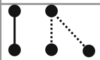
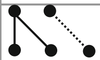
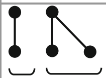
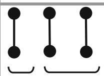
Transaction pattern	Downstream Upstream	l	p_{L}	q_{L}	CS	$\sum \pi$	SS	π_i^{du}	π^{d}	π_{u}
(I)		0	$\frac{a+c}{2}$	$\frac{1}{2}(a-c)$	0.1250	0.2500	0.3750		0.0625	0.0416
(II)		1	$\frac{2a+3c}{5}$	$\frac{3}{5}(a-c)$	0.1800	0.2400	0.4200	0.1600	0.0400	0.0200
(III)		2	$\frac{3a+4c}{7}$	$\frac{4}{7}(a-c)$	0.1632	0.2448	0.4081	0.1836	0.0204	0.0408
(IV)	 $i=1$ $i=2$	3	$\frac{a+2c}{3}$	$\frac{2}{3}(a-c)$	0.2222	0.2222	0.4444	$0.1111 (i = 1,2)$		
					Measured in $(a-c)^2$					

Table 18.2 Profit and welfare effects of full one-to-one backward integrations by establishing more downstream sections when $m = n = 3$

Transaction pattern	Downstream / Upstream	l	p_{L}	q_{L}	CS	$\sum\pi$	SS	π_i^{du}	π^{d}	π_{u}
(V)	 $i=1$ $i=2$	3	$\frac{a+3c}{4}$	$\frac{3}{4}(a-c)$	0.2812	0.1875	0.4687	0.0625($i = 1$)		
								0.1250($i = 2$)		
					Measured in $(a-c)^2$					

Getting back to economic welfare, the maximum social surplus SS can be realized under the conditions in which we achieve full, one-to-one backward integrations in pattern (V) when $l = 3$. In sharp contrast, total industry profit $\sum\pi$ reaches a maximum in pattern (I) when $l = 0$. However, the effect of backward integration on consumer surplus CS is not definitive in general: CS increases with an initial one-to-one backward integration in pattern (II) (when l goes from 0 to 1), whereas a decrease in CS is caused by extra backward integration by the original downstream real estate agent in pattern (III) (when l goes from 1 to 2).

18.5 Conclusion

Observations of Japan's real estate distribution system reveal that many real estate developers maintain separate sales channels by regions. Then, an intriguing question is: what economic rationale underlies such a policy? This question motivated us to present a successive Cournot oligopoly model of the real estate industry. We found that the distribution systems by regions are not necessarily an unexpected occurrence for the upstream and downstream businesses participating in a joint enterprise for the purpose of supplying residential lots. As was shown, during the final stage of full one-to-many integrations of real estate agents and landowners, the profits for joint enterprises that cannot go back to the original state of nonintegration are less than those during intermediate stages. However, these enterprises can turn the situation to their advantage if each real estate agent can build one-to-one distribution channels with landowners by establishing extra sales sections: the proposed strategy for the real estate agents is to undertake joint projects with landowners by regions by locating supplementary retail services in local land markets with no real estate agency.

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Chapter 19
Analysis of Regional Agricultural Productivity Growth Using the Malmquist Productivity Index: The Case of Chugoku, Japan

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Abstract This chapter quantitatively examines the characteristics of regional agricultural productivity change and the role of basic conditions in improving productivity, especially for hilly and mountainous municipalities. Using the municipality data of Chugoku agricultural region in Japan, which has many municipalities known for being less favored areas, we examine the characteristics of regional agricultural growth from 2005 to 2015 by measuring the Malmquist productivity index (MPI) based on the DEA model.

We obtain the following findings. First, regional disparities of agricultural growth expanded from 2005 to 2015. Efficiency change values were distributed more widely than technical change values. As a result, in many municipalities, the MPI was distributed under 1.0. These results indicated different trends between agricultural output and farm sales amount cases. Second, the increase in sales channel of JA cooperatives has positive influence on productivity change, while increase in sales channel of retailers has negative influence. In addition, farm management area per farmer has negative influence on productivity change. Third, gender of the manager and farmer diversity have positive influence on the productivity change. Farmers allowing others to use their land and community-level cooperation, such as farmland conservation, also play important roles in the efficient use of farmlands to promote productivity change. Fourth, competitiveness and cooperation elements such as the density of main farmers and mutual help in farm labor play important roles, especially in hilly and mountainous areas. These findings suggest that utilizing diversity of farmers and community-level cooperation is important in maintaining regional agriculture, especially in hilly and mountainous areas.

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19.1 Introduction

Since the late 1980s, that is, since agricultural products were liberalized after the end of the GATT Uruguay Round negotiations, Japanese agriculture has faced difficulties in sustaining farming in marginal areas. It became difficult to conserve farmlands because of aging farmers, especially in small rural communities in hilly and mountainous areas. There was an increase in the area of abandoned cultivated land. In the early 1990s, the Ministry of Agriculture, Forestry and Fisheries proposed green tourism to vitalize hilly and mountainous areas. Farm diversification has been proposed since the mid-1990s. Moreover, the ministry also proposed urban and rural exchange activities in the late 2000s. In the late 2000s, the Ministry of Economy, Trade and Industry proposed rural vitalization through the cooperation of agriculture, commerce, and industry. Through these policies, various rural agribusinesses have begun in the region. However, from the early to mid-2000s, government structural reforms resulted in the promotion of municipal mergers in each region. Municipalities in depopulated areas were merged in 2005. The municipalities' own policies on regional agriculture have also changed with decline in original subsidies by old local governments. Observing the actual situations in the hilly and mountainous areas, some areas host new business development, while others remain stagnant. It is difficult to grow a new business, as most such endeavors are small businesses. To maintain regional resources, such as rural residents and farmlands, it is essential to increase regional agricultural production output and improve the productivity of regional agriculture.

Some previous studies examine rural agricultural productivity and rural business in hilly and mountainous areas. In particular, despite the need to improve long-term productivity in agriculture, few studies examine the long-term productivity in hilly and mountainous areas. Kim et al. (2006) examined the actual conditions of farms in the Agimu region. Yasunaga (2013, 2014) examined the factors of farm productivity and the relationship between farm-related businesses and regional agriculture, theoretically and empirically, at the municipal and elementary district levels. These studies focused on individual farm management entities, such as diversification factors in farm management, actual diversification, and business efficiency due to the industrialization of agriculture; however, they do not sufficiently mention the latest developments in regional agriculture. Fujimoto (2000), Shimoura and Miyazaki (2002), and Shimoura et al. (2004) examined the economic linkage effect of urban-rural exchange and farm inns using a regional input-output model. Although they are regional unit studies, such studies are static and examine the economic linkage effects in a certain regional area. Therefore, it is difficult to explain the growth characteristics of hilly and mountainous agriculture from the medium- or long-term perspective. It is useful to examine the growth characteristics of agriculture quantitatively in considering future promotion measures and policies in hilly and mountainous areas.

This study quantitatively examines the growth characteristics of regional agriculture, especially for hilly and mountainous areas, considering changes in agribusinesses, structural change in agriculture, and initial rural characteristics. We first construct a framework to capture the growth potential based on the DEA framework. Next, we try to quantitatively examine the growth disparities among municipalities. We then consider regional factors that affect the growth potential of regional agriculture using regression models. Based on these results, we discuss the basis of regional cohesion for the sustainable growth of regional agriculture.

19.2 Methods

19.2.1 Hypothesis

To consider the growth potential of regional agriculture, this study first considers the following production function:

$$Q = A \cdot F\,(\mathrm{L}, \mathrm{AL}, \mathrm{K}) \tag{19.1}$$

Equation (19.1) represents the agricultural production in a regional agriculture. L, AL, and K also represent the use of labor resources for agriculture, the use of land resources, and the use of capital. $F(\cdot)$ represents the function. A is an index indicating productivity and can be expressed in Eq. (19.2):

$$A = Q/F\,(\mathrm{L}, \mathrm{AL}, \mathrm{K}) \tag{19.2}$$

This study defines the above change in productivity A as the growth potential of regional agriculture. We considered that growth is affected by the regional characteristics of the production environment as shown in Eq. (19.3):

$$G(A) = H\,(\mathrm{CAB}, \mathrm{CAS}, \mathrm{IC}; \mathrm{LF}) \tag{19.3}$$

This equation represents the growth of A as it is affected by the change in the concentration of rural agribusiness (CAB), the structural change in local agriculture (CAS), the initial environment related to agricultural resource use (IC), and other regional characteristics to be controlled (LF) such as geographical factors.

Changes in the Concentration of Rural Agribusinesses

As Syrquin (1986) noted, growth is affected by resource reallocation. Agglomerations and changes in new agricultural-related businesses that utilize local agricultural resources, such as direct sales by farmers, development of new processed products, and farmhouses, are considered factors that increase the potential growth of agricultural production.

Structural Change of Regional Agriculture

Penrose (1995) noted that the internal economy available to individual companies lead to expansion in a particular direction. Penrose called this characteristic "the economy of growth." Although Penrose focuses on the existence of available unused resources that can be created within companies, changes in the use of farmland, employment conditions, and employment for farmers are necessary for the smooth structural transformation of regional agriculture. Thus, the changes in the connection between land and labor were considered factors that enhanced the growth potential of regional agriculture.

Initial Conditions (Initial Environment Related to Agricultural Resource Use)

Glaeser et al. (1992) and Dekle (2002) noted that changes in agricultural productivity depend on the region's initial production environment, such as competition, specialization, and diversity in regional agriculture. However, the concentration of farmers is inadequate in hilly and mountainous areas because of the declining population. Areas with a certain concentration of farmers develop competition and cooperative relationships; these factors have positive effects on growth potential. The diversity of farmers was also considered a factor because it is a basic element of agricultural production. The participation of organizations also suggests a cooperative environment for exchanging agricultural resources.

19.2.2 Econometric Model for Measurement

In this study, we applied the Malmquist productivity index (MPI) to measure the changes in regional agricultural productivity. MPI is an extension of the index concept proposed by Malmquist (1953), as an indicator of productivity change. It measures the change in DMU (measurement unit) productivity over a certain period using DEA (data envelopment analysis). The DEA used for measuring the productivity index captures the input-output relationship of multiple inputs and multiple outputs without specifying the functional form. It is appropriate to consider the growth potential of hilly and mountainous agriculture from multiple aspects because the productivity change can be grasped from changes in technology and efficiency. In addition, this study used MPI based on the output-oriented models in DEA to consider how value can be increased under limited production factors in regional agriculture.

The MPI measurement uses a distance function defined by Shephard (1970). Assuming that the input production factor is $x = (x_1, ..., x_N) \in R^N{}_+$ and the output factor is $y = (y_1, ..., y_M) \in R^M{}_+$, the production technology T is expressed by the following Eq. (19.4), as a set of combinations between x and y:

$$T = \{(x, y) : x \ \text{can produce} \ y\} \tag{19.4}$$

Then, the production set can be defined as Eq. (19.5) with the given production technology:

$$P(x) = \{y : (x, y) \in T\} \tag{19.5}$$

The upper limit is defined as $I(x) = \{y : y \in P(x), \theta \cdot y \notin P(x), \forall \theta > 1\}$. Based on the aforementioned equations, the output-directed distance function at $P(x)$ is defined as follows:

$$D(x, y) = \min\{\theta : (x, y/\theta) \in P(x)\} \tag{19.6}$$

Equation (19.6) shows the ratio of the actual input-output level with the production technology T, which is referred to as the "production frontier." Production on the frontier can be recognized as a benchmark. If the samples are the same period, the values are taken 1 or less than 1 from the definition of the upper limit of $P(x)$.

That is, if $y \in P(x)$, then $D(x, y) \leq 1$; if $y \in I(x)$, then $D(x, y) = 1$.

Figure 19.1 shows an example of production in period s based on Fried et al. (2008) and Färe et al. (1994). For y_s in the producible set, φ is assumed to be the ratio to reach a point on the production frontier T_s from the view of x_s. If $y_s/(\phi \cdot y_s) = \theta = D(x_s, y_s) \leq 1$, then (x, y) is within the producible set; if $y_s/(\phi \cdot y_s) = \theta = D(x_s, y_s) = 1$, then, (x, y) is on the production frontier, which is most efficient. MPI is measured using the distance of the aforementioned distance function D. However, the value differs depending on the production technology used as a benchmark. Caves et al. (1982) defined productivity change as Eqs. (19.7) and (19.8):

$$\text{MPI}^s = (oe/oc)\,/\,(oa/ob) = D^s(x_t, y_t)\,/D^s(x_s, y_s) \tag{19.7}$$

$$\text{MPI}^t = (oe/of)\,/\,(oa/od) = D^t(x_t, y_t)\,/D^t(x_s, y_s) \tag{19.8}$$

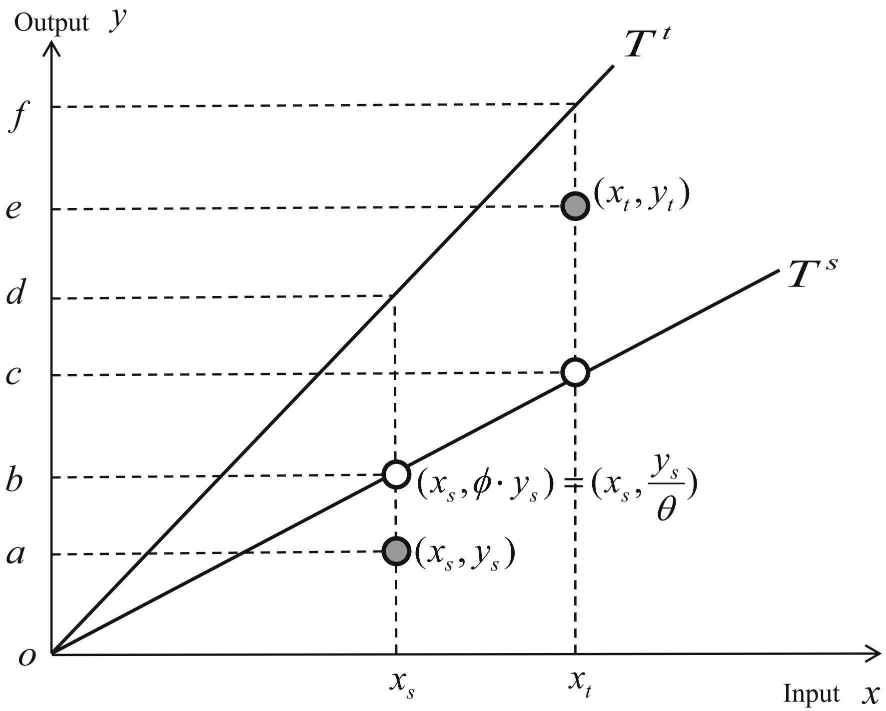

Fig. 19.1 Measurement of productivity. (Note: This figure is based on Fried et al. (2008))

Equation (19.7) is the ratio of the distance function defined based on the production frontier in period *s*. Equation (19.8) is the ratio of the distance function defined based on the production frontier in period *t*. In this study, we use Eq. (19.9), which is the geometric mean of the two indices proposed by Färe et al. (1992):

$$\text{MPI} = \left(\text{MPI}^s \cdot \text{MPI}^t\right)^{1/2} = \left(\frac{oe/oc}{oa/ob} \cdot \frac{oe/of}{oa/od}\right)^{1/2}$$
$$= \left(\frac{D^s\,(x_t, y_t)}{D^s\,(x_s, y_s)} \cdot \frac{D^t\,(x_t, y_t)}{D^t\,(x_s, y_s)}\right)^{1/2} \tag{19.9}$$

If MPI in (19.9) is greater than 1, productivity increases. If MPI is less than 1, productivity decreases (Cooper et al. 2007).

Productivity is also defined by technology and efficiency (Weil 2008). By transforming the right side of Eq. (19.9) into Eq. (19.10), MPI can be decomposed into an efficiency change index (EC) and a technical change index (TC) (Färe et al. 1992, 1994):

$$\begin{aligned} \text{MPI} &= \left(\frac{D^t(x_t,y_t)^2}{D^s(x_s,y_s)^2}\cdot\frac{D^s(x_t,y_t)}{D^t(x_t,y_t)}\cdot\frac{D^s(x_s,y_s)}{D^t(x_s,y_s)}\right)^{1/2} \\ &= \frac{D^t(x_t,y_t)}{D^s(x_s,y_s)}\left(\frac{D^s(x_t,y_t)}{D^t(x_t,y_t)}\cdot\frac{D^s(x_s,y_s)}{D^t(x_s,y_s)}\right)^{1/2} \end{aligned} \tag{19.10}$$

EC and TC are defined by Eqs. (19.11) and (19.12) using Eq. (19.10). EC shows the changing effectiveness for approaching the production frontier for a given technology. TC shows changes in the combination of factors of production:

$$\text{EC} = \frac{oe/of}{oa/ob} = \frac{D^t\ (x_t, y_t)}{D^s\ (x_s, y_s)} \tag{19.11}$$

$$\text{TC} = \left(\frac{oe/oc}{oe/of}\cdot\frac{oa/ob}{oa/od}\right)^{1/2} = \left(\frac{D^s\ (x_t, y_t)}{D^t\ (x_t, y_t)}\cdot\frac{D^s\ (x_s, y_s)}{D^t\ (x_s, y_s)}\right)^{1/2} \tag{19.12}$$

To capture the MPI between periods s and t, it is necessary to find the four distance functions in Eq. (19.9) by solving the output-oriented DEA linear programming problem shown in Eqs. (19.13) to (19.16). Equations (19.13), (19.14), (19.15), and (19.16) are linear programming problems used to determine the value of the minimum value of θ:

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{s.t. } Y^s\cdot\lambda \geq (1/\theta)\cdot y_i^s \\ &x_i^s \geq X^s\cdot\lambda \\ &\lambda \geq o \\ &e'\cdot\lambda = 1 \quad i = 1,\cdots,N \end{aligned} \tag{19.13}$$

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{s.t. } Y^t\cdot\lambda \geq (1/\theta)\cdot y_i^t \\ &x_i^t \geq X^t\cdot\lambda \\ &\lambda \geq o \\ &e'\cdot\lambda = 1 \quad i = 1,\cdots,N \end{aligned} \tag{19.14}$$

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{s.t. } Y^s\cdot\lambda \geq (1/\theta)\cdot y_i^t \\ &x_i^t \geq X^s\cdot\lambda \\ &\lambda \geq o \\ &e'\cdot\lambda = 1 \quad i = 1,\cdots,N \end{aligned} \tag{19.15}$$

$$
\begin{aligned}
&\text{Min}_{\theta,\lambda}\ \theta \\
&\text{s.t. } Y^t \cdot \lambda \geq (1/\theta) \cdot y_i^s \\
&x_i^s \geq X^t \cdot \lambda \\
&\lambda \geq o \\
&e' \cdot \lambda = 1 \quad i = 1, \cdots, N
\end{aligned}
\tag{19.16}
$$

M is the number of output elements; N is the number of sample municipalities. θ is a scalar, λ is an $N \times 1$ vector indicating a nonnegative weight, and o is an $N \times 1$ zero vector. $e' \cdot \lambda = 1$ is a constraint condition used when constant to scale is assumed, and e' represents a $1 \times N$ vector that all elements are 1.

One problem with the DEA is that the production technology used as the benchmark will change depending on the target sample. For the first problem, we excluded the municipalities with small values, including zero, on regional agriculture. The other problems with DEA, as Coelli and Rao (2005) and Grifell-Tatjé and Lovell (1995) noted, is that the MPI measurement results may be biased if CRS is not assumed. However, this is an empirical task, requiring that this study estimate both CRS and VRS.

We clarify the growth potential of hilly and mountainous agriculture by regressing the growth index MPI from period s to period t as expressed in Eq. (19.17):

$$
\text{MPI}_{t-s} = f\,(\text{CAB}_{t-s}, \text{CAS}_{t-s}, \text{IC}_s; \text{LF}) \tag{19.17}
$$

f (•) is a function of change of rural agribusiness (CAB), change in agricultural structure (CAS), initial condition of resource use (IC), and location factors (LF) that farmers face in the region. Location factors are introduced for control.

19.3 Data Collection

19.3.1 Target Area and Target Period

For our study, we selected the Chugoku agricultural region. This region consists of five prefectures: Tottori, Shimane, Okayama, Hiroshima, and Yamaguchi. The Chugoku agricultural region has many mountainous and remote areas far removed from metropolises. Farm management is relatively smaller than the whole country. Population decline has caused small municipalities to merge.

Tables 19.1 and 19.2 show the agricultural conditions of the target area. Agricultural output in Japan has tended to decline since 2000. However, the trend reversed from 2010 to 2015. This trend can be seen in the Chugoku region. Agricultural output in the Chugoku region accounts for 5% of the whole country. This is about half of that of Hokkaido. Of the prefectures in the Chugoku region, Okayama prefecture accounts for 30% of the regional total. Contrarily, the trend in Yamaguchi prefecture has been one of decrease. Farmers with farm sales of less

Table 19.1 Total agricultural output and agricultural production income in Chugoku region

									Unit: billion
				Chugoku agricultural region					
	Whole country	Whole country except Hokkaido	Hokkaido	Total	Tottori	Shimane	Okayama	Hiroshima	Yamaguchi
Agricultural output									
2000	9130	8074	1055	481	77	69	136	116	84
2005	8807	7740	1066	443	71	65	127	108	73
2010	8255	7260	995	412	67	55	124	102	64
2015	8863	7678	1185	438	70	57	132	116	63
Agricultural production income									
2000	3556	3162	394	154	25	20	43	41	26
2005	3263	2866	397	140	21	20	39	36	24
2010	2904	2543	361	144	23	21	40	35	26
2015	3270	2786	484	161	25	24	45	41	26

Source: Ministry of Agriculture, Forestry and Fisheries, “Agricultural income statistics”

Table 19.2 Distribution of agricultural entities by farm sales amount

									Unit: %
				Chugoku agricultural region					
	Whole country	Whole country except Hokkaido	Hokkaido	Total	Tottori	Shimane	Okayama	Hiroshima	Yamaguchi
Number of agricultural entities	1,377,266	1,336,552	40,714	126,448	18,381	19,920	36,801	29,929	21,417
Percentage									
Non-sales	9.6	9.7	5.5	10.1	8.3	8.8	8.6	12.3	12.5
Less than 500,000	34.2	35.1	4.6	52.5	51.7	53.5	54.7	51.7	49.8
500 thousand to 1 million	15.3	15.7	3.1	16.3	13.5	17.3	15.9	17.4	17.0
1 to 2 million	12.1	12.3	4.2	8.7	8.8	8.5	8.9	8.1	9.5
2 to 3 million	6.5	6.6	3.9	3.6	4.8	3.1	3.8	2.9	3.5
3 to 5 million	6.2	6.2	6.1	3.1	4.4	3.0	3.0	2.5	2.8
5 to 7 million	3.5	3.4	5.4	1.5	2.2	1.5	1.4	1.2	1.4
7 to 10 million	3.6	3.4	8.3	1.3	2.0	1.2	1.2	1.1	1.2
10 to 15 million	3.2	2.9	11.3	1.1	1.8	1.1	1.0	0.9	0.8
15 to 20 million	1.7	1.5	9.6	0.5	0.8	0.5	0.4	0.5	0.4
20 to 30 million	1.7	1.3	13.1	0.5	0.7	0.5	0.4	0.5	0.3
30 to 50 million	1.3	0.9	14.2	0.4	0.5	0.4	0.3	0.5	0.4
5000 to 100 million	0.8	0.6	7.6	0.2	0.3	0.2	0.2	0.3	0.2
100 to 300 million	0.3	0.3	2.5	0.1	0.2	0.2	0.1	0.1	0.1
300 to 500 million	0.1	0.1	0.4	0.0	0.1	0.1	0.0	0.0	0.0
Over 500 million	0.1	0.1	0.3	0.1	0.0	0.0	0.1	0.1	0.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Ministry of Agriculture, Forestry and Fisheries, "2015 Census of Agriculture and Forestry" than 500,000 yen comprise about 50% of farmers in each prefecture in the Chugoku region.

Regarding the concentrated agribusinesses shown in Table 19.3, the percentage of farmers engaged in farm-related businesses in the Chugoku region is relatively higher than that of the whole country and Hokkaido. Prefecture-level differences among farm-related agribusiness activities are seen in the Chugoku region. The percentage of farmers engaged in direct sales to consumers is over 90% in each prefecture, which is relatively higher than the whole country and Hokkaido. The percentage of farmers engaged in processing farm products is over 10% in Tottori and Shimane prefectures, which is relatively higher than whole country. On the other hand, the percentage of farmers engaged in rental farm and experience farm, tourist farm, farm inn, and farm restaurant are relatively lower than the whole country and Hokkaido. The supply of farm-related services is insufficient in the Chugoku region.

The target area for analysis is based on the municipality classification in 2015. This is because of the availability of study data on agricultural output in municipalities. With the discontinuation of municipality-level statistics, it became difficult to take the income of regional agriculture. In recent years, the degree of aggregation of statistical data has been higher, such as at the prefectural level.

The target period was from 2005 to 2015. The merger of municipalities has progressed greatly since around 2005. Therefore, we captured the structural changes under municipal mergers. The central government and local governments promoted urban and rural exchange and farm diversification in this period. The range of farm activities in each rural area was changing due to the transition in this period.

19.3.2 Variables

Growth Index of Regional Agriculture

The indicators for the investigation are as follows:

Inputs The input indicators are the number of people working in agriculture (population engaged in farming), farm management areas (cultivated land in hectares), and the number of agricultural tractors, from the Census of Agriculture and Forestry by the Ministry of Agriculture, Forestry and Fisheries, used as inputs of human resources, land resources, and capital use, respectively.

Output Element (Outcome) We used two indicators. First, we used the amounts of agricultural output in municipalities. The outputs were obtained from the Statistics on Agricultural Production of the Ministry of Agriculture, Forestry and Fisheries. The amount of agricultural output represents the estimated sales based on the prices of farm products at the farmer level (farmhouse prices). Agricultural output in each municipality was deflated using the agricultural price index (2015 = 100). We obtained this from statistical prices in agriculture published by the Ministry of Agriculture, Forestry and Fisheries. We calculated real agricultural output by

Table 19.3 Actual condition of conducted farm-related business

				Chugoku agricultural region					Unit: %
	Whole country	Whole country except Hokkaido	Hokkaido	Total	Tottori	Shimane	Okayama	Hiroshima	Yamaguchi
Farm-related business 2015									
Number of farm-related business	251,073	245,787	5286	23,828	2567	3642	6116	6861	4642
Percentage farm-related business	18.2	18.4	13.0	18.8	14.0	18.3	16.6	22.9	21.7
Detailed percentage of farm-related business									
Percentage of food processing	10.0	9.8	16.7	8.2	10.2	12.7	7.9	6.5	6.1
Percentage of direct sales to consumers	94.3	94.4	87.0	96.1	95.0	93.8	95.5	97.4	97.4
Percentage of rental farm and experience farm	1.5	1.4	5.6	0.8	0.6	0.9	0.8	0.8	0.7
Percentage of tourist farm	2.6	2.6	5.5	1.8	2.8	1.6	1.3	1.4	2.5
Percentage of farm inn	0.7	0.6	4.1	0.3	0.3	0.7	0.2	0.3	0.2
Percentage of farm restaurant	0.5	0.5	2.6	0.4	0.5	0.5	0.3	0.4	0.3
Percentage of export	0.2	0.2	0.9	0.1	0.3	0.1	0.1	0.1	0.0

Source: Ministry of Agriculture, Forestry and Fisheries, "2015 Census of Agriculture and Forestry"
Note: This is a detailed percentage of each farm-related business to the total number of farm-related business

adding the output of each crop sector multiplied by the price index of each crop sector. Note that the municipal-level agricultural output data for 2010 was not available for government financial reasons. Therefore, we estimated this data using the linear interpolation method based on the available 2006 and 2014 municipal data. Moreover, each municipal output value was adjusted by comparing the sum total with the total value of each prefecture level in 2010. Second, we uniquely estimated the amount of agricultural output based on the farm sales classification of agricultural management entities obtained from the Census of Agriculture and Forestry multiplying the median values and the number of agricultural entities in each classification. To make the estimated agricultural sales a real value, we deflated it using the weighted average of the aforementioned price index of each crop, which was calculated by the percentage of each crop's agricultural output in the municipality. Thus, both output indicators reflected the crop composition in each municipality.

Table 19.4 presents the index of agricultural productivity used in this study. In the MPI measurement, DEA model 1 of input element 3 and output element 1 was used when regional agricultural output estimated based on the crop production was used as the output element. DEA model 2 of the aforementioned elements was used when agricultural output in terms of uniquely estimated farm sales was used as the output element.

Table 19.4 Index of agricultural productivity used in this study

	Element	Index	Unit	Source
Output	Agricultural output	Total agricultural output (Real value)	10 million	Agricultural production income statistics
				Statistics of prices in agriculture
		Farm sales amount (Real value)	10 million	Agricultural production income statistics
				Statistics of prices in agriculture
Input	Labor use	Population mainly engaged farming	Person	Census of Agriculture and Forestry
	Land use	Farm management area	Ha	Census of Agriculture and Forestry
	Capital use	Number of Tractors	Tractor	Census of Agriculture and Forestry

Note: Data were obtained from the above source of 2005, 2010, and 2015

Indicators of Factors Affecting the Agricultural Productivity

Changes in Concentration of the Farm-Related Agribusinesses

This study considers that farmers conduct farm-related agribusiness to increase the value of agricultural products using resources in rural areas. Specifically, it will be a farm-related business such as sales by farmers themselves or agricultural product processing. As indicators of changes in the concentration of rural agribusiness, we considered the change rates of agricultural management entities that have channels for sales to JA cooperatives (Japan Agricultural cooperatives), retailers, food industries, and consumers directly to the number of total agricultural entities. We also considered the dummy variables if the rate of agricultural management entities that have channels of top sales increased from 2010 to 2015, then 1, otherwise 0. For the change rate, we considered the four channels of JA cooperatives, retailer, food industry, and consumers. In addition, we considered the change rate of agricultural management entities that engaged in agricultural processing (CPROC). Increases in these channels can positively contribute to agriculture sales. In contrast, these elements can also be expected to have a negative impact on agricultural productivity depending on the specific sales channel. The sign conditions are not assumed in advance.

Structural Changes in Regional Agriculture

We considered changes in the area of farm management (cultivated land) per farm household (CFMA) and changes in non-rice cropped area in paddy fields (CNRC). In addition, we also considered changes in the number of permanent employment workers in agricultural management entities (CEMPP) and changes in the number of temporary employment workers in agricultural management entities (CEMPT). These variables can be expected to have positive impacts on agricultural productivity. However, an increase in the farm management area per farm household may mean that—owing to the aging of farmers—specific farmers have no choice but to rent small parcels of farmlands in the rural community. It is difficult for farmers in Japan to simply abandon their paddy fields in a community because of the risk of pest outbreaks. This sign condition is not assumed in advance.

Initial Conditions of Environment Related to Agricultural Resource Use

Competitiveness and Cooperation in Farm Management We considered the density of full-time farmers (DENF). This was calculated as the number of full-time farm households with a younger male farmer in the household, per regional farm management areas in the region. In addition, we considered the percentage of farm managers under the age group of 40s and female farm managers at the regional level. They were calculated as the percentage of farm managers under the age group of 40s to the total number of farm managers (YM) and the percentage of female farm managers to the total number of farm managers in agricultural management entities (FM). The expected sign condition is positive.

Diversity and Specialization We used the Herfindahl-Hirschman Index (HHI) as an index to indicate the diversity and specialization of farmers based on the age classification of farmers (HHIL) and the farm-scale classification in view of farm management area (HHIS). If the value of HHI is high, the specialization (the degree of concentration in a specific group) is relatively high, and vice versa. The accumulation of diverse human resources and diverse-scale farmers in the region will allow them to cooperate, accept new initiatives, and increase the agricultural output by new ideas. The expected sign condition is negative.

Agricultural Labor Use Conditions For new initiatives to be accepted and expanded, it is essential that farmers have an environment in which they can hire diverse people flexibly. The percentage of permanent employment in agricultural management entities (EMPP) and the percentage of temporary employment in agricultural management entities (EMPT) were considered as labor use conditions. The expected sign conditions for these flexible workforce indicators are positive.

Agricultural Land Use Conditions The scale of farms and the number of farmers lending their farmlands are essential to using farmland flexibly. We considered the percentage of farmers renting out their farmlands (RENT). The sign conditions are expected to be positive because the farmers allowing others to use their land help to expand regional agriculture through the flexible use of the farmlands in the rural community. In addition, we also considered the paddy conversion rate (CC). However, it is expected to have negative effects because the land use environment has been already changed.

Community-Level Cooperation The presence of an agricultural machine use organization (AMU) is generally organized in marginal rural areas. In addition, labor exchanges, among farmers without payment in busy farming seasons (LEX), are a known altruistic behavior in rural areas. We also considered the percentage of rural communities that conserve their farmlands at the community level in the municipality (CONS), as a community-level cooperation factor. These elements can be expected to have a positive or negative impact on agricultural productivity. The sign conditions are not assumed in advance.

Location Factors for Control Variables

Regional specific factors were used for control.

Dependence on Other Industries We considered the part-time job ratio (PTF) calculated as the number of part-time farm households versus the total number of farm households. It means that the higher the ratio of part-time farmers, the more changes in rural agriculture cannot be accepted. In contrast, part-time farmers have a complementary role in regional agriculture. In addition, part-time work by farm household members is common in the hilly and mountainous areas in the Chugoku region. The sign condition is not assumed in advance.

Geographical Factors To capture the effect of the regional agriculture type within the municipality, we introduced the variables of percentage of urban farming areas (URB), percentage of hilly and mountainous areas (HM), and percentage of mountainous areas (MOUN). Thus, we examined the effects of differences in agricultural conditions based on flat farming (i.e., baseline is flat farming). These indicators also express the homogeneous degree of regional agriculture. We also considered the number of rural communities per arable land (10 ha) in the community area (NCOM). This indicator expresses the variability of community. These sign conditions are not expected in advance due to locational variation. Moreover, we also considered regional specific factors, using the dummy variables (RD1 to RD5) of each prefecture, the total amount of farm area under management, and the percentage of mountainous areas in the municipalities. These sign conditions are also not expected in advance.

Table 19.5 reports the summary of the samples along with the indicators of explanatory variables. We excluded samples with missing input and output values and samples where the value of agricultural output exceeds the value of the originally estimated farm product sales amount. Thus, we used the remaining 102 samples to present all municipalities, with 68 samples from these representing only hilly and mountainous municipalities. To calculate the MPI, we used the DEA-Solver-Pro13.0 software provided by SAITECH.

19.4 Results and Discussion

19.4.1 Growth Characteristics of Regional Agriculture

Tables 19.6 and 19.7 show the distribution of regional agricultural productivity based on the measured MPI. In the case of model 1–1 (CRS model), which considers the output of regional agriculture from 2005 to 2015, the MPI values were distributed from 0.3 to 3.6 but mostly range between 0.9 and 1.4. In terms of the EC and TC distribution, most regions saw TC values over 1.5. However, the EC value varies widely, and many regions are under 1.0. Looking at model 1–2, TCs were distributed mainly from 0.8 to 1.2 and had a larger variation than in model 1–1. As a result, the values of MPI were distributed from 0.7 to 1.2. We can conclude that productivity changes were mainly affected by TC shifts, although there were some significantly improved regions catching up the production frontier. The results also suggest that the regional disparity between the advanced and other regions had expanded. In the case of model 2–1 (VRS model), considering the estimated total amount of farm sales from 2005 to 2015, MPI values were distributed from 0.4 to 3.5. MPI value variations were larger than in model 1–1. Focusing on the EC and

Table 19.5 Summary of regional agriculture

		All municipality				Only hilly and mountainous municipality			
	Unit	Average	SD	Max	Min	Average	SD	Max	Min
(a) Change in agglomeration of farm-related business									
Sales to JA	Change rate	−0.138	0.080	0.433	−0.288	−0.142	0.087	0.433	−0.288
Sales to retailers	Change rate	0.003	0.016	0.059	−0.061	0.003	0.015	0.059	−0.028
Sales to food industries	Change rate	0.004	0.007	0.022	−0.038	0.004	0.006	0.020	−0.013
Sales to consumers directly	Change rate	−0.058	0.059	0.078	−0.251	−0.049	0.053	0.078	−0.201
Processing agricultural products	Change rate	−0.005	0.008	0.008	−0.042	−0.004	0.008	0.008	−0.041
Mainly sales to JA	Dummy variables	0.265	0.443	1.000	0.000	0.265	0.444	1.000	0.000
Mainly sales to retailer	Dummy variables	0.833	0.375	1.000	0.000	0.824	0.384	1.000	0.000
Mainly sales to food industries	Dummy variables	0.735	0.443	1.000	0.000	0.721	0.452	1.000	0.000
Mainly sales to consumers directly	Dummy variables	0.431	0.498	1.000	0.000	0.441	0.500	1.000	0.000
Processing agricultural products	Dummy variables	0.353	0.480	1.000	0.000	0.441	0.500	1.000	0.000
(b) Change in agricultural structure									
Farm management area per farmer	Change rate	−0.166	0.424	0.647	−0.904	−0.152	0.399	0.497	−0.904
Rice crop diversion per paddy field	Change rate	−0.035	0.159	1.500	−0.300	−0.031	0.194	1.500	−0.300
Farmers hired permanent employee	Change rate	0.062	0.078	0.608	−0.043	0.056	0.054	0.265	−0.043
Farmers hired temporary employee	Change rate	0.132	0.215	0.734	−1.359	0.138	0.158	0.734	−0.263
(c) Initial conditions (environment for resource use)									
Competition and cooperation conditions									
Density of main farmers	Household per ha	0.062	0.038	0.286	0.008	0.056	0.037	0.286	0.008
Female managers	Percentage	0.078	0.031	0.184	0.020	0.074	0.026	0.150	0.022
Young managers	Percentage	0.088	0.035	0.171	0.018	0.096	0.033	0.171	0.018
Diversity									
Diversity of farm management areas	HH index	0.317	0.065	0.525	0.170	0.312	0.052	0.430	0.205
Diversity of farm labors	HH index	0.196	0.020	0.256	0.136	0.202	0.019	0.256	0.158

(continued)

Table 19.5 (continued)

	Unit	All municipality				Only hilly and mountainous municipality			
		Average	SD	Max	Min	Average	SD	Max	Min
Agricultural labor use conditions									
Farmers that employ permanent workers	Percentage	0.005	0.005	0.029	0.000	0.005	0.004	0.023	0.000
Farmers that employ temporary workers	Percentage	0.068	0.034	0.213	0.000	0.068	0.031	0.197	0.000
Agricultural land use conditions									
Rice crop diversion	Percentage	0.143	0.117	1.000	0.000	0.150	0.132	1.000	0.000
Lending farmers	Percentage	0.161	0.065	0.476	0.052	0.156	0.045	0.290	0.059
Organization and social capital									
Participation in shared use of farming machine	Percentage	0.104	0.086	0.358	0.000	0.120	0.089	0.358	0.000
Community-level conservation of farmlands	Dummy variables	0.328	0.301	1.000	0.000	0.428	0.283	1.000	0.000
Voluntary labor exchange	Percentage	0.202	0.058	0.384	0.044	0.193	0.055	0.384	0.044
Degree of dependency on nonfarm work									
Part-time farm household	Percentage	0.653	0.107	0.842	0.218	0.652	0.112	0.815	0.218
Geographical factors									
Number of rural communities per arable land	Community number per 10 ha	0.957	0.809	5.714	0.168	0.936	0.809	5.714	0.309
Farm management area	Ha	1623	1800	10,647	16	1457	1485	6544	28
Tottori (RD1)	Dummy variables	0.178	0.384	1.000	0.000	0.186	0.392	1.000	0.000
Shimane (RD2)	Dummy variables	0.178	0.384	1.000	0.000	0.257	0.440	1.000	0.000
Okayama (RD3)	Dummy variables	0.252	0.436	1.000	0.000	0.243	0.432	1.000	0.000
Hiroshima (RD4)	Dummy variables	0.215	0.413	1.000	0.000	0.171	0.380	1.000	0.000
Yamaguchi (RD5)	Dummy variables	0.178	0.384	1.000	0.000	0.143	0.352	1.000	0.000

Note: Sample sizes for all municipality samples and only hilly and mountainous municipality are 102 and 68, respectively
Note 2: Change rate of (a) expresses the change rate to the number of agricultural management entities from 2010 to 2015
Note 3: Dummy of (a) if the percentage of farm-related agribusiness changed positively, then 1, otherwise 0

Table 19.6 Growth distribution of regional agriculture

	All municipality												Only hilly and mountainous municipality											
	Model 1–1 (CRS)			Model 1–2 (CRS)			Model 2–1 (VRS)			Model 2–2 (VRS)			Model 1–1 (CRS)			Model 1–2 (CRS)			Model 2–1 (VRS)			Model 2–2 (VRS)		
	Agricultural output			Farm sales amount			Agricultural output			Farm sales amount			Agricultural output			Farm sales amount			Agricultural output			Farm sales amount		
	EC	TC	MPI	EC	TC	MPI	EC	TC	MPI	EC	TC	MPI	EC	TC	MPI	EC	TC	MPI	EC	TC	MPI	EC	TC	MPI
Over 1.5	0	100	26	2	0	1	0	43	16	0	0	0	0	66	24	0	0	0	0	43	15	0	0	0
1.4–1.5	1	0	7	1	0	0	4	9	6	1	0	0	1	0	6	0	0	0	1	10	4	1	0	1
1.3–1.4	0	0	15	3	0	3	3	15	6	2	0	2	0	0	11	2	0	2	2	8	6	1	0	2
1.2–1.3	1	1	8	5	8	6	2	16	10	8	0	4	0	1	6	0	9	6	3	3	6	4	4	1
1.1–1.2	1	1	10	9	25	16	0	13	13	11	3	5	1	1	5	10	25	7	1	2	13	8	13	7
1.0–1.1	2	0	11	12	21	13	4	2	12	17	21	14	2	0	6	6	20	10	1	0	7	14	5	4
0.9–1.0	5	0	10	29	29	24	9	0	12	20	32	17	5	0	5	11	8	14	6	0	6	12	7	10
0.8–0.9	5	0	4	19	14	20	17	0	13	25	25	21	4	0	1	14	3	13	8	0	4	14	31	15
0.7–0.8	13	0	5	14	4	11	22	0	5	9	16	20	12	0	2	16	2	12	17	0	2	6	4	14
0.6–0.7	20	0	2	4	1	2	19	0	3	3	1	8	17	0	1	6	1	0	14	0	3	3	1	8
0.5–0.6	29	0	0	1	0	4	7	0	0	1	0	7	16	0	0	1	0	2	8	0	0	1	1	4
Less than 0.5	25	0	4	3	0	2	11	0	2	1	0	0	10	0	1	2	0	2	5	0	0	2	0	0
Sum total	102	102	102	102	102	102	98	98	98	98	98	98	68	68	68	68	68	68	66	66	66	66	66	66

Note: Samples that LP problems in VRS model were infeasible were excluded

Table 19.7 Growth type of regional agriculture

	All municipality				Only hilly and mountainous municipality			
	Model 1–1 (CRS)	Model 1–2 (CRS)	Model 2–1 (VRS)	Model 2–2 (VRS)	Model 1–1 (CRS)	Model 1–2 (CRS)	Model 2–1 (VRS)	Model 2–2 (VRS)
Type1 (EC > 1, TC > 1, MPI > 1)	5	10	13	7	4	12	8	7
Type2 (EC > 1, TC < 1, MPI > 1)	0	14	0	15	0	2	0	5
Type3 (EC > 1, TC < 1, MPI < 1)	0	8	0	17	0	4	0	16
Type4 (EC < 1, TC > 1, MPI > 1)	72	15	50	3	54	11	43	3
Type5 (EC < 1, TC > 1, MPI < 1)	25	29	35	14	10	31	15	12
Type6 (EC < 1, TC < 1, MPI < 1)	0	26	0	42	0	8	0	23
	102	102	98	98	68	68	66	66

Note: Samples that LP problems in VRS model were infeasible were excluded

TC distribution, the TC value in each region was over 1.1. However, EC values varied more than the TC values, and agricultural efficiency was under 1.0 in many regions. Model 2–2 was similar to model 1–2 in that TCs were distributed mainly from 0.7 to 1.1, and ECs and TCs in models 2–2 had larger variations than in model 2–1. As a result, MPI values were distributed from 0.7 to 1.1. We can conclude that productivity change in terms of farm sales varies more than in model 1. Many subsequent regions have not improved, relatively speaking. In addition, there are a certain number of regressed regions.

Table 19.8 shows the percentage of regions that have values greater than 1 in terms of EC, TC, and MPI. Looking at regional agriculture in areas such as prefectures and hilly and mountainous areas where EC and TC were greater than 1, several regions have TCs of over 1 in the last 10 years. In addition, a relatively larger number of mountainous agricultural regions have MPI values greater than 1 than do hilly agricultural regions. Overall, mountainous farming has improved more than hilly (intermediate) farming. However, EC values show different trends in each model. In terms of prefectural differences, Hiroshima prefecture has a relatively larger number of regions with EC values over 1 than the other prefectures in models 1–2, 2–1, and 2–2. Comparing the two periods, more progress was made in the 2010 to 2015 period than in 2005 to 2010, in models 1–1 and 2–1. By contrast, in models 1–2 and 2–2, the percentage of municipalities in each type of agricultural region with an MPI over 1 in the 2005 to 2010 period is slightly lower than of those in the 2010 to 2015 period. This difference is a result of the difference in output data (i.e., regional data based on crop production or farm-level data). This result reflects that agricultural improvements have been made at the regional level, but not at the farmer level. The differences are similar for both ECs and TCs. In particular, the TC values indicate a different trend. In terms of farm sales output level, it can be inferred that hilly and mountainous regions caught up with the production frontier in the 2005 to 2010 period.

These results imply that many regions, including the hilly and mountainous ones, could not reach the production frontier, although the production frontier overall has improved. These results are consistent with the results of previous studies, such as Yasunaga (2013). This suggests that regional agricultural growth was achieved through technological changes (TC). That is, the combination of production and production factors has improved. In addition, we can infer that the disparity in regional agriculture productive levels expanded between 2005 and 2015 because of different rates of change in efficiency (EC). In addition, some regions may have experienced improvement in efficiency from 2005 to 2015.

19.4.2 Factors Affecting the Growth of Regional Agriculture

Tables 19.9 and 19.10 report the results of regressing MPI on regional characteristics to examine the factors that affect the aforementioned growth. The parameters were estimated using ordinary least squares with a logarithmic linear formula on the

Table 19.8 Location characteristics of regional growth

		Model 1–1 (CRS)			Model 1–2 (CRS)			Model 2–1 (VRS)			Model 2–2 (VRS)		
		Agricultural output			Farm sales amount			Agricultural output			Farm sales amount		
	Number of sample	EC > 1	TC > 1	MPI > 1	EC > 1	TC > 1	MPI > 1	EC > 1	TC > 1	MPI > 1	EC > 1	TC > 1	MPI > 1
Period: 2005 to 2015													
Chugoku region													
Tottori	18	0.056	1.000	0.722	0.222	0.500	0.389	0.056	1.000	0.667	0.389	0.278	0.278
Shimane	18	0.056	1.000	0.944	0.333	0.722	0.444	0.056	0.944	0.722	0.389	0.389	0.333
Okayama	27	0.074	1.000	0.815	0.222	0.593	0.296	0.185	0.963	0.704	0.296	0.333	0.296
Hiroshima	21	0.048	1.000	0.714	0.429	0.333	0.381	0.286	0.952	0.619	0.429	0.000	0.095
Yamaguchi	18	0.000	1.000	0.556	0.389	0.500	0.444	0.000	0.944	0.333	0.444	0.167	0.222
Urban farming region	30	0.033	1.000	0.533	0.400	0.367	0.300	0.067	0.933	0.267	0.367	0.133	0.133
Flat farming region	4	0.000	1.000	0.750	0.250	1.000	0.750	0.000	1.000	0.500	0.750	0.250	0.250
Hilly farming region	40	0.100	1.000	0.775	0.275	0.525	0.375	0.200	0.975	0.675	0.350	0.150	0.225
Mountainous region	28	0.000	1.000	0.964	0.286	0.643	0.429	0.107	0.964	0.929	0.393	0.464	0.393
Only HM samples													
Hilly farming region	40	0.100	1.000	0.775	0.225	0.725	0.350	0.125	0.975	0.650	0.400	0.175	0.175
Mountainous region	28	0.000	1.000	0.964	0.321	0.893	0.393	0.107	0.964	0.893	0.429	0.536	0.286

Period: 2005 to 2010													
Urban region	30	0.033	1.000	0.500	0.500	0.433	0.600	0.100	0.733	0.233	0.467	0.033	0.400
Flat farming region	4	0.000	1.000	1.000	0.000	1.000	0.750	0.000	1.000	0.750	1.000	0.000	0.500
Hilly farming region	40	0.075	1.000	0.750	0.425	0.700	0.475	0.275	0.950	0.600	0.625	0.025	0.400
Mountainous region	28	0.071	1.000	0.821	0.500	0.643	0.643	0.107	0.964	0.643	0.643	0.071	0.571
Only HM samples													
Hilly farming region	40	0.075	1.000	0.750	0.300	0.900	0.500	0.150	0.975	0.600	0.450	0.225	0.350
Mountainous region	28	0.071	1.000	0.821	0.321	0.929	0.607	0.107	0.964	0.536	0.429	0.536	0.500
Period: 2010 to 2015													
Urban region	30	0.133	1.000	0.633	0.300	0.167	0.200	0.100	0.933	0.467	0.167	0.233	0.100
Flat farming region	4	0.000	1.000	0.750	0.750	0.750	0.750	0.000	1.000	0.500	0.500	0.500	0.500
Hilly farming region	40	0.150	0.925	0.800	0.300	0.325	0.200	0.200	0.975	0.675	0.200	0.400	0.150
Mountainous region	28	0.071	1.000	0.929	0.393	0.321	0.321	0.250	0.964	0.929	0.286	0.714	0.357
Only HM samples													
Hilly farming region	40	0.150	0.925	0.800	0.300	0.325	0.200	0.225	0.975	0.675	0.325	0.225	0.125
Mountainous region	28	0.071	1.000	0.929	0.393	0.321	0.321	0.214	0.964	0.929	0.286	0.536	0.357

Note: Values are percentages of municipalities with EC > 1, TC > 1, and MPI > 1

Table 19.9 Factors that affect the productivity growth of regional agriculture in municipalities

	Expected sign conditions	Model 1–1 (CRS) Agricultural output			Model 1–2 (CRS) Farm sales amount			Model 2–1 (VRS) Agricultural output			Model 2–2 (VRS) Farm sales amount		
		Coef	*t*-value		Coef	*t*-value		Coef	*t*-value		Coef	*t*-value	
(a) Change in concentration of agribusiness (CAB)													
Mainly sales to JA (CSJA)	?	0.252	3.900	***	0.074	1.551		0.175	2.833	***			
Mainly sales to retailer (CSRETAIL)	?	−0.158	−2.075	**	0.137	2.434	**	−0.089	−1.182		0.080	1.510	
Mainly sales to manufacturers (CSMANU)	?										0.108	2.300	**
Mainly sales to consumers directly (CSCONS)	?												
Processing agricultural products (CPROC)	?												
(b) Change in agricultural structure (CAS)													
Farm management area per farmer (CFMA)	?							−0.111	−1.375				
Rice crop diversion per paddy field (CNRC)	+							−1.572	−1.513				
Farmers hired permanent employee (CEMPP)	+	1.125	2.309	**				1.046	2.364	**	0.388	1.389	*
Farmers hired temporary employee (CEMPT)	+				0.426	4.090	***				0.336	2.494	***
(c) Initial conditions (environment for resource use) (IC)													
Competition and cooperation conditions													
Density of main farmers (DENF)	+				2.280	2.151	**	−1.598	−1.724				
Female managers (FM)	+	2.138	1.770	**				1.707	1.419	*			
Diversity													
Diversity of farm laborers (HHIL)	–	−2.404	−1.168		−3.695	−2.427	***	−2.442	−3.730	***			
Diversity of farm management areas (HHIS)	–	−1.712	−2.422	***	−1.229	−2.329	**				−3.385	−2.557	***

Agricultural labor use conditions													
Farmers that employ permanent workers (EMPP)	+	18.063	2.548	***				16.843	2.332	**			
Farmers that employ temporary workers (EMPT)	+	−1.634	−1.465					−1.428	−1.419		−1.641	−1.986	
Agricultural land use conditions													
Rice crop diversion (CC)	−	−0.473	−1.514	*	−0.665	−2.879	***	−1.218	−2.208	**			
Farmers renting out their land (RENT)	+	0.783	1.347	*	1.959	4.211	***				1.012	2.588	***
Community-level cooperation													
Participation of shared use of farming machine (AMU)	?												
Community-level conservation of farmlands (CONS)	?	0.149	1.419		0.189	2.291	**				0.123	1.677	*
Voluntary labor exchange (LEX)	?												
(d) Location factors (LF)													
Percentage of part-time farm household (PTF)	?				1.665	4.770	***				0.487	2.066	**
Percentage of urban farming areas (URB)	?							−0.218	−1.610		−0.219	−2.162	**
Percentage of hilly and mountainous areas (HM)	?	0.634	4.725	***	0.264	2.574	**	0.353	2.815	***			
Number of rural communities per arable land (NCOM)	?				0.207	3.974	***						
Logarithm of Farm management area (LFMA)	?	0.107	3.821	***				−0.076	−2.066	**	−0.105	−5.371	***
Regional dummy (base is Hiroshima)													
Tottori (RD1)	?				−0.095	−1.428							
Shimane (RD2)	?	0.166	1.833	*							0.125	2.097	**
Okayama (RD3)	?	0.182	2.217	**				0.142	2.010	**			
Yamaguchi (RD5)	?	−0.146	−1.494		0.131	2.062	**	−0.236	−2.535	**	0.158	2.805	***
Constant term	?	−0.312	−0.502		−1.048	−2.391	**	1.183	2.452	**	0.587	1.568	
Adj-R^2		0.541			0.464			0.446			0.326		
F-value		8.442		***	7.232		***	5.884		***	4.603		***

Note: ***, **, and * represents statistical significance at 1%, 5%, and 10% levels, respectively

Table 19.10 Factors that affect the productivity growth of regional agriculture in hilly and mountainous municipalities

	Expected sign conditions	Model 1–1 (CRS) Agricultural output			Model 1–2 (CRS) Farm sales amount			Model 2–1 (VRS) Agricultural output			Model 2–2 (VRS) Farm sales amount		
		Coef	t-value		Coef	t-value		Coef	t-value		Coef	t-value	
(a) Change in concentration of agribusiness (CAB)													
Sales to JA (CSJA)	?				1.445	3.459	***				1.290	2.701	***
Sales to retailers (CSRETAIL)	?	−5.800	−2.770	***				−4.134	−2.208	**			
Sales to manufacturers (CSMANU)	?	−7.592	−1.511					−6.103	−1.335				
Sales to consumers directly (CSCONS)	?				−1.019	−2.079	**	1.153	1.839	*	−0.707	−1.293	
Processing agricultural products (CPROC)	?	−8.793	−2.524	**	−4.009	−1.419		−6.687	−1.896	*	−3.295	−1.046	
(b) Change in agricultural structure (CAS)													
Farm management area per farmer (CFMA)	?	−0.291	−3.789	***				−0.370	−4.512	***			
Rice crop diversion per paddy field (CNRC)	+												
Farmers hired permanent employee (CEMPP)	+	1.828	3.226	***	0.611	1.300	*	1.583	2.787	***			
Farmers hired temporary employee (CEMPT)	+							0.314	1.704	**			
(c) Initial conditions (environment for resource use) (IC)													
Competition and cooperation conditions													
Density of main farmers (DENF)	+	1.785	1.288		5.961	4.911	***				5.671	4.294	***
Female managers (FM)	+	4.304	2.855	***	3.953	3.701	***	1.548	1.145		3.139	2.706	***
Diversity of farmers													
Diversity of farm management areas (HHIS)	−	−2.011	−2.587	***	−1.992	−2.629	***	−2.138	−2.536	***	−2.806	−4.332	***

Agricultural labor use conditions													
Farmers that employ permanent workers (EMPP)	+	19.414	2.570	***				20.877	2.947	***	9.910	1.705	**
Farmers that employ temporary workers (EMPT)	+	−2.132	−1.899		−1.949	−2.428		−3.190	−3.298		−3.611	−4.004	
Agricultural land use conditions													
Rice crop diversion (CC)	−				−0.955	−3.012	***				−1.440	−4.080	***
Farmers renting out their land (RENT)	+	1.899	2.326	**	2.102	3.335	***	1.654	2.483	***	2.015	3.309	***
Community-level cooperation													
Participation of shared use of farming machine (AMU)	?	−1.151	−2.951	***				−0.964	−2.655	**	0.458	1.361	
Community-level conservation of farmlands (CONS)	?				0.418	4.207	***	−0.239	−1.873	*	0.347	3.317	***
Voluntary labor exchange (LEX)	?	1.147	1.742	*	−0.579	−1.084		2.205	3.548	***			
(d) Location factors (LF)													
Percentage of part-time farm household (PTF)	?	0.669	1.418		2.390	6.428	***				2.174	4.858	***
Percentage of mountainous areas (MOUN)	?	0.384	4.038	***	0.126	1.669		0.256	2.806	***	0.088	1.137	
Number of rural communities per arable land (NCOM)	?	−0.125	−2.059	**	0.144	2.870	***	−0.117	−1.633		0.177	3.232	***
Logarithm of Farm management area (LFMA)	?				0.059	2.312	**	−0.171	−4.456	***	−0.052	−1.893	*
Regional dummy (base is Hiroshima)													
Tottori (RD1)	?	−0.167	−1.871	*							0.117	1.482	
Shimane (RD2)	?												
Okayama (RD3)	?										0.084	1.223	
Yamaguchi (RD5)		−0.373	−3.657	***	0.119	1.395		−0.233	−2.287	**	0.139	1.698	*
Constant term	?	−0.370	−0.783		−2.250	−5.590	***	1.474	2.988	***	−1.117	−1.924	*
Adj-R^2		0.630			0.650			0.614			0.582		
F-value		7.33		***	8.329		***	6.433		***	5.761		***

***, **, and * represents statistical significance at 1%, 5%, and 10% levels, respectively dependent variables MPI to deal with the heteroscedasticity problem (Yasunaga 2013; Fujie and Senga 2019). Variables with strong correlations confirmed by the VIF standard and for those for which low statistical significance was confirmed were excluded from the regression models.

Models 1–1 and 1–2 are estimated using the MPI estimated by CRS as dependent variables with a logarithmic linear formula. Different samples were applied for each regression equation. That is, we used all municipality samples and only hilly and mountainous municipality samples. Models 2–1 and 2–2 are estimated using the MPI estimated by VRS as dependent variables with a logarithmic linear formula. Samples for model 2 depend on the aforementioned method.

The estimation results for models 1 and 2 show generally similar trends. In particular, model 1 fitted the data better than model 2. We discussed our hypotheses based on the common trends in the models.

Regarding the effects of the change in the agribusiness (CAB), the positive changes in the sales channel of farmers that have sales channels had both positive and negative influences on productivity changes. In particular, the change in the sales channel of farmers that mainly sell to JA had a significant positive influence on the change. By contrast, the change in the sales channel of farmers that mainly sell to retailers had a negative effect. This implies that farm products are bought at a low price. A change in the sales channel of farmers that mainly sell to the food industry and those that mainly sell directly to consumers had no significant effect except for some models. In addition, a change in the concentration of farmers that process farm products had a significant negative effect in the model that used only hilly and mountainous municipality samples. These results imply that the JA channel still plays an important role in promoting regional agriculture, especially in hilly and mountainous areas. New channels and direct marketing may not necessarily lead to an increase in overall agricultural productivity in these regions. Changes in agricultural productivity and the development of processing of farm products are closely related in hilly and mountainous municipalities.

Regarding the effects of structural changes in regional agriculture (CAS), the change in permanent employment in farms had a significantly positive effect on productivity change, which is consistent with the results of previous research (Yasunaga 2013). This suggests that a stable work environment is necessary to grow regional agriculture. Changes in crop conversions of paddy fields had no significant effect. By contrast, the change in farm management area per farm household had a significantly negative effect in hilly and mountainous municipality samples. This suggests that the conservation of farmlands plays an important role in maintaining living conditions in hilly and mountainous areas. Therefore, specific farmers maintain farmlands that can no longer be cultivated because of aging farmers, to conserve the community environment. This reduces long-term efficiency.

Regarding the effects of the initial conditions (IC), the density of full-time farmers, which is a proxy for the competitive condition, had a significant positive effect on productivity change. In addition, the percentage of female farm managers had a significantly positive effect. Moreover, the diversity of farm management areas and farm labors had significant negative effects. The results imply that the diversity of farmers in terms of the existence of main farmers, gender, and farm scale plays an important role in enhancing the growth potential of regional agriculture.

In terms of agricultural labor and land use conditions, the percentage of farmers that employ permanent workers had a significantly positive effect. This suggests that a stable utilization environment of labor resources is important for the development of farm management. In addition, the percentage of farmers renting out their lands had a significantly positive effect. A relationship based on trust among farmers may have led to the effective use of regional resources. Moreover, the crop conversion rate in paddy fields had significant negative effects in some models. The utilization environment of farmlands may have restricted the scope for changes in agriculture. Since the 2000s, the Ministry of Agriculture, Forestry and Fisheries introduced direct payment policies for paddy field utilization. A strong dependency on this rice crop diversion subsidy may affect the efficiency use of farmlands.

In terms of community-level cooperation, the participation rate of farmers in farm machine use organizations had a negatively significant effect in models 1–1 and 1–2, which used only hilly and mountainous municipalities. It is not consistent with the results of previous research. The increasing dependency on specific organizations may reduce potential of regional growth. By contrast, variables regarding community-level farmland conservation had a significant positive effect in models 1–2 and 2–2. In addition, voluntary labor exchange as community-level cooperation had significant positive impacts in models 1–1 and 2–1, which used only hilly and mountainous municipalities. These results suggest that community-level cooperation factors partially play an important role in hilly and mountainous areas.

Regarding the location factors (LF) as control variables, the percentage of part-time farm households had a significantly positive effect. We can infer that the diversity in operations of farm households (i.e., continuing farming in various forms) is positively related to growth. In addition, the percentages of hilly and mountainous areas had positive effects. The policy for such areas may affect regional agriculture. Simultaneously, the number of rural communities per 10 hectares of arable land had a significantly positive effect in some models, which used farm sales amount. The diversity of rural communities can also play an important role in farm-level growth. Finally, there were few significant differences between prefectures except for Yamaguchi prefecture. We assume that political and geographic differences among prefectures do not have little influence on productivity changes.

19.5 Summary

We quantitatively examined the type of growth in the role of basic conditions in improving regional agriculture, especially for hilly and mountainous municipalities. There is disparity in regional agricultural output in terms of MPI. Furthermore, changes in the concentration of agribusinesses can affect income generation positively and negatively. In particular, the JA cooperative marketing channel still plays an important role in regional agriculture. Moreover, regarding initial conditions, management factors in farms such as the existence of female managers, density of main farmers, diversity of farmers, and changes in the permanent employment environment play important roles in the growth of regional agriculture. In addition, community factors such as the existence of farmers renting out their lands and community-level conservation of farmlands becomes a basis for positive change in agriculture. Simultaneously, the high rate of rice conversion means that regional agriculture depends on government subsidies and there is little room for adjusting recent economic conditions over a 10-year period.

The results imply that farmer diversity in the region is important as a growth base. The concentration of diverse farmers in regional agriculture creates competitiveness and cooperation among farmers and leads to growth in productivity. Maintaining farmer diversity and improving stable employment locally to make use of the diversity of these human resources are both required to enhance the growth potential of regional agriculture. Competitiveness and cooperation elements such as the concentration of main farmers and mutual help in farm labor are important factors, especially in hilly and mountainous areas.

Finally, productivity analysis using DEA has limitations, in that the result depends on the range of the selected sample. In this study, the target areas were limited to the Chugoku region, although there are data restrictions due to mergers and reduction in official statistical data. It is also important to understand the input-output relationship at the rural community level. We leave these issues for study in the future.

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