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Abstract

This study develops a multi-region computable general equilibrium model (CGE model), which analyzes the influence on a regional economy of a reduction in the transportation cost. The reduction in transportation cost is, in a word, reduction of the logistics cost. Logistic competition has accelerated with recent economic development. The Northern Kyushu region, which is the focal region of this study, is located near East Asian countries, including China and South Korea, but this area has fallen behind in the logistic competition. Therefore, immediate countermeasures are needed.

This study analyzes the economic effect on the Northern Kyushu region and on surrounding regions of the cost reduction caused by the logistic policy of the Northern Kyushu region. To achieve this purpose, several assumptions were made in the CGE model. First, the study analyzes 10 regions, namely Fukuoka City, Kitakyushu City, the rest of Fukuoka Prefecture, and Yamaguchi Prefecture (the northern Kyushu area consists of these regions), the rest of Japan, China, South Korea, Taiwan, ASEAN countries, and the USA. Second, in the production system, the transportation industry engenders transportation costs and these are added to the price of the commodity. Third, increasing returns to scale which Fujita et al. (1999) suggest was utilized for the manufacturing industry. Fourth, the number of firms belonging to industries with increasing returns was calculated endogenously based on the above assumption.

As a result, the logistic improvement will be shown to have had an economic effect, including an increase in the number of firms in the Northern Kyushu region.

JEL classification: C68, D58, O53, R15, R39, R49
Keywords: Northern Kyushu, Transportation cost, Regional economy, CGE model

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1. Introduction

Logistics became important as the world economy developed. There was a time when Japan's logistic competitiveness as a trading nation was high. However, that competitiveness has decreased relative to Japan's stagnating economy and the increasing power of newly industrializing economies, including China's. To recover the competitiveness, first of all, it is important to recover the Japanese economy itself. On the other hand, it is necessary to improve the logistic competitiveness. This study examines the economic effect when logistic competitiveness rises. There has been considerable discussion on how to raise the competitiveness. However, it is important to know beforehand what economic effect would be realized as a result of improving competitiveness. This study analyzes the improvement of logistic competitiveness in the form of the reduction of logistics cost.

In an analysis of the regional economy, the transportation cost is an important variable. Although this viewpoint goes back as far as Von Thünen, Krugman and others advocate it as the new economic geography theory (Krugman, 1991, and Fujita et al., 1999). On the other hand, it is necessary to replace these theories with a more realistic model. In this regard, the computable general equilibrium model (CGE model) by which the general equilibrium theory is applied to economic statistical reality is employed. Therefore, the study analyzes the improvement of logistic competitiveness by using the CGE model.

Because the CGE model is used to analyze the transportation cost in the region, a multi-region model is necessary. The Northern Kyushu region in Japan was the fourth region known for its steel, and follows Tokyo, Osaka, and Nagoya in economic importance; these four form an economic bloc. Moreover, it is geographically close to East Asia, including China and South Korea. Hence, its geographic situation can be exploited, and improvement of the logistic competitiveness has been identified as a key policy to activate the economy.

This study analyzes the economic effect on the region itself and on the surrounding region of the cost reduction engendered by the logistic policy of the Northern Kyushu region. To achieve this purpose, several assumptions were made in the CGE model.

First, 10 regions were analyzed including Fukuoka City, Kitakyushu City, the rest of Fukuoka Prefecture, and Yamaguchi Prefecture (the Northern Kyushu region consists of these regions), the rest of Japan, China, South Korea, Taiwan, ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, Thailand), and the USA. Figures 1 to 4 show the economies of those countries. The USA is the largest economy in Figure 1, Japan is second, but China has recently caught up with Japan.[1] All the countries have seen expanding international trade, except in 2009 (due to the financial crisis) (see Figures 2 and 3). Because the populations of China and ASEAN are large, their per capita GDP is extremely low (see Figure 4).

Fukuoka Prefecture has two government-designated major cities. One is Fukuoka City, which is the central city in Fukuoka Prefecture. The other is Kitakyushu City, which is a large city with a population of about one million. The administrative relationship between Fukuoka City and Kitakyushu City is not without problem. Because the two cities are being independently administered, it is possible for each city's government to execute a policy that would benefit its city the most. Figures 5 to 8 show the economy of the Northern Kyushu region. The 2000 price of gross regional product (GRP) of Fukuoka Prefecture shows an increasing trend during the period; however, its share in Japan's GRP is only about 3.5%. That of Yamaguchi Prefecture is only 1.1%, less than that of Fukuoka City. The GRP of Kitakyushu City is half or more than half that of Fukuoka City (see Figure 5). Yamaguchi Prefecture's GRP per capita falls below the national average, but is higher than Fukuoka Prefecture's. That of Kitakyushu City is lower than that of Yamaguchi Prefecture, though Fukuoka City's is higher than Yamaguchi Prefecture's (see Figure 6). Fukuoka Prefecture's population shows an increasing tendency and that of Yamaguchi Prefecture a decreasing one (see Figure 7). In Fukuoka City, the ratio of manufacturing is extremely low and indicates an economic structure of the city type. The ratio of manufacturing in Kitakyushu City is the same as for the national economy, and Yamaguchi Prefecture's ratio of manufacturing is higher than that of the national economy (see Figure 8). It is understood that there are some differences in the economic structure and these economy are very small.

[1] Japan was second but China has now outstripped Japan to become the second largest.

Second, in the production system, the transportation industry engenders transportation costs and they are added to the price of the commodity. Third, increasing returns to scale which Fujita et al. (1999) suggest is applied to the manufacturing industry. Fourth, the number of firms due to the increasing returns in industry is calculated endogenously on the basis of the above assumption. Although these are related to the Fujita et al. (1999) model, some improvements are made to make it applicable to the CGE model.

The model and data are explained in the next section. Section 3 explains the simulation design. Section 4 gives the results of the simulation, and the last section states the conclusion.

2. Model structure

This model utilizes 10 regions, two factors of production (labor and capital), and 18 industries. The background of this model in large measure rests on the new economic geography theory (Fujita et al., 1999). Incidentally, of the theory, (1) the iceberg style transportation cost, (2) the Dixit and Stiglitz (1977) type utility function, and (3) the production function equipped with increasing return technology are adopted into the model. In this paper, we devise a method for treating these assumptions that makes it easy to incorporate them into the CGE model. All the mathematical notations of this model are described in the appendix.

2-1. Transportation costs

The iceberg style transportation cost is assumed in the most of the new economic geography literature. Although this refers to goods moving between different regions, it reflects reality in that it takes into consideration the melting down in time and is an assumption that is easy to treat as a theoretical model. Adopting the iceberg cost in the CGE model is possible: one example of this is Kilkenny's (1998) prototype model; the other is in the SCGE literature. However, since the CGE model deals with the actual social accounting matrix (SAM) using an input-output table, on the premise that the whole economy is balanced in value, the treatment of diminishing value may make construction of the model difficult. Moreover, while the model applies the transportation cost to the dealings between regions, it does not take into account the transportation cost within a region. It is not appropriate to apply the transportation cost to the dealings between regions only, either. Therefore, it is necessary to consider another assumption that extends the iceberg style regarding the transportation cost.

The transportation industry of each region produces a transportation service and adds it to the purchase price. Since the purchasing sector covers not only its own region but other regions, the transportation industry can impose transportation costs on both local and external dealings. Therefore, the purchase price (for example, purchase by a private consumer) which is added to transportation costs is as follows:

$$PPC_{r,s,ii} = PD_{r,ii}\left(1 + tpc_{r,s}\right) \quad (1)^{2}$$

where *tpc* is the exogenous transportation cost parameter that decides the rate of the transportation cost, and is calculated from the SAM database as follows:

$$tpc_{r,s} = \frac{PD_{r,trans}PC_{r,s,trans}}{\sum_{ii} PD_{r,ii}PC_{r,s,ii}}. \quad (2)^{3}$$

These parameters differ according to each region and purchasing sector and the demand for the transportation service that the transportation industry should produce is decided by summing all transportation costs.

2-2. Consumer demand

The consumer demand has the Cobb-Douglas type utility function for the 17 final products. However, since the 8 final products of the industrial sector are implicitly several different small products, the sub-utility function for those small products is assumed tentatively to be the following Dixit and Stiglitz (1977) type CES function:

[2] Suffix “*ii*” means all sectors except the transportation sector. Also “*i1*” means the sector that has a constant return in production and “*i2*” means the sector that has an increasing return in production (see appendix).

[3] The row data of the transportation sector in the SAM are used.

$$X_{i2} = \left[\int_0^{n_{i2}} x(j)_{i2}^{\rho_{i2}} \, dj \right]^{\frac{1}{\rho_{i2}}}, \quad \rho_{i2} = 1 + \frac{1}{\sigma_{i2}}, \quad \sigma_{i2} < -1 \quad (3)$$

σ is the elasticity of substitution between each small product, and n is the number of small products. Based on this assumption, the utility function of each consumer is as follows:[4]

$$U = \prod_{ii}^{17} X_{ii}^{\alpha_{ii}} = \prod_{i1}^{9} X_{i1}^{\alpha_{i1}} \prod_{i2}^{8} \left[\int_0^{n_{i2}} x(j)_{i2}^{\rho_{i2}} \, dj \right]^{\frac{\alpha_{i2}}{\rho_{i2}}}. \quad (4)$$

Adopting the consumer problem for maximizing its utility subject to budget constraints, the demand function is solved as follows:

$$X_{ii} = \frac{\alpha_{ii} DISINCOME}{PD_{ii}}. \quad (5)$$

As regards the demand for small goods, it is as follows:

$$x_{i2} = \frac{\alpha_{i2} DISINCOME}{N_{i2} PA_{i2}}. \quad (6)$$

This is because the demand for small goods is the same at the equilibrium.[5]

When the consumer carries out demand for the same quantity of each small good, each small firm that produces will also attach the same price at the equilibrium. In this case, the relation between the price that a small firm attaches and the price index that is made is as follows:

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[4] Flôres (1997) also uses this type of utility function for assuming increasing return.

[5] *X*, *x* and *DISINCOME* in eq(3) to eq(6) are tentative notations for explaining the model. Actual demand function is defined as equations E-29, E-33, and E-37 in the appendix.

$$PD_{r,j2} = PA_{r,j2} N^{\frac{1}{1+\sigma_{r,j2}}} \left(1 + ntax_{r,j2}\right). \quad (7)$$

It turns out that the price index of the industry to which the small firm belongs depends on the number of firms producing similar goods and the elasticity of substitution of small goods.

2-3. Firm's production

As regards the production structure of the firms, the composite factor (value added) of production uses two factors of production, the intermediate goods produced locally and externally, the composite goods by factor and the intermediate goods, and the final goods with the imported goods from the rest of the world through a nested type production structure. Such a multi-tier production function system imitates the context of a certain CGE model. It assumes the (A-5-1) CES type production function for producing composite factors using two factors of production, the (A-5-2) CES type for intermediate goods produced locally and externally, the (A-5-3) Leontief type with composite factor and intermediate goods, and the (A-5-4) CES type for adding the imported goods from the rest of the world. The "Armington" assumption is used, which adopts the CES type in tier (A-5-2) and (A-5-4) (Armington, 1969). The final goods are divided according to each demand (private consumption, government consumption, private investment, inventory, intermediate goods sold locally and externally, and goods exported to the rest of the world) by perfect substitution. The demand and price of exported goods are assumed exogenously.

As regards the production in 8 industries to which many small firms belong, each small firm produces unique products. To achieve this, the firm needs a fixed cost for its production, but it can use the technology of increasing returns to scale and can decide on a sales price under the maximizing profit condition. In this model, the fixed cost is set in the final tier of the nested system. Therefore, the production function of each small firm facing fixed setup costs is as follows:

$$Q_{r,j2} + FIX^{*}_{r,j2} = \gamma^{Q}_{r,j2}\left[\alpha^{QY}_{r,j2} Y^{\rho^{M}_{j2}}_{r,j2} + \alpha^{QM}_{r,j2} M^{\rho^{M}_{j2}}_{r,j2}\right]^{\frac{1}{\rho^{M}_{j2}}}, \quad \alpha^{QY}_{r,j2} + \alpha^{QM}_{r,j2} = 1. \quad (8)$$

As mentioned before, each small firm can decide on its sales price as a monopolistic enterprise, and the markup price that a firm determines becomes the following:

$$PA_{r,j2} = \frac{1}{\rho_{i2}} PQ_{r,j2} = \frac{\sigma_{r,j2}}{1+\sigma_{r,j2}} PQ_{r,j2}. \quad (9)$$

The base price of the products before markup is assumed as numeraire.

In order that 10 industries including the transportation industry may assume constant returns to scale, excess profits are not generated at the equilibrium. Moreover, it is assumed that excess profits do not similarly occur when the increasing returns of the industries are at the equilibrium. This is the famous monopolistic competition approach. When this condition is assumed, market equilibrium is as follows for the increasing returns of an industry:

$$PD_{r,j2} / \left(1 + ntax_{r,j2}\right) Q_{r,j2} = PQ_{r,j2} Q_{r,j2} + FIX^{*}_{r,j2} \quad (10)$$

The number of small firms is determined at the equilibrium endogenously.

2-4. Database, SAM, and calibration

In this paper, the multi-region input-output table is adopted as a database. This table consists of two parts. One is a table of five regions in Japan and another is an international table. The interregional input-output table of Japan is estimated by using the following input-output tables: Japan, Fukuoka Prefecture, Yamaguchi Prefecture, Fukuoka City, Kitakyushu City, and the interregional table comparing Fukuoka Prefecture and the rest of Japan. The base year is 2000. These tables are available on the regions' administration websites. The disaggregated interregional input-output tables of five regions are estimated mechanically by using proportional and RAS methods. The international table is based on the "2000 Asian International Input-Output Table (estimated by Institute of Developing Economies, Japan External Trade Organization)." Because the information from five regional tables in Japan was used for the international table, the part on Japan is divided into five regions. Since ASEAN was divided into several countries in the international table, these were brought together into one region, and finally, the 10-regions table is used in this paper. The multi-region input-output table was adjusted for building SAM which the CGE model uses and is treated based on this data.

The model is calibrated using the database. All parameters except elasticity are estimated by the database and the maximizing condition. Elasticity parameters are selected on the basis of the literature. Exogenous variables are also decided from the database. Moreover, the number of firms in the industry to which small firms belong is assumed to be equal to 1 as the solution of the base case, and uses a relative measure. One reason is that dealing with the actual number of firms is not helpful, since the number of firms in each industry is too much. This approach simplifies the calculation.

As regards the solution method in this model, the computation is performed by regarding it as the summed up data. Although each small firm faces the same quantity of production and the same price at the equilibrium, in order to assume the number of firms to be 1 in the base case solution, it becomes equal to the summed up data. In addition, since the number of firms in the industry to which small firms belong is determined by equation (7) endogenously, when an exogenous shock occurs, the number of firms changes. When the number of firms exceeds 1, it means that the number of firms of a certain industry in the region increases, and thus the agglomeration effect of the industry between regions can be seen.

3. Simulations

The importance of international logistics has risen steadily along with economic growth. In order for logistics to become important, economic growth is necessary. The fact that the world economy including China has grown, while the Japanese economy has stagnated means there is a relative decrease in the logistics of Japan (see Figure 1). On the other hand, the efficiency of Japan's logistics management is called into question.

Therefore, the method for activating the economy must be examined, starting with improving the efficiency of the logistics. The study simulates how the improved efficiency of logistics influences the agglomeration of industry and the regional economy. The simulation assumes the case where the transportation cost is reduced by improved logistical efficiency. Of course, the policy leading to the reduction in transportation cost is not the object of this study.

This discussion concentrated only on the measurement of the economic effect induced by the reduction in the mechanical transportation cost. The method of reducing transportation cost can be measured by reducing the exogenous transportation cost parameter such as *tpc*, *tgc*, *tiv*, *te*, and *txm* in the model.[6] The region where the transportation cost is reduced is determined, and the effects of the policy are compared in the study. First, the paper considers the Northern Kyushu region, and measures the reduction in the transportation cost of Fukuoka City, Kitakyushu City, and the entire Fukuoka Prefecture (Fukuoka City, Kitakyushu City, and the rest of Fukuoka Prefecture), respectively. Fukuoka City and Kitakyushu City are very small economic areas in this model. However, they have independent harbors and airports, and the logistics policy can be executed by each city individually. On the other hand, a more inclusive logistics policy should be executable at the level of the prefecture, and the effect of the policy in this case measured. Second, the paper considers the influence on the Northern Kyushu region when transportation cost in the region other than the Northern Kyushu region is reduced. The region of interest is the rest of Japan and China. As for the rest of Japan, Tokyo, Osaka, and Nagoya are included in the regions, but not the Northern Kyushu region. The case in which the logistics policy was previously executed on these cities and the transportation cost reduced is measured. The reducing transportation cost in China is based on infrastructure maintenance along with economic growth.

Therefore, 6 simulations are given above.

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[6] Because we use aggregated input-output data for calibrating the transportation cost parameter, the transportation sector includes all modes of transportation in this study. Moreover, because inner regional transaction is included in the database, reducing the transportation cost means reducing domestic trading costs as well as international trading costs.

Simulation 1: 10% reduction of the total transportation cost parameter in Fukuoka City.
Simulation 2: 10% reduction of total transportation cost parameter in Kitakyushu City.
Simulation 3: 10% reduction of total transportation cost parameter in Fukuoka Prefecture.
Simulation 4: 10% reduction of total transportation cost parameter in the rest of Japan.
Simulation 5: 10% reduction of total transportation cost parameter in China.
Simulation 6: 50% reduction of total transportation cost parameter in China.

The evaluation of the simulation takes three forms: (1) change of the number of firms in industries with increasing returns, (2) change of industrial structure, and (3) change of macro value of regions. Labor is able to move among regions and industries as the number of firms changes (E-4). However, the capital cannot be moved (E-5). Therefore, the change of labor becomes an important item for observation after the simulations. The output of each industry and regional income are also items for observation in the paper. All have the solution of a base case with 1, and the change between items can be understood by the increase and decrease from 1.

4. Results

All tables show the degree of change under the simulation when setting the results relative to a base case with 1. Table 1 shows the change of the number of firms in industries with increasing returns, in Simulations 1-3. Each region's agglomeration effect is clearly seen. In Fukuoka City's case, a 10% reduction in transportation cost leads 0.9% increase in firms in the food industry (i002) and 10.2% of firms in the chemical industry (i004). In Kitakyushu City's case, the reduction results in a 1.2% increase in firms in the electronic industry (i007) and a 5.3% increase in the textile industry (i003). In Fukuoka Prefecture's case, the reduction results in a 1.0% increase in firms in the transport equipment industry (i008) in the rest of Fukuoka prefecture and a 9.7% increase in the chemical industry (i004) in Fukuoka City. The reason for the difference in results may be that the industrial structure and transportation cost structure differ between regions. Moreover, the number of firms increases in some regions or industries; consequently, there is a decreasing tendency of firms in surrounding regions.

On the other hand, the number of foreign firms does not change greatly due to the transportation cost reduction in the Northern Kyushu region. It can be said that the influence of the Northern Kyushu region on the world economy is very small.

This is understood from Table 2. Table 2 shows the total of labor (ilabo), total of gross production (iout), and total of production per labor unit (ioula) in each industry. Most changes are not seen, and the negligible influence of the Northern Kyushu region on the world economy can be understood.

Table 3 shows each region's macro value, that is, total of labor (tlabo), total of gross production (tout), value added income (inco), price fixed income (rinc), and per labor unit of them (toula, incla, and rinla) in each region. The transportation cost reduction increases the labor force, and increases the nominal value of added income in the region. However, the increase of labor is larger than the increase of production, and leads to a decrease in productivity as a macro.[7] Moreover, increase in real income is also smaller than increase in labor, and the economic effect might not be induced by added labor. However, attracting firms and increasing the labor force lead to the activation of the region. Therefore, it can be said that the transportation cost reduction has an economic effect on the region.

Tables 4-6 show the same result as in Simulations 4-6. The transportation cost reduction of the rest of Japan has a dramatic effect on the decrease in the number of firms in Northern Kyushu. On the other hand, though it is not the rest of Japan, the transportation cost reduction of China also decreases the number of firms of the Northern Kyushu region. Even with a 50% reduction and the transportation cost of China being greatly reduced, this tendency is similar. In a word, it is due to the heavy influence of the logistics competition on Japan.

The transportation cost reduction of the rest of Japan causes the reduction of labor, largely in the transportation industry (s015). This is because the transportation cost reduction brings a decrease of production demand for the transportation industry, and a reduction of labor follows. On the other hand, the transportation cost reduction of China increases the amount of labor in agriculture (a001), and the decrease of labor in the

[7] One of the possibilities is shown in the model specification. Because labor is a part of production and intermediate goods are included in production, labor might not increase production very much even if the simulation shows an increase in labor.

transportation industry is small. This difference shows Japan's transportation industry is more active. The influence on the macro is the same as seen in Table 3. The region where the transportation cost was reduced is activated, and another region influences it. Therefore, it is important that the authorities introduce a transportation cost reduction policy as early as possible, judging from these simulations.

5. Concluding remarks

This study develops a multi-region CGE model that analyzes the influence on the regional economy of a reduction in the transportation cost. Reducing the transportation cost in the Northern Kyushu region is expected to attract firms and increase the amount of labor, as well as revitalize the regional economy. On the other hand, the opposite results were seen, with negative activation of the Northern Kyushu region leading to reduction in the rest of Japan. Therefore, a logistics policy should be speedily implemented, the result of which would be reflected in the economic effect.

The reduction in the transportation cost is directly connected with the decline in demand of the transportation industry, though this CGE model is constructed from the theoretical model of Fujita et al. (1999). It is necessary to examine this assumption thoroughly.

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Figure 1 Nominal GDP of selected countries (Billion UD$)

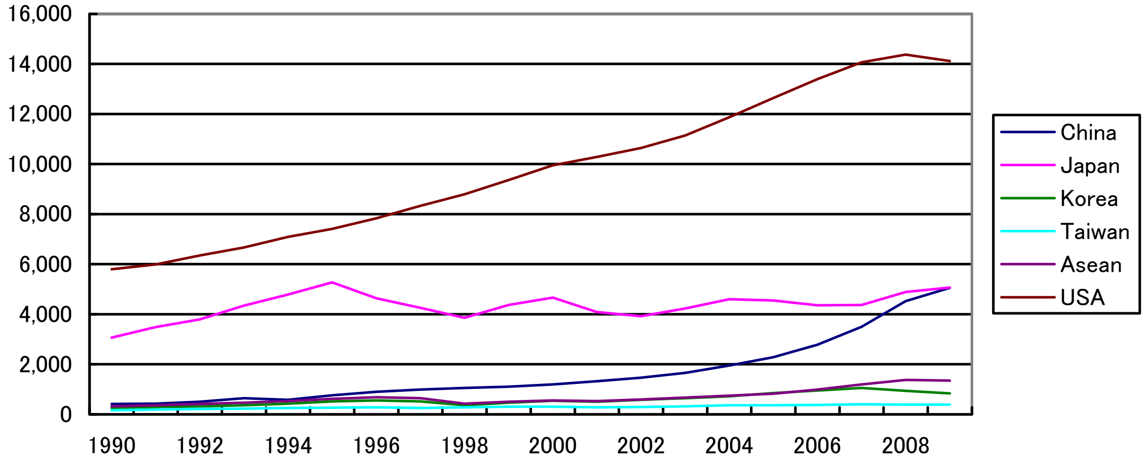


Figure 2 Export of selected countries (Billion UD$)

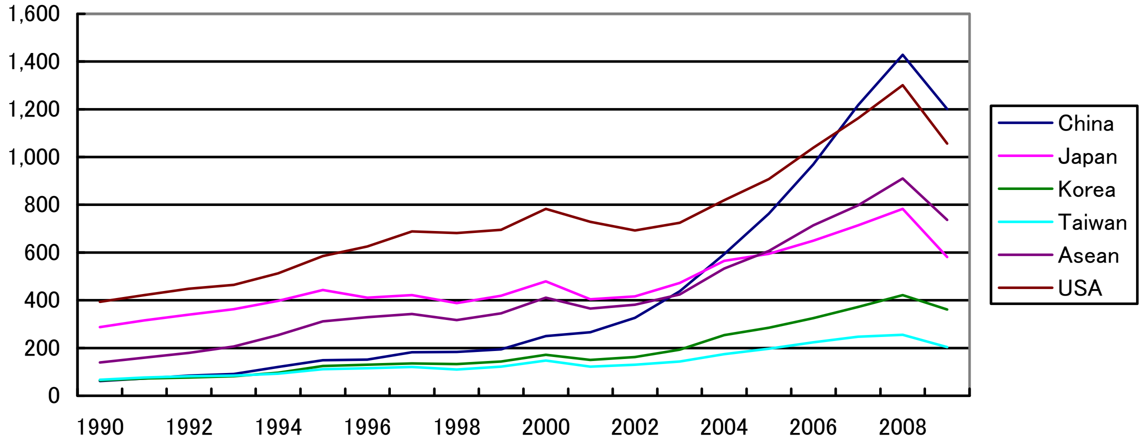


Figure 3 Import of selected countries (Billion UD$)

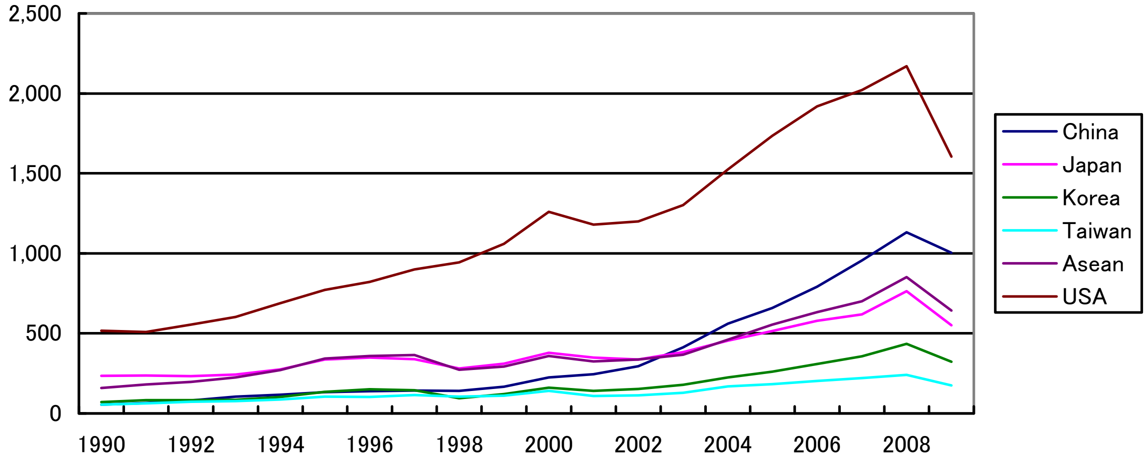
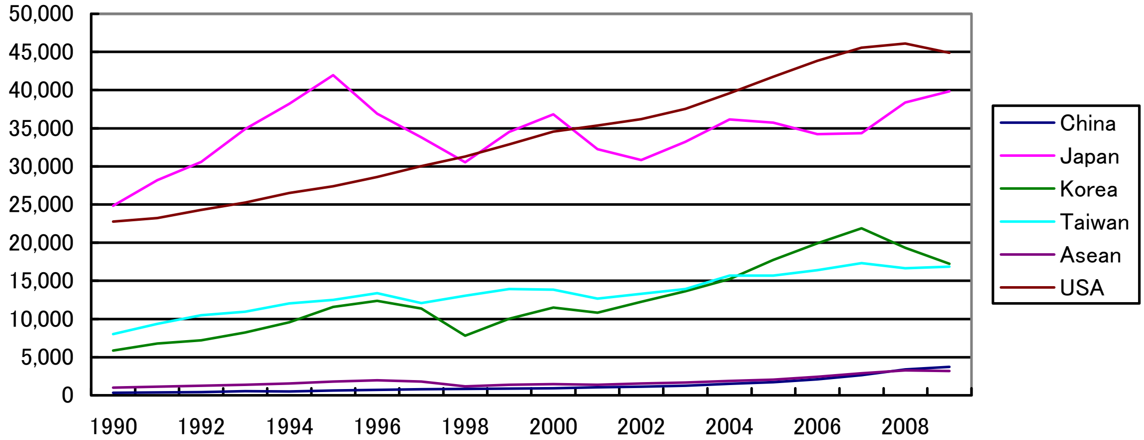


Figure 4 Per capita GDP of selected countries (UD$)



(Source) International Monetary Fund, 2010, *International Financial Statistics*, December 2010 CD-ROM.
Republic of China, Directorate-General of Budget, Accounting, and Statistics, *National Statistics* website (http://eng.stat.gov.tw/mp.asp?mp=5) for Taiwan.

Figure 5 Gross regional products (GRP) of objective regions (2000 price, Billion yen)

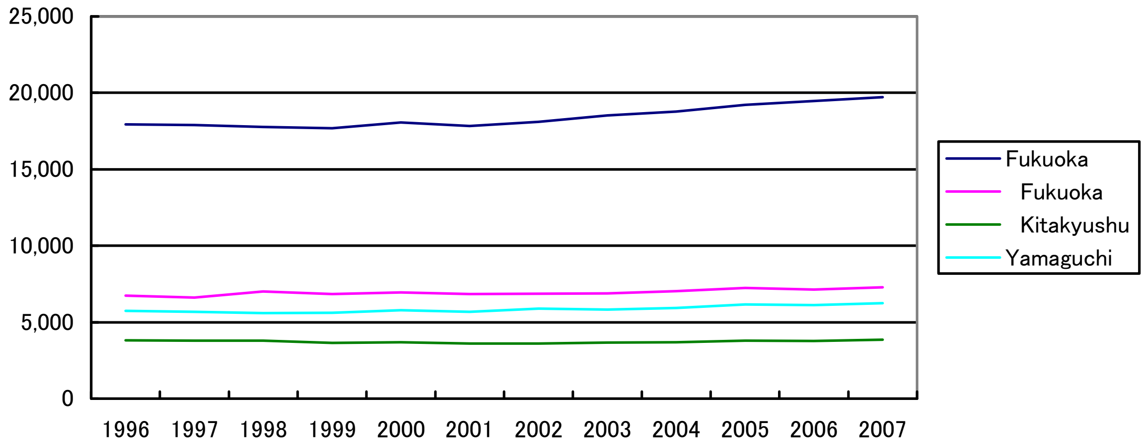


Figure 6 Per capita GRP of selected regions (Thousand yen)

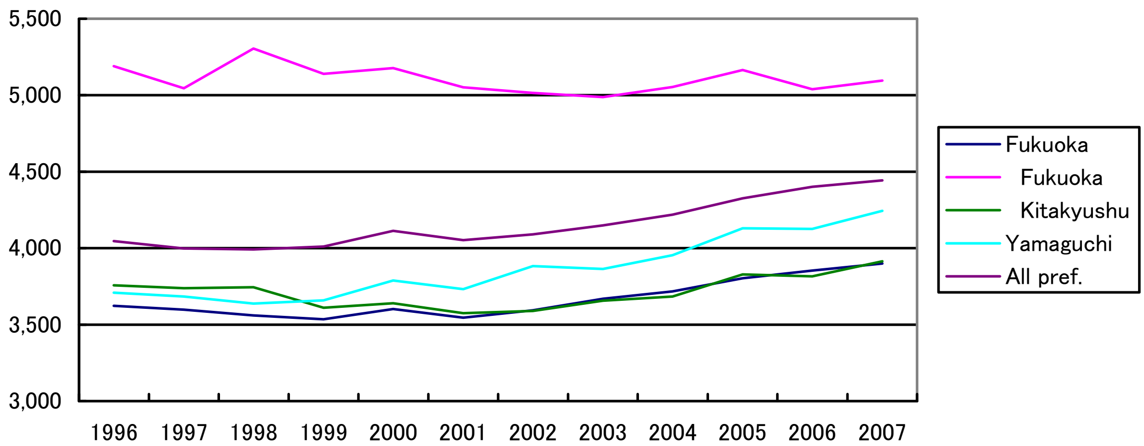


Figure 7 Population of selected regions (10,000 persons)

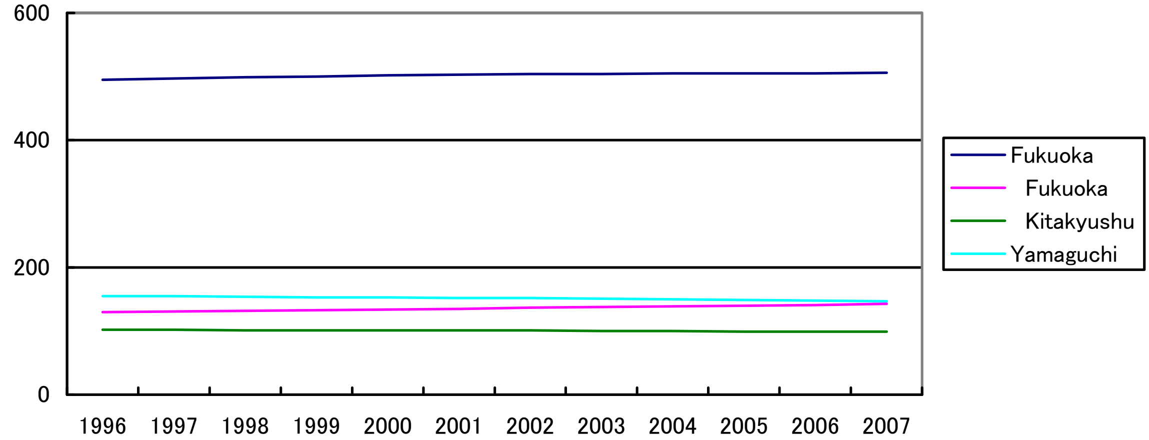
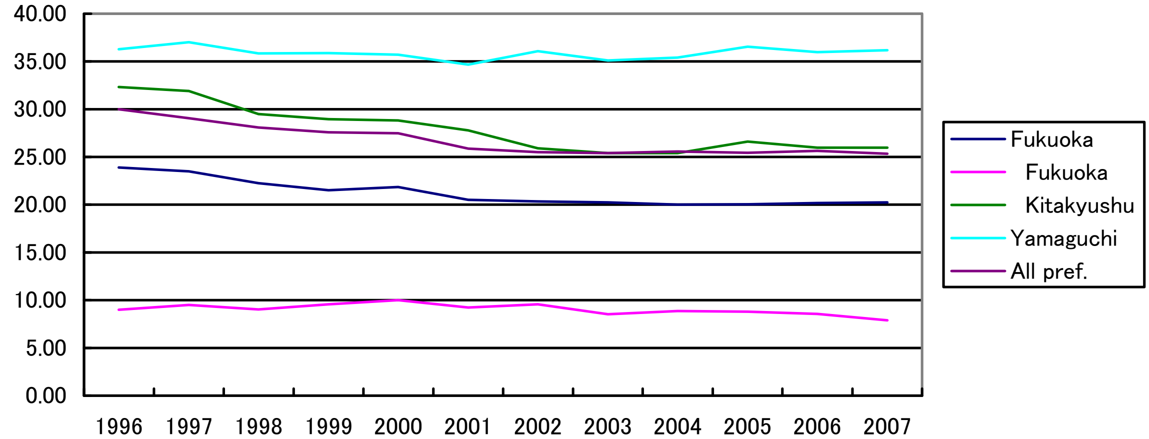


Figure 8 Share of secondary industry (percent)



(Source) *Kenmin Keizai Keisan*, Cabinet Office, Government of Japan

Table 1 Number of firms for each simulation

		fc*0.9	kc*0.9	fp*0.9			fc*0.9	kc*0.9	fp*0.9
cn	i002	0.9999	1.0000	0.9999	op	i002	0.9997	1.0000	0.9997
cn	i003	0.9999	1.0000	0.9999	op	i003	0.9998	0.9999	0.9992
cn	i004	0.9999	1.0000	0.9999	op	i004	0.9998	0.9998	0.9989
cn	i005	0.9999	1.0000	0.9999	op	i005	0.9999	0.9996	0.9991
cn	i006	0.9999	1.0000	0.9999	op	i006	0.9998	1.0000	0.9998
cn	i007	0.9999	1.0000	0.9999	op	i007	0.9999	1.0000	0.9998
cn	i008	0.9999	1.0000	0.9999	op	i008	0.9999	1.0000	0.9997
cn	i009	0.9999	1.0000	0.9999	op	i009	0.9998	0.9999	0.9996
fc	i002	1.0089	1.0002	1.0107	kr	i002	0.9999	1.0000	0.9999
fc	i003	1.0462	0.9999	1.0427	kr	i003	1.0000	1.0000	0.9999
fc	i004	1.1018	0.9991	1.0972	kr	i004	1.0000	1.0000	0.9999
fc	i005	1.0454	0.9991	1.0442	kr	i005	1.0000	0.9999	0.9999
fc	i006	1.0160	1.0003	1.0180	kr	i006	0.9999	1.0000	0.9999
fc	i007	1.0150	1.0001	1.0158	kr	i007	0.9999	1.0000	0.9999
fc	i008	1.0245	1.0001	1.0254	kr	i008	1.0000	1.0000	0.9999
fc	i009	1.0199	0.9995	1.0206	kr	i009	0.9999	1.0000	0.9999
kc	i002	0.9996	1.0281	1.0289	tn	i002	0.9999	1.0000	0.9999
kc	i003	0.9997	1.0533	1.0505	tn	i003	1.0000	1.0000	1.0000
kc	i004	0.9998	1.0416	1.0398	tn	i004	1.0000	1.0000	0.9999
kc	i005	0.9999	1.0260	1.0259	tn	i005	1.0000	0.9999	0.9999
kc	i006	0.9998	1.0129	1.0132	tn	i006	0.9999	1.0000	0.9999
kc	i007	0.9998	1.0121	1.0123	tn	i007	0.9999	1.0000	0.9999
kc	i008	0.9999	1.0131	1.0132	tn	i008	0.9999	1.0000	0.9999
kc	i009	0.9998	1.0345	1.0369	tn	i009	0.9999	1.0000	0.9999
of	i002	0.9996	1.0006	1.0146	aa	i002	0.9999	1.0000	0.9999
of	i003	0.9999	1.0000	1.0366	aa	i003	0.9999	1.0000	0.9999
of	i004	1.0002	0.9999	1.0360	aa	i004	1.0000	1.0000	0.9999
of	i005	1.0008	0.9984	1.0390	aa	i005	0.9999	0.9999	0.9998
of	i006	1.0000	1.0009	1.0142	aa	i006	0.9999	1.0000	0.9999
of	i007	1.0002	1.0007	1.0231	aa	i007	0.9999	1.0000	0.9999
of	i008	1.0001	1.0003	1.0103	aa	i008	0.9999	1.0000	0.9999
of	i009	0.9998	0.9990	1.0256	aa	i009	0.9999	0.9999	0.9998
yp	i002	0.9996	1.0000	0.9998	us	i002	1.0000	1.0000	1.0000
yp	i003	0.9997	0.9992	0.9970	us	i003	1.0000	1.0000	1.0000
yp	i004	0.9997	0.9986	0.9964	us	i004	1.0000	1.0000	1.0000
yp	i005	0.9999	0.9963	0.9955	us	i005	1.0000	1.0000	1.0000
yp	i006	0.9998	1.0002	1.0000	us	i006	1.0000	1.0000	1.0000
yp	i007	0.9998	1.0003	1.0003	us	i007	1.0000	1.0000	0.9999
yp	i008	1.0000	1.0001	0.9997	us	i008	1.0000	1.0000	1.0000
yp	i009	0.9997	0.9982	0.9975	us	i009	1.0000	1.0000	1.0000

Table 2 Change of industrial structure for each simulation

	fc*0.9			kc*0.9			fp*0.9		
	ilabo	iout	ioula	ilabo	iout	ioula	ilabo	iout	ioula
a001	0.9999	0.9999	1.0001	1.0000	1.0000	1.0000	0.9999	1.0000	1.0001
i002	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000	1.0001	1.0000	1.0000
i003	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
i004	1.0000	0.9999	1.0000	1.0001	1.0000	1.0000	1.0001	1.0000	0.9999
i005	1.0000	0.9999	1.0000	1.0001	1.0001	1.0000	1.0001	1.0001	1.0000
i006	0.9999	0.9999	1.0000	1.0001	1.0000	1.0000	1.0000	1.0000	1.0000
i007	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000	1.0001	1.0000	1.0000
i008	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
i009	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
i010	0.9999	0.9999	1.0000	1.0001	1.0001	1.0000	1.0001	1.0000	1.0000
s011	0.9999	1.0000	1.0001	1.0001	1.0000	0.9999	1.0001	1.0000	0.9999
s012	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001	1.0000	1.0000
s013	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
s014	0.9999	1.0000	1.0001	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
s015	0.9994	0.9997	1.0002	0.9997	0.9998	1.0001	0.9987	0.9991	1.0005
s016	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
s017	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
s018	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table 3 Change of macro value of region for each simulation

		tlabo	tout	inco	rinc	toula	incla	rinla
fc*0.9	cn	0.9999	0.9999	0.9998	0.9999	1.0000	1.0000	1.0001
	fc	1.0040	1.0032	1.0053	1.0024	0.9993	1.0013	0.9985
	kc	0.9996	0.9998	0.9995	0.9998	1.0001	0.9999	1.0002
	of	0.9998	0.9999	0.9998	0.9999	1.0001	1.0000	1.0001
	yp	0.9996	0.9997	0.9996	0.9998	1.0001	0.9999	1.0002
	op	0.9997	0.9998	0.9997	0.9999	1.0001	0.9999	1.0001
	kr	0.9999	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000
	tn	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
	aa	0.9999	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000
	us	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
kc*0.9	cn	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	fc	1.0003	1.0002	1.0004	1.0002	0.9999	1.0001	0.9999
	kc	1.0166	1.0140	1.0209	1.0096	0.9975	1.0043	0.9931
	of	1.0009	1.0005	1.0011	1.0006	0.9996	1.0002	0.9997
	yp	0.9993	0.9993	0.9993	0.9996	1.0000	1.0000	1.0003
	op	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
	kr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	tn	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	aa	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	us	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
fp*0.9	cn	0.9999	0.9999	0.9998	0.9999	1.0000	1.0000	1.0001
	fc	1.0062	1.0047	1.0079	1.0038	0.9985	1.0018	0.9976
	kc	1.0176	1.0145	1.0222	1.0101	0.9970	1.0046	0.9927
	of	1.0142	1.0122	1.0180	1.0089	0.9980	1.0037	0.9948
	yp	0.9983	0.9984	0.9982	0.9990	1.0001	0.9999	1.0007
	op	0.9996	0.9997	0.9995	0.9997	1.0001	0.9999	1.0002
	kr	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000	1.0001
	tn	0.9999	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000
	aa	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000	1.0001
	us	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table 4 Number of firms for each simulation

		op*0.9	cn*0.9	cn*0.5			op*0.9	cn*0.9	cn*0.5
cn	i002	0.9980	1.0080	1.0406	op	i002	1.0073	0.9992	0.9960
cn	i003	0.9990	1.0043	1.0215	op	i003	1.0049	0.9993	0.9966
cn	i004	0.9987	1.0035	1.0152	op	i004	0.9990	0.9994	0.9970
cn	i005	0.9982	1.0056	1.0273	op	i005	1.0050	0.9992	0.9960
cn	i006	0.9981	1.0056	1.0271	op	i006	1.0030	0.9993	0.9965
cn	i007	0.9986	1.0055	1.0273	op	i007	1.0048	0.9995	0.9973
cn	i008	0.9985	1.0016	1.0039	op	i008	1.0025	0.9996	0.9979
cn	i009	0.9983	1.0057	1.0274	op	i009	1.0063	0.9991	0.9952
fc	i002	0.9943	0.9992	0.9958	kr	i002	0.9982	0.9992	0.9962
fc	i003	0.9757	0.9990	0.9951	kr	i003	0.9990	0.9993	0.9966
fc	i004	0.9777	0.9985	0.9923	kr	i004	0.9984	0.9992	0.9959
fc	i005	0.9825	0.9986	0.9932	kr	i005	0.9979	0.9990	0.9950
fc	i006	0.9896	0.9990	0.9949	kr	i006	0.9981	0.9993	0.9964
fc	i007	0.9948	0.9993	0.9967	kr	i007	0.9984	0.9995	0.9977
fc	i008	0.9904	0.9995	0.9973	kr	i008	0.9988	0.9995	0.9977
fc	i009	0.9886	0.9993	0.9966	kr	i009	0.9979	0.9993	0.9963
kc	i002	0.9899	0.9990	0.9950	tn	i002	0.9985	0.9993	0.9966
kc	i003	0.9775	0.9992	0.9959	tn	i003	0.9992	0.9995	0.9975
kc	i004	0.9854	0.9991	0.9956	tn	i004	0.9988	0.9992	0.9960
kc	i005	0.9785	0.9987	0.9936	tn	i005	0.9982	0.9986	0.9931
kc	i006	0.9921	0.9991	0.9957	tn	i006	0.9983	0.9995	0.9977
kc	i007	0.9943	0.9994	0.9969	tn	i007	0.9983	0.9996	0.9979
kc	i008	0.9931	0.9997	0.9983	tn	i008	0.9986	0.9996	0.9979
kc	i009	0.9852	0.9988	0.9936	tn	i009	0.9987	0.9995	0.9975
of	i002	0.9917	0.9991	0.9955	aa	i002	0.9982	0.9996	0.9979
of	i003	0.9604	0.9991	0.9957	aa	i003	0.9983	0.9996	0.9980
of	i004	0.9549	0.9993	0.9967	aa	i004	0.9985	0.9995	0.9975
of	i005	0.9592	0.9991	0.9956	aa	i005	0.9967	0.9993	0.9966
of	i006	0.9891	0.9991	0.9956	aa	i006	0.9976	0.9994	0.9969
of	i007	0.9881	0.9989	0.9945	aa	i007	0.9988	0.9996	0.9982
of	i008	0.9894	0.9996	0.9979	aa	i008	0.9978	0.9996	0.9980
of	i009	0.9760	0.9989	0.9944	aa	i009	0.9964	0.9993	0.9966
yp	i002	0.9899	0.9991	0.9954	us	i002	0.9995	0.9998	0.9992
yp	i003	0.9793	0.9992	0.9961	us	i003	0.9996	0.9999	0.9993
yp	i004	0.9868	0.9994	0.9968	us	i004	0.9996	0.9999	0.9993
yp	i005	0.9770	0.9989	0.9946	us	i005	0.9995	0.9998	0.9989
yp	i006	0.9892	0.9991	0.9954	us	i006	0.9994	0.9998	0.9991
yp	i007	0.9924	0.9993	0.9965	us	i007	0.9992	0.9998	0.9988
yp	i008	0.9931	0.9997	0.9987	us	i008	0.9994	0.9999	0.9994
yp	i009	0.9850	0.9986	0.9926	us	i009	0.9994	0.9998	0.9992

Table 5 Change of industrial structure for each simulation

	op*0.9			cn*0.9			cn*0.5		
	ilabo	iout	ioula	ilabo	iout	ioula	ilabo	iout	ioula
a001	0.9992	0.9997	1.0005	1.0074	1.0033	0.9959	1.0382	1.0170	0.9796
i002	1.0025	1.0014	0.9988	1.0017	1.0011	0.9994	1.0091	1.0056	0.9966
i003	1.0015	1.0007	0.9993	1.0009	1.0009	1.0001	1.0044	1.0047	1.0004
i004	0.9999	0.9989	0.9990	1.0013	1.0008	0.9995	1.0061	1.0034	0.9973
i005	1.0021	1.0009	0.9988	1.0008	1.0010	1.0002	1.0042	1.0049	1.0008
i006	1.0016	1.0009	0.9993	1.0006	1.0007	1.0001	1.0030	1.0036	1.0006
i007	1.0022	1.0009	0.9986	1.0006	1.0006	1.0000	1.0030	1.0029	0.9999
i008	1.0012	1.0007	0.9995	1.0001	1.0000	1.0000	1.0001	0.9998	0.9997
i009	1.0014	1.0006	0.9992	1.0014	1.0008	0.9994	1.0069	1.0038	0.9969
i010	1.0021	1.0014	0.9993	1.0006	1.0011	1.0004	1.0034	1.0054	1.0020
s011	1.0018	1.0004	0.9986	1.0019	1.0007	0.9987	1.0095	1.0031	0.9937
s012	1.0023	1.0015	0.9992	1.0000	1.0001	1.0002	0.9999	1.0007	1.0007
s013	1.0003	1.0001	0.9998	1.0000	1.0000	1.0000	1.0001	0.9999	0.9998
s014	1.0010	1.0000	0.9990	1.0003	1.0000	0.9997	1.0015	1.0001	0.9986
s015	0.9707	0.9812	1.0109	0.9948	0.9963	1.0015	0.9730	0.9772	1.0044
s016	1.0015	1.0007	0.9993	1.0003	1.0002	0.9999	1.0015	1.0010	0.9995
s017	1.0004	1.0002	0.9998	1.0000	1.0001	1.0001	1.0001	1.0005	1.0005
s018	1.0010	1.0006	0.9996	1.0000	1.0001	1.0001	0.9999	1.0003	1.0004

Table 6 Change of macro value of region for each simulation

		tlabo	tout	inco	rinc	toula	incla	rinla
op*0.9	cn	0.9980	0.9985	0.9977	0.9988	1.0005	0.9996	1.0007
	fc	0.9945	0.9962	0.9935	0.9966	1.0017	0.9989	1.0021
	kc	0.9882	0.9906	0.9870	0.9932	1.0024	0.9988	1.0050
	of	0.9870	0.9875	0.9864	0.9918	1.0005	0.9994	1.0049
	yp	0.9879	0.9900	0.9870	0.9929	1.0022	0.9992	1.0051
	op	1.0019	1.0013	1.0038	1.0011	0.9994	1.0019	0.9992
	kr	0.9983	0.9988	0.9979	0.9992	1.0005	0.9996	1.0009
	tn	0.9987	0.9989	0.9984	0.9993	1.0002	0.9997	1.0006
	aa	0.9982	0.9988	0.9978	0.9994	1.0006	0.9995	1.0012
	us	0.9995	0.9996	0.9994	0.9997	1.0001	0.9999	1.0002
cn*0.9	cn	1.0078	1.0058	1.0082	1.0050	0.9980	1.0003	0.9971
	fc	0.9992	0.9995	0.9991	0.9995	1.0002	0.9998	1.0003
	kc	0.9990	0.9993	0.9988	0.9994	1.0003	0.9998	1.0004
	of	0.9992	0.9994	0.9990	0.9995	1.0002	0.9998	1.0003
	yp	0.9991	0.9994	0.9990	0.9995	1.0002	0.9998	1.0004
	op	0.9993	0.9995	0.9991	0.9996	1.0002	0.9998	1.0003
	kr	0.9993	0.9995	0.9991	0.9996	1.0002	0.9998	1.0004
	tn	0.9994	0.9995	0.9992	0.9997	1.0001	0.9998	1.0003
	aa	0.9996	0.9997	0.9995	0.9999	1.0001	0.9999	1.0003
	us	0.9999	0.9999	0.9998	0.9999	1.0000	1.0000	1.0001
cn*0.5	cn	1.0389	1.0268	1.0428	1.0246	0.9884	1.0037	0.9862
	fc	0.9962	0.9974	0.9953	0.9976	1.0012	0.9991	1.0015
	kc	0.9951	0.9964	0.9942	0.9971	1.0013	0.9992	1.0021
	of	0.9959	0.9969	0.9951	0.9974	1.0010	0.9992	1.0015
	yp	0.9956	0.9967	0.9948	0.9974	1.0012	0.9992	1.0018
	op	0.9965	0.9975	0.9957	0.9979	1.0010	0.9992	1.0015
	kr	0.9963	0.9974	0.9954	0.9982	1.0011	0.9991	1.0019
	tn	0.9969	0.9975	0.9961	0.9983	1.0007	0.9993	1.0014
	aa	0.9979	0.9985	0.9973	0.9993	1.0007	0.9994	1.0014
	us	0.9993	0.9994	0.9991	0.9995	1.0002	0.9998	1.0003

(Source) Author’s calculation

Appendix: Model description

A-1. Set

(r, s, u) Region

cn: China
fc: Fukuoka City
kc: Kitakyushu City
of: the rest of Fukuoka Prefecture
yp: Yamaguchi Prefecture
op: the rest of Japan
kr: South Korea
tn: Taiwan
aa: ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, Thailand)
us: United States

(i, j), (ii, jj), (i1, j1), (i2, j2) Industry

a001: agriculture (CRS) (i, ii, i1)
i002: food products (IRS) (i, ii, i2)
i003: textile, wearing apparel, and wooden products (IRS) (i, ii, i2)
i004: chemical products (IRS) (i, ii, i2)
i005: metal products (IRS) (i, ii, i2)
i006: machinery (IRS) (i, ii, i2)
i007: electronic products (IRS) (i, ii, i2)
i008: transport equipment (IRS) (i, ii, i2)
i009: other manufacturing (including mining) (IRS) (i, ii, i2)
i010: construction (CRS) (i, ii, i1)
s011: electricity, gas, and water supply (CRS) (i, ii, i1)
s012: trade (CRS) (i, ii, i1)
s013: banking (CRS) (i, ii, i1)
s014: real estate (CRS) (i, ii, i1)
s015: transport (CRS costs) (i)
s016: telecommunication (CRS) (i, ii, i1)
s017: public services (CRS) (i, ii, i1)
s018: other services (CRS) (i, ii, i1)

A-2. Parameters

$mtax_{r,i}$	The import tax rate on imported goods
$frei_{r,i}$	The freight and insurance rate on imported goods
$ntax_{r,i}$	The value added tax rate on the goods
$itax_r$	The income tax rate of the private institution
psr_r	The saving rate of the private institution
gsr_r	The saving rate of the government
$tpc_{r,s}$	The transportation cost rate for the consumption demand by the private institution
$tgc_{r,s}$	The transportation cost rate for the government demand
$tiv_{r,s}$	The transportation cost rate for the investment demand
te_r	The transportation cost rate for the exported goods

$txm_{r,s,j}$	The transportation cost rate for the intermediate goods
$\alpha^{PC}_{r,s,ii}$	The share parameter of the goods for private consumption
$\alpha^{GC}_{r,s,ii}$	The share parameter of the goods for government consumption
$\alpha^{IV}_{r,s,ii}$	The share parameter of the goods for investment
$\alpha^{FCL}_{r,j}$	The share parameter of labor in the production function
$\alpha^{FCK}_{r,j}$	The share parameter of capital in the production function
$\gamma^{FC}_{r,j}$	The productivity parameter of the value added in the production function
$\alpha^{ZXM}_{r,ii,s,j}$	The share parameter of the intermediate goods in the production function
$\gamma^{ZM}_{r,ii,j}$	The productivity parameter of the intermediate goods in the production function
$\delta^{FC}_{r,j}$	The share parameter of the composite goods for the Leontief function
$\delta^{ZM}_{r,ii,j}$	The share parameter of the composite goods for the Leontief function
$\alpha^{QY}_{r,j}$	The share parameter of the domestic intermediate goods
$\alpha^{QM}_{r,j}$	The share parameter of the imported intermediate goods
$\gamma^{Q}_{r,j}$	The productivity parameter of the intermediate goods
$\sigma^{FC}_{r,j}$	Elasticity of substitution between labor and capital
$\sigma^{XM}_{r,j}$	Elasticity of substitution among intermediate goods
$\sigma^{M}_{r,j}$	Elasticity of substitution between composite goods and imported goods
$\sigma^{Q}_{r,j2}$	Elasticity of substitution between goods (Dixit and Stiglitz)

A-3. Endogenous variables

$PC_{r,s,i}$	The consumption demand by the private institution
$GC_{r,s,i}$	The consumption demand by the government
$IV_{r,s,i}$	The investment demand
$IN_{r,s,i}$	The inventory
$L_{r,j}$	The labor demand by firm
$K_{r,j}$	The capital demand by firm
$FC_{r,j}$	The composite factor
$XM_{r,i,s,j}$	The intermediate goods
$ZM_{r,ii,j}$	The intermediate goods except transport sector
$Y_{r,j}$	The composite goods
$M_{r,j}$	The imported goods
$Q_{r,j}$	The aggregated goods
$E_{r,i}$	The exported goods
$D_{r,i}$	The domestic goods
$N_{r,i2}$	The number of firms
PL_{r}	The price of labor
PK_{r}	The price of capital
$PFC_{r,j}$	The price of the composite factor
$PZM_{r,ii,j}$	The price of the intermediate goods except transport sector
$PY_{r,j}$	The price of the composite goods
$PM_{r,j}$	The import price of the intermediate goods
$PQ_{r,i}$	The goods price

$PA_{r,i2}$	The price of the marked up goods
$PE_{r,i}$	The export price of the goods
$PD_{r,i}$	The domestic price of the goods
$PPC_{r,s,ii}$	The price of the consumption demand by the private institution
$PGC_{r,s,ii}$	The price of the consumption demand by the government
$PIV_{r,s,ii}$	The price of the investment demand by the private institution
$INCOME_r$	The income of the private institution
$GOINCO_r$	The income of the government
$INVEST_r$	The investment

A-4. Exogenous variables

$PL^*_{r,j}$	The labor price
$K^*_{r,j}$	The capital supply
$E^*_{r,i}$	The exported goods
$PM^*_{r,j}$	The import price of the intermediate goods
$PE^*_{r,i}$	The export price of the goods
$FIX^*_{r,j2}$	The fixed cost for IRS sector
$IN^*_{r,s,i}$	The inventory
$INVN^*_r$	The inventory transfer
FTR^*_r	The foreign transfer
$TFRE^*$	The total value of the freight and insurance

A-5. Equations

A-5-1. Value added (CES)

$$L_{r,j} = \left(\alpha^{FCL}_{r,j}\, PFC_{r,j}\big/ PL_r\right)^{-\sigma^{FC}_j} \left(\gamma^{FC}_{r,j}\right)^{-\sigma^{FC}_j-1} FC_{r,j} \qquad \text{(E-1)}$$

$$K_{r,j} = \left(\alpha^{FCK}_{r,j}\, PFC_{r,j}\big/ PK_r\right)^{-\sigma^{FC}_{r,j}} \left(\gamma^{FC}_{r,j}\right)^{-\sigma^{FC}_j-1} FC_{r,j} \qquad \text{(E-2)}$$

$$PFC_{r,j} = \left(\left(\alpha^{FCL}_{r,j}\right)^{-\sigma^{FC}_j}\left(\frac{PL_r}{\gamma^{FC}_{r,j}}\right)^{1+\sigma^{FC}_j} + \left(\alpha^{FCK}_{r,j}\right)^{-\sigma^{FC}_j}\left(\frac{PK_r}{\gamma^{FC}_{r,j}}\right)^{1+\sigma^{FC}_j}\right)^{1/1+\sigma^{FC}_j} \qquad \text{(E-3)}$$

$$PL_{r,j} = PL^*_{r,j} \qquad \text{(E-4)}$$

$$K_{r,j} = K^*_{r,j} \qquad \text{(E-5)}$$

A-5-2. Intermediate (CES)

$$XM_{s,ii,r,j} = \left(\alpha^{ZXM}_{s,ii,r,j} \, PZM_{r,ii,j} \Big/ \left(PD_{s,ii} \left(1 + txm_{s,r,j} \right) \right) \right)^{-\sigma^{XM}_{r,j}} \left(\gamma^{ZM}_{r,ii,j} \right)^{-\sigma^{XM}_{r,j} - 1} ZM_{r,ii,j} \qquad \text{(E-6)}$$

$$PD_{r,trans} XM_{r,trans,s,j} = TXM_{r,s,j} \sum_{ii} PD_{r,ii} XM_{r,ii,s,j} \qquad \text{(E-7)}$$

$$PZM_{r,ii,j} ZM_{r,ii,j} = \sum_{s} PD_{s,ii} \left(1 + txm_{s,r,j} \right) XM_{s,ii,r,j} \qquad \text{(E-8)}$$

A-5-3. Composite (Leontief)

$$FC_{r,j} = \delta^{FC}_{r,j} Y_{r,j} \qquad \text{(E-9)}$$

$$ZM_{r,ii,j} = \delta^{ZM}_{r,ii,j} Y_{r,j} \qquad \text{(E-10)}$$

$$PY_{r,j} Y_{r,j} = PFC_{r,j} FC_{r,j} + \sum_{ii} PZM_{r,ii,j} ZM_{r,ii,j} \qquad \text{(E-11)}$$

A-5-4. Import (CES)

$$PM_{r,j} = PM^{*}_{r,j} \qquad \text{(E-12)}$$

$$Y_{r,j1} = \left(\alpha^{QY}_{r,j1} \frac{PQ_{r,j1}}{PY_{r,j1}} \right)^{-\sigma^{M}_{j1}} \left(\gamma^{Q}_{r,j1} \right)^{-\sigma^{M}_{j1} - 1} Q_{r,j1} \qquad \text{(E-13)}$$

$$Y_{r,j2} = \left(\alpha^{QY}_{r,j2} \frac{PQ_{r,j2}}{PY_{r,j2}} \right)^{-\sigma^{M}_{j2}} \left(\gamma^{Q}_{r,j2} \right)^{-\sigma^{M}_{j2} - 1} \left(Q_{r,j2} + FIX^{*}_{r,j2} \right) \qquad \text{(E-14)}$$

$$M_{r,j1} = \left(\alpha^{QM}_{r,j1} \frac{PQ_{r,j1}}{PM_{r,j1} \left(1 + mtax_{r,j1} + frei_{r,j1} \right)} \right)^{-\sigma^{M}_{j1}} \left(\gamma^{Q}_{r,j1} \right)^{-\sigma^{M}_{j1} - 1} Q_{r,j1} \qquad \text{(E-15)}$$

$$M_{r,j2} = \left(\alpha^{QM}_{r,j2} \frac{PQ_{r,j2}}{PM_{r,j2} \left(1 + mtax_{r,j2} + frei_{r,j2} \right)} \right)^{-\sigma^{M}_{j2}} \left(\gamma^{Q}_{r,j2} \right)^{-\sigma^{M}_{j2} - 1} \left(Q_{r,j2} + FIX^{*}_{r,j2} \right) \qquad \text{(E-16)}$$

$$PQ_{r,j1} Q_{r,j1} = PY_{r,j1} Y_{r,j1} + PM_{r,j1} \left(1 + mtax_{r,j1} + frei_{r,j1} \right) M_{r,j1} \qquad \text{(E-17)}$$

$$PQ_{r,j2} Q_{r,j2} + FIX_{r,j2} = PY_{r,j2} Y_{r,j2} + PM_{r,j2} \left(1 + mtax_{r,j2} + frei_{r,j2} \right) M_{r,j2} \qquad \text{(E-18)}$$

A-5-5. Market clearing

$$PD_{r,j2} \Big/ \left(1 + ntax_{r,j2} \right) Q_{r,j2} = PQ_{r,j2} Q_{r,j2} + FIX^{*}_{r,j2} \qquad \text{(E-19)}$$

$$PA_{r,j2} = \sigma_{r,j2} \Big/ \left(1 + \sigma_{r,j2} \right) PQ_{r,j2} \qquad \text{(E-20)}$$

$$PD_{r,j1} = PQ_{r,j1} \left(1 + ntax_{r,j1} \right) \qquad \text{(E-21)}$$

$$PD_{r,j2} = PA_{r,j2} N^{\frac{1}{1 + \sigma_{r,j2}}} \left(1 + ntax_{r,j2} \right) \qquad \text{(E-22)}$$

$$D_{r,i} = Q_{r,i} - E_{r,i} \qquad \text{(E-23)}$$

$$D_{r,j} = \sum_s PC_{r,s,i} + GC_{r,s,i} + IV_{r,s,i} + IN_{r,s,i} + \sum_s \sum_j XM_{r,i,s,j} \qquad \text{(E-24)}$$

A-5-6. Export (exogenous)

$$PE_{r,ii} = PD_{r,ii}\left(1 + te_r\right) \qquad \text{(E-25)}$$

$$E_{r,i} = E^*_{r,i} \qquad \text{(E-26)}$$

$$PD_{r,trans} E_{r,trans} = te_r \sum_{ii} PD_{r,ii} E_{r,ii} \qquad \text{(E-27)}$$

A-5-7. Private consumption

$$PPC_{r,s,ii} = PD_{r,ii}\left(1 + tpc_{r,s}\right) \qquad \text{(E-28)}$$

$$PPC_{s,r.ii} PC_{s,r,ii} = \alpha^{PC}_{s,r,ii}\left(1 - itax_r - psr_r\right) INCOME_r \qquad \text{(E-29)}$$

$$PD_{r,trans} PC_{r,s,trans} = tpc_{r,s} \sum_{ii} PD_{r,ii} PC_{r,s,ii} \qquad \text{(E-30)}$$

$$INCOME_r = \sum_j \left(PL_{r,j} L_{r,j} + PK_{r,j} K_{r,j}\right) \qquad \text{(E-31)}$$

A-5-8. Government consumption

$$PGC_{r,s,ii} = PD_{r,ii}\left(1 + tgc_{r,s}\right) \qquad \text{(E-32)}$$

$$PGC_{s,r,ii} GC_{s,r,ii} = \alpha^{GC}_{s,r,ii}\left(1 - gsr_r\right) GOINCO_r \qquad \text{(E-33)}$$

$$PD_{r,trans} GC_{r,s,trans} = tgc_{r,s} \sum_{ii} PD_{r,ii} GC_{r,s,ii} \qquad \text{(E-34)}$$

$$GOINCO_r = itax_r INCOME_r + \sum_j mtax_{r,j} PM_{r,j} M_{r,j} + \sum_j \frac{ntax_{r,j}}{1 + ntax_{r,j}} PD_{r,j} Q_{r,j}$$

(E-35)

A-5-9. Private investment

$$PIV_{r,s,ii} = PD_{r,ii}\left(1 + tiv_{r,s}\right) \qquad \text{(E-36)}$$

$$PIV_{s,r,ii} IV_{s,r,ii} = \alpha^{IV}_{s,r,ii}\left(INVEST_r - \sum_u \sum_j PD_{u,j} IN_{u,r,j} - FTR^*_r\right) \qquad \text{(E-37)}$$

$$PD_{r,trans} IV_{r,s,trans} = tiv \sum_{ii} PD_{r,ii} IV_{r,s,ii} \qquad \text{(E-38)}$$

$$INVEST_r = psr_r INCOME_r + gsr_r GOINCO_r \qquad \text{(E-39)}$$

A-5-10. Inventory

$$IN_{r,s,i} = IN^*_{r,s,i} \qquad \text{(E-40)}$$