

A System Dynamics Approach to the Regional Macro-economic Model

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Abstract

The advent of a depopulating society has become apparent in Japanese economy. There is a rising concern that a declining population diminishes Japanese economic growth. This concern is much more significant in regional economies, in which aging workers in the basic industry or an excessive population decline have been longstanding problems, than the national economy. I have developed a quantitative method for population and economic forecasting to examine the current status of a declining population. Linking the population estimates, which are consistent with the population census, to the macroeconomic model with gross domestic product by industry, we are able to examine the effect of a depopulating society on the regional economy. The simulation of this model reveals following future pictures: industries, which are dependent on domestic demand, will decline and per capita income will increase for the while. A declining population has an impact not only on macroeconomic outcomes but also on microeconomic aspects inside the region. Many core areas in the economic growth are losing their positions. I will also point out that the interdependency between core areas and peripheral areas has started changing.

Keyword : declining population, economic growth, regional economy

1. Introduction

The population of Japan ended the era of a growth and rushed into a phase of decline in 2005. The population decline is not a new phenomenon in a regional level; however, this is the first decrease in the national level. We observed a social decrease in the population, caused from the number of out-migrants exceeded the number of immigrants, at different regions in the high economic growth period of the centre of the 1950's. We have observed a natural decrease, caused from the number of deaths exceeds the number of births, since the first half of the 1990's.

However, the population decline becomes the negative impact of economic growth both on the supply side and on the demand side through the decrease in the labor supply and the decline in the consumer demand. As a result, the income level might drop. Therefore, the problem how to keep the economic strength under the population decline is essential for the regional economy than before.

This study aims to develop the system dynamic model of the regional economy under the population decrease. The reason to adopt the system dynamics approach is as follows:

- Using the concept of flow and stock is useful to model the change of the population structure and the industrial structure.
- It is easy to model nonlinear relational expressions.
- There is an area where the time-series data has not been fully supplied in regional statistics.

When we take up regional economic problems from a policy viewpoint, there are many dynamic elements. It is difficult to analyse these elements by the ordinary macroeconomic approach. Moreover, it is necessary to consider the qualitative goal, in addition to the quantitative goal, such as an economic growth rate, *etc.*, because we are now facing aging and environmental issues.

After the publication of *The Limits to Growth* (1972), there were several attempts to develop a regional model by system dynamics as a simulation tool for the decision support of the prefecture master plan in

Japan¹. Among them, Hyogo dynamic model (1973), which tried to explain the limit of growth from the viewpoint of the restriction of the environment and resources in Hyogo Prefecture, is well known (Matsuzaki and Miyazaki (1976)). This model is now used as a communication tool between the government and citizens rather than an analytical model. In Shizuoka Prefecture, prefectural office developed Shizuoka SD model in 1984; however, based on the input-output table, this model is unsuitable to examine the economic growth. Most of the regional models in Japan were developed from the 1970's to the 80's, and they postulated the steadily growing economy. Therefore, they are not the ones to investigate the mechanism of the population decrease and the end of economic growth.

It is necessary to estimate the population more accurately than before facing an unknown era of depopulating society. The estimate of the working age population is indispensable. There is a limit to the population estimate calculated from one or a few equations in the most system dynamic model. Moreover, it is necessary to examine the industrial structures more in detail than three categories of the primary, the secondary, and the tertiary industry, to understand the influence of labor shortage by the population decrease and the shrinking domestic demand.

Therefore, I adopt the cohort-component method for the population estimate and introduce the SNA (system of national accounts) industrial classification for the economic forecast. I make many variables endogenous, and incorporate the adjustment process of regional investment. As a result, it is possible to draw the future image of Shizuoka Prefecture under the depopulating society based on the dynamic economic simulation. I had developed a regional system dynamic model to investigate the image of the future of Shizuoka Prefecture by using the population census in 1975-2000, and had clarified a concrete influence such as the "Year 2007 Problem"². In this study, I propose the model based on the 2005 Population Census of which all reports published in 2009, and to examine the problem of the depopulating society³.

2. Problems of the Regional Economy

It is not an exaggeration to say that the prime concern for the regional economy is economic growth. The modernization of Japan since Meiji Restoration has achieved the sustained growth of the per capita income and the improvement of the living standard. Although this modernization was the growth of aggregate production brought by the rapid population growth, it accompanied the movement of labor from the primary industry to the secondary industry and the movement of people from farm villages to cities. Many regional economies have been faces to the problem of the population outflow and the de-industrialization in Japan where a political, economic centralization to the Tokyo metropolis continues. The population outflow from provinces has started again since the latter half of the 1990's, though we observed the demographic shift from provinces to cities at the rapid economic growth from the 1950's to the middle of the 1970's, and then we observed the U-turn phenomenon to the provinces around 1980.

While the tertiary industry, and especially the high-value-added type tertiary industry, shows an over concentration in Tokyo, there is a common feature among the regional economies which enjoy strong economic growth. Table 1 is an extraction of five high-ranking regions of the average economic growth rate of fiscal year 2004 - 2006, and it is easily understood that the region which enjoys the high economic growth rate usually shows a high value of location quotient in manufacturing. These prefectures are production areas of export commodities, such as automobiles and liquid crystal television, though Japanese economy itself is often referred like a trading nation.

¹ The prefectures of Japan are the nation's 47 sub-national jurisdictions: one "metropolis", Tokyo; one "circuit", Hokkaidō; two urban prefectures, Osaka and Kyoto; and 43 other prefectures.

² The "Year 2007 Problem" (*nisen-nana-nen mondai*) was the concern that the 2007 would bring serious problems to companies and industries because of the retirement of Japanese baby boom generation, born mainly between 1947 and 1949.

³ The population census in Japan has been conducted every five years since 1920, the 2005 Population Census of Japan being the eighteenth. The 2010 Population Census of Japan was taken on the 1st October 2010, but we cannot use these data until a few years later.

Recently, the income gap has become widened among regions in parallel with centralization to the Tokyo metropolis. Table 2 is five high-ranking regions of per capita income. It is easy to understand that the region where the location quotient of manufacturing is high occupies the top rank except Tokyo and Kanagawa Prefecture.

In this study, I take up Shizuoka Prefecture, based on above preliminary consideration. It is because of Shizuoka has a character of the local economy in population outflow and shows an average pace of population decrease, while it enjoys a high economic strength.

Shizuoka Prefecture dominates the domestic market and is a world leader in several industries. We can confirm this feature from the location quotient.

Inside the prefecture, location quotients of manufacturing are high in the eastern area, in the western area, and in the west-central area. Yamaha Motor and Suzuki brand motorcycles started their production in the western area and are still manufactured locally, with 66% of the Japan's motorcycle production. Yamaha piano started their production in the late nineteenth century and is now a global brand. There are machine apparatus industries in the west-central area. There are the paper manufacturing and the chemical industry in the eastern area. Other Shizuoka-based leading products are plastic models (80% of Japan's production), and green tea (45% of Japan's production).

Table 1 Economic growth rate and location quotients

Ranking	Prefecture	Economic growth rate (%)	Location quotient (manufacture)
1	Mie	6.238	1.426
2	Okayama	5.108	1.147
3	Aomori	4.546	0.599
4	Shizuoka	4.305	1.507
5	Aichi	4.096	1.527

Source: Annual Report on Prefectural Accounts, Population Census

Table 2 Per capita income and location quotients (FY2005)

Ranking	Prefecture	Per capita income (thousands yen)	Location quotient (manufacturing)	Location quotient (services)
1	Tokyo	4,497	0.690	1.314
2	Aichi	3,495	1.527	0.961
3	Shizuoka	3,332	1.507	0.934
4	Kanagawa	3,219	0.908	1.206
5	Shiga	3,200	1.562	0.962

Source: Annual Report on Prefectural Accounts



Figure 1 Areas and cities in Shizuoka Prefecture

3. Structure of the Model

An economic activity is continuously taking place concerning production and consumption of goods, in other words, the supply and the demand of goods. The Keynesian theory as the theory of national income determination can be applied to the adjustment of supply and demand in a region. There is a close connection between the economy and the population. The income is essential for people to live and they obtain most of income by working. Therefore, employment by regional industries is a decisive factor to determine the population of a region.

I construct a regional economic model from the above-mentioned viewpoint with three sectors (population, labor, and economy). The basic structure is as follows (Figure 2).

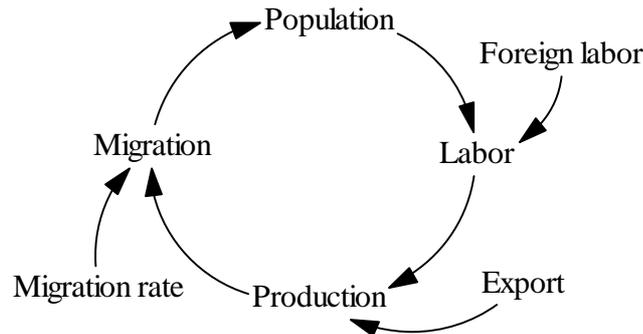


Figure 2 Basic structure of the model

Only few system-dynamics studies have so far been made at the impact of decreasing population on economic activities. Kopainsky (2005) developed a system dynamic model to study the effect of decreasing population on rural development. The model simulated the population and the labor force by a differential equation. That approach is appropriate if we examine only the number of the population, but is not effective if we want to consider the age and sex composition. So I use the population census instead of differential equations. Although we need a careful recombination of data to use labor force data, which is consistent with SNA industry classification, we can obtain a complete picture of the population decrease.

3.1 Modeling the Dynamics of Population

It was obvious that the population of Shizuoka Prefecture had shifted to the population decrease phase by the census of 2005. The Japanese population changed to a decrease after a peak of 3,726 thousand in 2003 according to "Intercensal Adjustment of Current Population Estimates (2000 - 2005)" by The Statistics Bureau and the Director-General for Policy Planning of Japan in the Ministry of Internal Affairs and Communications, although the increasing tendency of the total population continues because of an increase of the foreigner (Figure 3).

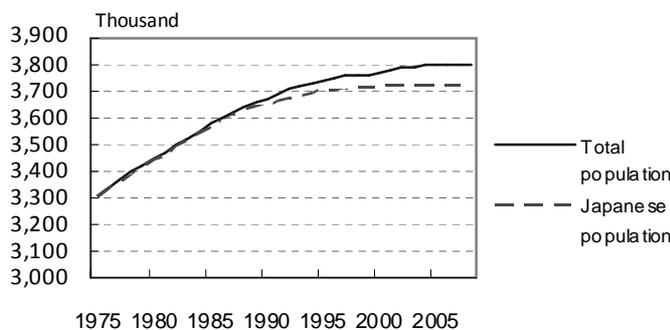


Figure 3 Population in Shizuoka Prefecture

Estimation of Japanese population in individual years of age uses the cohort-component method⁴. The equation for estimating the population aged from 1 to 100 is as follows:

$$P_{x+1} = P_x \times S_x + M_x \quad (3.1)$$

where P_{x+1} is the population aged $x+1$, P_x is the population aged x , S_x is the survival rate aged x , M_x represents migration. The population is a stock variable

⁴ Assumptions of the birth rate, the survival rate, and the migration rate were based on the method of estimating National Institute of Population and Social Security Research. The difference between the national average and Shizuoka Prefecture is considered.

of which status is changing by births, deaths and migration (Figure 4)⁵.

The population of the foreigner has been increasing rapidly in the western area of Shizuoka Prefecture (Hamamatsu City, etc.) where manufacturing is a basic industry. Because the statistical material concerning births, deaths, and migrations that become the basic data of the estimate does not become complete with the population of the foreigner, an increase (3,666 per annum on average from fiscal year 2000 to fiscal year 2005) by a past pace is assumed.

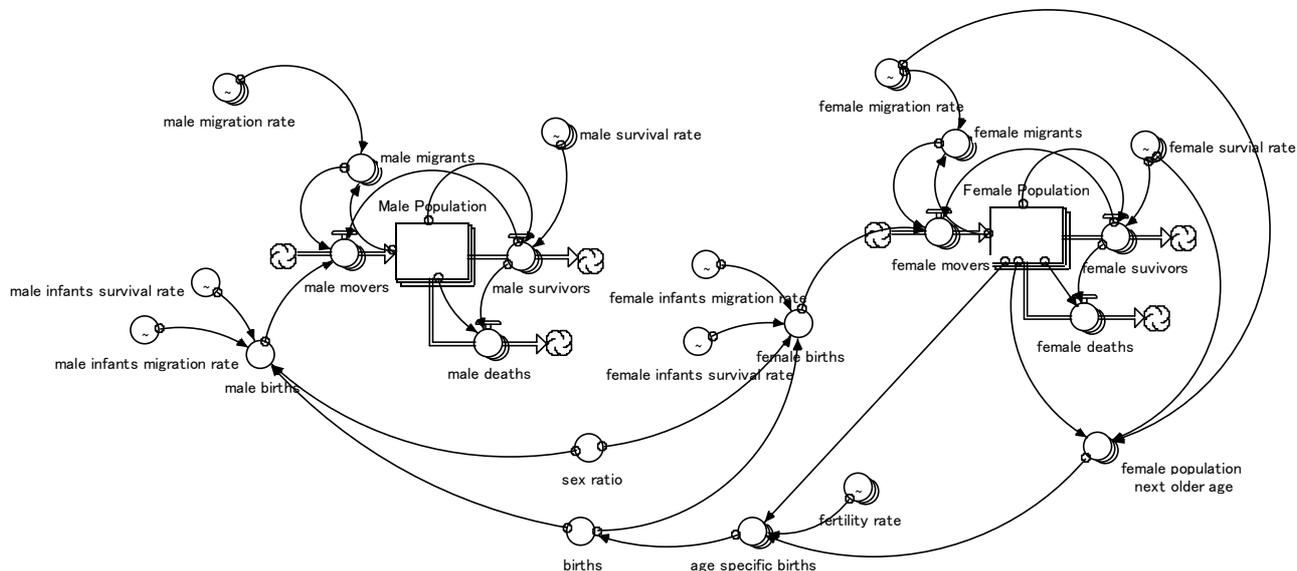


Figure 4 Structure of population sector

3.2 Modeling Labor Force

When I calculated the number of labor force, I paid attention to 5-year age groups' data of the census. I multiplied the number of male (female) 5-year age group by the male (female) 5-year age group employment ratio to obtain the number of male (female) labors (Figure 5). There is hardly any change of the employment rate in each age group since 1975, except a slight decreasing trend in 15-19 and 20-24 age groups from 1975 to 1995. Accordingly, I assumed the latest employment rate in 2005 for an estimate in the future.

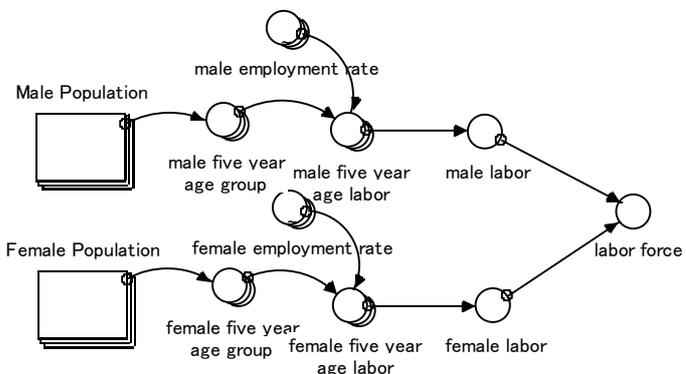


Figure 5 Deriving the number of labor force

In addition, the labor force is employed divided into each industry. There I found the cohort in the ratio of labor force by industry, as well as there was the cohort in the vital statistics. Each cohort moved older while keeping the ratio when that generation had been newly employed. The Petty-Clark's Law that labor force shifts from the primary sector to the secondary sector, and moreover, to the tertiary sector is effective only in 15-19 age group and in 20-24 age group that is newly employed.

This phenomenon was an unexpected finding. Therefore, I moved the employment ratio to 5-year elder age group in every five years and filled the gap between five years linearly, to calculate the number of labor force in each industry.

3.3 Modeling the Demand Side

The macro-economic model models the demand side of the regional economy as a system of the prefectural account by SNA statistics. Gross prefectural domestic expenditure (GDE_t) consists of private final

⁵ The model was developed with STELLA Ver.9.

consumption expenditure (CP_t), private capital formation (I_t), public capital formation (IG_t), government final consumption expenditure (G_t), regional exports and imports ($EX_t - IM_t$), and statistical discrepancy (DIS_t).

$$GDE_t = CP_t + I_t + IG_t + GC_t + EX_t - IM_t + DIS_t \quad (3.2)$$

GDE_t is the aggregate flow of economic activities in a region during one year. A subscript means time t .

Private final consumption expenditure

Private final consumption expenditure is a large and stable component in GDE. Private final consumption expenditure function is assumed as a Keynesian type function in which the level of consumption depends on the gross prefectural domestic product (GDP_t). To investigate the influence of the falling birth rate, the demographic composition or the household composition should be added. Therefore, the population was added as a dependent variable in the present study.

$$CP_t = POP_t \times cp_t(GDP_t) \quad (3.3)$$

where POP_t represents the total population.

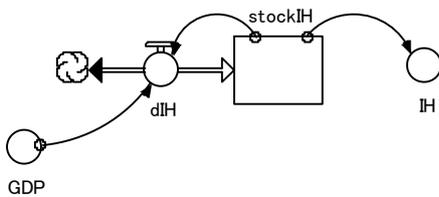
Gross private fixed capital formation

The gross private fixed capital formation consists of the private residential investment (IH_t), the private nonresidential investment (IP_t), the private inventories (J_t).

$$I_t = IH_t + IP_t + J_t \quad (3.4)$$

The private residential investment is primarily an action of the household while private nonresidential investment and private inventories are actions of the firm. Therefore, we assume that it is influenced by the degree of the private residential investment and the economic growth at the time $t-1$.

$$IH_t = IH_t(IH_{t-1}, \Delta GDP_t) \quad (3.5)$$



where $\Delta GDP_t \equiv GDP_t - GDP_{t-1}$. It is an advantage the model is developed in the system dynamics that control the variable with the delay easily (Figure 6).

Fixed capital formation by the firm occupies the majority of private investment. The level of investment depends on income in the region and the income outside the region.

Figure 6 Private residential investment

Because it is a feature of Shizuoka Prefecture, that the export is extremely high, we assume the private nonresidential investment depended on the nationwide GDE except Shizuoka Prefecture ($JGDE_t$) as well as on GDP of Shizuoka Prefecture itself.

$$IP_t = IP_t(GDP_{t-1}, JGDE_t) \quad (3.6)$$

Private inventories show a strong change, though the proportion of them in the gross capital formation is a little. A gap between production and shipment is related to business fluctuations. The inventory balance is generated from the delay of the production adjustment to the demand fluctuation, the firm need one year or more to adjust production. Although the estimation is quite difficult, we assume that the production plan of the firm is influenced by the economic growth rate in the previous period.

$$J_t = J_t \left(\frac{GDP_{t-1} - GDP_{t-2}}{GDP_{t-2}} \right) \quad (3.7)$$

Gross government fixed capital formation

We model the gross government fixed capital formation affected by the capital formation at the previous period and the economic growth rate in a region concerned.

$$IG_t = IG_t \left(IG_{t-1}, \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}} \right) \quad (3.8)$$

Government final consumption expenditure

In 93SNA⁶, social security funds must be recorded on government final consumption expenditure.

$$GC_t = GC1_t + GC2_t \quad (3.9)$$

$GC1$ is a standard government expenditure and $GC2$ is social security funds.

Government final consumption expenditure has been traditionally considered being an exogenous variable not well explained in the economic model⁷. However, it is not determined without any relation to the economic movements. In this study, we assume a correlation between income and the population ratio of senior citizens.

$$GC1_t = GC1(GDP_t, SNR_t) \quad (3.10)$$

The following equation is added from fiscal year 1990.

$$GC2_t = GC2(POP_t, SNR_t) \quad (3.11)$$

Regional exports and imports

Regional exports are composed of exports to other regions in the country and exports to other countries. Regional imports are also composed of imports from other regions in the country and imports from other countries. However, both types of imports are considered to depend on the regional income, thus we assumed following regional imports function.

$$IM_t = IM(GDP_t) \quad (3.12)$$

We distinguished two types of the exports as follows.

$$EX_t = EXD_t + EXF_t \quad (3.13)$$

Exports to other regions in the country are assumed to depend on the size of the national GDE minus a regional GDE of Shizuoka Prefecture.

$$EXD_t = EXD(JGDE_t) \quad (3.14)$$

On the other hand, the exports to other countries are assumed to depend on the exchange rate (YEN_t).

$$EXF_t = EXF(YEN_t) \quad (3.15)$$

Statistical discrepancy

Gross domestic production must be equal to gross domestic expenditure by definitions. However, the difference might be caused because the estimate procedures are differed. Statistical discrepancy is a component to adjust this gap, and it is quite difficult to model it theoretically. We found the approximate relationship in data from fiscal year 1975 to 2008.

$$DIS_t = DIS(GDP_{t-1}, GDP_{t-2}) \quad (3.16)$$

⁶ 93 SNA is the system of national accounts that the United Nations recommended in 1993. The Japanese national accounts were shifted from 68 SNA to 93 SNA in 2000.

⁷ On interpretation of government final consumption expenditure, see the chapter 13 of Hall and Taylor (1997).

3.4 Modeling the Supply

We have the following production function to model the supply side of the economy.

$$\ln Y_i = A_i + \alpha_i \ln K_i + \beta_i \ln L_i \quad i = 1, 2, \dots, 14 \quad (3.17)$$

The subscript i represents the industrial classification. In this estimate, we used SNA industry classification⁸. Y_i is the output, K_i is the capital stock, L_i is the labor of the industry i . A_i , α_i and β_i are estimated using econometrics. Parameter A_i explains the change that cannot be explained by the capital or labor. We call it the total factor productivity (TFP). The change of TFP often represents technological progress⁹.

On the production function of the manufacturing industry ($i = 5$), I introduced the rate of technological progress (λ).

$$\ln Y_i = A_i + \lambda t + \alpha_i \ln K_i + \beta_i \ln L_i \quad i = 5 \quad (3.18)$$

Labor

Labor was calculated from working hours h and the number of labor force employed E .

$$L_i = h_i E_i \quad (3.19)$$

Capital stock

The capital stock is an amount of all the mechanical equipment that exists at the point of time. The capital stock is growing with investment I . However, it wears out if an operation continues. To incorporate depreciation, we assume a small fraction δ of the capital stock wears out each year. We can express the relation between the capital stock and investment using the depreciation rate δ .

$$K_{it} = K_{it-1} + I_{it} - \delta_{it} K_{it-1} \quad (3.20)$$

$\Delta K_t \equiv K_t - K_{t-1}$, then we can obtain

$$\Delta K_{it} = I_{it} - \delta_{it} K_{it-1} \quad (3.21)$$

On the other hand, if we consider activities of the firm in goods market, the production plan and the investment plan are invoked by the excess demand $ED_i \equiv D_i - Y_i$. D_i represents the demand in the market. Therefore, we can assume the following relation between the net investment and the excess demand.

$$I_{it} - \delta_{it} K_{it-1} = v_i ED_{it} \quad (3.22)$$

From (3.21) and (3.22), the growth of the capital stock is modelled as follows.

$$\Delta K_{it} = K_i(I_{it}, \delta_{it} K_{it-1}, ED_{it}) \quad (3.23)$$

The investment in each period is calculated by multiplying private residential investment IP_t with the share of the capital stock of the relevant industry in the previous period. We can rewrite (3.23).

$$\Delta K_{it} = \frac{K_{it-1}}{\sum K_{it-1}} IP_t - \delta_{it} K_{it-1} + v_i ED_{it} \quad (3.24)$$

Figure 7 shows an outline of the supply side in the model.

⁸ They are the agriculture, the forestry, the fishing, the mining, the manufacturing, the construction, the electricity, gas and water supply, the wholesale and retail trade, the finance and insurance, the real estate, the transport and communications, the service activities, the producers of government services, and the producers of private non-profit services to households. The census classification is a little different from the SNA classification, and it was necessary to recombine the census data.

⁹ See the chapter 6 of McCann (2001).

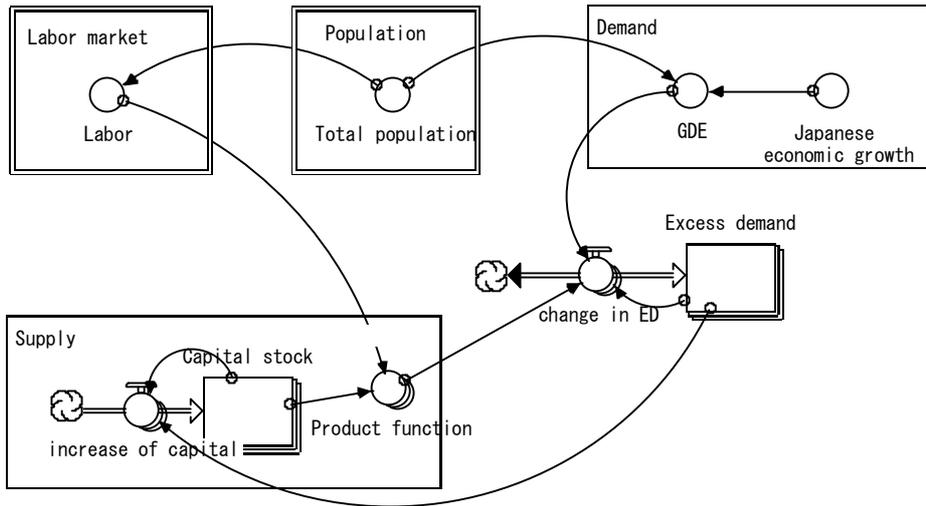


Figure 7 Supply side

3.5 Total Image of the Model

According to the prefectural accounts, we call it as the gross domestic prefectural production that we add the taxes and duties on imports to the total of the output of each industry and subtract the consumption taxes for gross capital formation and the imputed bank service charge from it. The behaviour of the demand side which GDE shows and the supply side which GDP shows are adjusted in the markets. The demand is distributed to each industry according to the input-output table of 2000. The total image of the model is shown in Figure 8.

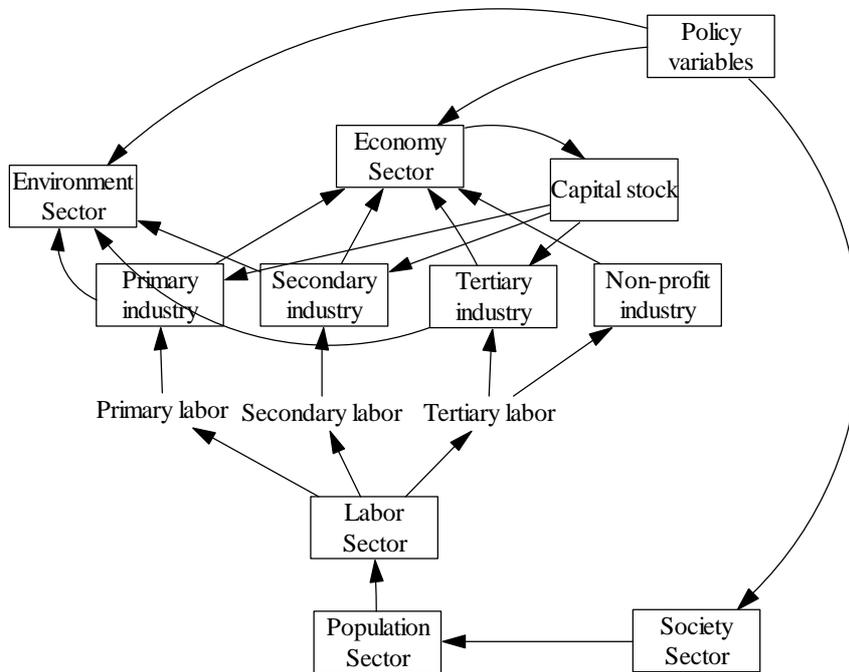


Figure 8 Total image of the model

4. Simulation and Forecast

Most of the functions that composed the model are estimated using the actual value at market prices in calendar year of 2000. Let us examine the future image of Shizuoka Prefecture. The length of the simulation is fifty-five years from fiscal year 1975 to 2030¹⁰.

4.1 Forecast of the Gross Domestic Product

The economic climate of Shizuoka Prefecture depends on the economic growth of Japan. Figure 9 shows simulations of the gross domestic prefectural product of Shizuoka Prefecture according to the assumption that the Japanese growth rate (the growth rate of $JGDE_t$) is 1.5% and 3.0% after fiscal year 2008. Symbol + in the graph shows the observed value before fiscal year 2007 (same as follows)¹¹.

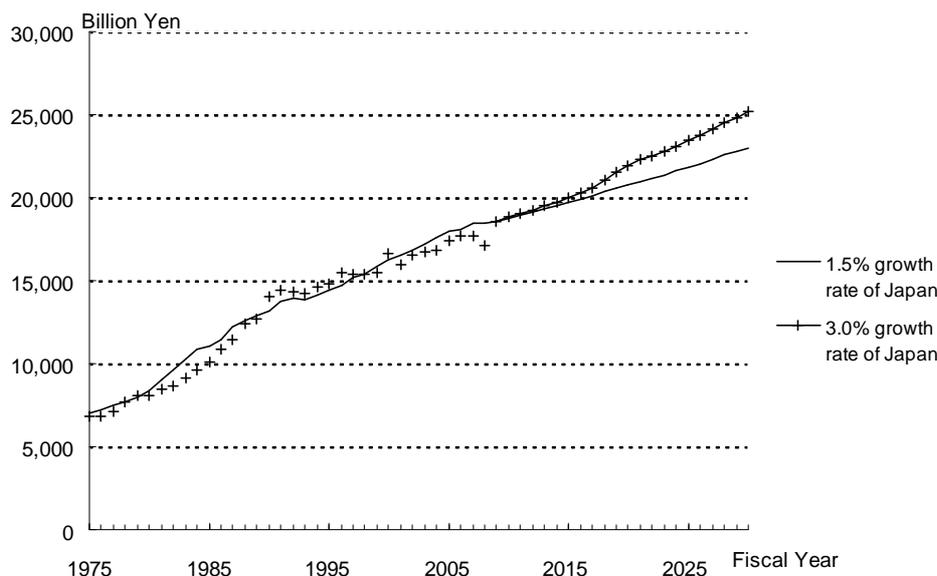


Figure 9 Forecast of the gross domestic product

4.2 Forecast of the Per Capita Gross Domestic Product

If the macro-economy is shrinking, the population decline may increase the per capita income for a while. Figure 10 shows the per capita gross domestic prefectural product. In figure 10, the growth rate over the past year tends to decrease after the peak in fiscal year 2027 at the 1.5% growth rate or in fiscal year 2019 at the 3.0% growth rate of $JGDE_t$.

¹⁰ The purpose of setting the period of simulation by 2030 is for a current master plan to be contemplating the 2020s.

¹¹ 1.5% is the average growth rate of $JGDE_t$ from fiscal year 1998 to 2007.

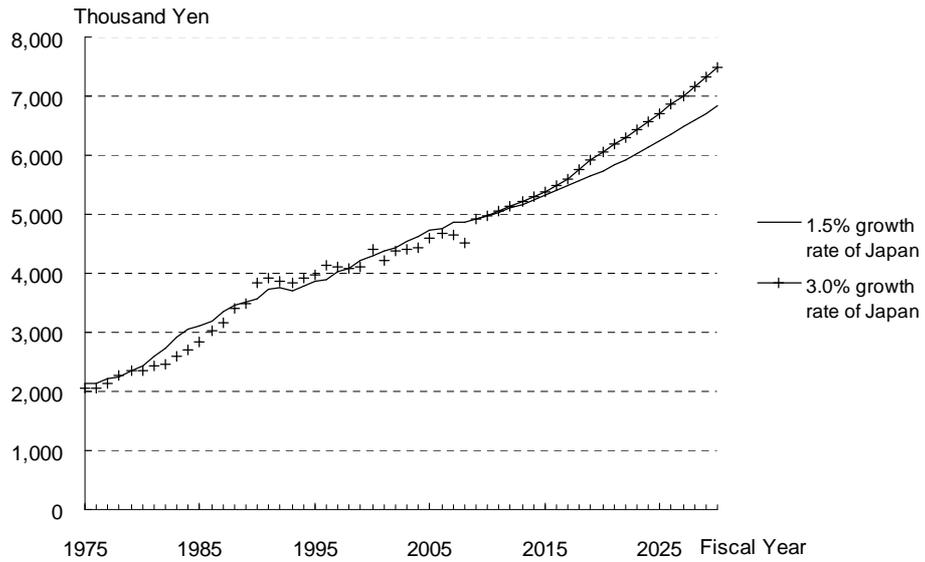


Figure 10 Forecast of the per capita gross domestic product

4.3 Forecast of the Industries

Simulations of the output in each industry are shown in Figure 11, 12, and 13, assuming the growth rate of $JGDE_t$ is 1.5%. Historical values were reproduced in the model.

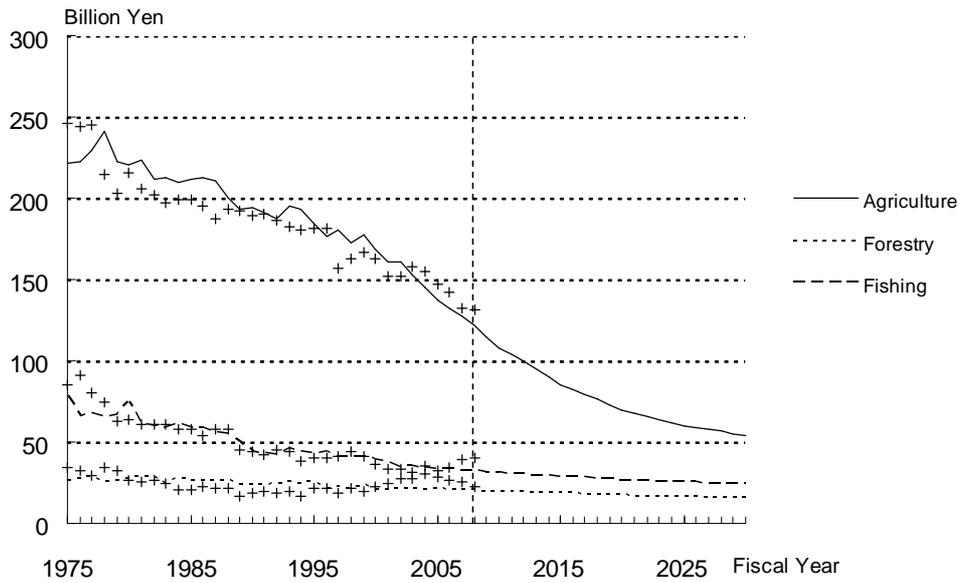


Figure 11 Forecast of the primary industry

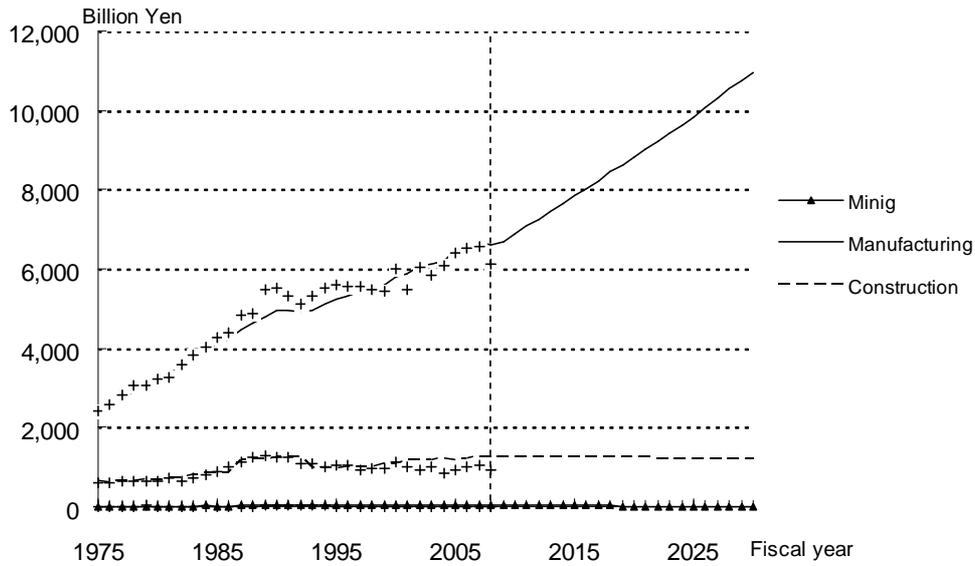


Figure 12 Forecast of the secondary industry

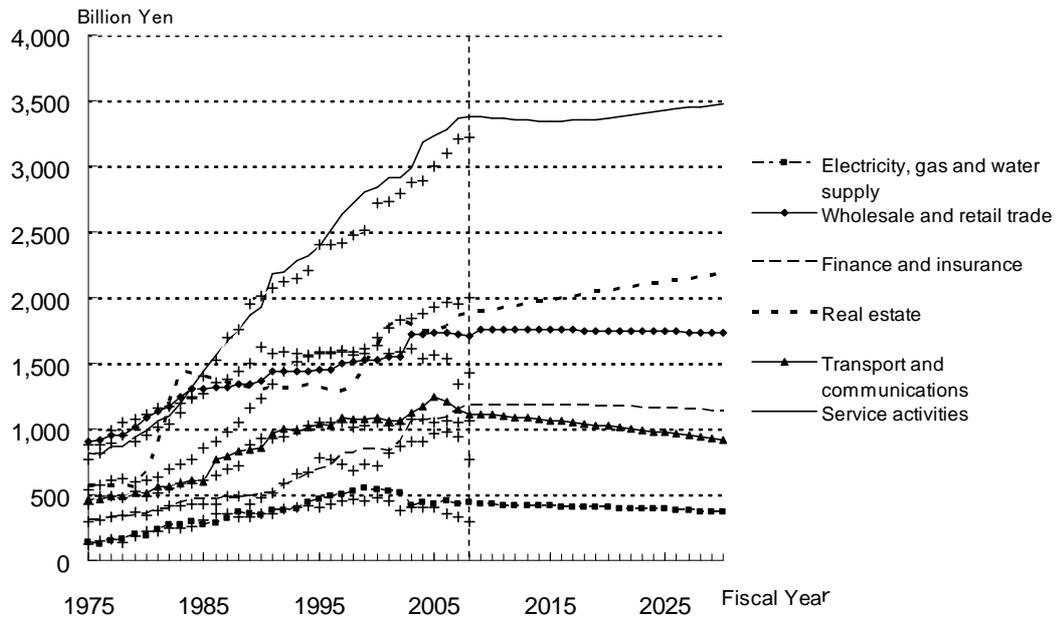


Figure 13 Forecast of the tertiary industry

4.4 Year 2007 Problem

In Japan, mandatory retirement is the age of 60. Baby boomer, born from 1947 to 1949, reached the age 60 in 2007. There was a rising concern that business activities would be stagnant. Especially, there was a prime concern in manufacturing industry because the number of skilled labor would fall sharply. This “Year 2007 Problem” highlighted the tight labor market under a depopulating society. A simulation reveals the impact of labor policy. Figure 14 shows the output paths under the retirement age of 60 and 65 in Shizuoka Prefecture.

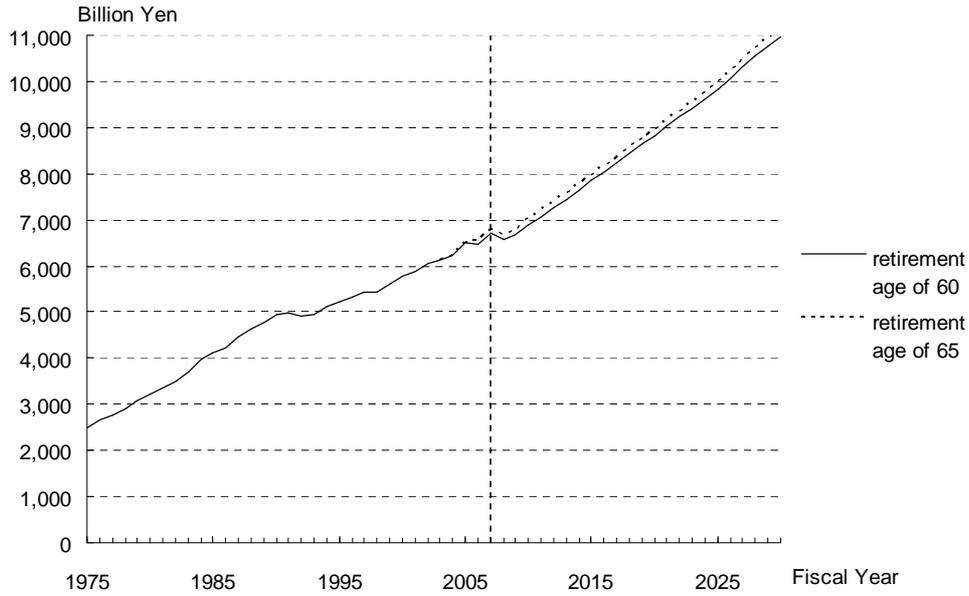


Figure 14 Simulation of the manufacturing industry

The latest data confirm this simulation. Table 3 tells us how to handle the year 2007 problem. Firms employed the retired labor and the foreign labor.

Thus, we avoid the economic decline caused by the year 2007 problem. However, the year 2007 problem procrastinated just 5 years ahead. Now the year 2007 problem is close-upped again under the name of the year 2012 problem.

Table 3 Employed persons in manufacturing industry

	2000	2005
Total employed	569,212	516,654
Female employed (25-39 years old)	53,012	48,128
Employed over 60 years old	58,111	63,850
Foreign employed	23,080	25,569

Source: Annual Report on Prefectural Accounts, Population Census

4.5 Core and Periphery

The regional economy is not uniform. More or less, each industry is located unevenly inside the region. Using the scheme of the shift-share analysis, we can find the core-periphery relation in the region. In relative term, the regional growth in employment is

$$\frac{\sum_{i=1}^n e_{ir}^t - \sum_{i=1}^n e_{ir}^0}{\sum_{i=1}^n e_{ir}^0} = \left(\frac{E_n^t}{E_n^0} - 1 \right) + \frac{\sum_{i=1}^n \left(e_{ir}^t - \frac{E_{in}^t}{E_{in}^0} e_{ir}^0 \right)}{\sum_{i=1}^n e_{ir}^0} + \frac{\sum_{i=1}^n \left(\frac{E_{in}^t}{E_{in}^0} - \frac{E_n^t}{E_n^0} \right) e_{ir}^0}{\sum_{i=1}^n e_{ir}^0} \quad (4.1)$$

where i denotes the sector, while r and n respectively stand for the region and the country (prefecture in our model). The second term in the right hand of (4.1) is the relative differential shift (RS_d). The third term is the relative proportional shift (RS_p). On the basis of shift-share analysis, we can classify regions according to Boudeville (1966).

Table 4 Core-periphery classification

Type	Differential shift	Proportional shift		Shift	Classification
1	+	+	$ RS_d < RS_p $	+	Core
2	+	+	$ RS_d > RS_p $	+	Core
3	+	-	$ RS_d > RS_p $	+	Spill over
4	-	+	$ RS_d < RS_p $	+	Core
5	-	+	$ RS_d > RS_p $	-	Core
6	+	-	$ RS_d < RS_p $	-	Spill over
7	-	-	$ RS_d > RS_p $	-	Periphery
8	-	-	$ RS_d < RS_p $	-	Periphery

Figure 15 shows the current core-periphery relationship in Shizuoka Prefecture.

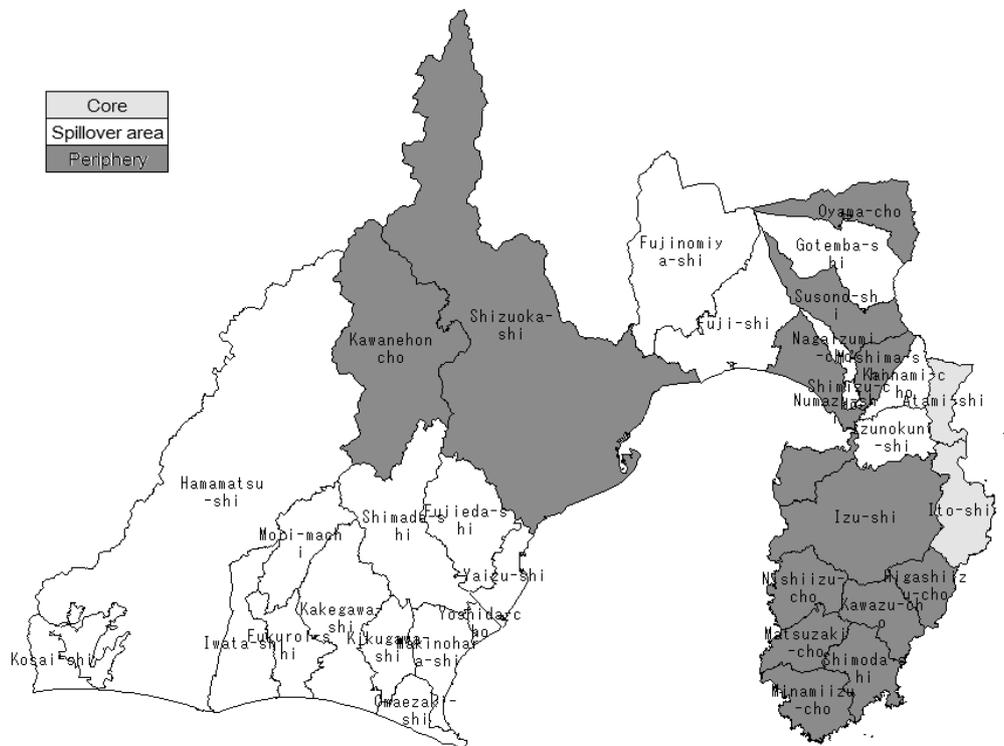


Figure 15 Core and periphery in Shizuoka Prefecture (2005)

Surprisingly, the largest cities, such as Shizuoka and Numazu, which led the economic growth in 1960-1980, turn to the peripheries. We can examine the background of this phenomenon. Figure 16 shows the estimation of productive-age population (from 15 to 65 years old) in five areas from the model. The center area (Shizuoka City) and the eastern area (Numazu City *etc.*) reveals sharp decline in productive age population.

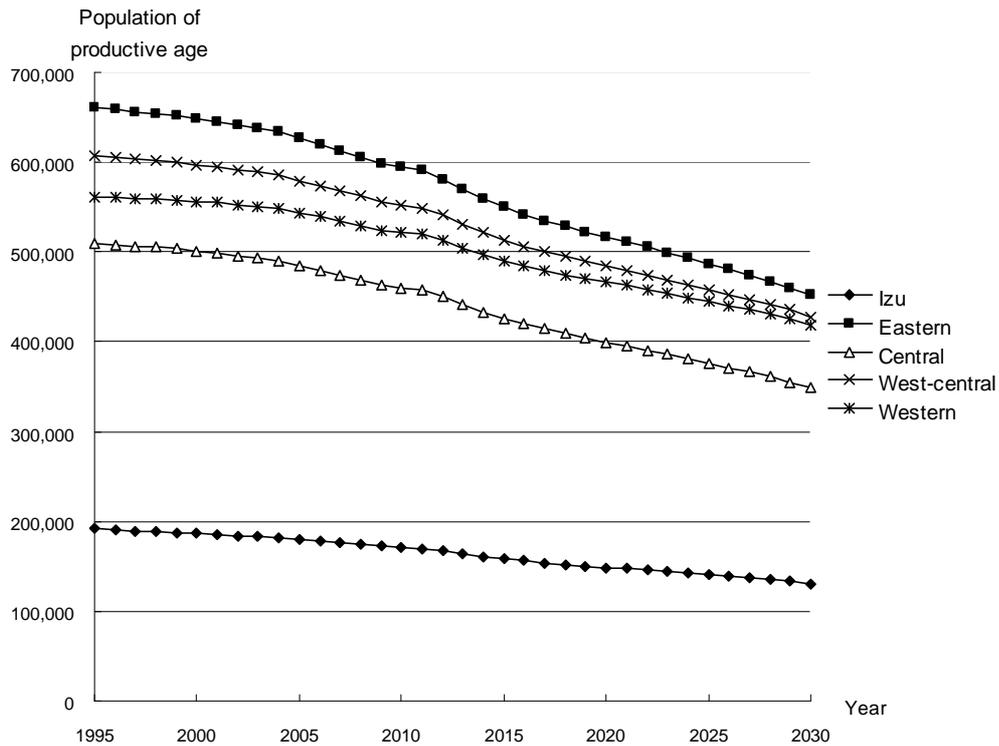


Figure 16 Population of productive age (1995-2030)

4.6 External Shock: Earthquake and Tsunami

The strongest earthquake occurred off the coast of the east Japan (the Tōhoku district) on the 11th March 2011. It was the most powerful earthquake and triggered extremely destructive tsunami waves. Prefectures in the Tōhoku district welcomed auto parts factories and electronic parts factories since 1990's. Tsunami waves destroyed those factories and traffic network. Although Shizuoka Prefecture is outside the east Japan, the manufacturing industry has been obliged to halt their production for several weeks due to the lack of parts and the breakdown of supply chain.

Manufacturing industry in Shizuoka Prefecture stopped their production due to after quakes and loss of parts for several weeks. In addition to loss of life, the tsunami caused a number of nuclear accidents, primarily the level 7 meltdowns at the nuclear power plant in Fukushima Prefecture. These accidents brought rolling blackouts in the eastern area of Shizuoka Prefecture, because electricity is supplied by Tokyo Electric Power Company, which owns the nuclear plant in Fukushima Prefecture. Electricity in other areas of Shizuoka Prefecture is supplied by Chubu Electric Power Company. However, the political shutdown of the nuclear plant in Hamaoka City reduces electric power supply in other areas of Shizuoka Prefecture.

The economy of Shizuoka Prefecture is a typical export-led economy as we discussed, the shrinking export of motorbikes, automobiles, and Japanese tea may undermine its economic potential. A tangible data is not available yet. We will examine these damages by using capacity operation ratio.

Figure 17 tells us the cut-down effect of capacity operation rate in manufacturing industry. The line marked by a cross shows the effect of 85 % of cut-down on gross prefectural domestic product.

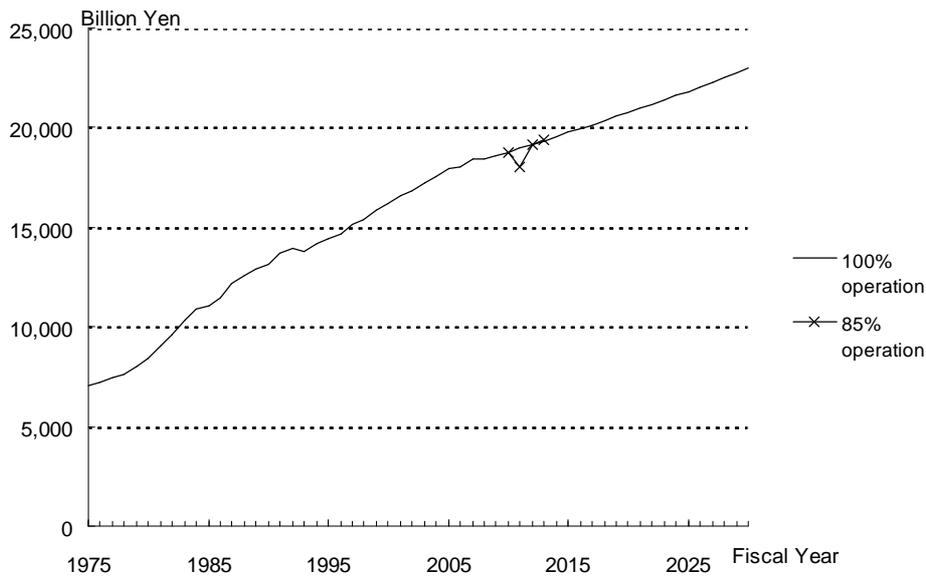


Figure 17 The effect of earthquakes and tsunami on GDP

5. Conclusion

We have been carrying out the simulation analysis by a regional economic model, as mentioned above. Whether or not the population of productive age can support the burden of social security commands interest now, because the population decrease in Japan accompanies rapid aging. On the other hand, a system dynamic simulation in this study proves a possibility that the growth rate of the per capita income is high as Figure 10 shows in the phase of the population decrease. Then, we need to design the social security where this growth of income is not absorbed in the burden but expands the consumption and the savings, because active consumption and savings of the household support the macroeconomic demand side.

Recently, people are much interested in the trend toward the service economy or the IT-oriented economy seeking a high-value added and a new business. However, as Figure 13 shows, we cannot expect the growth of the industry for domestic demand than we expected in a depopulating society, because of the lack of domestic demand. It is a steady growth strategy for most of the regional economies to improve the manufacturing, as shown in Figure 12, without sticking to the growth pattern of Tokyo.

Let me summarize the main points in this paper.

- 1) Synchronizing a regional economic model with the population model brings us the image of the depopulating society. Modeling the cohort-component method in system dynamics clarifies the detail of the depopulating society. There is a delay in the influence of the population decrease on the per capita income, because the gross domestic production keeps rising for a while after the population faces the decline phase.
- 2) Characteristics of the regional economic growth could be expressed in detail by modeling the productive activity according to industry.
- 3) A problem to the region could be clarified by combining the policy simulations with the model. The policy simulations can be freely combined by constructing a regional economic model as a system dynamics model.

I will examine the migrations between regions that will become crucial in the depopulating society as a future task.

Appendix Estimation of Functions

A value in parentheses under the coefficient is t-distribution, R^2 is a coefficient of determination, \bar{R}^2 a coefficient of determination adjusted for the degrees of freedom.

$$CP_t = POP_t(0.004831 + 0.0000000845 GDP_t) \quad R^2 = 0.968153$$

(13.21076) (30.69865)

$$IH_t = 535.8356 + 0.879356 IH_{t-1} + 0.083022 \Delta GDP_t \quad \bar{R}^2 = 0.762300$$

(0.910570) (10.12508) (3.057306)

$$IP_t = -5162.965 - 0.063266 GDP_{t-1} + 0.007596 JGDE_t \quad \bar{R}^2 = 0.769497$$

(-1.177560) (-0.622757) (1.865556)

$$J_t = 393.8019 + 14531.30 \frac{GDP_{t-1} - GDP_{t-2}}{GDP_{t-2}} \quad R^2 = 0.216783$$

(1.778971) (2.881592)

$$IG_t = 139.0962 + 0.959804 IG_{t-1} + 5045.624 \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}} \quad \bar{R}^2 = 0.867421$$

(0.292032) (14.02900) (1.903117)

$$GC1_t = -1110.942 + 0.038115 GDP_t + 45798.02 SNR_t \quad \bar{R}^2 = 0.962421$$

(-2.661709) (4.203154) (5.883783)

$$GC2_t = -63880.94 + 0.017124 POP_t + 41672.27 SNR_t \quad \bar{R}^2 = 0.946344$$

(-2.730881) (2.592420) (4.621495)

$$EXD_t = -2413.514 + 0.027773 JGDE_t \quad R^2 = 0.962163$$

(-0.586015) (28.07689)

$$EXF_t = 27260.64 - 70.23132 YEN_t \quad R^2 = 0.836328$$

(27.28730) (-12.58582)

$$IM_t = 23562.95 + 0.681894 GDP_t \quad R^2 = 0.941714$$

(5.861061) (22.73795)

$$DIS_t = -9559.384 - 0.146274 GDP_{t-1} + 0.262115 GDP_{t-2} \quad \bar{R}^2 = 0.703477$$

(-4.853638) (-1.117302) (2.032169)

$$\ln Y_1 = -6.242561 - 0.061565 \ln K_1 + 0.686239 \ln L_1 \quad \bar{R}^2 = 0.884680$$

(-3.597967) (-.787144) (11.72650)

$$\ln Y_2 = -1.157894 + 0.252434 \ln K_2 + 0.318611 \ln L_2 \quad \bar{R}^2 = 0.464027$$

(-0.416529) (1.008477) (4.099451)

$$\ln Y_3 = -1.237120 - 0.026201 \ln K_3 + 0.449974 \ln L_3 \quad \bar{R}^2 = 0.851884$$

(-0.819540) (-0.155110) (13.83329)

$$\ln Y_4 = -10.23357 + 0.440990 \ln K_4 + 0.844436 \ln L_4 + 0.358837 D_1 \quad \bar{R}^2 = 0.730730$$

(-5.499822) (5.598710) (8.237382) (5.037198)

D_1 is a dummy variable for the bubble economy era from fiscal year 1987 to 1992.

$$\ln Y_5 = -9.676659 + 0.025439 t + 0.093934 \ln K_5 + 0.906066 \ln L_5 \quad \bar{R}^2 = 0.976526$$

(-9.295005) (5.271721) (0.921397) (0.921397)

$$\ln Y_6 = 1.58847 + 0.430497 \ln K_6 + 0.189328 \ln L_6 + 0.299554 D_1 \quad \bar{R}^2 = 0.904217$$

(0.305486) (8.308815) (0.672668) (7.744544)

$$\ln Y_7 = -20.97867 + 0.742716 \ln K_7 + 1.303992 \ln L_7 \quad \bar{R}^2 = 0.917184$$

(-4.485774) (18.24317) (4.647155)

$$\ln Y_8 = 1.688051 + 0.548451 \ln K_8 + 0.125214 \ln L_8 \quad \bar{R}^2 = 0.945205$$

(0.744038) (23.23788) (1.155841)

$$\ln Y_9 = -0.936927 + 0.638944 \ln K_9 + 0.242164 \ln L_9 \quad \bar{R}^2 = 0.956738$$

(-0.330157) (26.33153) (1.589534)

$$\ln Y_{10} = 6.271571 + 0.793854 \ln K_{10} - 0.222884 \ln L_{10} \quad \bar{R}^2 = 0.975018$$

(4.2779964) (22.70997) (-2.227992)

$$\ln Y_{11} = -9.319300 + 0.374312 \ln K_{11} + 0.762221 \ln L_{11} \quad \bar{R}^2 = 0.967116$$

(-1.285265) (10.75301) (1.942416)

$$\ln Y_{12} = -12.51872 + 0.409626 \ln K_{12} + 0.902234 \ln L_{12} \quad \bar{R}^2 = 0.991023$$

(-2.980747) (11.72147) (4.069286)

$$\ln Y_{14} = 3.464534 + 0.528566 \ln K_{14} + 0.049634 \ln E_{14} \quad \bar{R}^2 = 0.977790$$

(9.172585) (20.17068) (0.369284)

The output of government services was estimated by the following equation.

$$Y_{13} = -454.9493 + 0.064642 GDE_t + 0.012429 E_{13} \quad \bar{R}^2 = 0.943265$$

(-0.232006) (8.440735) (0.468347)

References

- Boudeville, J.-R. (1966), *Problems of Regional Economic Planning*, Edinburgh: Edinburgh University Press.
- Capello, R. (2007), *Regional Economics*. London: Routledge.
- Fujimasa, I., and Matsutani, A. (2000), *Japan's Economic Structure by System Dynamics Model (1955-1998)*. National Graduate Institute for Policy Studies. (藤正巖・松谷明彦, 『システムダイナミクス (SD) モデルによる日本の経済構造 (1955-1998)』政策研究大学院大学。)
- Hall, R.E. and Taylor, J.B. (1997), *Macroeconomics*, 5th ed.. New York: W.W.Norton & Company.
- Heijman, W.J.M. and R.A.Schipper (2010), *Space and Economics: An Introduction to Regional Economics*, Wageningen, Netherlands: Wageningen Academic Publishers.
- Kopainsky, B. (2005), *A System Dynamics Analysis of Socio-economic Development in Lagging Swiss Regions*. Aachen: Shaker Verlag.
- Matsuzaki, T. and Miyazaki, H. (1976), "A Support System for Designing a Long-term Master Plan by SD: Hyogo Dynamic Model," *Communications of the Operations Research Society of Japan*, Vol.1 No.1, pp.143-151. (松崎功保・宮崎秀紀, 「SDによる長期総合計画策定支援システム—兵庫ダイナミック・モデル—」『オペレーションズ・リサーチ』第21巻第3号, pp.143-151。)
- McCann, P. (2001), *Urban and Regional Economics*. Oxford: Oxford University Press.
- Meadows, D.H., et. al., (1972), *The Limits to Growth*. New York: Universe Books.
- Thirlwall, A.P. (1980), "Regional Problems are 'Balance-of-Payments' Problems," *Regional Studies*, Vol.14 No.5, pp.419-25.
- Yamashita, T. (2007), "Macroeconomic Model of the Regional Economy in a Society with a Declining Population: A Simulation of Shizuoka Prefecture's Economy," *Journal of Economic Policy Studies*, Vol.4 No.2, pp.67-70. (山下隆之, 「人口減少社会の地域マクロ経済モデル—静岡県経済のシミュレーション—」『経済政策ジャーナル』第4巻2号, pp.67-70。)

Data

Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts*.

(<http://www.esri.cao.go.jp/jp/sna/menu.html>)

Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on Prefectural Accounts*.

(http://www.esri.cao.go.jp/jp/sna/sonota/kenmin/kenmin_top.html)

Economic and Social Research Institute, Cabinet Office, Government of Japan, *Preliminary Quarterly Estimates of Gross Capital Stock of Private Enterprises*.

(http://www.esri.cao.go.jp/jp/sna/sonota/minkan/minkan_top.html)

Ministry of Internal Affairs and Communications, *Population Census*.

Shizuoka Prefecture, *2010 Strategic Plan*. (静岡県『魅力ある“しずおか”2010年戦略プラン』, 2002年。)

Shizuoka Prefecture, *Annual Report on Monthly Labor Survey*. (静岡県『静岡県毎月勤労統計調査年報』。)

Shizuoka Prefecture, *Annual Report on Prefectural Accounts*. (静岡県『静岡県の県民経済計算』。)

Shizuoka Prefecture, *Census of Commerce*. (静岡県『商業統計調査報告書』。)

Shizuoka Prefecture, *Input-Output Tables*. (静岡県『静岡県産業連関表』。)

Shizuoka Prefecture, *Shizuoka Statistical Yearbook*. (静岡県『静岡県統計年鑑』。)

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