

A System Dynamics Approach to Regional Income Disparities

Takayuki Yamashita

Department of Economics
Shizuoka University
Ohya 836, Suruga-ku, Shizuoka City, 422-8529, Japan
e-mail: yamashita.takayuki@shizuoka.ac.jp

Abstract

The excess concentration of population and industry in the Tokyo Metropolitan is now activating arguments on regional income disparities in Japan. From the statistical investigation, regional income disparities have a close relation with the balance of payments. Incomes in the trade-deficit regions are lower than those in the trade-surplus regions. Based on the system dynamics approach, this study develops a regional economic model under interregional trade and examines how the money inflow from exports brings the economic growth. The two regions model clarifies significant results by mutual dependency. The issue of regional disparities in the standard of living is a common hotly debated topic in many countries. Findings of this study are valuable to reconsider the public policy to correct those disparities.

Keyword : regional disparities, macroeconomic model, balance of payments

1. Introduction

The issue of regional disparities in the standard of living and quality of life has been debated in recent decades. According to the statistical finding by Kuznets (1955), inequality in the distribution of income increases in the early stage of development but decreases in the long terms. According to the neo-classical economic growth model, every region within a single country will converge the similar steady state. Regional disparities must be diminishing. There is a growing number of attempts to assess the question of regional convergence.

Economic growth raises an average income but often widens the income disparities within the country. Although nearly a quarter century has passed since the Maastricht Treaty was signed, regional disparities in income are still raising economics and political issues in European countries. Regional disparities are seen in the North America.

In Japan, the regional income inequality was high in the prewar period and turned to decrease in the postwar high economic growth period (from 1950s to 1970s). Recently, the bankruptcy of Yūbari City¹ and the excess concentration of population in the Tokyo

¹ Yūbari is a city in Hokkaido. The city was founded on April 1, 1943 as a coal mining town. When the

Metropolitan² are re-activating arguments on regional disparities. These arguments invoke social unrest. Based on the Annual Report on Prefectural Accounts, we calculated the coefficient of variation (CV) for per capita income for the 47 prefectures³ (Figure 1). CV represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another. A high value indicates a large disparity.

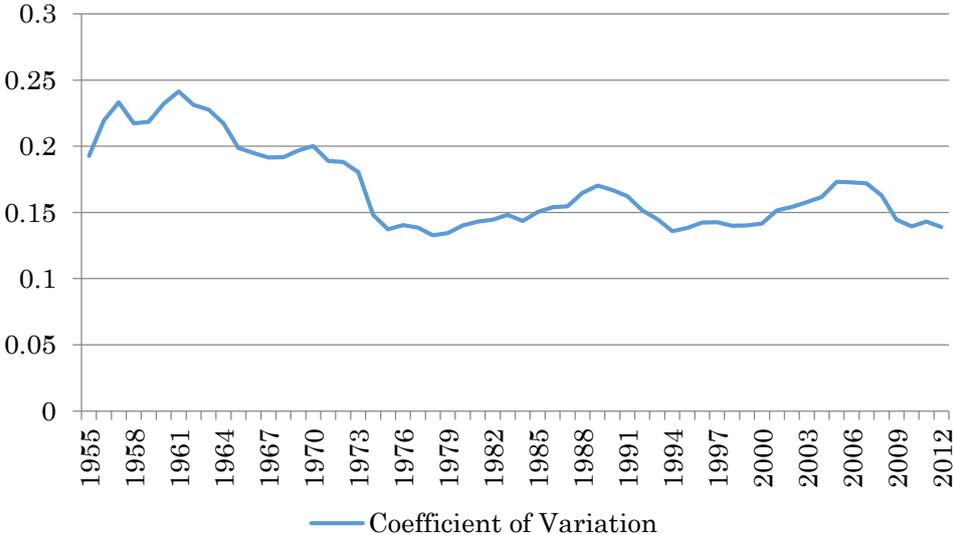


Figure 1. Coefficient of variation of per capita income (47 pref.)

Source: Economic and Social Research Institute (Cabinet Office), *Annual Report on Prefectural Accounts*.

CV was decreasing in the second decade of high economic growth period (from 1962 to 1973), indicating that income equality had been achieved. The Japanese post-war economic miracle created the equality of income as well as the growth of income. However, CV has risen since the recovery from “Lost Decade” (from 1991 to 2000), showing the income inequality has increased.

The regional economy is connected to each other through exports and imports. Exports increase monetary flows which are necessary for the regional economy to grow, whereas imports decrease monetary flows in the regional economy. The economic performance of regional economy is closely related to the balance of payments.

Figure 2 shows the relationship between the percentage of the balance of payments in the

mines were operating, Yūbari had as many as 116,908 people. With the closing of the mines in the 1980s, an attempt was made to convert the economic base to tourism, but few visitors came. In 2007 the city went bankrupt with ¥358 billion financial loss. City services has been severely cut and Yūbari has only 9,968 people in 2013.

² According to *Global Metro Monitor 2014* by the Brookings Institution, Tokyo is the world’s largest metropolitan with US\$1,616,792 GDP and 37,027,800 population. The third part of GDP and population of Japan concentrate in Tokyo. <http://www.brookings.edu/research/reports/2015/01/22-global-metro-monitor>

³ Prefectures are the main subdivisions of Japan, consisting of 47 prefectures, or 1 “to” (都), 1 “dō” (道), 2 “fu” (府), and 43 “ken” (県). Tokyo-to is a metropolitan.

gross prefectural product (GPP) and per capita income of the 47 prefectures in fiscal 2012⁴. The value for correlation coefficient is 0.808, and there is a significant correlation between those two variables. Per capita incomes in the favorable balance of payments are high, and per capita incomes in the unfavorable balance of payments are low. The national average of the percentage of the balance of payments in GPP was 6.26% and per capita income was 4,299 thousand yen⁵. Tokyo, Aichi, Shizuoka, and Shiga Prefectures exceed the average with both variables. These four prefectures are the representative base in Japanese manufacturing industry. This finding is a piece of evidence that the manufacturing industry is the engine of growth known as Kaldor's growth laws⁶.

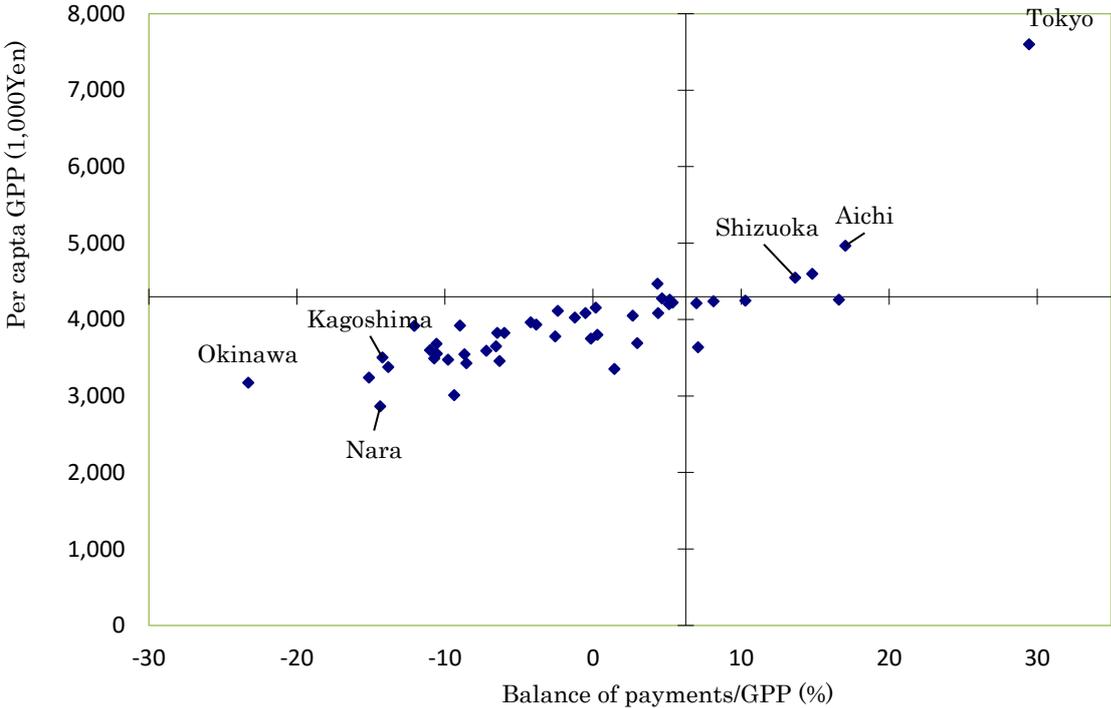


Figure 2. Balance of payments and per capita gross prefectural product (47 pref.)

Source: Economic and Social Research Institute (Cabinet Office), *Annual Report on Prefectural Accounts*, fiscal 2012.

The purpose of this paper is to examine how the imbalance of interregional trade raises the regional income disparities and to explore the way to compensate those differences. System dynamics is applied in this study for the following reasons:

- (1) Since Forrester’s pioneering work (1969), the system dynamics has been certified as a powerful approach to investigate the regional issues.
- (2) The flexibility in the model building makes us focus on the issue that the standard economic model cannot handle.
- (3) The structure-based approach of system dynamics works well for elucidating a

⁴ The gross regional product is called as the gross prefectural product in prefectural accounts.
⁵ At the time of writing, 1 US dollar equals 107 Yen, and 1 Euro equals 122 Yen.
⁶ The first law is that the growth of the GDP is positively related to the growth of the manufacturing sector.

phenomenon with limited information. It is hard to obtain a reliable econometric result when data is little. The structure-based approach gives us the ability to explore such a phenomenon.

Interregional trade is quite complex because many regions involve. In a simple approach, the volume of regional production is explained by the volume export from that region to the other region or the rest of the country. The basic model is explained in the next section. After that, two-way trade model is proposed.

2. Regional Keynesian model

This section gives the one region model. Demand-oriented approaches to the economic growth emphasize the role of exports. Exports differ from the other components of demand in two respects. Firstly, exports are primal way to increase monetary inflow in a local economy (North [1955]). Secondary, exports are the only autonomous component of demand in an economic system, in the sense of demand emanating from the outside the system (Thirlwall [2002]).

The export activity is the engine of economic growth. Income originally earned by the export sector is spent and re-spent locally, creating additional income through the multiplier. This idea is expressed regarding employment or incomes. The simplest way to model this idea is called exports base model or economic base model⁷. The income version of economic base model resembles a Keynesian approach of a regional economy⁸.

The standard Keynesian aggregate demand expression can be applied to a region as

$$E_t^r = C_t^r + I_t^r + G_t^r + X_t^r - M_t^r \quad (1)$$

where E_t^r represents regional expenditure, C_t^r represents regional consumption, I_t^r is regional investment, G_t^r is regional government spending, X_t^r are regional exports, and M_t^r are regional imports in period t .

Consumption expenditure is a stable component of regional expenditure. Consumption expenditure function is assumed as a Keynesian type function in which the level of consumption depends on regional income.

$$C_t^r = c^r Y_{t-1}^r \quad (2)$$

where c^r is regional marginal propensity to consume (MPC) and Y^r is gross regional product (GRP).

Regional investment is assumed to be exogenous.

$$I_t^r = \bar{I}^r \quad (3)$$

⁷ According to Andrews (1953), the export base concept dates back to Robert Haig in 1928 and the export base theory was developed by Homer Hoyt in the 1930s for city planning. Economic version of the export base model was developed by Richard Andrews, Douglas North, and Charles Tiebout, independently.

⁸ There are many attempts to model system dynamics version of the Keynesian macroeconomic model. Among them, Low (1980) was helpful to understand standard thought in system dynamics context.

Regional government spending is assumed to be exogenous⁹.

$$G_t = \bar{G}^r \quad (4)$$

In the export-base methodology, regional exports are assumed to be exogenous.

$$X_t = \bar{X}^r \quad (5)$$

Regional imports expenditure function is given as

$$M_t^r = m^r C_t^r + n^r X_t^r \quad (6)$$

where m^r is regional marginal propensity to import for consumption (MPMC) and n^r is regional marginal propensity to import for exports production (MPMP).

In the case of regional accounts, the definition of imports is expenditure on anything which is purchased from outside of the region, as well as outside of the country. A large part of regional imports are intermediate goods because there are extensive and deep supply chains within a country. This point is a major difference between the regional and national income-expenditure frameworks. Consequently, imports share of GRP is far larger than that of GDP. Although imports function is usually a function dependent on GDP only in the national model, the level of regional imports is dependent on regional exports as well as regional consumption. This formulation fits a regional data much better than the standard imports function¹⁰.

The regional economy is in equilibrium when income equals total expenditure.

$$Y_t^r = E_t^r \quad (7)$$

Figure 3 shows the basic idea of the regional macroeconomic model.

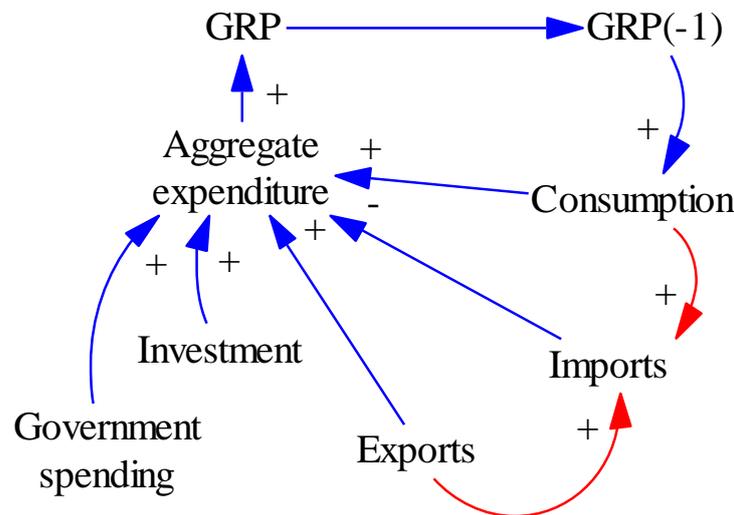


Figure 3. Basic regional macroeconomic model

Equations from (1) to (7) give the difference equation.

⁹ Government expenditure is treated as an exogenous variable in many macroeconomic studies.

¹⁰ For more details, see Yamashita [2016].

$$Y_t^r = \bar{I}^r + \bar{G}^r + (1 - n^r)X_t^r + c^r(1 - m^r)Y_{t-1}^r \quad (8)$$

The equilibrium level of income remains what it is in the static model. Since $Y_t^r = Y_{t-1}^r = Y^{r*}$ for all t in equilibrium, then

$$Y^{r*} = \frac{\bar{I}^r + \bar{G}^r + (1 - n^r)X^r}{1 - c^r(1 - m^r)} \quad (9)$$

3. Exporter region and importer region

Among 47 prefectures, Shizuoka prefecture is modelled as a net exporter region and Kagoshima Prefecture as a net importer region¹¹. These two prefectures have a tight economic relationship. Shizuoka Prefecture has been renowned for Japanese tea as well as for manufacturing. Shizuoka tea has been ranking first in crop acreage, production, and shipping. However, the amount of tea leaf is not enough for production, Shizuoka Prefecture is now ranking first in imports of tea leaf. Kagoshima Prefecture is a major supplier of tea leaf. Shizuoka Prefecture offers technical guidance in tea farming to Kagoshima Prefecture, and people exchange is active¹². Shizuoka Prefecture is a major production area of not only Japanese tea but also manufacturing products. Shizuoka is ranking first in production of motorcycles, musical instruments, medical appliances, and fishing boats. Those manufacturing products are sold in Kagoshima Prefecture. Table 1 summarize the brief comparison of two prefectures.

Table 1. Data for prefectures

	Real GPP, 2012 (million yen, 2007 base)	Real Exports, 2009 (million yen, 2007 base)	Real Imports, 2009 (million yen, 2007 base)	Population, 2012	Real per capita GPP, 2012 (thousand yen, 2007 base)
Shizuoka	15,798,754	15,011,812	13,187,180	3,734,540	4,550
Kagoshima	5,921,187	2,425,744	3,038,643	1,689,641	3,504

Source: Economic and Social Research Institute (Cabinet Office), *Annual Report on Prefectural Accounts*, fiscal 2012.

The official statistics of exports and imports have not been published since 2010.

Based on the Annual Report on Prefectural Accounts, we simulated the regional macroeconomic model for Shizuoka Prefecture from 1975 to 2012 fiscal¹³. The vertical axis in Figure 4 indicates billion yen. Simulated values fit historical data.

¹¹ In this paper, we call the region with the favorable balance of payments as exporter region, and the region with the unfavorable balance of payments as importer region.

¹² Mt.Fuji Shizuoka Airport has a Shizuoka-Kagoshima airline.

¹³ The value of MPC is obtained from calibration. The values of MPMC and MPMP are obtained from regression analysis because those values give good estimations. System dynamics and econometrics have advantages respectively as Meadows (1980) explained.

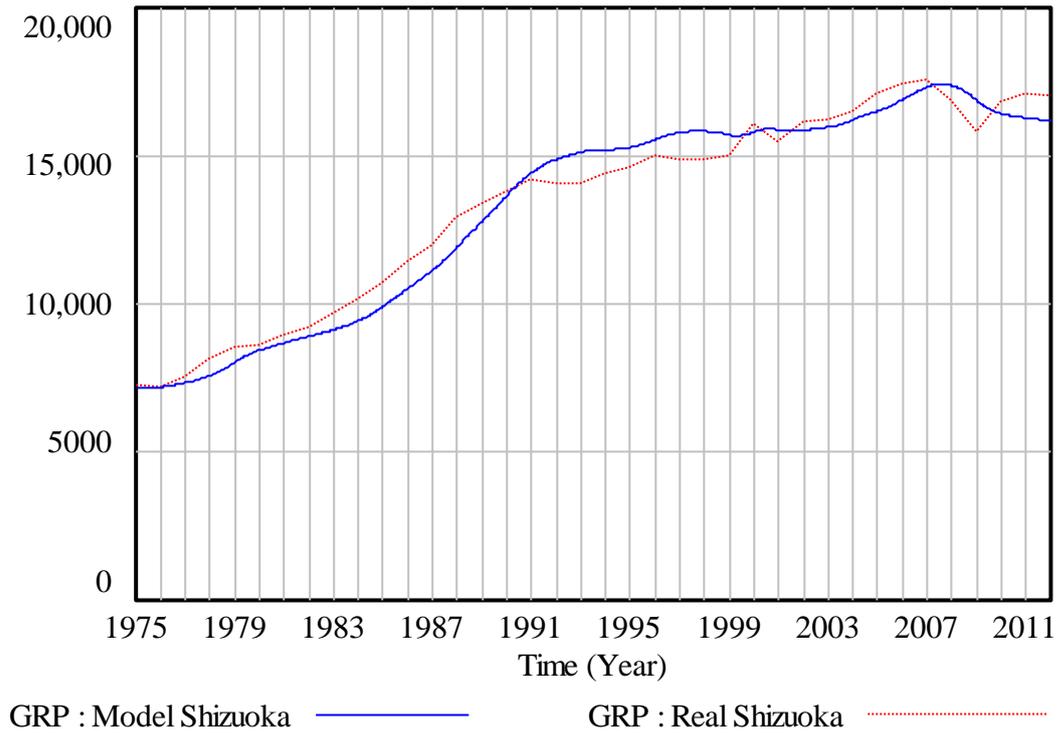


Figure 4. Shizuoka model

Figure 5 shows a simulation of Kagoshima Prefecture from 1975 to 2012 fiscal.

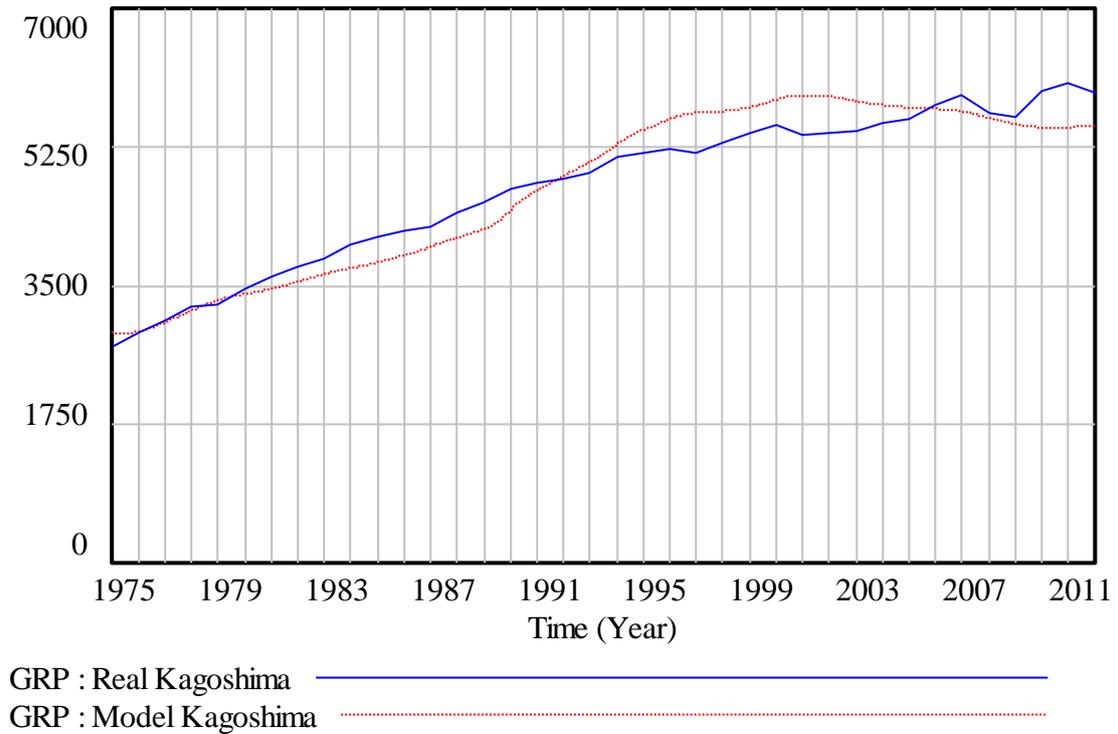


Figure 5. Kagoshima model

4. Two-region model

This section expands the one-region model to the two-region model. Exports from a particular region are imports into another region. Shizuoka Prefecture ($r=1$) and Kagoshima Prefecture ($r=2$) are mutually depending through exports and imports (Figure 6).

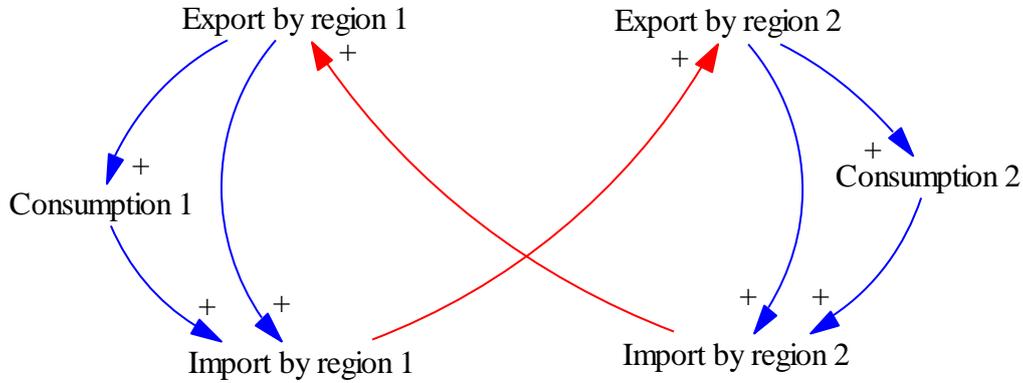


Figure 6. Interregional trade model

The following equation is assumed to connect two regions.

$$X_t^i = \alpha + \beta M_t^j, \quad i \neq j \quad (9)$$

The variable '1 to 2' named after money flow from region 1 to region 2 and '2 to 1' vice versa. Regression analysis estimated parameters because constant terms were needed to consider trade with other regions.

A considerable number of regional studies assume exports as an exogenous variable. Exports are autonomous or uncontrollable. Figure 7 shows the simultaneous simulation under fixed parameters $\bar{X}^r = X_{2012}^r$ and $\bar{M}^r = M_{2012}^r$. Under the fixed volume of trade, GRPs in both regions declined.

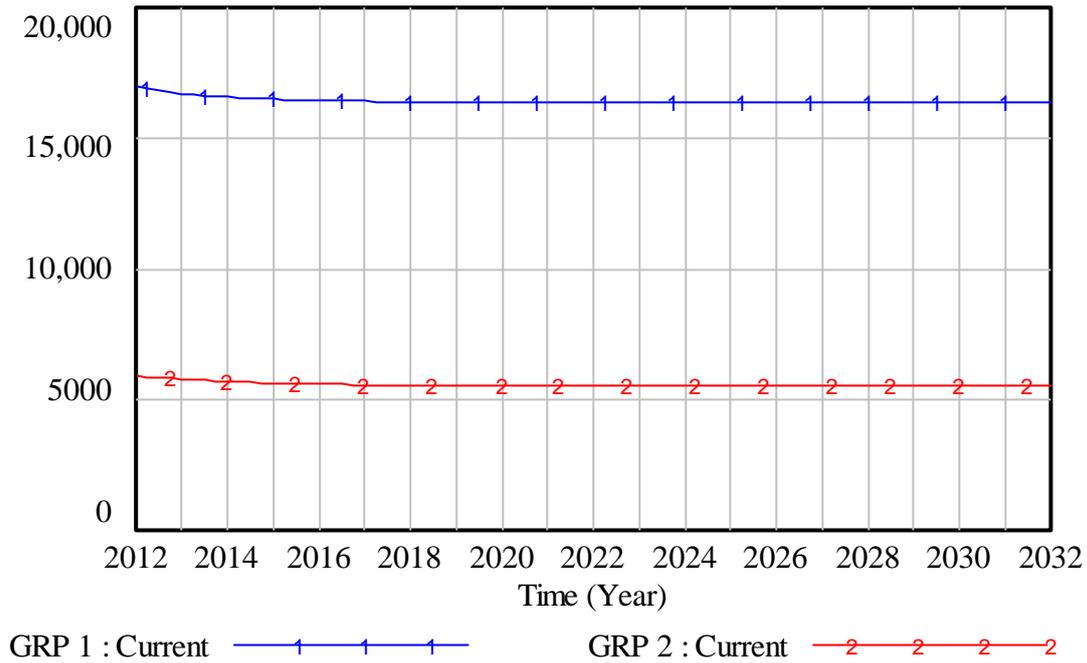


Figure 7. Simulation under fixed exports and imports

Figure 8 shows the simulation under endogenous imports and exports. Trade increased GRP in the net exporter region. Although GRP in the net importer region slightly declined, GRP was higher than that before the trade.

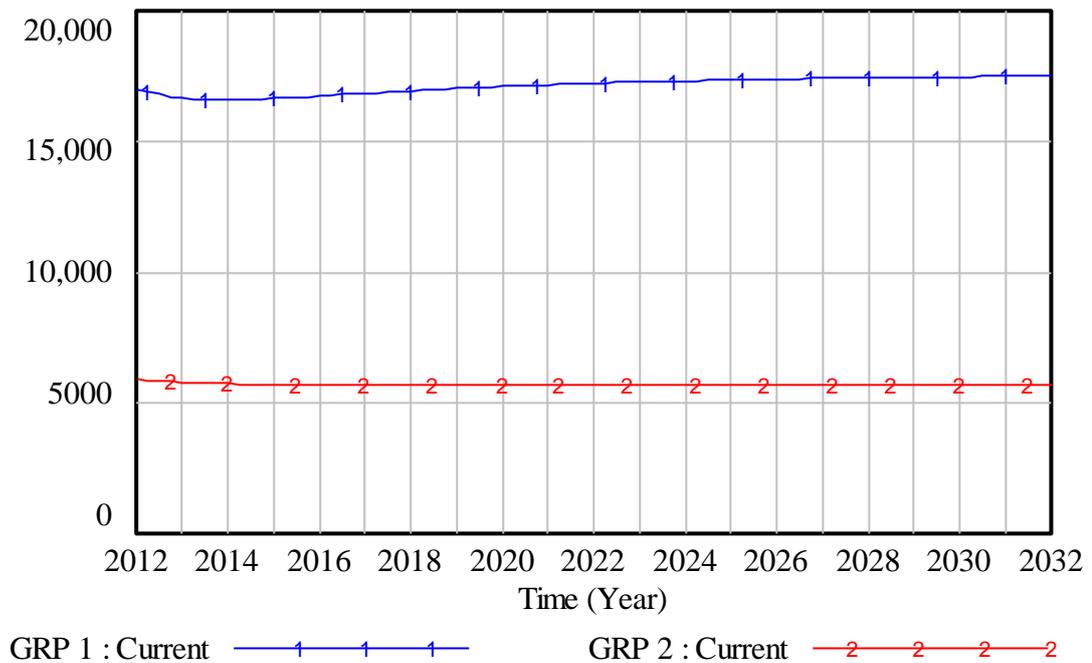


Figure 8. Simulation under interdependent exports

Methodologically, economic base analysis views the region as if it were a small nation and uses notions of comparative advantage from international trade theory. On the other hand, this two-region showed trade gains without production specialization. Trade gains arose from the economic growth.

5. Public policy for regional disparities

Now let us examine a policy to correct the income disparity between two prefectures. Trade is a beneficial activity for both regions, but cannot compensate the regional disparity by itself. There are many arguments on the regional disparities. Some argue that scaling back of public works be a cause of current income disparity.

There are two policy options: national government spending transferred into the net exporter region or the net importer region to increase public works and services. One example was the industrial areas in Tokyo, Aichi, and Gifu Prefectures invested heavily by the Japanese government in the 1950s; the other was local areas invested by the local allocation tax in the 1990s¹⁴. It is important to use a numerical simulation to choose right choice.

Assume that national government transfers 500 billion yen for the region 1 or the region 2 from 2017 to 2020. An increase in the local government expenditure affects not only this region but also the trading partner. Figure 9 shows the simulation result that 500 billion yen was transferred into the rich exporter region 1. The vertical axis indicates billion yen.

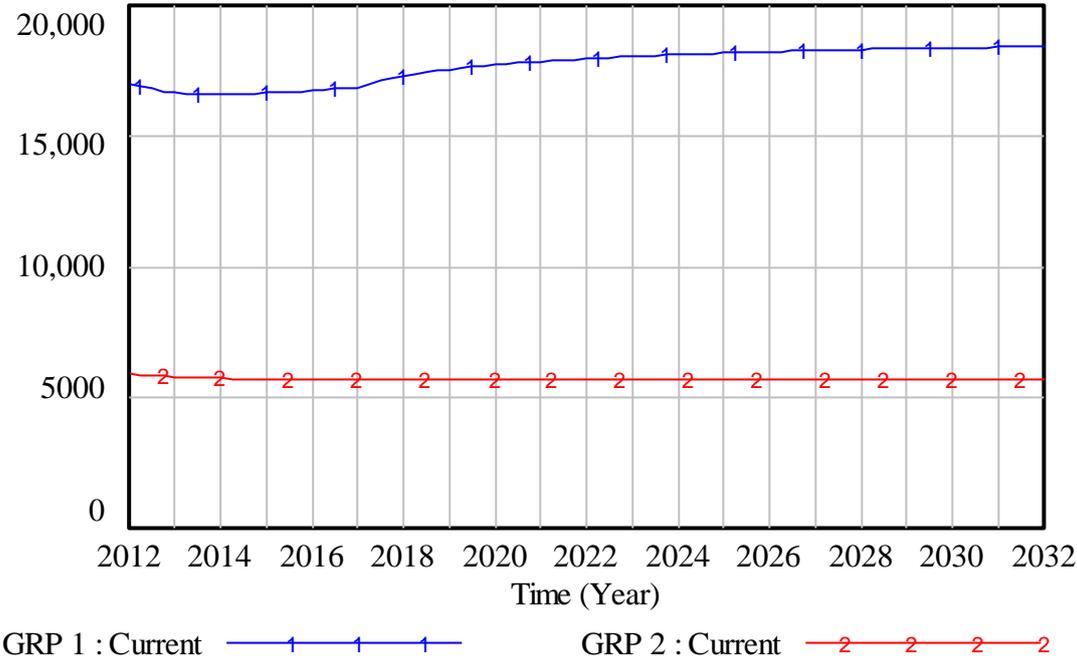


Figure 9. Supplementary budget for the region 1

A 4-year increase in intraregional demand improved the gross regional product of region

¹⁴ Heavy investment on 1964 Tokyo Olympic made Tokyo Prefecture grow rapidly. So there is an argument that stadiums of 2020 Tokyo Olympic should be decentralised to the outside of Tokyo.

1. Although this growth towed region 2 slightly, it did not correct the income gap.

Figure 10 shows the simulation result that 500 billion yen was transferred into the poor importer region 2. A 4-year increase in intraregional demand improved GRP of region 2, although it narrowed income gaps during just 2 years. An increase of intraregional demand of region 2 put region 1 on the growth path.

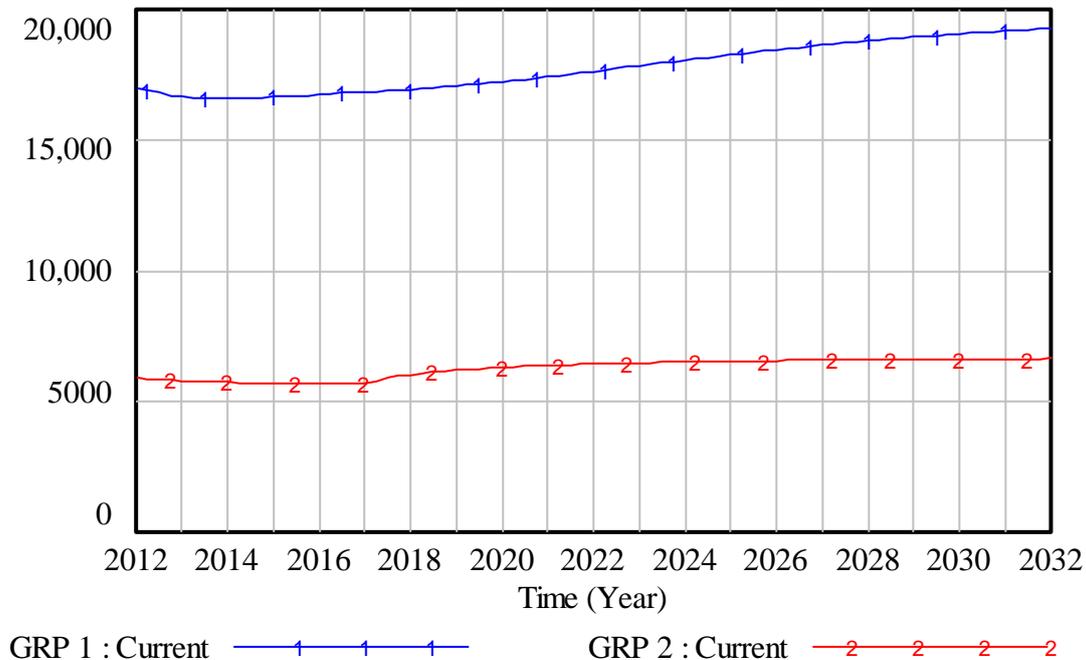


Figure 10. Supplementary budget for the region 1

The government spending in the net importer region improved the net exporter region more than the same spending in the net exporter region. These results suggest that government spending should be heavily invested in the poor importer region to correct the regional income gap.

6. Conclusion

According to the neo-classical growth theory, every region within a single country will converge the similar steady state. According to the international trade theory, factor prices will be equalised. However, there remain the regional income disparities even in the highly advanced economies and income disparities often poses policy issues. We must investigate the nature and the origin of regional disparities precisely. System dynamics approach is a helpful method to examine this unsolved problem. Findings of this paper are summarised as follows:

- 1) The imbalance of the balance of payments is the source of regional income disparities. However, participating in interregional trade is beneficial to net importer regions as well as the net exporter regions.
- 2) Reginal imports are affected by its exports as well as its consumption. This feedback mechanism is a source of regional economic growth. Although a considerable number of

regional studies and system dynamics studies assume exports as an exogenous variable, rise and fall of exports cause by imports are keys to regional income growth.

3) Connecting exports and imports are a simple but an effective idea to examine the interregional trade. The flexibility of system dynamics helps us to model the feedback mechanism. System dynamics approach also makes us observe the dynamic inflow and outflow of income with accuracy.

4) Redistribution of national government spending is effective to correct regional income disparities when it is invested in the poor importer regions. Government spending in the net importer region improves the importer region and reduces the income gap while it creates economic growth of the exporter region.

These years, many local governments in net importer regions promote sightseeing tours as a growth strategy. However, there are not many success examples. Public works are effective solutions to correct income gap. It is necessary to investigate other policy options such as private investment and immigration. Further studies are needed.

References

- Andrews, R. B. (1953), "Mechanics of the Urban Economic Base: Historical Development of the Base Concept," *Land Economics*, Vol.29, No.2, pp.161-167.
- Andrews, R. B. (1954), "Mechanics of the Urban Economic Base: The Problems of Base Measurement," *Land Economics*, Vol.30, No.1, pp.52-60.
- Forrester, J. (1969), *Urban Dynamics*. Waltham, MA: Pegasus Communications.
- Hartman, L. M. and Seckler, D. (1967), "Toward the Application of Dynamic Growth Theory to Regions," *Journal of Regional Science*, Vol.7, No.2, pp.167-173.
- Heijman, W. J. M. and Schipper, R. A. (2010), *Space and Economics: An Introduction to Regional Economics*, Wageningen: Wageningen Academic Publishers.
- Kaldor, N. (1967), *Strategic Factors in Economic Development*. New York: Ithaca.
- Kuznets, S. (1955), "Economic Growth and Income Inequality," *American Economic Review*, Vo.45 (March), pp.1-28.
- Low, G. (1980) "The Multiplier-accelerator Model of Business Cycles Interpreted from a System Dynamics Perspectives," in Randers,J.(ed.), *Elements of the System Dynamics Method*. Walham, MA:Pegasus Communications, pp.76-94.
- Meadows,D. (1980) "The Unavoidable A Priori," in Randers,J.(ed.), *Elements of the System Dynamics Method*. Walham, MA:Pegasus Communications, pp.23-57.
- North, D. C. (1955), "Location Theory and Regional Economic Growth," *Journal of Political Economy*, Vol.63, No.3, pp.243-258.
- Thirlwall, A.P. (1973), "Regional Economic Disparities and Regional Policy in the Common Market," *Urban Studies*,Vol.11, pp.1-12.
- Thirlwall, A.P. (1980), "Regional Problems are "Balance-of-payments" Problems," *Regional Studies*, Vol.14, No.5, pp.419-425.
- Thirlwall, A.P. (2002), *The Nature of Economic Growth: An Alternative Framework for Understanding the Performance of Nations*, Cheltenham: Edward Elgar Publishing.
- Tiebout, C. M., (1956), "The Urban Economic Base Reconsidered," *Land Economics*, Vol.32,

No.1, pp.95-99.

Tiebout, C. M., (1960), "Community Income Multipliers: A Population Growth Model," *Journal of Regional Science*, Vol.1, No.1, pp.75-84.

Weber, L. (2010), *Demographic Change and Economic Growth: Simulations on Growth Models*. Heidelberg: Physica-Verlag.

Yamashita, T. (2016), *Chiiki Keizai Bunseki Handbook (Handbook of Regional Economic Analysis)*. Kyoto: Koyo Shobo.