Social Overhead Capital Development and Geographical Concentration[1]

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I.   Introduction

In recent economic geography, it is emphasized that the effect of cost decreasing in transportation on agglomeration is nonlinear. It is said that the influence of traffic infrastructure investment and the change in transportation cost on urban agglomeration does not appear until the cost is below a certain amount, and that once agglomeration arises that effect would be kept with higher probability. In theoretical models such as Krugman (1991) and Fujita, Krugman and Venables (1999), multiple equilibria and path dependence are emphasized, as well as non linearity. Those models are intuitive, but it is hard to have a statistical analysis because of the non linearity.

About the macroeconomic effect of social overhead capital investment, starting from the analysis by Aschauer (1985, 1989), a lot of empirical research has been done on the productivity effect of social capital. For example, we have Asako et al. (1994), Mitsui and Ohta (1995). Moreover, Roback (1982) uses the Hedonic approach to find the effect of amenity-based social overhead capital (related to waste disposal plants, or sewage facilities), followed by Mitsui and Hayashi (2001) for a Japanese case. In these Japanese studies, they are only concerned about the topic about inefficiency of the social overhead capital distribution but not about theoretical progress in urban economics. If Krugman's model is true, however, there is a possibility that rural traffic infrastructure investment for the purpose of redistribution will experience both a decline in rural areas and agglomeration into urban areas.

Dekle and Eaton (1994) studied economies of agglomeration and the industrial specialization in Japan by using data. According to the analysis of this study, which uses

prefecture data, it is shown that the effect of economic accumulation in financial services is stronger than in manufacturing, and that economies of agglomeration has been almost fully attained.

Nakazato (2001) does a regression analysis following Barro (1991), adding the total road length of the prefectures to independent variables, and shows that the traffic infrastructure investment has contributed to economic growth more than to a straw effect. Yamaguchi et al. (2003) create a locational Gini index for each industry and accessibility index for each prefecture, and analyze the effect of agglomeration to production. They found that no geographical concentration has occurred in all industries except agriculture since 1975, and that the influence of accessibility on production is positive, but the accessibility indices have been decreasing in Tokyo-area and Osaka-area recently (while in the Barro-type growth regression analysis, the influence of accessibility on economic growth is not significant). Davis and Weinstein (2002) analyze the degree of geographical population concentration and why it occurred by using 8000 years worth of data. They conclude that population concentration occurred only after the Meiji industrial revolution, except in the initial period, which is consistent with Krugman's increasing return model.

As mentioned above, if non linearity is important as in Krugman's model, it is hard to find the effect through the usual regression analysis. Instead, we can evaluate the validity of the Krugman's hypothesis with checking the trend of agglomeration degree in the long term.

In the following, we will examine general theory about how we should observe the effect of traffic network provision in section II. We will estimate a market potential function and an index with which the geographical concentration degree is measured, and see how the agglomeration degree has changed historically. In section II we will conduct analysis through using prefecture data and municipal data, particularly in the Kyushu district[2].

The following points are shown through the analysis: First, it is shown that population concentration in Japan has been occurring since 1920s from the variance and the Gini coefficient of the prefecture population data. There had been two centers in Japan, Tokyo and Osaka, before the last war, but Tokyo has been the only center since WWII. Second, the speed of agglomeration into Tokyo slowed down after the high economic growth in the 1970s, but the speed has been increasing in recent years. Third, the agglomeration into Fukuoka has been occurring if we observe only the Kyushu district. Fourth, we derive a market potential function which has been rarely derived for the prefecture-level and municipal-level. Throughout the analysis we find that the regions for which the market potential is high and for which a highway network is provided are overlapping. But the relationship between transportation cost and

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[2] The reasons why I focus on Kyushu region are that a) it is compact (for example, we need to consider relationships to the neighboring regions from the viewpoint of land transportation if considering a region in Honshu Island, since it is not separated by the sea) and b) that it seems easy to find the influence, since the period for which the data is available coincides with the period of the highway network development.

geographical concentration of economic activity was not seen clearly in this limited data.

II.   How to understand the network effect

When we analyze the influence of traffic network investment on urban accumulation, the following two things should be noted: First, the influence of traffic infrastructure investment and decreasing cost of transportation on urban agglomeration might be nonlinear. Second, the influence of decreasing cost of transportation on each city is not uniform. Decreasing transportation cost has effect on the economies of agglomeration of a region having several cities than on that of a region having only one city. And it moves the center of industry or commerce (if the cost decreases to some extent), which affects the agglomeration degree of economic activity. Moreover, the provision of highway network services, port services, or airport services affects any industry differently, along with the degree of that effect.

Thus, the influence of transportation infrastructure investment is extremely complicated. Accordingly, if it is possible to have a simple index which summarizes those influences, we can gain a much better perspective in the analysis.

Among the indices which summarize the complicated interaction between two cities, the so-called market potential has been used in economic geography and urban economics. In addition, among the models dealing with trade between two cities, it is already well known that so-called gravity equation fits data well. On the other hand, for estimating degree of geographical concentration of industry, it is helpful to use the Gini coefficient for the analysis of income or asset distribution, or the Herfindahl index for measuring how heavily industry is concentrated. In the following, gravity equation, market potential function, and indices for measuring agglomeration degree are explained. We will see those existing methods for measuring the effect of traffic infrastructure investment and extension when considering the effect of economies of agglomeration, and point out that there are limits and problems with those methods.

II.1.   *Gravity equation and market potential function*

In physics, attraction between two objects is proportional to the product of the weights and inversely proportional to the square of the distance. It is known that this relationship also fits trade between two regions[3]. Generally, a gravity equation is represented as;

$$F_{i,j} = k\left(Y_i Y_j\right)\Big/ d_{i,j}{}^2 \qquad\qquad (1)$$

where Y_i and Y_j are the variables representing economic activity (for example, income) of two

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[3] In the "new trade theory" in which they emphasize product differentiation, monopolistic competition and economies of scale, a gravity equation is derived from a model. See Feenstra (2004).

regions i and j, $F_{i,j}$ is trade amount, $d_{i,j}$, is the distance (or the travel time) between the two regions, and k is a constant. The gravity equation is applicable not only to trade amount between two regions but also to the traffic, the transportation, the commute, and so on. From the estimated relationship, it is possible to guess the influence of decreasing the travel time on the variable such as the trade amount, the traffic, and the transportation. The "force" acting on a region i is the sum of attraction from the surrounding regions. Thus we define the potential of a region i as[4];

$$V_i = \sum_{j \neq i} kY_j \Big/ d_{i,j}{}^2 \; . \tag{2}$$

It is easily seen that the market potential is the sum of the forces acting on one unit of Y_i, which is an indicator summarizing the geographical advantage of a region i.

This indicator has some problems, two of which are pointed out here. First, if we use a geographical distance as the variable representing how far it is, an upward bias is estimated for the market potential of inland regions and a downward bias for that of coastal regions. A region with a big port clearly has an advantage of transportation cost since it is connected to far places over the sea. But when geographical distance is used for calculating the market potential, it is not reflected to the number. This would be important if we deal with overseas trade or domestic long distance transportation[5].

The second problem of the market potential function is that the data we need will increase dramatically as the number of regions increases. If the number of regions is n, then the number of data we need to have is $n(n-1)/2$. For example, if we deal with 47 prefectures data we need $47 \times 46/2 = 1081$, and if we have data on 501 municipalities as for Kyushu in this paper, we need 125,250 for the distance. Moreover, if we deal with all the municipalities in Japan, the necessary data will amount to 4.5 million. It is impossible to calculate such a big amount of data unless a program for automatic computation of travel time is available. On the other hand, it is relatively easy to derive a geographical distance from the longitude and latitude data. In this paper a program is made for calculating geographical distances from the longitude and latitude data of prefectures and municipalities, and with using them we compute the market potential. See the appendix for detail method.

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[4] This formulation is based on the assumption that each region is a point and does not have an area. That is why there is no indicator of economic activity level of the region we focus on in the formula. However, we need to take the economic activity of the region when we assume that each region has an area. A commonly used method, assuming the region is located evenly, is including the economic activity level of the region with using $d_{i,i}$ as the "distance" by calculating the radius from the area. Since there was still a problem with that method, in this paper we modified the method further to calculate $d_{i,i}$. The details are summarized in the Appendix.

[5] Theoretically, it should be used so that a travel time or a "transportation cost", which is calculated as the sum of an actual cost with monetary value of travel time. If those are available, the drawbacks from using a geographical distance will almost disappear.

II.2. *Gini coefficient*

The Gini coefficient is often used as an indicator of a degree of inequality. We can compute the number in the following way; first, we order the individuals by income (or asset) from poor to rich, and draw a Lorenz curve from the data by taking the cumulative relative frequency to horizontal axis and the income (or asset) to vertical axis. The Gini coefficient is defined by two times the area between the so-called line of perfect equality (the straight line *OC* in Figure.1) and the observed Lorenz curve (the curve *OC*), which can take between 0 and 1. A higher Gini coefficient means more inequality.

Figure 1.   Lorenz curve and Gini coefficient
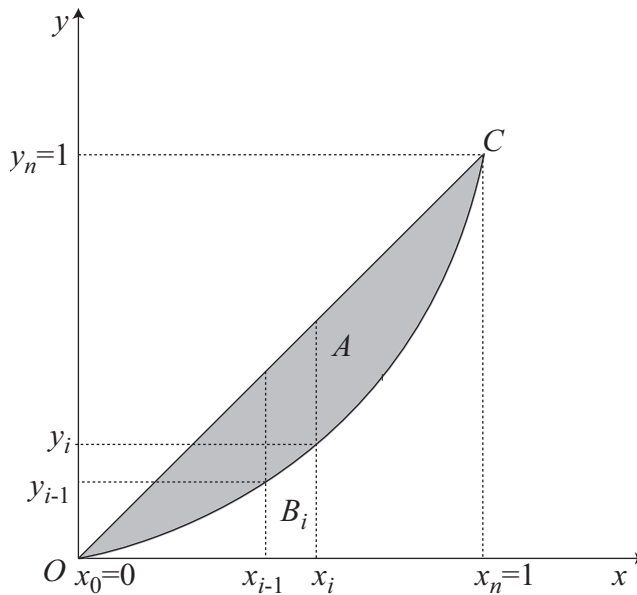
We can apply the same method for checking a degree of population concentration. In this case, we just need to do the following procedure: We order the regions by population from the one with lower population density to the one with higher, by taking the cumulative relative frequency of area to the horizontal axis and the cumulative relative frequency of population to the vertical axis. Following this method, we define the cumulative relative frequency of area up to the region i by x_i and the cumulative relative frequency of population by y_i. And then we connect those points (x_i, y_i) to construct the Lorenz curve and derive the Gini coefficient. In order to see geographical income concentration, we need to use per unit area income data for each region instead of region population and then apply the same procedure.

We denote A as the area between the Lorenz curve and the line of perfect equality, and also denote B as the trapezoid area between $[x_{i-1}, x_i]$ below the Lorenz curve. Then we can derive the

Gini coefficient G through the following formula[6];

$$G = 2A = 2\left(\frac{1}{2} - \sum_{i=1}^{n} B_i\right) = 1 - \sum_{i=1}^{n}(y_{i-1} + y_i)(x_i - x_{i-1}). \qquad (3)$$

II−3. Other indices of concentration

An index which has been used for measuring an industrial concentration degree is the sum of the market shares of several major firms, or the Herfindahl index. The Herfindahl index is defined as the sum of the squares of the market shares of each individual firm. In a case where we measure geographical concentration, we just set the economic activity share of region i as S_i and define the Herfindahl index by $H = \sum_{i=1}^{n} S_t^2$. If $S_i=1/n$ for all i, $H=1/n$. And if population or activity is concentrated in a specific area, H equals 1. H can take a number between 0 and 1, and the degree of concentration is higher as it is close to 1. Moreover, since there is a relationship between the variance of shares S_i and the Herfindahl index as $\sigma^2 = [H-1/n]/n$, it is possible to measure the concentration degree from the variance of shares. However,, the Herfindahl index or the variance of shares is inferior to the Gini coefficient as an indicator for measuring geographical concentration in the sense that the former does not take into account the difference of the area of each region. It will become a problem if the area of each municipal changes due to municipal integration.

III. Has geographical concentration occurred?

As already mentioned, an agglomeration will not occur until traffic infrastructure investment is below a certain level, and if an agglomeration is easily sustained once achieved, it is hard to detect the effect by using a usual regression analysis. Thus, at first, it is important to observe in the long term whether an agglomeration has actually occurred or not.

The problem is the limited time period for which the data is available. While the prefecture data is available for a long term, those of the municipalities are available only since 1970. As we will see later, the speed of the geographical concentration of population had declined along with the end of the high economic growth. The municipal data is only available for the period after the high economic growth finished. Therefore, the municipal data is not sufficient and we need to use the prefecture data.

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[6] It should be noticed that $x_{i-1}-x_i$ is not constant, since each region's area is not the same. In addition, the order is different for per unit area population and income.
  In economic geography, we often use a locational Gini index. That is for measuring the degree of geographical concentration of a specific industry as compared to the others, through setting cumulative relative frequency of total employment on the horizontal axis and cumulative relative frequency of the specific industry on the vertical axis. The coefficient in this paper is different from that one, as we are taking cumulative relative frequency of area on the horizontal axis.

III.1.   Population (the 47 prefectures)

The prefecture population data is available from 1884 to 2002. Using the data, we calculate the Gini coefficient (Figure 2). It is clear that the geographical concentration of population has been growing consistently since the 1920s, that the trend ceased for a while during the World War II, and that it restarted and continued until the end of the high economic growth in the beginning of the 1970s. After that, it still kept growing but the speed is slower than before. Since the end of the high economic growth and the change of the national land policy of Japan coincided, we cannot identify the actual reason why population concentration occurred—whether due to the declining economic growth rate or due to the decentralization-oriented national land policy.
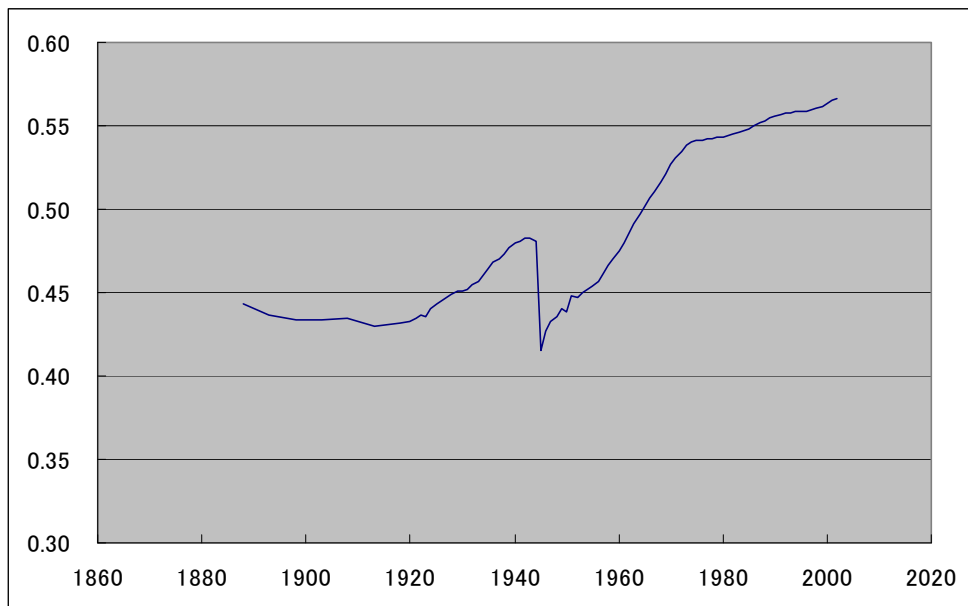
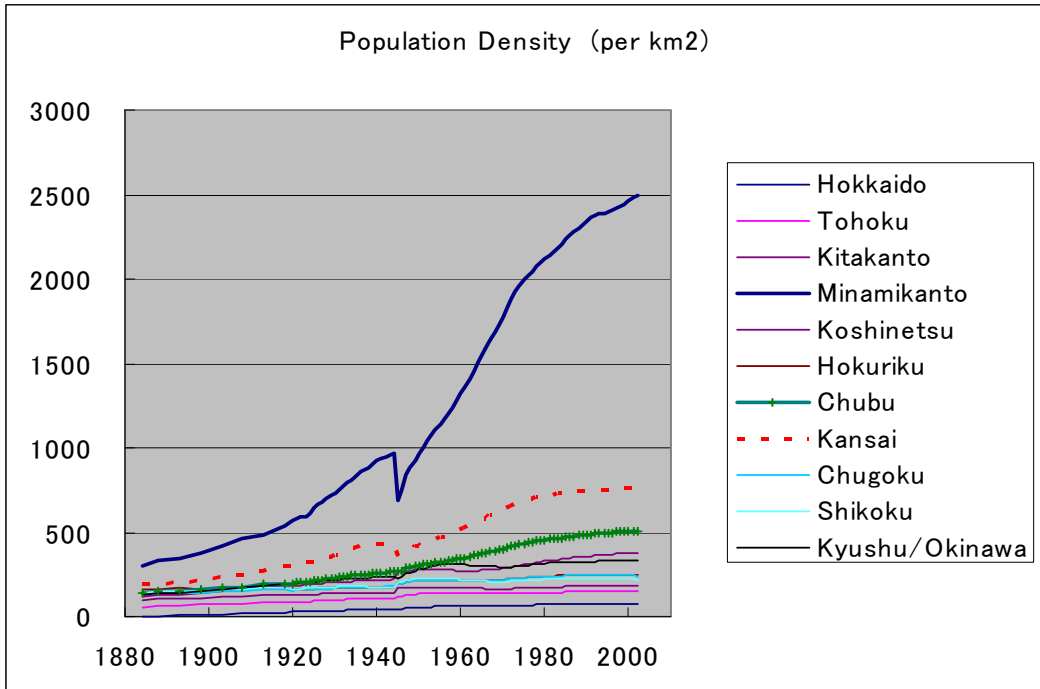**Figure 2.   Gini coefficient of the population**

Figure 3.   Regional population density trends

Population Density (per km2)

Next we will focus on the regional population distribution. Figure 3 shows the historical trends of population density for each region. We include the following 11 regions in the figure: Hokkaido, Tohoku, Kitakanto, Minamikanto, Koshinetsu, Hokuriku, Chubu, Kansai, Chugoku, Shikoku, and Kyushu−Okinawa. From the figure, we can see that the population is concentrated in the Minamikanto region (Tokyo, Chiba, Saitama and Kanagawa).

Examining the prefecture−level data in more detail, we can tell the following facts: Before the WWII, the population had been concentrated in both Tokyo and Osaka, and also in Hokkaido, Aichi and Fukuoka. But after the war, the concentration in Hokkaido and Fukuoka disappeared and we started to see the concentration only in the Minamikanto region containing Tokyo. There is a possibility that the concentration occurred because of the traffic network development and the declining transportation cost by innovation[7]. The Krugman's theory implies that we will have a center for each region if the transportation costs are high[8], but we will have only one center in a country when transportation costs are below a certain level.

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[7]   One reason for the relative decline of Hokkaido and Fukuoka is surely lowering the cost of transportation. During the same period, however, we have experienced the change of the main source of energy from coal to oil and the decline of coal mining areas (Hokkaido and Fukuoka). It is not clear which contributes more to the decline of those regions.

[8]   Focusing only on Kyushu and looking at the trend of population density of each prefecture, we can find the concentration in Fukuoka. But the population share of Fukuoka all around the country has not changed.

## III.2.   Economic Activity (the 47 prefectures)

Figure 4 shows the Gini coefficients for gross prefecture domestic product, private final consumption expenditure, gross prefecture domestic fixed capital formation, amount of manufactured product, added-value in manufacturing industry and price of residential lands (prefecture land price research)[9]. From the differences between those Gini coefficients, it is clear that, as compared to the Gini coefficient for population, the coefficient for consumption (private final consumption expenditure) is higher and that for income (gross prefecture domestic product) is much higher. Moreover, the Gini coefficient for added-value in the manufacturing industry and amount of manufactured product are higher than that for income. From these facts we can tell that geographical concentration of manufacturing industry is heavier than that of income.

Regarding the change of those Gini coefficients, while the one for population has been monotonically increasing, those for consumption and income have not shown that trend.
For land price, the coefficient fluctuates a lot, which soared up around the "bubble" period and has been decreasing after that. The coefficient for investment (gross prefecture domestic fixed capital formation) also fluctuates as much as that for land price. The coefficients for added-value in manufacturing industry and amount of manufactured product have been decreasing since 1975. These are consistent with the results of Yamaguchi (2003) showing that the "locational Gini index" for each industry has been decreasing from the data since 1975. But it is not correct to conclude from the result that the agglomeration degree has been decreasing. As is seen above, the coefficient for population has been going up consistently. Moreover, it is unfortunate that we missed the timing for which something changed.

It can be considered that the reason for decreasing Gini coefficients for added-value in manufacturing industry and amount of manufactured product is high land price in the urban areas. It means that manufacturing has moved from urban areas, where land price is high, to rural areas. Another possible reason is that we have laws to restrict new construction of big factories in the areas of Tokyo and Osaka.

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[9] For gross prefecture domestic product, private final consumption expenditure, and gross prefecture domestic fixed capital formation, the data for New SNA is only available after 1990. In our calculation, we used both Old SNA (1975-1998) and New SNA (1990-2000).

Figure 4.   Gini coefficient of the prefecture data
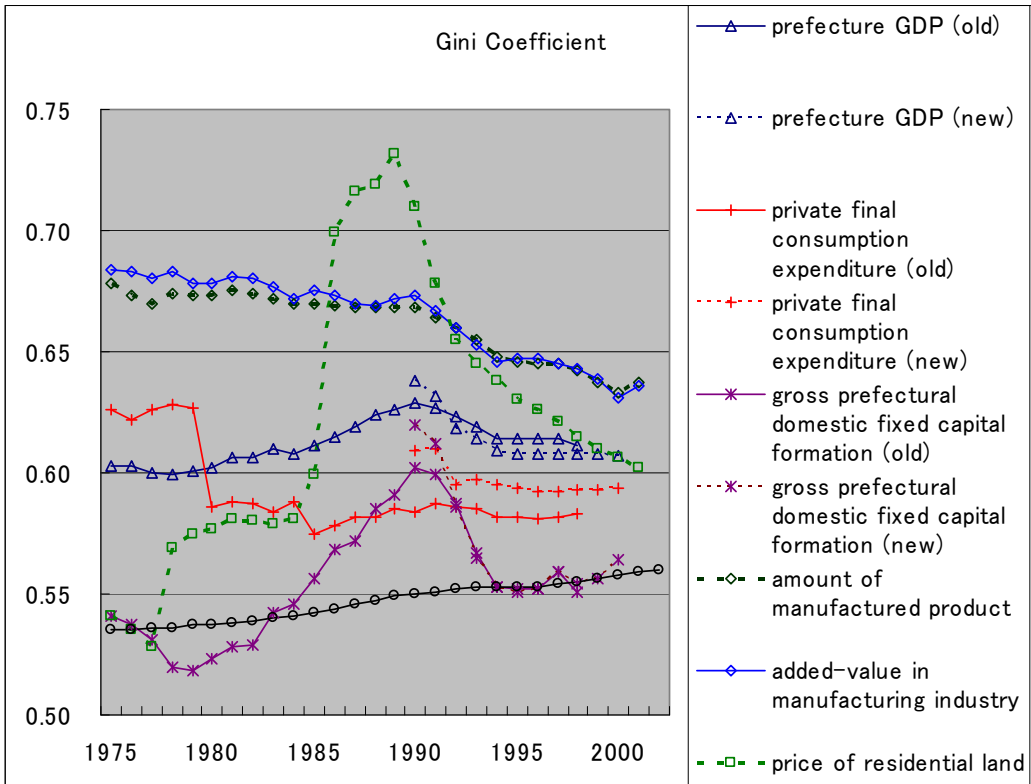
We calculated the market potential function from the same prefecture data. Figure 5 compares the value of the market potential function with the original data of gross prefecture domestic product in 2000. The market potential levels of Tokyo and Osaka area are very high. Taking the difference from the original data, the value is high in suburban areas. Namely, it is high in Shiga, Nara, Kyoto and Wakayama in Kansai (Osaka area) and Chiba and Saitama in Minamikanto (Tokyo area). The value is also high in Shikoku and Hokuriku, and that of Saga is high in Kyushu prefectures. On the other hand, the value of Hokkaido is lower than the original data, and those of Aichi and Fukuoka are not so different from the original data. Thus, the market potential function is an indicator which emphasizes benefits from agglomeration in Tokyo and Osaka areas[10].

Table 1 shows the results of a regression of growth rates on the initial data for population, income and so on. We take both original data and those market potential of the variable. For

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[10] We only focus on the domestic market but do not consider the distance to the surrounding countries such as China for the market potential in this study. As related to this, the market potential of prefectures facing the sea can be downward biased. But if a region facing to the sea has a big port, the travel time to the other regions is short. This face can be considered as the reason that the market potentials of Aichi, Fukuoka, and Hokkaido are low.

population, the larger the initial population is, the higher the growth rate is. There is no significant relationship for income and consumption, and negative relationship for added-value in manufacturing industry and amount of manufactured product. This result is the same as the one in Figure 4. For market potential, we did regressions for population and income, and both are positively significant. This result might have arisen because hardly even a small change has occurred since the market potential is affected by the economic activity of surrounding regions and calculated by using distances to other prefectures.

Figure 5. Gross prefecture domestic product (2000): original data and market potential
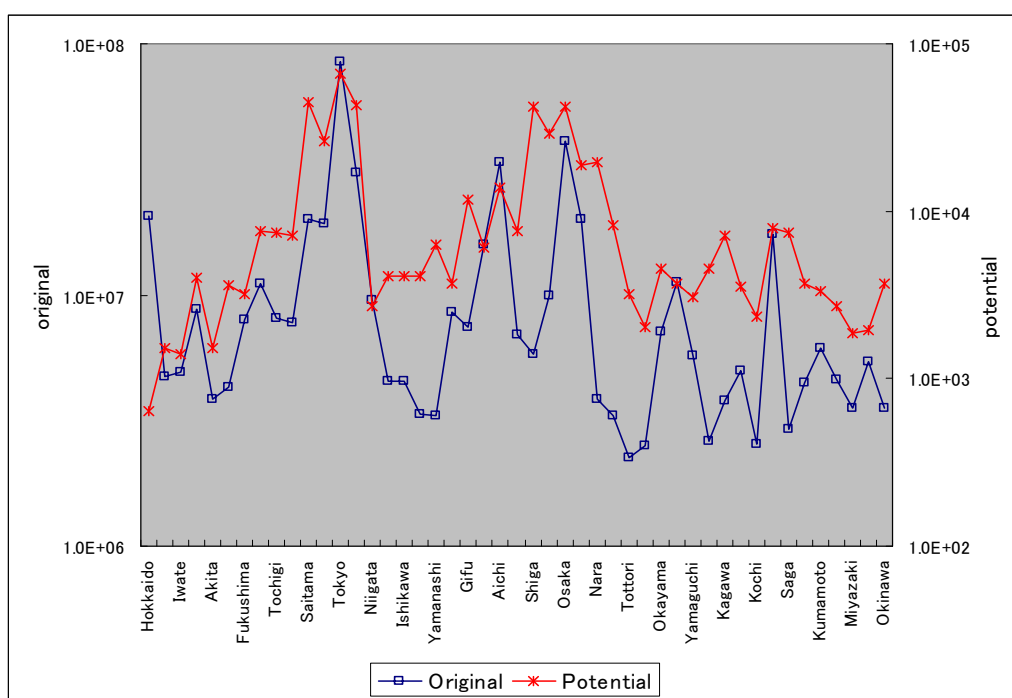

Table 1.   Result of Barro-type regression analysis[11]

|	Coefficient	S.E.	t-value	R^2
Population	0.049	0.021	2.33	0.108
Income	−0.002	0.022	−0.09	0.000
Consumption	−0.452	2.069	−0.22	0.011
Added-value	−0.116	0.038	−3.03	0.169
Product	−0.129	0.042	−3.06	0.173
Potential (pop)	0.030	0.007	4.13	0.275
Potential (inc)	0.027	0.007	4.00	0.262

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[11] The model is $\Delta \ln x = a + b * \ln x_0$ where x_0 is the initial value of x. We omit the result of the constant.

III.3.   The trend of population concentration, GDP, and transportation

We have already seen in III-1 that the Gini coefficient for population dramatically increased since about 1920 from the long-term time series population data. As already mentioned above, according to the Krugman's model, geographical concentration of population will occur if transportation cost declines or if income level rises beyond a certain level. Since it is hard to test this model with using a tool of econometrics for the non linearity, we will see long-term trends of transportation cost and income. Since transportation cost data is not available, we will use the transported cargo amount instead.

First, we will use the newer data from many types of the available national income data, and Figure 6 shows the result of the real GDP trend plotted in this way[12]. The logarithm is taken for the vertical axis. From the figure, the growth rate is different for (1) before the last war, (2) after the war until 1973 when the high economic growth finished and (3) after 1974. The annual growth rate was 2.8% before the war, 8.7% after the war until 1973, and 2.7% from 1974 to 2000.

Figure 6. Real GDP

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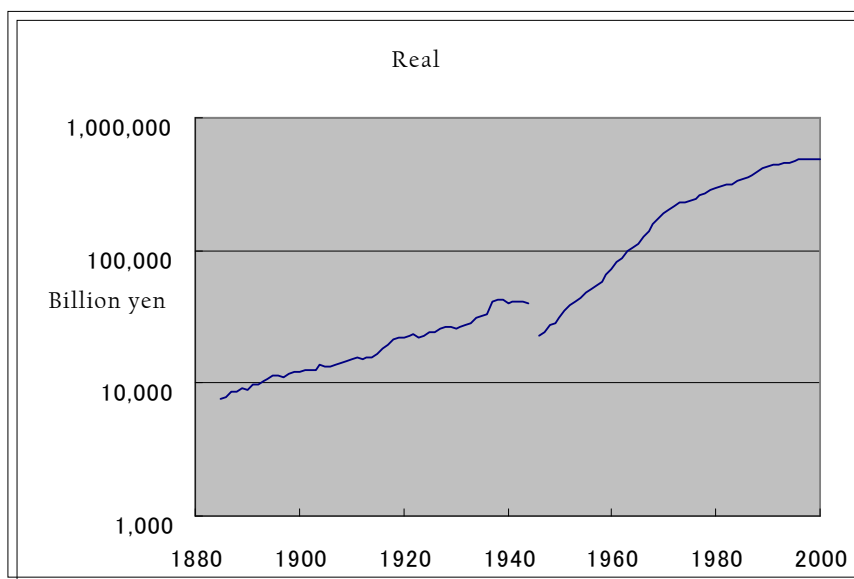
[12] The following data is available: Ohkawa-Takamatsu-Yamamoto estimation for gross national income from 1885 to 1940 (real, in the price of 1934-36), real GDP of Old National Income Statistics (in the price of 1934-36 for 1930-1951, and in that the price of 1970 for 1952-76) from 1930 to 1976, and real GDP of 68SNA (in the price of 1990) from 1955 to 2000. We simply connected these real GDP sequences. We used the newer one in the case where two sequences are available. For sequences for the price years are different, we simply took the ratio of those sequences and connected based on the ratio.

Second, let us check the trend of domestic freight transportation amount. Figure 7 shows the trend of domestic freight transportation amount (ton-kilo) divided by GDP[13]. For the freight transportation, it has been declining consistently since the last war (while the absolute amount has increased). The declining cost is likely to cause an increase of the transportation amount, but this opposite result occurred probably due to production efficiency. We can also consider the following reasons; (1) for the decline of heavy industries (2) for the shift in importance from freight transportation to information and communication, it is no longer appropriate to use freight amount as transportation amount (3) for the agglomeration having occurred (4) for the change in trade importance from domestic to foreign. However, we cannot explain the declining trend since WWII by either (1) or (2). Moreover, it should be noted that the relative decline of railway transportation and the decline of the ratio of total domestic freight transportation amount to GDP during the same period. The main transportation method had been shipping before the war, then by railroad after that, and then has been road transportation since the 1960s. Since the change of transportation cost is closely related to the change of technology, it is hard to calculate a proper indicator reflecting the transportation cost. One way to deal with the problem is to analyze by only using the main transportation for each period. If we use that method, however, it is getting hard to see the long-term relationship between transportation cost and agglomeration.

**Figure 7.   Amount of Domestic freight transportation/GDP**

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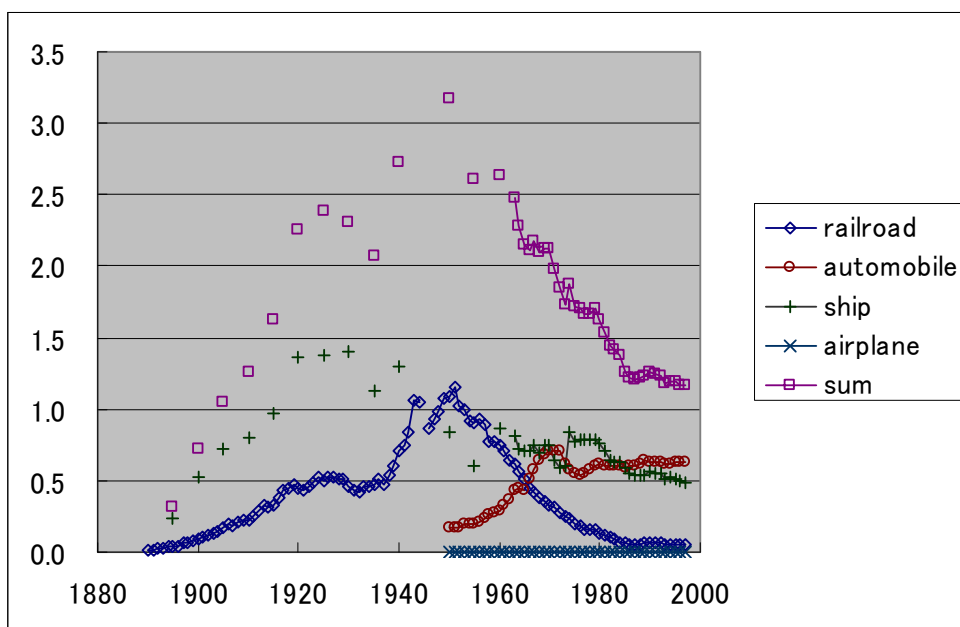
[13] We could observe almost the same trends in the amount of passenger transportation as Figure 7.

III.4.   *Municipal data in Kyushu island*

Using the municipal data of Kyushu (except Okinawa), we computed the Gini coefficients for population and taxable income. The population data starts from 1970, and the taxable income data from 1975. Figure 8 shows the result. First, it is clear that the Gini coefficients for income are higher than those for population. This result was also seen in the prefecture data. Second, focusing on the trends, we can see the Gini coefficient for population has been increasing consistently while that for taxable income has hardly changed. This means that geographical concentration of population has occurred but that of income has not.

Figure 8.   Gini coefficient: Kyushu municipal data
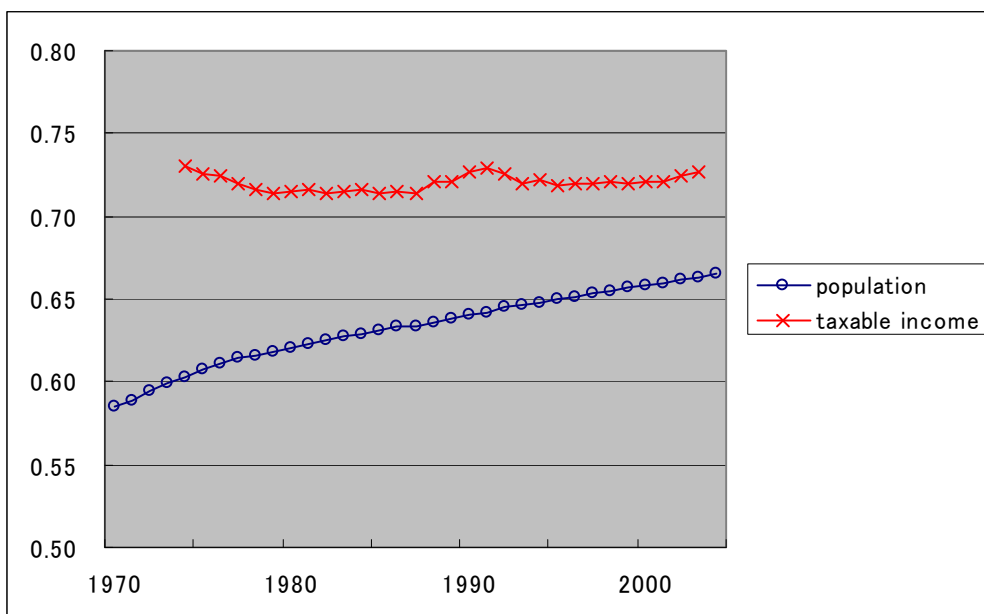
Why does it look as if population is getting more concentrated geographically but income is not? Looking at the distribution of per capita taxable income, we can tell that per capita income dispersion has been getting smaller over time. Dealing with per capita taxable income (logarithm) of each municipal as an observation and computing the coefficient of variation, we get the results that it is 0.14 in 1974, 0.10 in 1978 and below 0.05 recently[14]. Therefore, the income dispersion between municipals has been getting rapidly smaller. It is not clear yet what has made the income dispersion smaller. But the reason why we have not experienced

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[14] We calculated the number for 1974 to 2003. The decline of the coefficient of variation ceased in the end of 1980s temporarily, but from the beginning of 1990s it resumed declining. However, we cannot find the declining trend from the recent data (2000−03).

geographical concentration of income is that the per capita income dispersion has been getting smaller while the geographical concentration of population has occurred (which contributed for geographical concentration of income)[15].

III.5.   *Relationship to highway development: an analysis with GIS*[16]

Next, we will check the agglomeration degree in Kyushu through showing the current situation of municipal population and taxable income on map. Since our interest is in the relationship to social overhead capital investment, especially to highway development, let us see the history of highway development in Kyushu. The highway network we have now in Kyushu is cross-shaped; we have two highways crossing at Tosu, the one runs north–south from Kitakyushu and Fukuoka to Kagoshima, through Kumamoto (Kyushu Jukan Highway), and the other runs west–east from Nagasaki to Oita (Kyushu Odan Highway). We are planning to construct East Kyushu Highway, West Kyushu Highway, South Kyushu West-Side Highway, and Kyushu Odan Highway (Nobeoka line), and if all of them are constructed we will have a highway network.

We will briefly summarize the history of highway development in Kyushu roughly: The highway between Kitakyushu and Yatsushiro had opened by 1980, and the one between Nagasaki and Tosu had opened by 1990, which had connected Kyushu Odan Highway and Kyushu Jukan Highway. Moreover, the highway from Hitoyoshi to Ebino had opened by 1995, with which Jukan Highway was completed, and Odan Highway opened in 1996, when both north–south and west–east highways were completed. Hence, the important years for highway development are around 1980, 1990, and 1995–96.

From Figure 9 to 12 show that total income (total taxable income), population density, (residential) land price, and the market potential of population on map[17]. From these figures, economic activities in Kyushu are concentrated into the area from northern part of Kyushu to Kumamoto (which coincides to Kyushu Jukan Highway) and the area from Nagasaki and Saga to Oita through Tosu (which almost coincides to Kyushu Odan Highway). We can also see that the taxable income and the market potential of population are slightly higher in the southern area from Kagoshima to Miyazaki than in the neighboring area (but recently it is getting lower). From the point, we can see that there is a reason for the plan of highway network in Kyushu.

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[15] The decreasing gap of per capita income between municipalities should be owing much to labor migration. The following facts can be also considered as the reason: Most farmers and the self-employed became employees for the change of the industry structure; lowering the transportation cost enlarged the labor market geographically, which possibly lessened the interregional wage gap; the residential areas from which people can commute grew larger.

[16] We used Kenji Tani's software MANDARA (http://www5c.biglobe.ne.jp/~mandara/) for making the following maps.

[17] For calculating the market potential, we only considered the municipalities in Kyushu. Although Kitakyushu city is adjacent to Shimonoseki city in Honshu island, we consider as if it were an isolated northern city in Kyushu.

Figure 9. Total taxable income (2000)   Figure 10. Municipal population density（log, 2004）
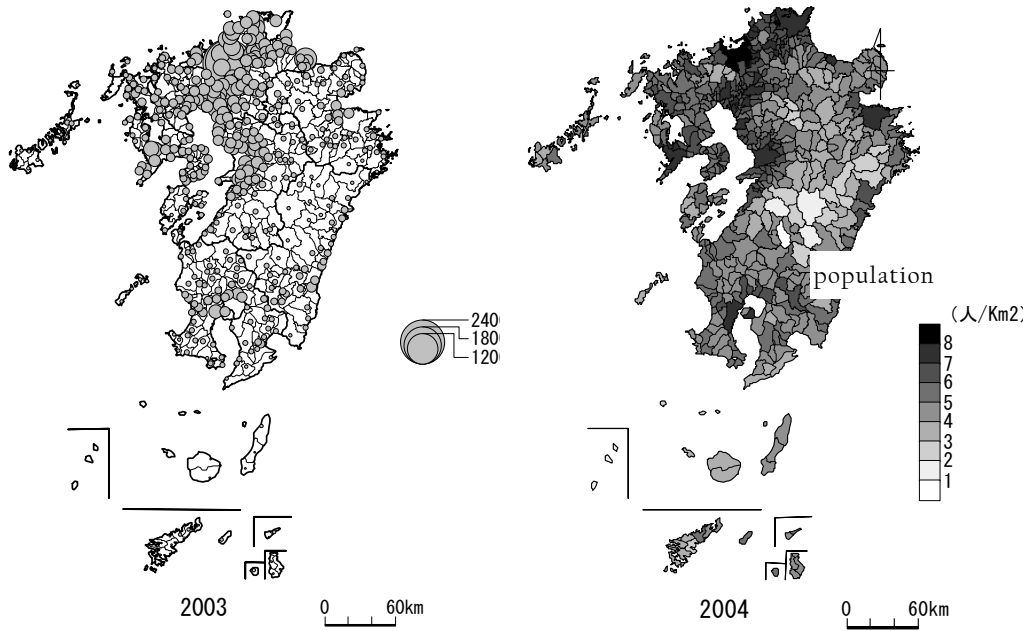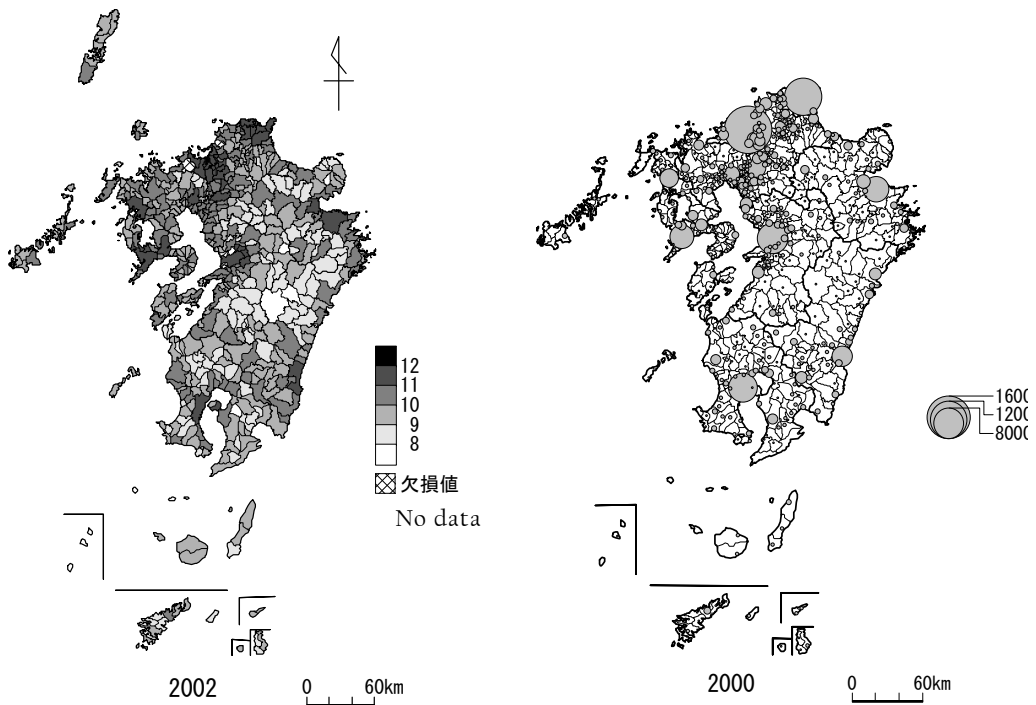

Figure 11. Residential Land price (log, 2002)   Figure 12. Population market potential (2003)

Then how are the relationships between the highway development trend and the population, income, and land price? As already mentioned above, Kyushu Jukan Highway developed during the 1980s and Jukan Highway and Odan Highway were completely opened in 1995 and 1996, respectively. The relationship to land price and population of an area near highway at this period was drawn and checked, but no clear relationship was found.

IV.   Conclusion

According to the recent theory of economic geography, there is non linearity in the effect of decline in transportation cost on agglomeration. If the model is true, it is hard to test the effect with using a common linear regression analysis. Hence, we tried to test whether agglomeration has actually occurred or not by using long-term data. Checking on the geographical concentration of population from prefecture data, we confirmed that the concentration has been occurring since before the last war, and that the speed of concentration slowed down after the high economic growth. However, in those periods we not only had the decrease of economic growth but also had many things changed such as the change in national land policy (to larger weight on region) and the change from railway transportation to road transportation. Thus, it is not clear why the speed of concentration has slowed down.

Focusing on the geographical concentration of population, we found that concentration to Tokyo has been occurring from a countrywide point of view, and that concentration to Fukuoka (more exactly, north-west region of Kyushu) from a viewpoint of Kyushu. The relationship between transportation infrastructure development and agglomeration is not clear in this analysis with municipal-level data of Kyushu, as well as in the analysis with using the prefecture-level data. But since it looks as if the market potential of population has been declining relatively in the area from Kagoshima to Miyazaki, it is possible that future infrastructure investment will induce more agglomeration to north-west region of Kyushu.

Provided that economies of agglomeration are big enough, the effect of geographical concentration on people's welfare will be positive. In the real world, however, we need to consider that (1) the transportation cost is not ignorable, (2) some people have cheap transportation costs and others have expensive costs, and the ones whose cost is expensive cannot move and suffer the loss, (3) there is congestion cost for agglomeration. With regard to (2), those people whose transportation cost is expensive are generally elderly or shop managers, who cannot easily attract their customers in another place. It should be noticed that these kinds of people may suffer from the decline of cities. Moreover, regional road construction is usually considered for "regional activation" or for attaining regional benefit, and most politicians from regional area are trying to get budgets for that. If Krugman's model is true, however, such behavior from politician's behavior may allow regional cities to decline and lose their own benefits (if the transportation cost of the residents is low, their benefits will be increased).

Lastly, we will see the remaining issues of this study. First, from the prefecture data, geographical concentration of population was clearly shown, but it was not clear for production activity. Since geographical concentration of industry was also not found in the preceding studies which checked on data for each industry, we may need to conduct research using a longer period for data starting before 1970. Second, since the length of the data length is also insufficient, we could not find a clear result from the municipal data (population is an exception). For this, we also need to have the same kind of analysis by using the number of each industry's workers and so on. Third, since we need   data for the distance between two points for measuring the market potentials, we used the method to calculate the geographical distance automatically. But it is natural that travel time should be better for the indicator than geographical distance. If we use travel time, we need to restrict the number of the cities we use in the analysis or to devise how to measure the time. For example, assuming some middle-sized cities, we measure the travel time between them. Then we measure the travel time to the nearest middle-sized city for the rest of the smaller cities. From this information, we can measure the travel time between arbitrary two cities. As we have seen in section III, considering the geographical distribution of land price, population and income, we can imagine that some middle-sized cities are important and it is useful to analyze from the viewpoint of how highway investment serves to make the travel time shorter. And from this viewpoint, we can apply the gravity equation, calculate the market potential, and compare the two numbers before and after the adjustment. In addition, considering the Krugman's discussion, we have to analyze how it affects the firm's decision making about location and the people's decision making about moving. For the analysis we might need to investigate the agglomeration degree of economic activity for each industry. These are issues that remain.

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Appendix: Calculation of market potential function

We need the data of distance between two arbitrary points for measuring a gravity equation or a market potential function. Since we need n(n-1)/2 distance data if there are n points, the amount of data we need will be increasing dramatically as n increases. It is actually impossible to obtain this data by manual calculation, so we use a programming to compute the distance between two points from geographical information (longitude and latitude) of prefectures or municipalities for obtaining such data. Here is the method we used:

First, we assume that the earth is a perfect sphere with the radius R. We take the point such that both of the latitude and the longitude are 0 as a reference point A. Taking the center of the earth as the origin O, we consider the three-dimensional coordinate system in which x-axis is line OA, y-axis the line from O to the point of 90 degrees east longitude on the equator, and z-axis the line from O to the north polar. If the longitude and the latitude of a point B are α and β, the address of B is represented as ($R \cos \beta \cos \alpha$, $R \cos\beta \sin \alpha$, $R \sin \beta$). From this fact, for two arbitrary points B_1 and B_2 we can compute the angle of two lines OB_1 and OB_2. If the longitude and the latitude of B_1 and B_2 are (α_1, β_1) and (α_2, β_2) respectively, the angle θ between two lines OB_1 and OB_2 is calculated with using the inner product formula by the following equation:

$$\theta = \cos^{-1}\left[\cos \beta_1 \cos \beta_2 \cos(\alpha_1 - \alpha_2) + \sin \beta_1 \sin \beta_2\right].$$

From this θ, it is possible to calculate the distance d between B_1 and B_2 (the distance on the Earth's surface, the length of arc B_1B_2) as $R\theta$.

For the geographical data of municipalities, we used ``Zenkoku todofuken shichoson ido keido ichi (countrywide prefecture and municipality longitude and latitude) data base for GPS (Ver.2.20)" (Takashi Takeda, http://www.asahi-net.or.jp/~xj6t-tkd/index.html, Copyright© Takeda Takashi 2000-2002). The data is CSV data of municipality longitude and latitude in

fiscal year 2002. As matching the variables representing the municipality population, area, and other economic activity with these data, we computed the market potential function.

While the market potential function is given by equation (2), if we apply this formula without any adjustment, the market potential of a municipality locating next to a big city can be big and that of the big city itself can be small. This especially true in a case when we use "coarse" regional data such as prefecture data. In order to avoid this, one solution is to redefine a market potential with including the economic scale of a big city itself. One possible way is that assuming that each city lies roundly, deriving the radius from the city area, and assuming that economic activity is concentrated only at the points a certain distance apart from the center. However, we still found there was a problem with this method. If we actually apply this method to prefecture-level data for calculating potential, those of Kyoto and Shiga are very large. The reason is as follows: For prefecture-level data, we used the city in which its central office exists as the place of prefecture to calculate the distance between two points, but the distance between Kyoto-city and Otsu-city (the city with its central office of Kyoto and Shiga, respectively) is only 9 kilometers. The areas of the prefectures are 4612 square kilometers and 4016 square kilometers and their radiuses are 38 and 36 kilometers, respectively, which means that the distance between two cities is smaller than the radiuses. For this reason, we calculate distance in this paper with assuming, although arbitrarily, that economic activity is concentrated in the area such that radius divided by $\sqrt{2}$ apart from the center. In other words, when we express the distance between i and j as $d_{i,j}$, we use $d_{i,i} = \sqrt{S_t/(2\pi)}$ to calculate the market potential function $V_i = \sum_j kY_j / d_{i,j}^2$.