EX-POST ANALYSIS OF EXPRESSWAY DEVELOPMENT IN JAPAN

AN EMPIRICAL APPROACH USING A PANEL DATA ANALYSIS

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ABSTRACT

It is commonly assumed that investments in road networks have economic and social effects. Some of the effects are positive, such as increasing productivity and inducing regional development, but some are negative, such as inducing the outflow of consumption from smaller cities and rural areas to larger cities. Although several examples of these phenomena have been reported in Japan, most have not been objectively studied at the regional scale. We used a fixed-effect model and panel data to clarify the positive and negative social effects of existing expressway development in Japan. Although fixed-effect models were originally used for the macroeconomy, we used one to examine the relationship between regional socio-economic factors (population and labor productivity) and expressway development in two case studies, one of Japan as a whole and the other for the Chugoku area. Accessibility has improved with expressway development in Japan as a whole, but some regions have experienced population decreases. Labor productivity was positively correlated with expressway development in some industrial zones during the period of economic expansion (1971–2001), but in the period of economic contraction (2001–2006) the correlations between road investment and labor productivity change were not statistically significant. In the case study of the Chugoku area, the advantage and disadvantage of expressway development were clear. The advantage was an increase in industrial activity through increased labor productivity, but the disadvantage was a population shift from small cities and rural areas to larger metropolitan areas. (This is known as the "Straw Effect" in Japan.)

1. INTRODUCTION

The assumption that investment in road networks has economic and social effects is very important in decision making for expressway development. Some of the effects are positive, such as increasing productivity and inducing regional development, but some are negative, such as inducing the outflow of consumption from smaller, local cities to larger cities. Although several examples of these phenomena have been reported in Japan, most have not been studied objectively at the regional scale.

Fuji (2006) described the social advantages and disadvantages of development of the expressway network. Advantages include increased convenience in a region, improved regional industrial economic activity, and improved national infrastructure. Disadvantages include a shift in commerce and industry from smaller cities to larger metropolitan areas, a decline in local production for local consumption, and a decline in what Fuji calls people's "richness of mind and climate". Fuji also claimed that the social advantages, which can spread through several regions, are short term, but the social disadvantage tend to have long-term effects on local residents, businesses, and industry.

These phenomena, however, have not been studied in practical terms. Existing ex-post evaluations of road development have generally applied a macroeconomic approach (e.g., Nakazato). In this type of analysis, the relationship between the gross volume of expressway

development and gross domestic product (GDP) or GDP growth rate are examined. It is impossible to analyze regional spatial effects by this approach. Japan, however, has panel data (time series and spatial statistical information) for socio-economic and transportation factors. Using these panel data, it is possible to analyze the spatial influence of road network development.

In this paper, the fixed-effect model and panel data are used to clarify the positive and negative social effects of existing expressway development in Japan. The fixed-effect model is constructed by formulating a correlation between expressway development (change of accessibility) and regional economic change (population and labor productivity).

2. INFRASTRUCTURE STOCK AND ECONOMIC GROWTH

Many researchers have discussed the appropriate level of public investment. In this discussion, it is important to consider that public investment policies affect not only short-term demand but also productivity and economic growth.

Many studies of infrastructure productivity have been conducted (e.g., Aschauer 1989). Researchers have estimated the production function including infrastructure stock as a production factor by using time-series and regional data as macro data and have determined whether or not infrastructure development has significant effects on activity of production. To measure the influence of infrastructure from the supply side, however, the influence of infrastructure on economic growth should be directly assessed (Canning et al. 1994; Easterly and Levine 1997; et al.) This type of analysis generally has not been conducted in Japan. Furthermore, Barro and Sala-i-Matin (1992) reported that the influence of accessibility improvement by infrastructure development has marginally decreased recently.

3. FIXED-EFFECT MODEL

The works of Maddala (1993) and Matyas and Sevestre (1996) are typical examples of studies in which a fixed-effect model is employed. However, this type of model has rarely been applied to public investment in Japan. The model can consider the difference among individuals in the specimen as a difference in the parameters of a regression function. This means that a fixed-effect model can estimate the effect of each specimen individually. Therefore, in this study, we use a fixed-effect model and panel data of regional economic conditions to analyze correlations between changes in road network accessibility by expressway development, as shown in Eq. (1).

$$ln\, y_{it} = \alpha + \left(f_0 + f_1 F_1 + \cdots f_p F_p\right) ln\, ACC_{it} + d_1 D_1 + \cdots d_p D_p + \gamma M_t \quad , \qquad (1)$$

where y is the dependent variable (either population or labor productivity), ACC is the explanatory variable, a, f, d, r are parameters, $D, F = 0 or 1$ are dummy variables, M is a macroeconomic variable, $i \in \{1,2,\cdots,p\}$ is the region, and t is the evaluation period.

The macroeconomic variable M is excludes the macroeconomics trend of the whole Japan. For example, we input total population in Japan when we analyzed about population.

Expressway development is formulated by change in the accessibility index, which is stated in Eq. (2).

$$Acc_i = \sum_j \exp(-t_{ij}) w_j \ , \qquad (2)$$

Where ACC_i is the accessibility function, t_{ij} is traffic time between regions i and j, and w_j is regional economic data (population of region j).

The traffic time is calculated by using Dijkstra algorism with the traffic speed in congestion time in road traffic census in Japan.

4. CASE STUDY OF WHOLE JAPAN

4.1 Regional Conditions, Scenario Settings, and Data Requirements

In this case study, we analyzed the correlation between expressway development and regional economic conditions for all of Japan (1,539 municipalities), excluding the Hokkaido area (see Fig. 1). Municipality level is the smallest zone in the statistical data.

The indexes of regional economic conditions were population and labor productivity. Statistical data from four years during the period of rapid economic expansion from 1971 to 2001 (1971, 1981, 1991, and 2001) and four years during the economic contraction from 2001 to 2006 (2001, 2002, 2004, and 2006) were used (Table 1). Table 2 lists the data requirements for each scenario.

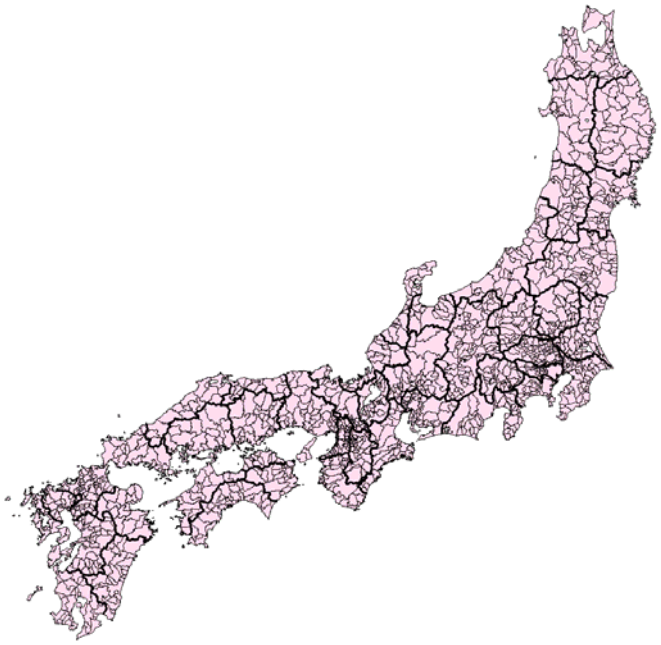


Figure 1 – Regional Conditions in the Study Area

Table 1 – Scenario Settings

Scenario	Index	Network	Time period[a]
1-1	Expressway development and population change	Expressway	About 30 years during 1971 to 2001 " economic expanding period"
1-2	Expressway development and population change	Expressway	About 6 years during 2001 to 2006 "economic shrinking period"
2-1	Expressway development and labor productivity change	Expressway	About 30 years during 1971 to 2001 " economic expanding period"
2-2	Expressway development and labor productivity change	Expressway	About 6 years during 2001 to 2006 "economic shrinking period"

[a] For 1971–2001, four annual values were used: 1971, 1981, 1991, and 2001. For 2001–2006, data from 2001, 2002, 2004, and 2006 were used.

Table 2 – Data Requirements

Scenario	Dependent variable	Explanatory variable	Macroeconomic variable	Evaluation period	Data Source
	y	x	M	t	
1-1	Population of each region	Accessibility by population	Total population of Japan	1971, 1981, 1991, 2001	Statistic data of Population Census in Japan
1-2	Population of each region	Accessibility by population	Total population of Japan	2001, 2002, 2004, 2006	
2-1	Labor productivity of each region	Accessibility by labor productivity	Average labor productivity in Japan	1971, 1981, 1991, 2001	Statistic data of Industrial Census in Japan
2-2	Labor productivity of each region	Accessibility by labor productivity	Average labor productivity in Japan	2001, 2002, 2004, 2006	

4.2 Accessibility Index

Calculating the transport time among all of the municipalities in Japan is quite difficult because of the huge data-processing and calculation requirements. We therefore subdivided Japan into eight regions and calculated the travel times between all municipalities in each region. Travel times between prefectural capital cities were used for travel times between the eight areas. Travel to islands was excluded, as was within-municipality transportation. The regions are shown in Fig. 2.

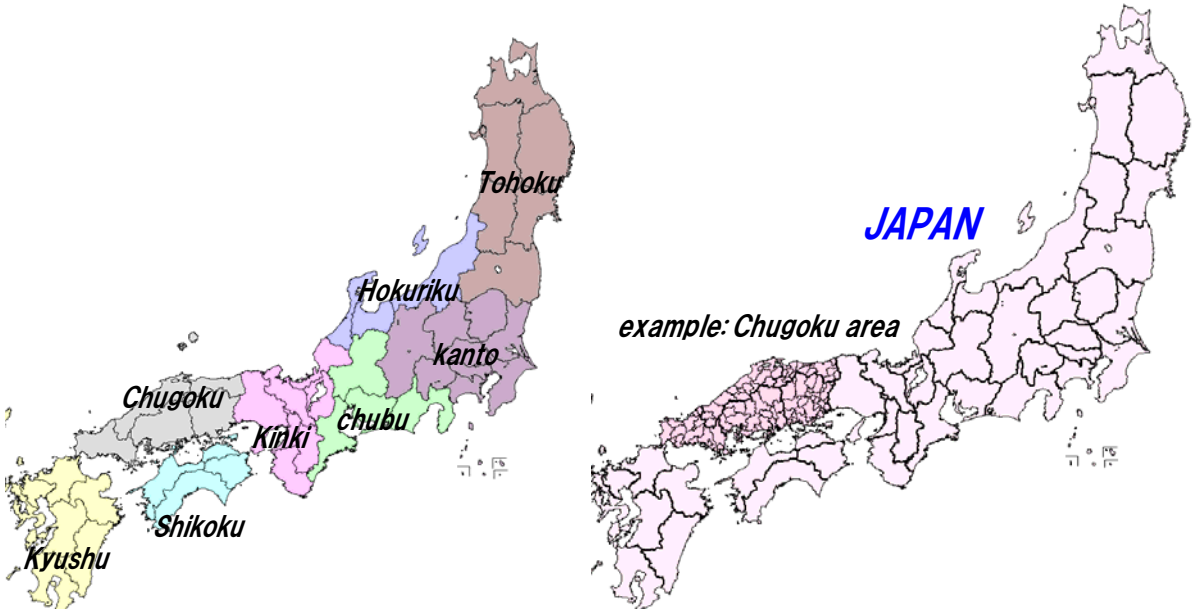
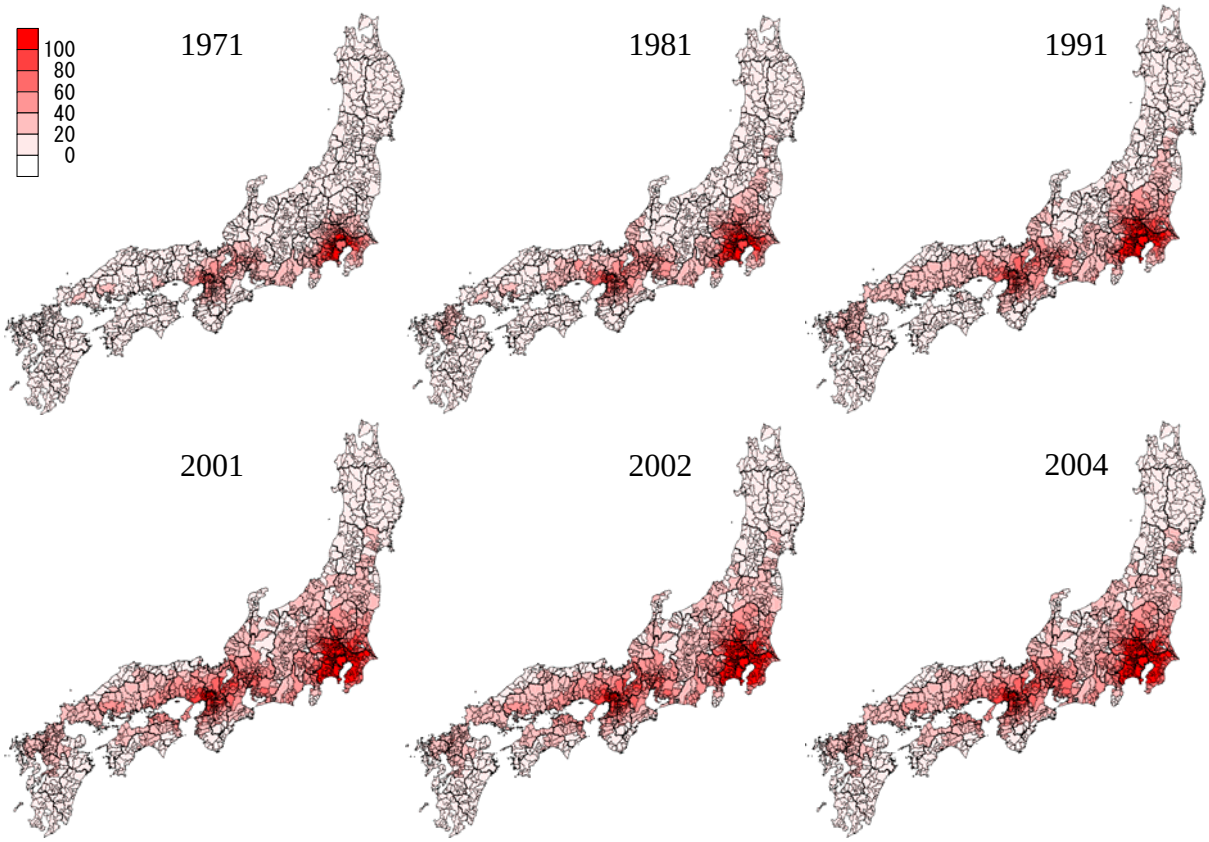


Figure 2 – Accessibility Index Regions

Figure 3 shows the results of calculations of the accessibility index with the population data for each municipality. The accessibility index increased from 1971 to 2007 (including the rapid expansion period) in regions with large economic scale, such as Tokyo and Osaka, but accessibility did not expand as rapidly in both urban and rural areas between 2001 and 2006 (in the period of contraction).



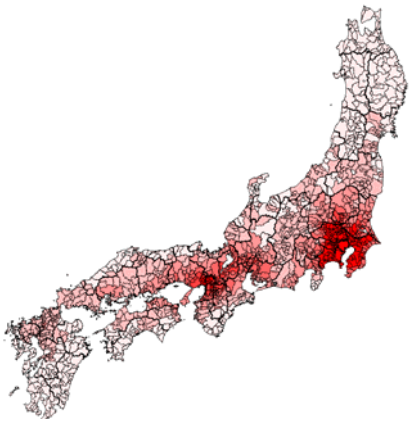
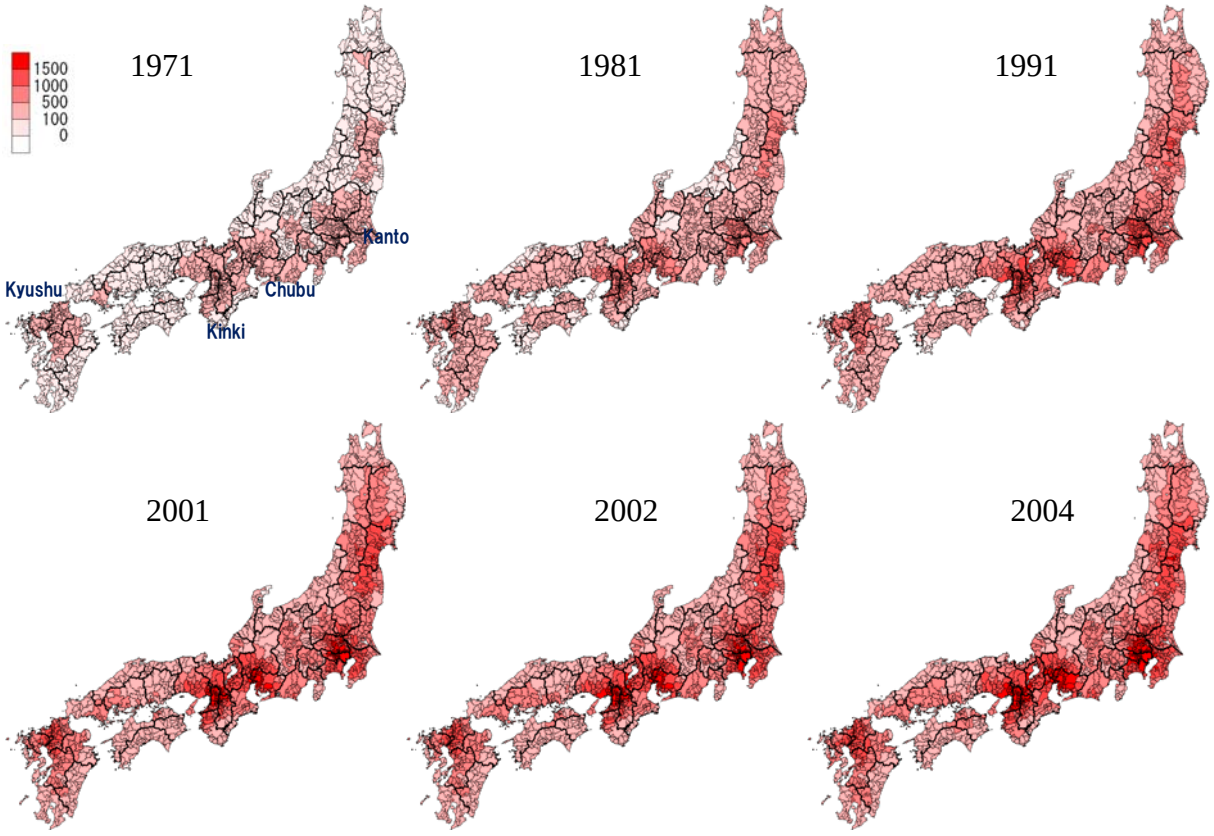


Figure 3 – Change of Accessibility Index with Population

Figure 4 shows the results of calculations of the accessibility index with labor productivity data for each municipality. The index increased in industrial regions, such as Kanto, Chubu, Kinki, and the northern Kyusyu area, from 1971 to 2007. The accessibility index did not expand as rapidly in both urban and rural areas between 2001 and 2006.



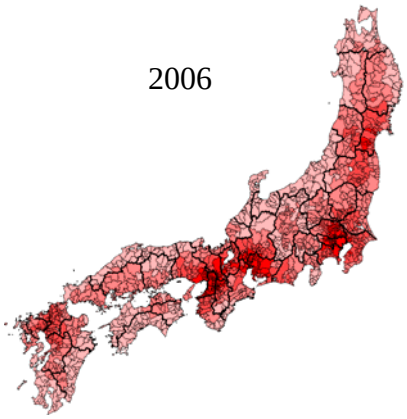
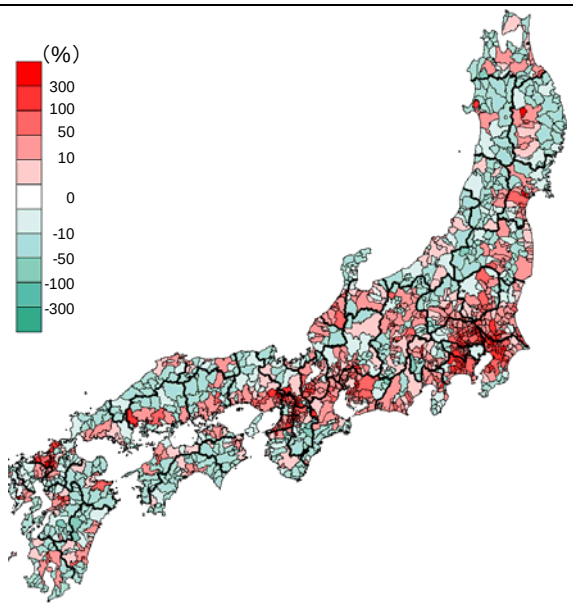
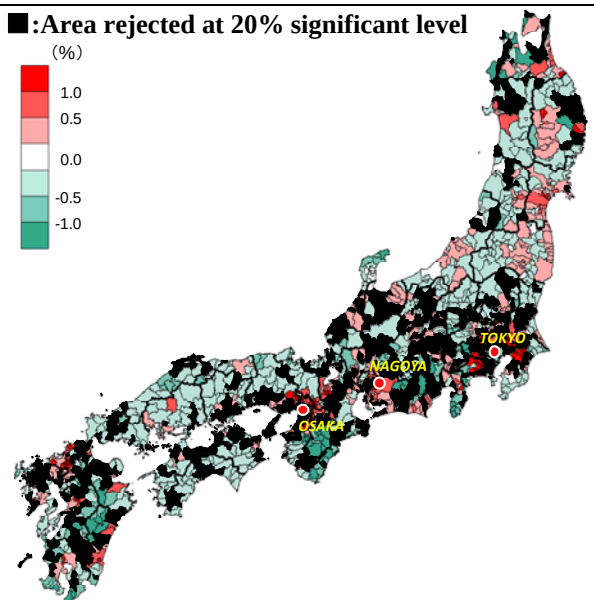


Figure 4 – Change of Accessibility Index with Labor Productivity

4.3 Expressway Development and Population Change

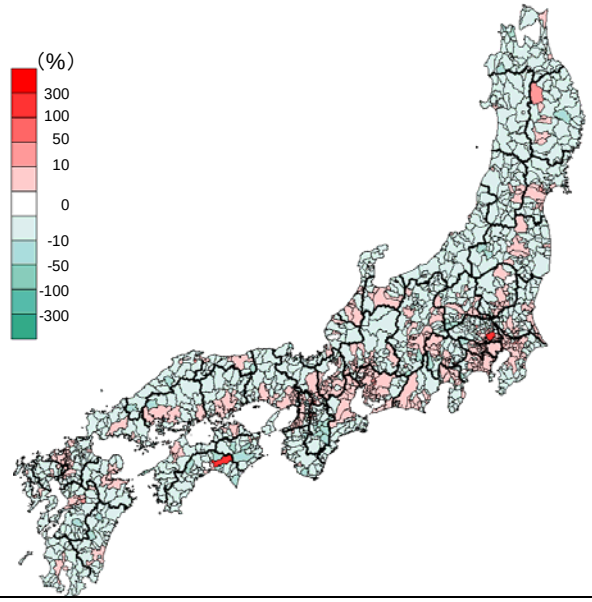
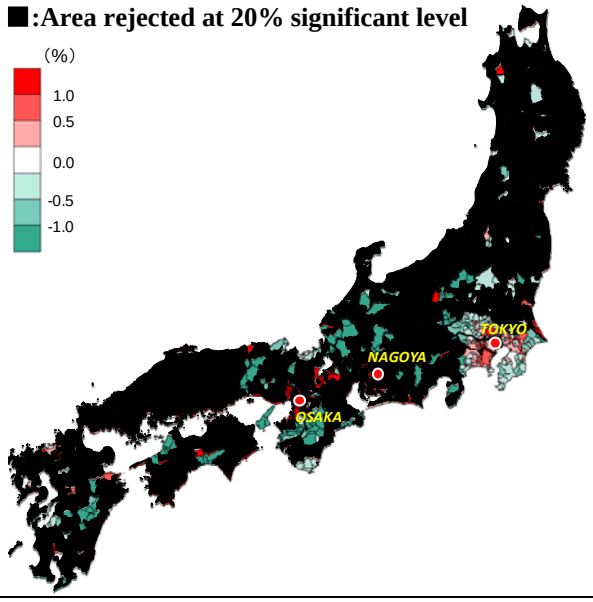
The percentage population change between 1971 and 2001 increased rapidly in Tokyo, Osaka, and other prefectural capital cities, but the population in rural areas decreased (Table 3). The percentage population change in response to expressway development increased between 1971 and 2001 in metropolitan areas, but only by about 1%.

Table 3 –Scenario 1-1 Results

Scenario1-1	**"Economic Expanding Period"**
Ratio of Statistical Population Change between 1971 and 2001	**Ratio of Population Change by Expressway Development between 1971 and 2001**
	

The percentage population change varied little between 2001 and 2006 (Table 4). The percentage population change with expressway development was positively correlated only in Tokyo, Osaka, and Nagoya in this period, indicating that expressway development did not influence population in the short term.

Table 4 – Scenario 1-2 Results

Scenario1-2	**"Economic Shrinking Period"**
Ratio of Statistical Population Changes between 2001 and 2006	**Ratio of Population Changes by Expressway Development between 2001 and 2006**
	

4.4 Expressway Development and Labor Productivity Change

The percentage change in labor productivity between 1971 and 2001 increased near industrial zones, such as Chukyo and Kyushu, where ports, roads, and railways were rapidly developed (Table5). The percentage labor productivity change with expressway development was about 50% in this period.

Table 5 – Scenario 2-1 Results

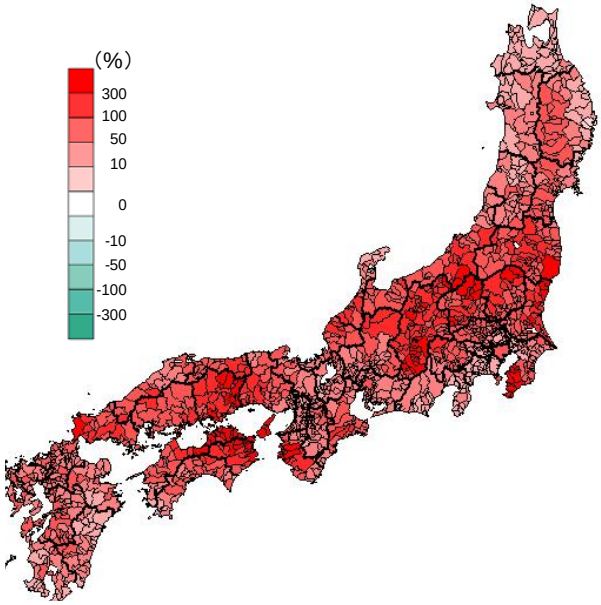
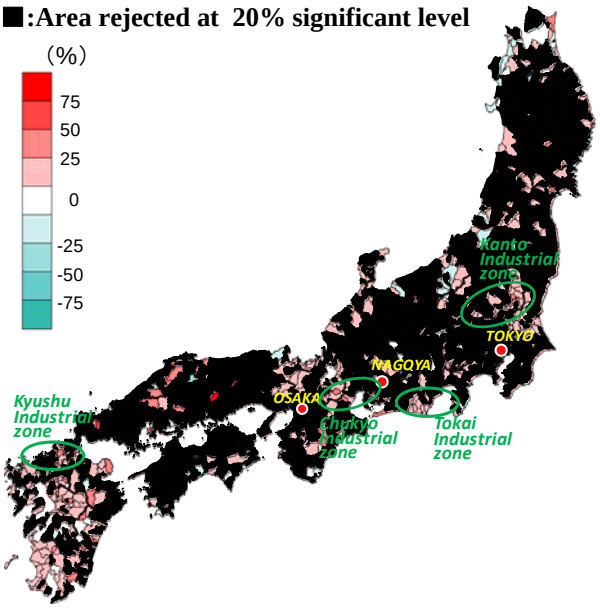
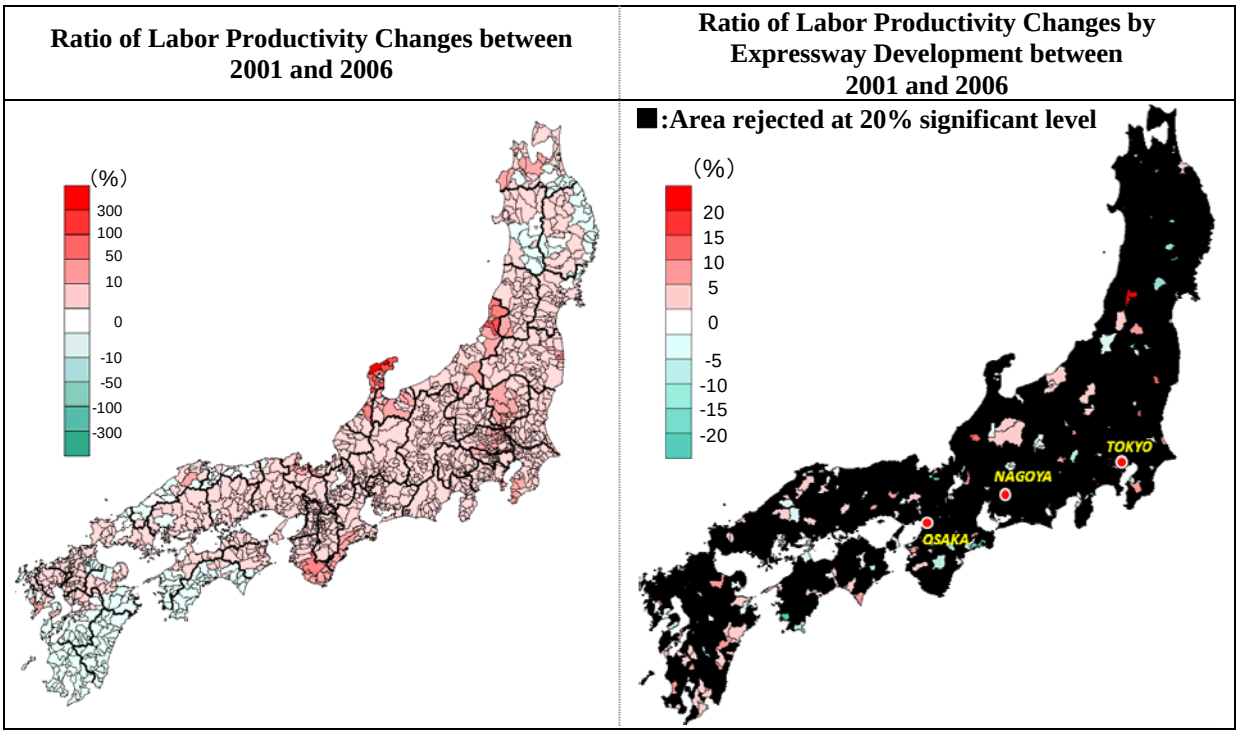
CASE2-1	**"Economic Expanding Period"**
Ratio of Labor Productivity Changes between 1971 and 2001	**Ratio of Productivity Changes by Expressway Development between 1971 and 2001**
	

Table 6 shows the percentage productivity change with expressway development between 2001 and 2006. The percentage change in productivity in this period is smaller than that in the previous period (50%), and the correlation between expressway development and labor productivity change was not statistically significant. This is because that the change native to each municipality could not be excluded by parameters.

Table 6 – Scenario 2-2 Results

CASE2-2	**"Economic Shrinking Period"**



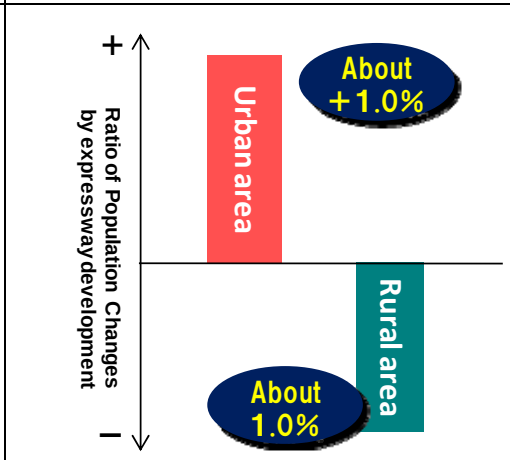
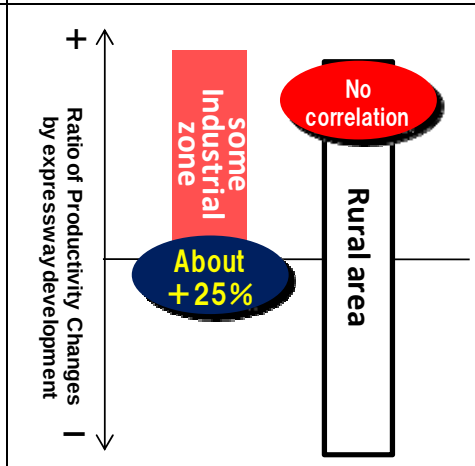
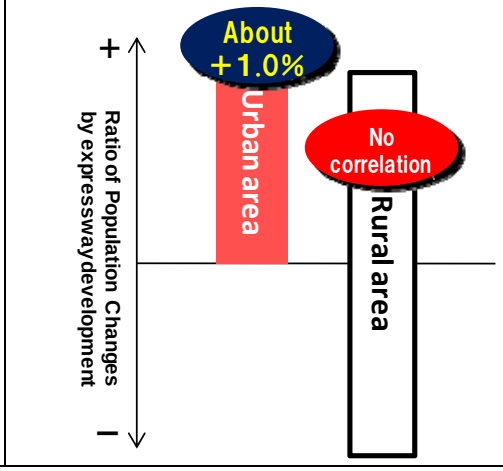
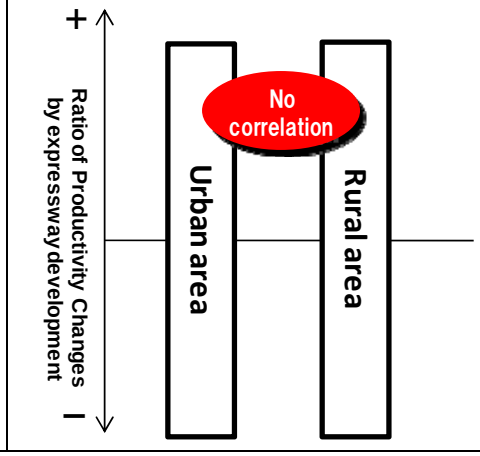
4.5 Conclusion

Table 7 summarizes the results of the case study of Japan. In the period of economic expansion (1971–2001), population increases in urban areas were positively correlated with expressway development, but that was not true in rural areas, in which population change was negatively correlated with expressway development. The development of road networks may have induced the outflow of population from smaller cities and rural areas to larger metropolitan areas; this is known as the “Straw Effect” in Japan. The influence of population change by expressway development appears to have been limited during the period of economic contraction.

Labor productivity in the period of economic expansion was positively correlated with expressway development in some industrial areas, but no correlation was found in other areas or in the period of economic contraction. Expressway development does appear to have supported economic growth, but further detailed statistical analyses should be conducted in this area.

In this case study, the methodology for calculating the accessibility index was not sophisticated because of the huge data processing and calculation requirements. Therefore, in the next case study, we focus on the Chugoku area in western Japan.

Table 7 – Effect of Expressway Development

	Population	Labor productivity
1971–2001 Economic expansion		
2001–2006 Economic contraction		

5. CASE STUDY OF THE CHUGOKU AREA

5.1 Regional Conditions, Scenario Settings, and Data Requirements

In the case study of whole Japan, we have subdivided in two periods. This is because of the difference situation of the economy between economic expanding period and economic shrinking period. On the other hand, in the case study of the CHUGOKU area, we don't subdivide periods. Because, we would like to analyze the long period on the reliability.

In a similar manner as in the study of Japan as a whole, we analyzed population and labor productivity changes in response to expressway development in the Chugoku area (including 105 municipalities) in western Japan from 1971 to 2007 (see Fig. 5; Table 8). Data requirements for each scenario are given in Table 9. Four years (1971, 1985, 1998, and 2007) were studied during this period of tremendous change in the expressway network in this area.

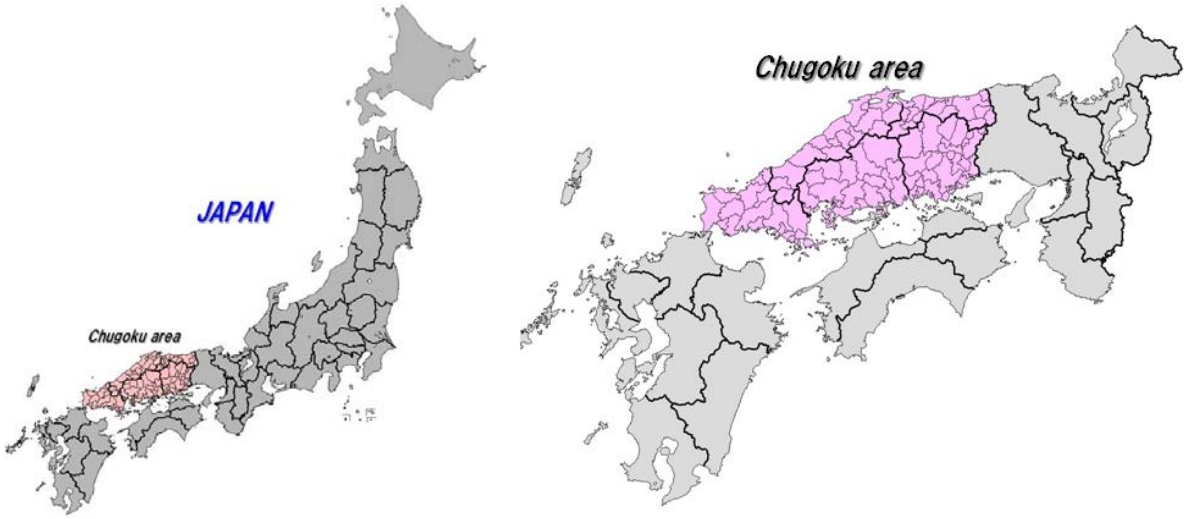


Figure 5 – Regional Conditions

Table 8 – Scenario Settings

Scenario	Index	Network	Time period
1	Expressway development and population change	Arterial road network	1971–2007
2	Expressway development and labor productivity change	Arterial road network	1971–2007

Table 9 – Data Requirements

Scenario	Dependent variable	Explanatory variable	Macroeconomic variable	Evaluation period	Data Source
	y	x	M	t	
1	Population of each region	Accessibility by population	Total population in Japan	1971, 1985, 1998, 2007	Statistic data of Population Census in Japan
2	Labor productivity of each region	Accessibility by labor productivity	Average productivity in Japan	1971, 1985, 1998, 2007	Statistic data of Industrial Census in Japan

5.2 Accessibility Index

We calculated the transport times between municipalities i and j in the Chugoku area and used the results to calculate the accessibility indices. This is because the transport time change influence in each municipality in Chugoku area has been calculated in detail. Only expressway networks were considered as part of the road network. Travel from islands was excluded, as was travel within a given municipality.

Figure 6 shows changes in the accessibility index for each municipality with population. The accessibility for regions with large economic scale, such as Okayama, Hiroshima, and Yamaguchi, increased between 1971 and 2007. The index in more rural areas, such as Tottori and Shimane, showed little increase. Accessibility increased rapidly from 1971 to 1998; this corresponds to the time when expressways were developed in the area.

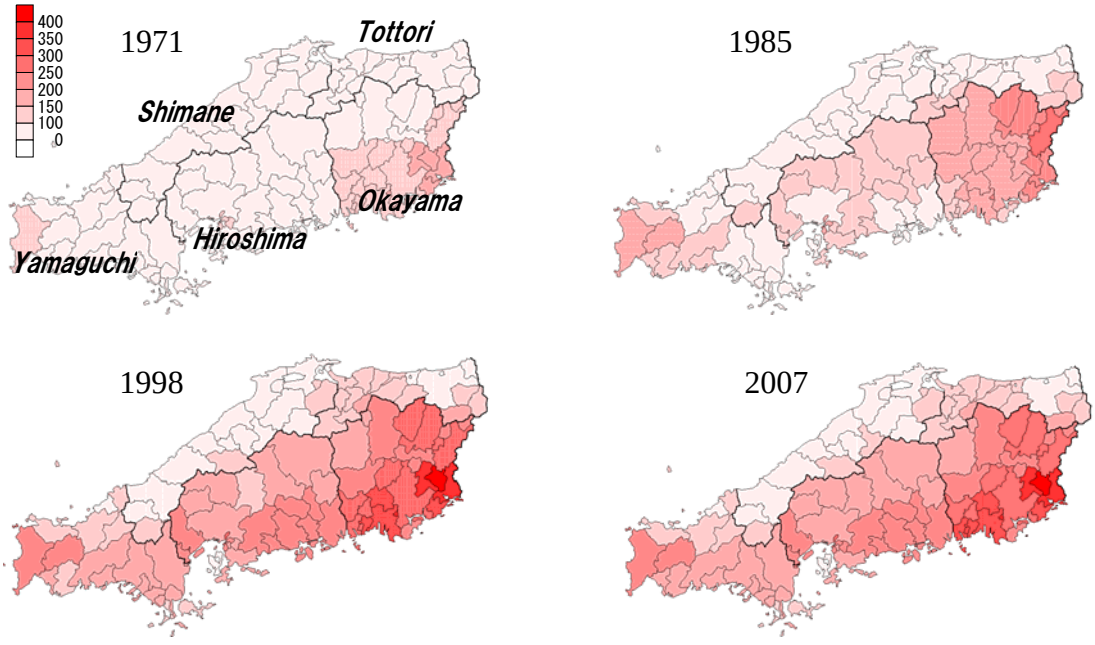


Figure 6 – Change in Accessibility Index with Population

Figure 7 shows changes in the accessibility index of each municipality with labor productivity. Accessibility of most municipalities increased between 1971 and 2007, especially in coastal regions, such as Okayama, Hiroshima, and Yamaguchi, which have a significant auto industrial sector.

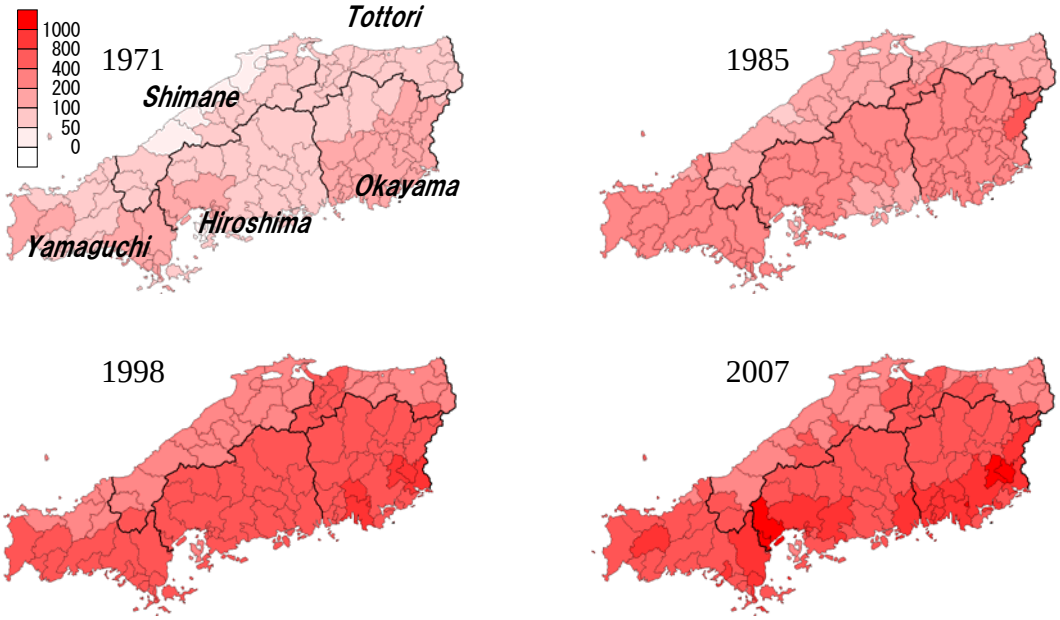


Figure 7 – Change in Accessibility Index with Labor Productivity

5. Expressway Development and Population Change

Figure 8 shows the percentage population changes between 1971 and 2007. The populations around capital cities in each prefecture (e.g., Tottori, Matsue, Okayama, Hiroshima, and Yamaguchi) increased from 30% to 60%, whereas the populations of smaller cities decreased by 30% to 60%.

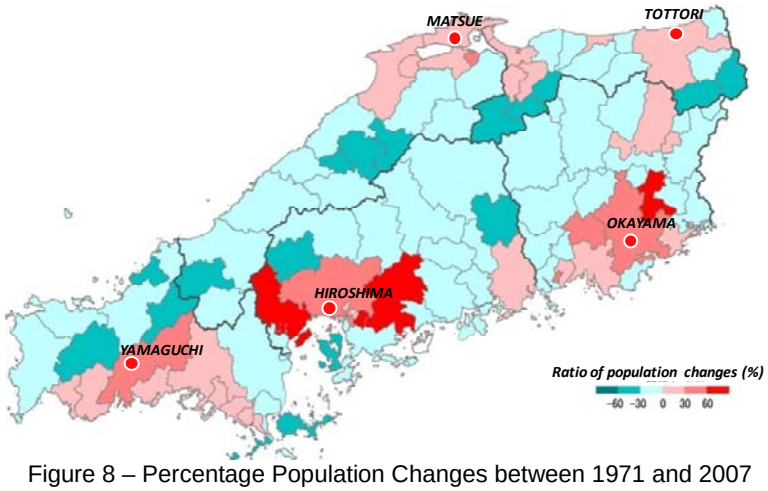


Figure 8 – Percentage Population Changes between 1971 and 2007

Figure 9 shows the percentage population change with expressway development between 1971 and 2007. The populations around capital cities in each prefecture were positively correlated with expressway development, whereas smaller cities and rural areas were negatively correlated. In both cases, however, the percentage change was only about 1.0%.

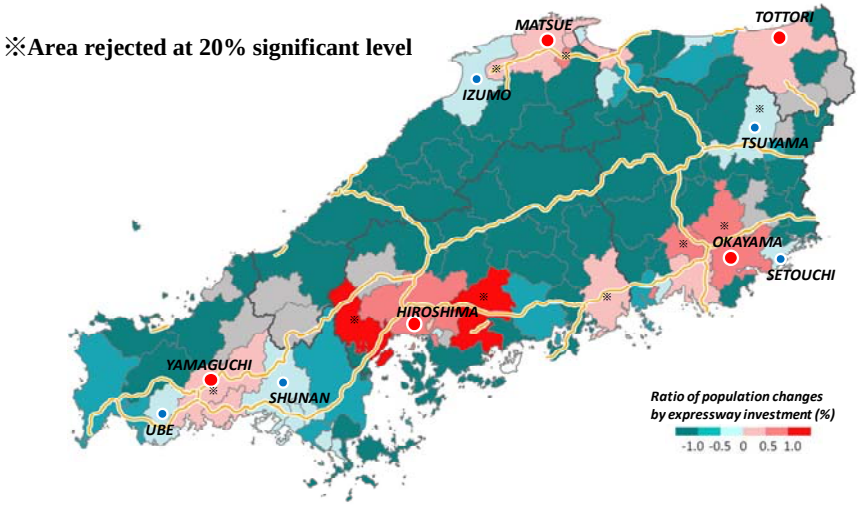


Figure 9 – Percentage Population Change with Expressway Development between 1971 and 2007

5.4 Expressway Development and Labor Productivity Change

Figure 10 shows the percentage labor productivity changes between 1971 and 2007, which were about 100% to 200% in most municipalities.

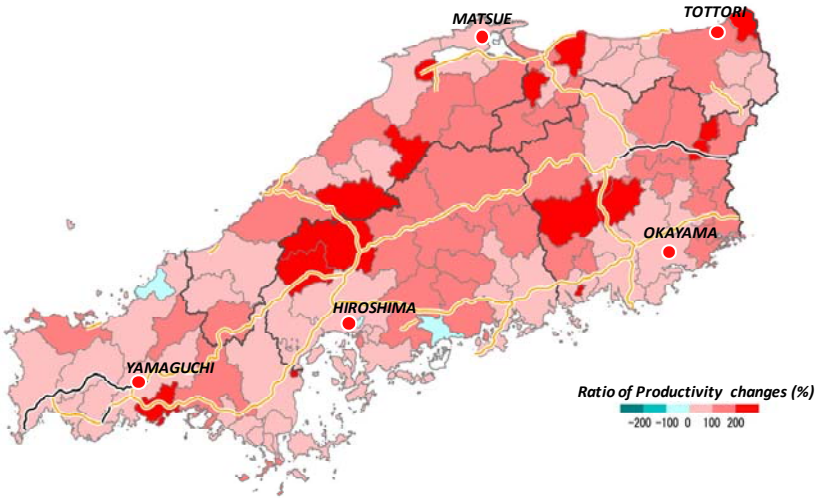


Figure 10 – Percentage Labor Productivity Changes between 1971 and 2007

Figure 11 shows the percentage labor productivity change with expressway development between 1971 and 2007; this increased by about 25% to 50% in most municipalities in the Chugoku area. Productivity in municipalities along the Chugoku expressway increased by more than 50%.

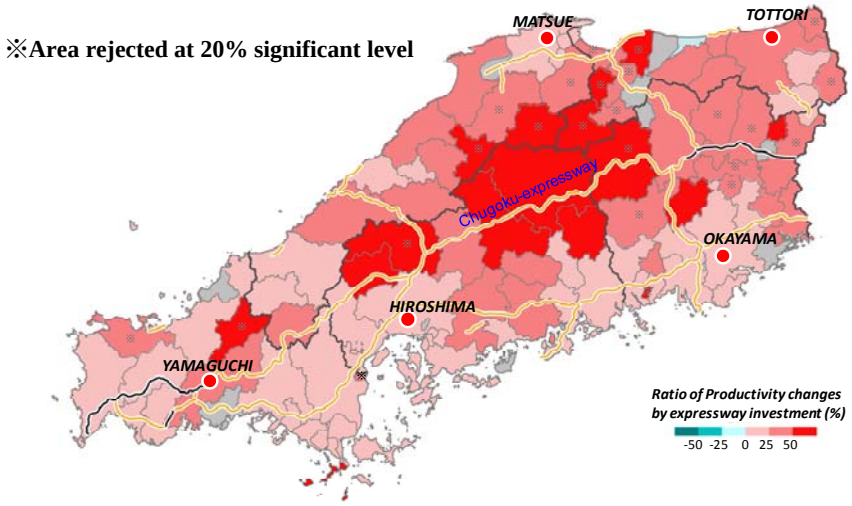


Figure 11 – Percentage Labor Productivity Change with Expressway Development between 1971 and 2007

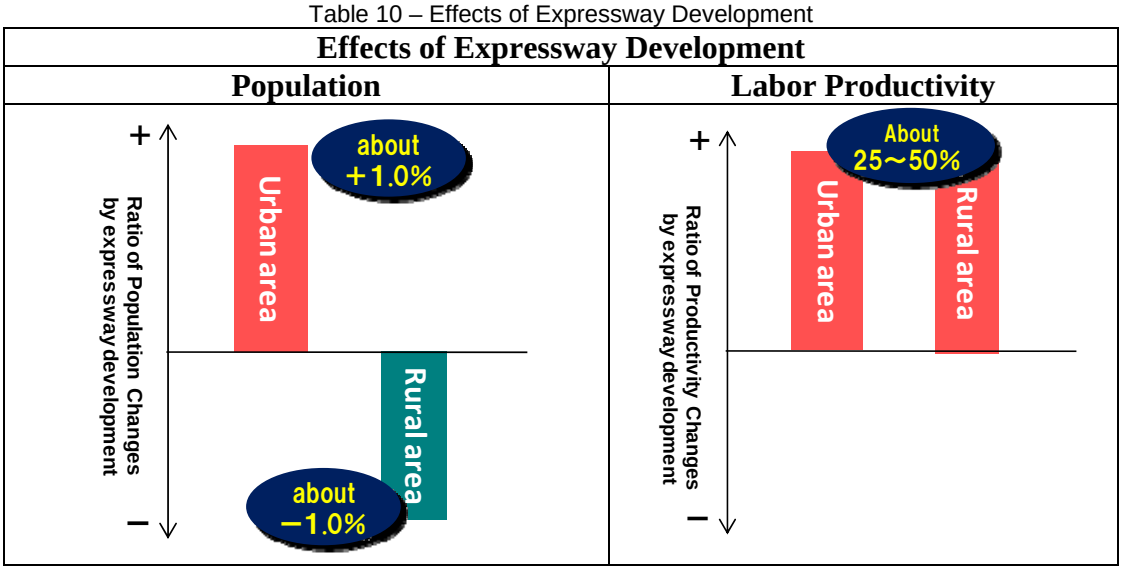
5.5 Conclusion

Table 10 summarizes the results of the case study of the Chugoku area. Population growth in urban areas was positively correlated with expressway development, and there was a negative correlation in rural areas. Municipalities near prefectural capital cities saw the greatest increases. Although the fixed-effect model does not distinguish cause and effect, expressway development might have induced an outflow of population from the smaller cities

and rural areas to larger metropolitan areas. The percentage population change with expressway development was only about 1%, however, so the effect was not strong.

In most regions, labor productivity was positively correlated with expressway development between 1971 and 2007. Labor productivity changes in response to expressway development increased by about 25% to 50% in most municipalities and by more than 50% in some municipalities near the Chugoku expressway. Therefore, expressway development appears to have had a strong influence on labor productivity between 1971 and 2001.

Table 10 – Effects of Expressway Development



6. CONCLUSIONS

We used a fixed-effect model with panel data to clarify the positive and negative social effects of existing expressway development in Japan. We made the following conclusions.

- In the case study of Japan, although accessibility has improved with expressway development, rural regions have experienced population decreases. Labor productivity improved with expressway development in some industrial zones during the period of economic expansion. During the period of economic contraction (2001–2006), however, the correlations between road investment and labor productivity change were not statistically significant.

- In the case study of the Chugoku area, the social advantage and social disadvantage (Fuji 2006) were clear. The advantage of expressway development was the strengthening of industrial activity through an increase in labor productivity. The disadvantage was that expressway development appears to have contributed to the “Straw Effect” in terms of the population structure.

- Population change in response to expressway development was clear in both case studies, but the influence on labor productivity was not as clear cut. More sophisticated analyses should be conducted in future research.

Project evaluation of road investments is a national obligation in Japan, and cost–benefit analyses are conducted for these types of projects. Most road developments are generally considered be efficient investments. Social disadvantages, however, may spread to rural areas as a result of expressway investments; this is a natural conclusion from the point of view of Hicks's and Kaldor's "Hypothetical Compensation Principle." Additional support is therefore necessary for disadvantaged regions, especially in rural areas.

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