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APPLIED GENERAL EQUILIBRIUM ANALYSIS ON THE EFFECTS OF MOTORWAY IMPROVEMENT UNDER RESTRUCTURING OF INDUSTRIES

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Abstract

In this paper the effects of motorway improvement in Japan are analyzed using a computable general equilibrium model. We can analyze the impact not only in a view of quantity, ie the change of demand and supply, but also quality, ie the change of price, income and utility.

INTRODUCTION

After World War II, many countries which had adopted a market economy experienced some problems in regional development and their governments carried out many regional policies. Analysis of the effects of these regional policies is useful for countries which are rapidly developing or which are changing from a socialist economic system to a market economy, because the process of economic development will lead to the same problems in regional development.

Since the first comprehensive national development plan was created in Japan in 1962, many regional policies were in fact carried out so as to secure a balanced regional development (RICE 1993). In particular motorway improvement was expected to remove the imbalanced development and actual motorway improvement did occur, which in turn, made interregional trade easier. It is said that motorway improvement contributed significantly to the economic development of Japan (Amano et al. 1970).

However, the effects of motorway improvement depended upon Japanese economic performance. So even if the same policies are carried out in other countries, the same effects are not always realized. Therefore, there are two important points in the analysis of the effects. First, we need to understand how regional policy influences the market economy. Secondly we need to understand the economic performance of the countries and the conditions under which the effects were realized.

Actual studies on the effect of motorway improvement were in the following two directions. One study throws light upon the mechanism which realizes the effects of motorway improvement using theoretical models based on micro-economic theory. The other study illustrates economic performance using statistical data. However as is mentioned above, we need to understand the structure of market economy and its economic performance. Therefore we need a new method which have both advantages of two studies.

We have already proposed a Computable General Equilibrium model for the analysis of the effects of regional policies (Okuda et al. 1994), which is based on Stochastic multiregional general equilibrium theory. In this paper we analyze the effects of motorway improvement using this model. First, our model for this analysis is explained and it is stated how it can represent the impact of this motorway improvement. Secondly, from estimated parameters of this model it is stated how the structure of Japanese economy was changed. Finally, through a policy test and estimation of equivalent value we analyze the impact of motorway improvement in Japan.

A MODEL FOR ANALYSIS

In another paper (Okuda et al. 1994), we introduced the model which is used in this analysis. In this section we explain the assumptions of this model and show simultaneous equations that define equilibrium conditions of multiregional general equilibrium theory.

Equations for interregional trade

It is assumed that consumers will purchase the cheapest commodities to minimize their expenditure and that the c.i.f. price, which consists of f.o.b. price and transportation cost, is a probabilistic variable which has Weibull distribution. Under this assumption the rate t_i^{rs} which consumers in region s purchase commodities from region r as follows.

$$t_i^{rs} = \frac{\exp[-\beta_i(p_i^r + \omega^s \theta_i d^{rs})]}{\sum_l \exp[-\beta_i(p_i^l + \omega^s \theta_i d^{ls})]} \tag{1}$$

where

p_i^r : f.o.b. price of commodity i in region r

d^{rs} : transportation time from region r to region s

ω^s: wage in region s

θ_i: constant of the proportion between transportation time and its cost

β_i: parameter of Weibull distribution

Then the mean cost per unit consumption of commodity i in region s, which is assumed as q_i^s, is as follows.

$$q_i^s = \sum_r t_i^{rs} p_i^r + \omega^s \sum_r t_i^{rs} \theta_i d^{rs} + \sum_r \frac{1}{\beta_i} t_i^{rs} \ln_{ij}^s t_i^{rs} \tag{2}$$

Equations for consumption

It is assumed that households have labor and supply it to receive income. They maximize their utility subject to their budget constraint and their utility is represented by the Cobb-Douglas function. In this assumption the following equation is introduced as conditions of optimization.

$$\delta_i^s = \xi_i^s \frac{\omega^s}{q_i^s} e^s, \qquad \rho^s = \eta^s \frac{\omega^s}{r^s} e^s \tag{3}$$

where

δ_i^s: amount of commodities i which households in region s consume

ρ^s: amount of land which households in region s consume

r^s: rent in region s

e^s: amount of labor which household in region s have

ξ_i^s, η^s: parameter of Cobb-Douglas function

Equations for production

In this model, it is assumed that producers are in a perfect competitive market, maximize their profits subject to technological constraints, and Leontief Technologies are assumed. Under these assumptions, we can introduce the following equation to represent the optimal conditions of the producer.

$$p_j^s = \sum_i \sum_r a_{ij}^s t_i^{rs} p_i^r + \omega^s \left(\sum_i \sum_r a_{ij}^s t_i^{rs} \theta_i d^{rs} + b_j^s\right) + r^s c_j^s + \sum_i \sum_r \frac{1}{\beta_i} a_{ij}^s t_i^{rs} \ln_{ij}^s t_i^{rs} \tag{4}$$

where

a_{ij}^s : amount of factor i to produce unit commodity j in region s

b_j^s: amount of labor to produce unit commodity j in region s

c_j^s: amount of land to produce unit commodity j in region s

Equations for market conditions

It is assumed that supply can be equal to demand in all markets, ie markets of products, transportation, labor and land. Thus, we can obtain the following equations for market conditions.

$$X_i^r = \sum_j \sum_s a_{ij}^s t_i^{rs} X_j^s + \sum_s \delta_i^s t_i^{rs} H^s \tag{5}$$

$$T_i^{rs} = \sum_j a_{ij}^s t_i^{rs} X_j^s + \delta_i^s t_i^{rs} H^s \tag{6}$$

$$e^s H^s = \sum_j b_j^s X_j^s + \sum_i \sum_r \theta_i d^{rs} T_i^{rs} \tag{7}$$

$$S^s = \sum_j c_j^s X_j^s + \rho^s H^s \tag{8}$$

where

X_i^r : supply of commodities i in region r

H^s: number of households in region s

T_i^{rs}: transportation supply of commodities i between region r and s

S^s: total land supply in region s

Impacts of motorway improvement

Figure 1 represents the impact of motorway improvement, first, motorway improvement reduces travel time, so that transportation cost can be lowered. Because producers are assumed to be in perfect competitive markets, the reduction of transportation cost causes a lower f.o.b. price than before (equation (4)). Moreover the reduction of the f.o.b. price allows households and producers to purchase commodities from other regions (equation (1)), so that the f.o.b. price and c.i.f price is reduced more and more (equation (2) and (4)). Such lower prices cause households to change their pattern of consumption (equation (3)) and increases production (equation (5)). In the transportation market, demand is increased (equation (6)), in labor and land markets an imbalance between demand and supply occurs (equation (7) and (8)). But in these markets changes in wage and rent keep the balance. Finally, the changes in wage and rent influence production and consumption. In this way the impact of motorway improvement spreads to all markets in every region.

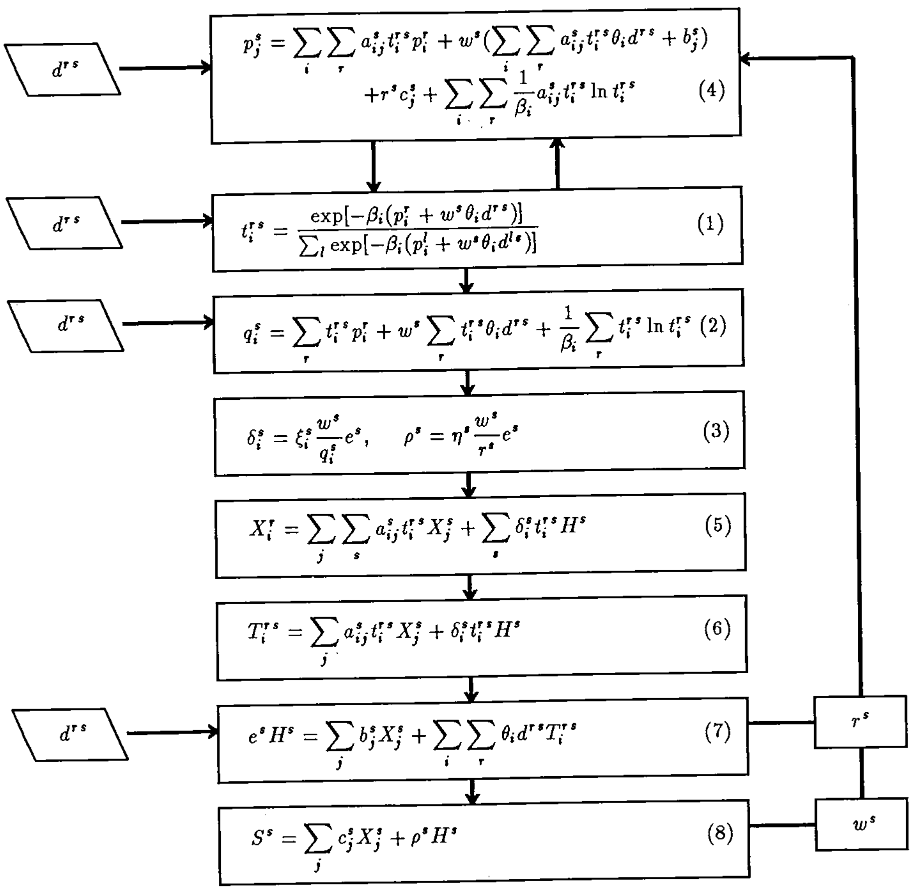


Figure 1 Impact of motorway improvement in the model

Explanation from welfare economics

We can consider the impact of motorway improvement from a viewpoint of welfare economics. Unknown variables of the above simultaneous equation can be obtained by solving the following mathematical program:

$$\sum_s (\sum_i \xi_i^s \ln \delta_i^s + \eta^s \ln \rho_i^s) H^s \rightarrow \max \tag{9}$$

subject to

$$\sum_r y_i^{rs} = \delta_i^s H^s \tag{10}$$

$$\sum_r x_{ij}^{rs} = a_{ij}^s X_j^s \tag{11}$$

$$X_i^r \geq \sum_j \sum_s x_{ij}^{rs} + \sum_s y_i^{rs} \tag{12}$$

$$T_i^{rs} \geq \sum_j x_{ij}^{rs} + y_i^{rs} \tag{13}$$

$$e^s H^s \geq \sum_j b_j^s X_j^s + \sum_i \sum_r \theta_i d^{rs} T_i^{rs} \tag{14}$$

$$S^s \geq \sum_j c_j^s X_j^s + \rho^s H^s \tag{15}$$

$$L_i \geq -\sum_j \sum_r \sum_s x_{ij}^{rs} \ln \frac{x_{ij}^{rs}}{a_{ij}^s X_j^s} - \sum_r \sum_s y_i^{rs} \ln \frac{y_i^{rs}}{\delta_i^s H^s} \tag{16}$$

$$\delta_i^s, \rho^s, X_j^s, T_i^{rs}, x_{ij}^{rs}, y_i^{rs} \geq 0 \tag{17}$$

where L_i are the upper limit of entropy. In this formulation, the objective function is the sum of households' utilities which are equally weighted. It means that this function is a social welfare function in welfare economics and that it is maximized by the market mechanism. This mathematical program includes some constraints. In particular, equation (14) means the conditions of labor market and travel time are included. Motorway improvement can reduce travel time between regions and this constraint can be relieved, so that households in each region can be obtain higher utility than before.

STRUCTURE OF THE JAPANESE ECONOMY

Data used

To analyze the effects of motorway improvement, we need to know the structure of the Japanese economy. The Japan Ministry of International Trade and Industry has estimated interregional input/output tables in Japan every five years since 1960. In this study we used this data and we analyzed how the economic structure of Japan has changed. In Figure 2 we show the categories of sector and region that we used in this analysis.

Structure of consumption

Figure 3 represents trends of private consumption expenditures. Japan experienced economic growth after the World War II. As income increased, percentage of food, fabricated textile products, agriculture and fishing decreased every five years, while on the other hand, the percentage of service and durable goods such as transportation equipment increased.

a) Sector
1 Agriculture and Fishing
2 Coal mining
3 Mining
4 Food
5 Fabricated textile products
6 Lumber and wood products
7 Pulp, paper and paper products
8 Leather and rubber
9 Chemical products
10 Petroleum products
11 Ceramic, stone and clay products
12 Steel and steel products
13 Non-ferrous metals and products
14 Other metal products
15 General machinery
16 Electric machinery
17 Transportation equipment
18 Other machines and instruments
19 Other manufactured products
20 Construction
21 Electricity, gas, city water
22 Commerce
23 Service

b) Region
1 Hokkaido
2 Tohoku
3 Kanto
4 Chubu
5 Kinki
6 Chugoku
7 Shikoku
8 Kyushu

Figure 2 Sector and region

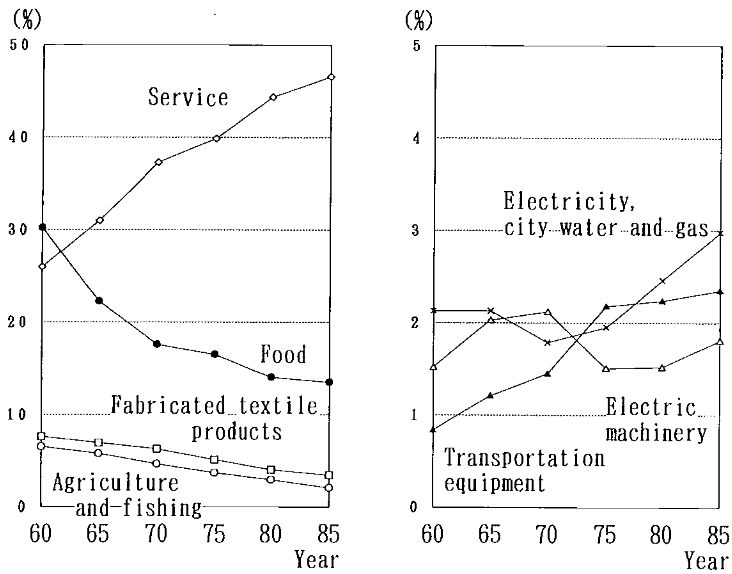
Structure of production

Figure 4 represents regional difference in production technique. In this figure, to represent regional difference of the input/output coefficient, the mean distance between coefficient vectors of every two regions is used. In the case of petroleum products, non-ferrous metals and products, steel and steel products, the coefficients vary greatly in each region. On the other hand, in the case of transportation equipment, electric machinery, other machines and instruments, they do not vary in each region. This means that machinery is a footloose industry which can be transferred easily so that it can be located to rural areas more easily by motorway improvement.

EFFECTS OF MOTORWAY IMPROVEMENT

Motorway improvement in Japan

Figure 5 represents motorway improvement in Japan. Japanese motorway construction was started in the 1960s and in 1970 the motorway which connects the Kanto and Kinki regions was completed and in 1980 the motorway network was extended to the Tohoku region and Chugoku region. Moreover, in the 1980s motorways which connect the main route with other cities were constructed. This project is continuing now.



Private consumption expenditures in which percentage is larger than 1% in 1985 are shown

Figure 3 **Trends of private consumption expenditure**

Transportation cost

Figure 6 represents percentage of transportation cost to price of commodities. In all industries, transportation cost included in all processes of the production, including the cost incurred in the process of its primary materials, is twice or three times higher than the cost directly incurred in just the process of production. Especially in the case of general machinery and electric machinery, the directly incurred cost is only a small percentage to its price, but the cost including indirectly incurred cost is not small. Thus motorway improvement reduces the prices of these industries.

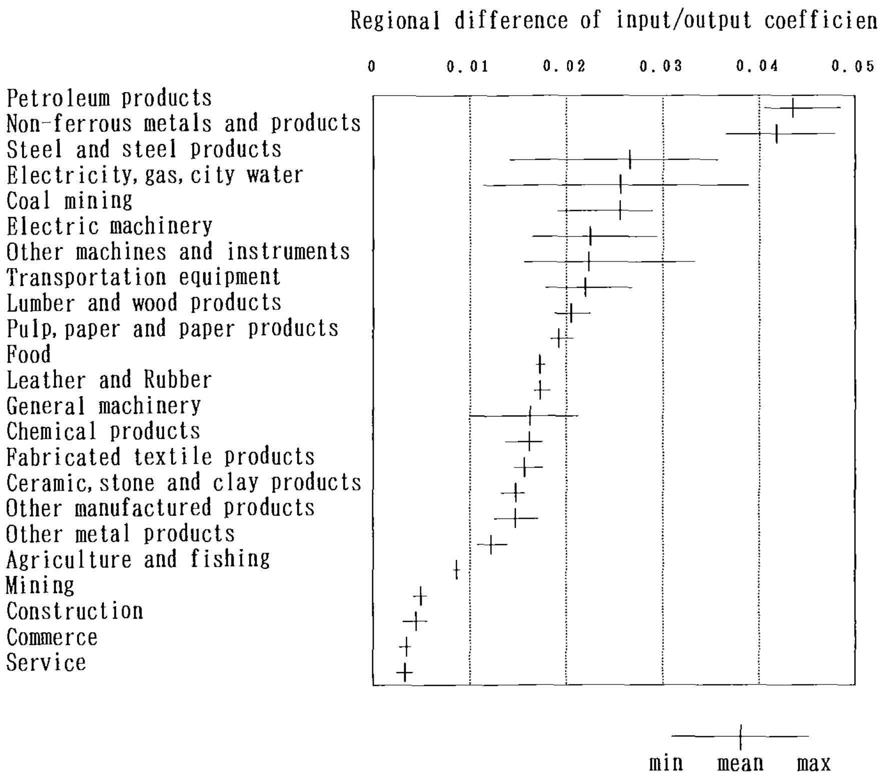
Policy test

To study the impact of motorway improvement, policy simulation is applied in the following cases.

Case 1: Real case of motorway improvement

Case 2: 10 year delay in motorway improvement

Figure 7 represents the results of these simulations. In this figure, the Y-axis is the production index of electric machinery which is 100 in 1965. The solid line represents the result in case 1 and the broken line represents the result in case 2. As is mentioned earlier, Japanese economic growth increased households' income and the propensity to consume durable goods has grown. On the other hand, if motorway improvement is delayed by 10 years, the demand does not rise because the price of durable goods is very high. When the motorway improvement was started 10 years later, production of electric machinery rapidly increased in Kanto, Chubu and Kinki regions, where the motorway was constructed. Actually, with the restructuring of these industries, they located in rural areas, but this phenomenon would not appear in the case where motorway improvement was delayed by 10 years.



$$\text{Regional difference} = \frac{\sum_i \sum_r \sum_s (a_{ij}^r - a_{ij}^s)}{n^2}$$

where

a_{ij}^r : input/output coefficient
i, j : sector
r, s : region
n : number of regions

In this calculation, data from '70,'75,'80 and '85 are used.

Figure 4 Regional difference of production technique

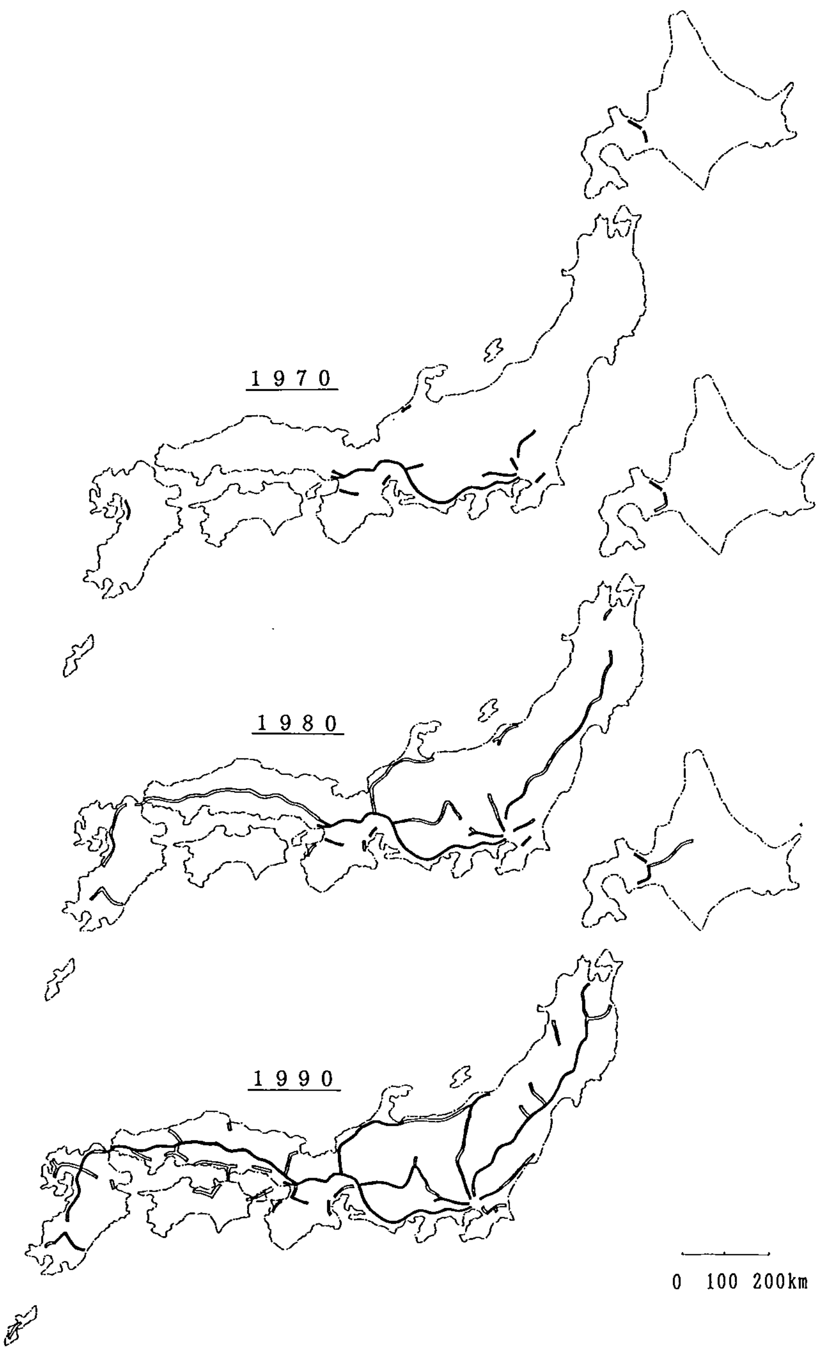


Figure 5 Motorway improvement in Japan

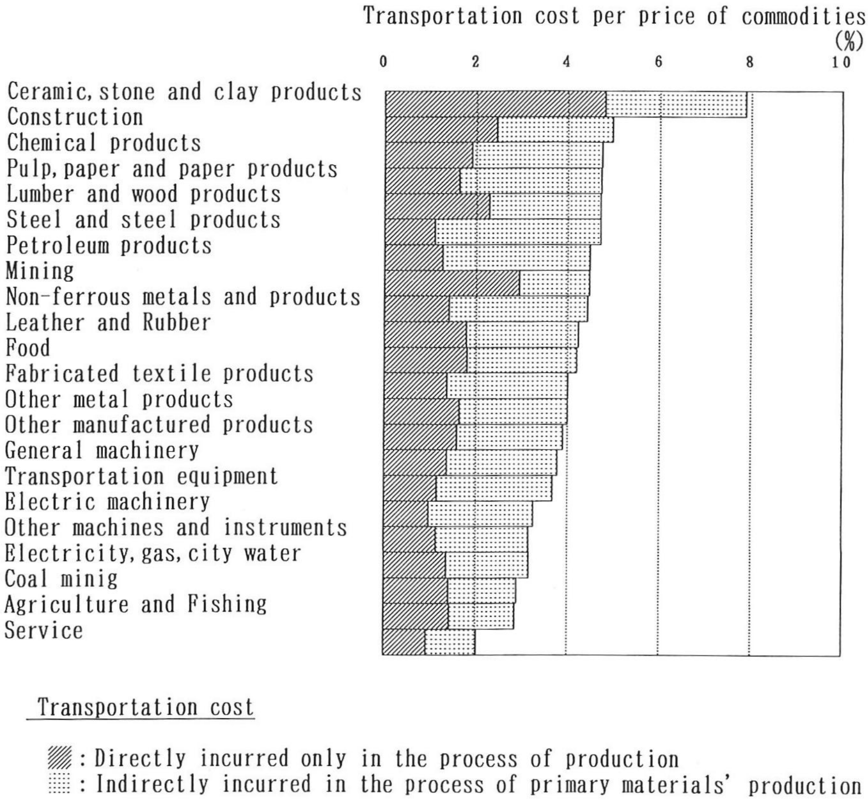
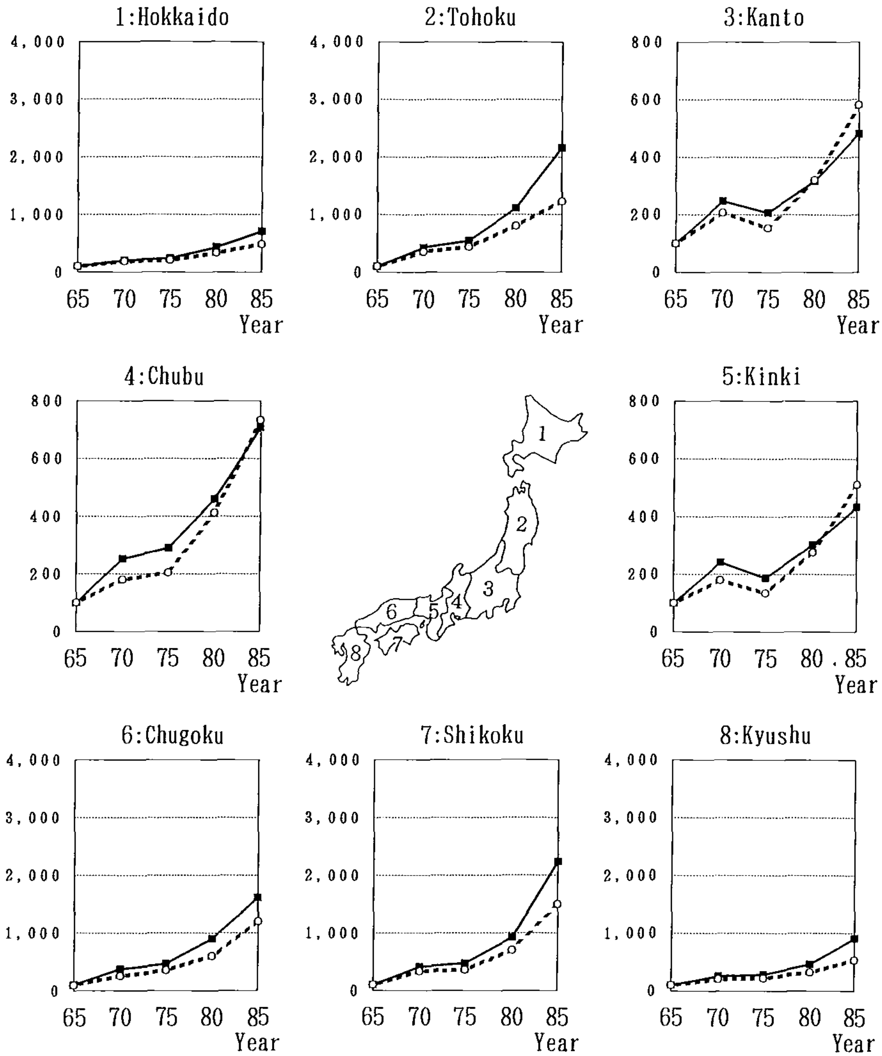


Figure 6 Percentage of transportation cost to price of commodities

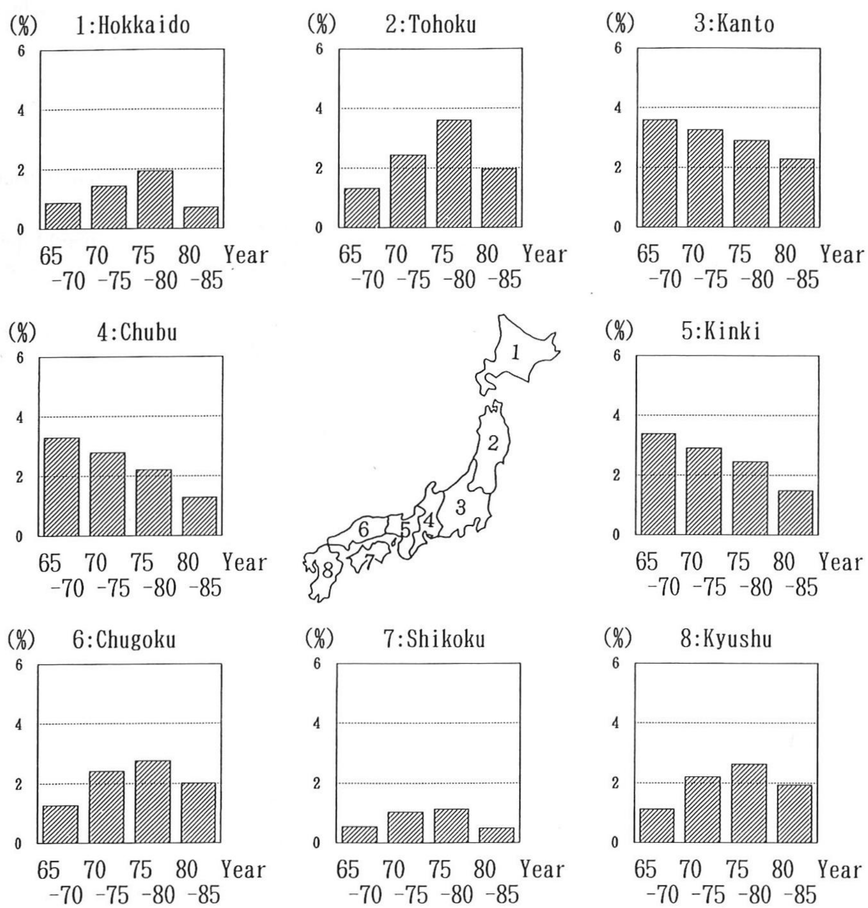


—■ : real case of motorway improvement
···○ : case where motorway improvement is delayed by 10 years
The Y-axis is production index of Electric machinery which is 100 in 1965.

Figure 7 Impact of motorway improvement on electric machinery

Equivalent value of motorway improvement

If the price of commodities is lowered by motorway improvement, households can obtain higher utilities than before. The equivalent value of motorway improvement can be calculated by our model. Figure 8 represents the result of these calculations. In the 1960s, when the motorway connecting the Kanto and Kinki regions was constructed, households in the Kanto, Chubu and Kinki regions received benefits of the motorway improvement. In the 1970s, when the motorway network was expanded to the Tohoku and Chugoku regions, households in these regions received benefits and households in the Kanto, Chubu and Kinki regions received some of the benefits too. As a dense motorway network was constructed, the benefits of motorway improvement was spread to all regions.



The Y-axis is the rate of equivalent value to income.

Figure 8 Equivalent value of motorway improvement

CONCLUSIONS

In this paper, we have studied the effects of motorway improvement in Japan. In this study we used an applied general equilibrium model and it allows us to study impacts not only in a view of quantity, that is, the change in demand and supply, but also in a view of quality, that is, the change in price, income and utility. Through this study, the following things have appeared. When the motorway connecting metropolitan area with rural area was constructed, industrial structure was changing in Japan. The new industries, for example electronic machinery, Transportation equipment and so on, have no regional difference in technology. But transportation cost is a very important factor for these assembly industries. Motorway improvement reduced transportation cost in rural area, such new industries could be located there avoiding metropolitan area where location cast have been very high. And if its construction was delayed 10 years, assembly industries could not be located in the rural area and industrial structure change was not successful in the area. And the benefits of the motorway improvement were inputed to the rural area and it was efficient for increase of its attractiveness. On the other hand, they were also inputed to metropolitan area and keep its economic growth after then.

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