THE SENSITIVITY OF MULTIREGIONAL ECONOMIC STRUCTURE TO IMPROVED INTERREGIONAL ACCESSIBILITY

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The Sensitivity of Multiregional Economic Structure to Improved Interregional Accessibility [1]

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Abstract: Our recently developed Japanese Multi-Regional Econometric Input-output Model is an extended interregional econometric IO model. The interregional economic transactions by sectors are endogenously determined from the conditions of economic situation and trade barriers. In Japan, a society with a decreasing population, further investment in the transportation infrastructure has become a pressing issue. Employing the trade endogenized framework, the exogenous changes in the transportation network can be taken into account in our model. The numerical analysis of improved accessibility provides the economic impacts on regional economies as well as disparities. The result of sensitivity analysis shows that the improved accessibility induces the convergence of per capita labor productivity. The expansion of infrastructure has tremendous effects in the periphery regions at the initial stage, but the positive effects fade with time, and the geographical advantage of the regions located in the central part of Japan become even stronger than the base case at the later phase of the simulation.

Keywords: Regional Econometric Input-Output Model, Interregional Trade, Transport Infrastructure

1. Introduction

This paper presents a recently developed multiregional model that is used to examine the economic impact of changes in trade structures. Significant changes in trade structure have been observed during the last two decades in the Japanese regional economies. Earlier analysis, Hitomi *et al*. (2000) found that the most important change in the interregional output multiplier of the 1980s in Japan has been generated by the change in interregional trade. Local purchases (intraregional) have been replaced by interregional flows, and this pattern has dominated changes

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generated by international trade and changes in production technology. In other words, the regional production process is becoming more dependent on external sources of inputs and on demands in markets located in other regions.

Since the interregional transactions have been increasing in the regional economies, the role of transport infrastructure such as airports, express railroads, and highways are becoming more important than ever before. In response to increasing traffic demand of commodities and services, the expansion of investment for highways and super-express railways were always accorded high priority in national budgets until recently.

In discussions on fiscal reform, the future expansion plans of highways and express railways have been reconsidered. The further tight budget and decrease in transport demand are anticipated due to the inevitable aging and decreasing population in Japan. The current plans for proposed highways and railroads therefore should be reconsidered in terms of economic efficiency.[2] It is obvious that the economic effect of transport infrastructures last for many years, and there are intricate spillover effects. The economic effect of current transport facilities must be precisely examined using an appropriate numerical model of multiregional economies.

To capture the interindustry effect, the methodology applied in this paper is based on a regional econometric interindustry model (REIM). To put it simply, a REIM type model is the integrated model of input-output and econometric models using the regional IO table and time series expenditure dataset. While the ordinary interregional input-output model and general equilibrium type models cannot treat the long-term cumulative effects, the REIM type system has an advantage of conjoining the precise sector information and time series expenditure analysis (West. 1995). The cumulative effects of investment and consumption due to the exogenous change in trade structures can be captured within this system.

The single region REIM type forecasting models have already been developed and stably operated in many regions. The precedent REIM type models are those such as Washington region by Conway (1990), Chicago (Israilevich *et al.* 1997) and the U.S. Midwest states model by Regional Economics Application Laboratory, University of Illinois. Subsequently, Japanese

[2]The current expansion plan of the highway network proposes 2,000km, more than 25% of the current network (Ministry of Land, Infrastructure, and Transportation. 1999). The total investment amount of proposed highways is as much as 20 trillion yen, more than 60% of public

single region models for Chugoku, Hokkaido, and Kyushu regions are also being developed at Central Research Institute of Electric Power Industry, and the Okinawa model at Nansei Shoto Industrial Advancement Center.

Using our originally estimated interregional IO table and regional economic database, the single region REIM is revised and upgraded to a multiregional system in this paper. Our multiregional model basically takes the classical form of a Chenery-Moses type regional transaction model, but a time series expenditure system is embedded within the system. The demographic and energy demand models are also being simultaneously developed as the sub models of the multiregional core-model.

In order to develop a dynamic system for the multiregional economic model, there are many issues to be solved: a) Choice of trade models,[3] b) Estimation methodology, and c) choices of interregional distance and specific trade friction factors. McCallum (1995) examined the trade barriers of US-Canada transactions using the modified gravity model. The trade friction analysis has been extended by many studies such as Anderson and van Wincoop (2003), and Santos Silva and Tenreyro (2003). The previous studies conclude that the simple OLS estimate methodology of the trade model is biased, so the qualitative dependent models seem in need of evaluation (for further evaluation of this point, see Yamano, 2005).

In addition to the modeling issues, a proper interregional distance metric must be selected. Ordinary Euclidean distance has been used in most of the preceding studies; however, this distance measure may not reflect the actual transport method route chosen. The manufacturing commodities are traded via trucks and the service trades are made by passenger transportation. In the following numerical example, we employed the actual road and passenger travel time as the interregional economic distances.

This paper is organized as follows. Section 2 is a brief summary of the trade endogenized multiregional econometric input-output model. In Section 3, we then estimate the trade models, and the result of sensitivity analysis of an alternative transportation infrastructure is presented in Section 4. The final section contains some concluding remarks.

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investment in 2001.

[3]The reviews of development and applications of interregional transaction model are reviewed in Isard (1998).

2. Modeling a Multiregional Econometric Input Output System

2.1. Redefined Interregional Input-Output Table

The interregional input-output tables published by the Ministry of Economy, Trade and Industry (METI table), the only interregional tables available in Japan, have been re-estimated for 10 power supply regions (see figure 1) in the Central Research Institute of Electric Power Industry. Details of the spatial transformation may be found in Hitomi (2000) for the 1990 table and Karato *et al.* (2002) for the 1995 table. The 46 sectors in the original METI table have been aggregated to 26 sectors (see table 1) due to the limitations of related statistics.[4]

The major modification in the original table and our table focuses on Kanto, the capital region, which has been divided into North Kanto and Shutoken. The Kanto region in the original METI table has nearly 40% of the Japanese GDP in 1995, whereas North Kanto and Shutoken have quite different economic bases. North Kanto has an agglomeration of the manufacturing sectors and Shutoken has the world centers of business services and financial institutions.

The redefined 10 regions IO table was estimated by the following procedures. First, for the intraregional transactions within prefectures, domestic final demand and foreign exports were taken from the corresponding prefectural input-output tables. Then, the interregional transaction and final demands were calculated. The major difficulties were in the estimation of the interregional transactions of non-manufacturing sectors. The manufacturing sectors are easily divided into subregions using the commodity flows survey of the Ministry of Land, Infrastructure, and Transportation. There are, however, few survey-based statistics for the tertiary sectors; hence, a gravity type trade models was used to estimate the interregional activities. Finally, the interregional input-output table is balanced by a modified RAS technique. Since the regional divisions of Hokkaido, Chugoku, Shikoku, Kyushu and Okinawa are unchanged from the original table, the elements in these regions are omitted from the balancing procedure. Thus, the tables of the modified interregional tables are estimated for 1990 and 1995. The two tables then are linked at a constant price from 1990 using the deflators from the national input-output table.

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[4]The number of sectors are limited in the commodity flows survey and in the system of national

2.2 Multiregional Econometric IO System

The multiregional model applied in this study follows the Chenery-Moses type formulations. The model and equations are described as follows.[5] Figure 2 shows our multiregional system. Including the sub-modules and endogenized trade transactions, there are about 3000 endogenous variables in our multiregional system.

2.2.1. The Model of Multiregional Input-Output

The output vector of the multiregional input-output system is written as:

$$X = (S \otimes T) AX + (S \otimes T) F + E \tag{1}$$

where X is the gross output column vector, S is the domestic self-sufficiency coefficient matrix (=one minus the foreign import coefficient), $\otimes$ indicates the element by element (Hadamard) product. The elements of the self-sufficiency matrix for non-intraregional transactions take 1.0. T is the domestic trade matrix, A is the regional technological coefficient, F is the domestic final demand vector, and E is the foreign export vector.

The regional final demands are composed of consumption expenditures outside households (CO), private consumption expenditure (CP), government consumption expenditure (CG), investment, and net increase in inventories (IV). The private (IP), public (IG), and housing investment (IH) are not separated in the interregional input-output table. Note that each series of final demands has interregional interactions.

The domestic interregional trade matrix table of 10 regions, 26 sectors is defined as

$$T = \begin{bmatrix} t_1^{1,1} & & 0 & & t_1^{1,10} & & 0 \\ & \ddots & & \cdots & & \ddots & \\ 0 & & t_{26}^{1,1} & & 0 & & t_{26}^{1,10} \\ & \vdots & & & & \vdots & \\ t_1^{10,1} & & 0 & & t_1^{10,10} & & 0 \\ & \ddots & & \cdots & & \ddots & \\ 0 & & t_{26}^{10,1} & & 0 & & t_{26}^{10,10} \end{bmatrix}$$

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account.

[5]See Miller (1998) for the detailed formulation of multiregional input-output model.

where $\tau_i^{k,l}$ is the trade coefficient of sector i, defined as

$$\tau_i^{kl} = TRD_i^{kl} / \sum_k TRD_i^{kl},$$

where $TRD_i^{kl} = \sum_j z_{ij}^{kl} + f_i^{kl}.z_{ij}^{kl}$ and f_i^{kl} are the transactions of intermediate and regional final demand goods respectively.

The trade flow from region k to region l is assumed to be a function of the output of the source region, the demand of destination region, and the distance between the source and destination regions. With regard to distance, we employed the automobile travel time for primary and manufacturing sectors, and the passenger travel time is used to estimate the trade flows of tertiary sectors. There are no interregional transactions for construction and government sectors by definition. Obviously, the trade coefficient matrix for the non-trade sector becomes diagonal matrix ($\tau_i^{kl} = 0$, if $k \neq l$). The trade coefficient of the utility sector is also exogenously given, and the coefficients are fixed at the base year, because the commodity flows in the utility sector are traded under the constraint of network capacities.

The regional demand vector of aggregated final demands in the model is written as

$$F = \left[\Theta_o CO + \Theta_c CP + \Theta_g CG + \Theta_i (IP + IG + IH) + \Theta_v IV \right] \tag{2}$$

where Θ_o, Θ_c, Θ_g, Θ_i, and Θ_v are the block diagonal converter matrices. For example the converter matrix of household consumption (Θ_c) is defined as

$$\Theta_c = \begin{bmatrix} \theta_{c,1}^{1} & & & 0 \\ \vdots & & & \\ \theta_{c,1}^{26} & & & \\ & \theta_{c,2}^{1} & & \\ & \vdots & & \\ & \theta_{c,2}^{26} & & \\ & & \ddots & \\ & & & \theta_{c,10}^{1} \\ 0 & & & \vdots \\ & & & \theta_{c,10}^{26} \end{bmatrix},$$

and $\theta_{c,r}^{s}$ is the converter for sector s of region r and $\sum_{s=1}^{26} \theta_{c,r}^{s} = 1.0$

The total demand vector of period t is then written as:

$$Xd_t = \left(S \otimes T_t A X_t\right) + \left(S \otimes T_t\right)\left[\Theta_0 CO_t + \Theta_0 CP_t + \Theta_g \bar{C}\bar{G}_t + \Theta_i\left(IP_t + \bar{I}\bar{G}_t + IH_t\right) + \Theta_v IV_t\right] + \bar{E}_t \tag{3}$$

where $\bar{\ }$ indicates an exogenous variable. The exogenous variables in our system are the regional technical coefficients, export vector, the regional import coefficients, government consumption, and public investment. Note that Xd_t is not equal to X_t, except for the base year.

2.2.2. Supply/Demand Adjustment in MREIM

The procedure of supply/demand adjustment in our model is the quantity adjustment model known as regional econometric input-output model (REIM). In the REIM system, the adjustment has been referred to as a Mashallian equilibrium model that markets clear as a result of changes in the level of production. Modifying the single region REIM system of Israilevich *et al.* (1997), the supply/demand adjustment of the multiregional input-output model is formulated as:

$$X_t = \hat{\Omega}_t\left(S \otimes T_t\right) A X_t + \Omega_t\left(S \otimes T_t\right) F_t + \Omega_t E_t \tag{4}$$

where $\hat{\Omega}_t$ is the diagonal matrix of supply/demand adjustment coefficient. The adjustment coefficient is defined as $\omega_{i,t}^{k} = X_{i,t}^{k} / Xd_{i,t}^{k}$. In the following numerical example, we assume the partial adjustment relationship, so that $X_{i,t}^{k}$ is a function of total demand ($Xd_{i,t}^{k}$) and the previous year's output ($X_{i,t-1}^{k}$).

The supply/demand ratios of some sectors are compared to Tohoku and Shutoken in figure 3. Since by definition, the levels of supply and demand exactly match in the base year, the ratio is equal to 1.0 in 1990. Comparing the supply/demand ratios in these sectors, while the ratios of those industries declining in importance are declining, the ratios of the tertiary sectors are increasing slightly. The ratios of some sectors certainly have different trends across regions. For example, the supply/demand ratio of the medical service sector in Shutoken increased fastest, while the ratio increased more gradually in Tohoku.

2.2.3. Final Demand

The equations of final demand are briefly described as follows. Consumption expenditures outside households (CO) and Private investment (IP) are determined to correspond to the change in regional production as

$$CO_t^l = f(C, CO_t^l, GDP_t^l)$$

and

$$IP_t^l = f(C, IP_{t-1}^l, GDP_t^l)$$

where C is the constant term, $t-1$ indicates the data of previous period, and GDP_t^l is the total value-added in region l.

The other investment component, the housing investment is a function of labor force population ($P1565_t^l$), the population group ages between 15 to 64 and GDP as

$$IH_t^l = f(C, IH_{t-1}^l, P1565_t^l, GDP_t^l)$$

and the regional public investment ($\overline{IG_t^l}$) is exogenously given. The regional demographic figures by age groups are exogenously given from the population forecast sub-model of Yamano and Sakurai (2004). In the population forecast model, the population by age group is given with other demographic figures; life expectancy, net migration rate, fertility rate of woman's age groups, and rate of natural increase (birth rate minus the death rate). The labor force population is exogenously given from the population sub-model.

The per capita household consumption is assumed to be a function of regional income, and as

$$CP_t^l/Dc_t/P_t^l = f(C, YI_t, CP_{t-1}^l/Dc_{t-1}/P_{t-1}^l),$$

where P_t^l is the regional population, $YI_t = \alpha \sum_1^{26} X_i^l/Dg_t$, Dc_t and Dg_t are the consumption and GDP deflators respectively. The series of deflator (D_t) is exogenously given. The other demand components, the public expenditure and public investment are exogenously given outside the model.

3. Interregional Distance and Trade Models

In the previous section, we show that one of the most significant features of our model is the formulation of interregional trade transactions. The changes in industrial activity and endowment of transportation facilities are reflected in interregional trade flows within the model. The definition of interregional distance and estimates of the trade model are summarized in this section.

3.1. Interregional Distances

There are several choices for interregional distance: Euclidean linear distances, network distances of railroad, highway, and airlines, and travel time distances of automobile and passengers. The distance via the actual network is known as the economic distance. In the following panel estimates of trade coefficient models, we employ the travel time distances of automobile and passengers using the actual road network, and train and flight schedule books for 1990 and 1995.

3.1.1. Automobile Travel Time

The automobile travel time is initially calculated for 285 cities. The travel time between cities is estimated using the best route calculation referred to as the Dijkstra method. This simulation algorithm calculates the shortest path between all regions from the information of connectivity and distance between neighboring nodes. All combinations of travel time are estimated without measuring all combinations of cities. The 10 regional distances are then aggregated from the 285 cities data.

Obviously, the opening of new highways and bypass roads has tremendous time saving effects in many regions. The new routes not only benefit the establishments located along the highways directly, but remote establishments also indirectly benefited through the interregional trade activities. Since many highways were opened to traffic after 1980, the average travel time between regions declined from 11.7 hours in 1980 to 10.4 hours in 1999, about a 10% decrease in travel time. The effects are much larger in the rural regions than the large metropolitan regions. Most of the major highway routes were already open in the early 1980s in the large metropolitan regions.

3.1.2. Passenger Travel Time

The calculation of passenger travel time is thus more complicated than automobile travel time, because we must consider the choices of travel modes. The passengers choose their travel mode by taking everything into consideration: cost, time, delay risks, and service frequency. The cheapest or fastest routes are not necessarily chosen. We considered the waiting time additionally to the travel time.

The passenger travel time data is measured for all combinations of regions using the actual timetables of flights and train services. There is also a “rush hour” for interregional travel demand in the mornings and evenings just the same as urban commuting travels, so the average waiting time is adjusted by the hourly demand fluctuation. The travel time between regions k and $l (Dp(i,k,l,h))$ at hour h of transportation mode i is defined as

$$Dp(i,k,l,h) = DT(i,k,l) + WT(i,k,l,h)$$

where $DT(i,k,l)$ is the travel duration via transportation mode i, $WT(i,k,l,h)$ is the waiting time for the next flight or train service at hour h. For simplicity, the flights and train departure times are evenly distributed over the operating hours from 5am to 10pm, so the average waiting duration becomes

$$WT(i,k,l) = (22-5)/\phi_i^{kl}$$

where ϕ_i^{kl} is the number of flights per one weekday.

The average travel time between regions k and l considering the event probability of travel demand is given by

$$Dp(i,k,l) = DT(i,k,l) + \frac{\sum_t^{24} WT(i,k,l)\, prob[NP(t)]}{\sum_t^{24} NP(t)}$$

where $prob[NP(t)]$ is the expected number of passengers at hour t, and travel demands distribution is counted from the numbers of flights and express trains at each hour on weekdays. The demand distribution is estimated from the number of seats of super-express trains and domestic flights. If the waiting time of the primary transportation mode is relatively long, then passengers are likely to choose another transportation mode. Usually, there are few direct flights from local carriers, so the passengers choose the connecting flights and trains via hub airports and stations. The weighted average travel time of transportation modes i and j is then defined in the few frequent travel nodes as:

$$\bar{D}\bar{P}(kl)=\frac{\phi_i^{kl}Dp(i,k,l)+\phi_j^{kl}Dp(j,k,l)}{\phi_i^{kl}+\phi_j^{kl}} \tag{5}$$

if $DT(i,k,l)<DT(j,k,l)$ and $DT(i,k,l)+WT(i,k,l)>DT(j,k,l)$.

3.2. Modeling the Interregional Trade Flows

3.2.1. Estimation Models

We used a gravity type interregional trade flow model that is widely used in the empirical analysis of regional trade. The interregional transaction of sector i is written as:

$$TRD_i^{kl}=\frac{\left(X_i^k\right)^{\beta_i}\left(\sum_k TRD_i^{kl}\right)^{\gamma_i}}{\left(D^{kl}\right)^{\delta_i}} \tag{6}$$

β_i,γ_i and δ_i are parameters to be estimated, X_i^k is the output of sector i in trade origin region k, and D^{kl} is the economic distance between regions k and l. The automobile travel time (Da) is used for the estimates of primary and manufacturing sectors[6], and the passenger travel time (Dp) is used for the estimates of tertiary sectors. The sign of β_i,γ_i and δ_i must be positive to ensure the distant decay relationship. Depending on the case, some dummy variables for intraregional trade flows are introduced to obtain the better fit.

Accurate estimates of trade coefficients are required for the viable analysis of interregional interactions. The performances of all estimation models are compared, and a best-fit model will be selected in the following analysis. Trade estimate analysis by Santos Silva and Tenreyro (2003) implies that the estimators of ordinary least square and nonlinear least square are severely biased. Hence, we also estimated the qualitative choice models; modified multinomial logit

[6]A recent survey (Ministry of Land, Infrastructure, and Transportation) of interregional commodity flow shows that automobiles carry more than 90% of interregional trade in terms of quantity. The rest of the transactions are carried by train, ship, and air freights. Therefore the highly productive lean manufacturing system (Just-In-Time) now heavily depends on the road

(MLGT) and maximum likelihood estimator (TOBIT) in addition to the OLS estimate. The interregional trade flows in a multiregional input-output model is the summation of intermediate and final demand. Using the panel dataset of the 1990 and 1995 interregional input-output table, the following four models are estimated to obtain the best-fit trade model.

1. Ordinary Least Square (OLS)

The log-linear form of (6). The zero trade observations are omitted from the estimation sample.

2. Nonlinear Least Square Estimator (NLS)

Without omitting the zero flows from the estimation sample, the nonlinear gravity model is estimated directly with a restricted model of parameter sign by following the revised equation of (6),

$$\mathrm{TRD}_i^{kl} = \frac{(X_i^k)^{\beta_i^2} (\sum_k^{10} TRD_i^{kl})^{\gamma_i^2}}{(D^{kl})^{\delta_i^2}}.$$

3. Multinomial Logit Estimator (MLGT)

Assuming the parameter constraints on the interregional gravity model of (?) is written as

$$\mathrm{TRD}_i^{kl} = \frac{\left(X_i^k\right)^{\beta_i} \left(\sum_k TRD_i^{kl}\right)^{\gamma_i}}{\left(D^{kl}\right)^{\delta_i}} \; where \; \beta_i + \gamma_i = 1.$$

Dividing both sides of (8) by the total input of goods i in region l, the logarithm of trade coefficients are defined as the model:

$$\ln t_i^{kl} = \beta_i \ln\left(\frac{X_i^k}{\sum_k TRD_i^{kl}}\right) - \gamma_i \ln D^{kl} \, where \, \mathrm{t}_i^{kl} = TRD_i^{kl} / \sum_k TRD_i^{kl}.$$

Cleary, $\sum_k TRD_i^{kl}$ should be unity for all i and l. When we interpret the equation of (9) as the one that explains how the purchasers of goods i reside in region l and choose the

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network.

purchasing regions k, the formal similarity between our model and the Logit Model is clear[7]. The variables in model (9) have two explanatory variables $\frac{X_i^k}{\sum_k^{10} TRD_i^{kl}}$ and D^{kl}, and both of them are attributes,[8] so that we can utilize the estimation technique for the conditional logit model in order to have estimates of our model.

4. Maximum Likelihood Estimator (TOBIT)

The qualitative dependent model of the TOBIT estimate is formulated as follows:

The log-linear gravity model of the TOBIT model is written as: $LTRD^{kl*} = \alpha_i + \beta_i \ln X^k + \gamma \ln \sum_k^{10} TRD^{kl} - \delta \ln D^{kl} + \varepsilon \quad \varepsilon \sim \left(0, \sigma^2\right)$

where $LTRD^{kl} = \ln TRD^{kl}$, but $LTRD^{kl} = 0$, if $TRD^{kl} = 0, \alpha_i, \beta_i, \gamma_i,$ and δ_i are parameters to be estimated. The forecasted trade flow becomes

$$TRD^{kl} = \begin{cases} 0, & \text{if } LTRD^{kl} * \leq 0 \\ exp(LTRD^{kl} *), & \text{if } LTRD^{kl} * > 0 \end{cases}$$

3.2.2 Estimate Results of Trade Models

The results of estimate models in the above four models using our dataset of interregional input-output tables are given in tables 2 to 5, and the best specification model is selected in this section. Although almost all signs of coefficients meet the economic conditions of the gravity model in the OLS estimates, there remains a decisive problem. The zero trade interaction is omitted from the original sample due to the log linear transformation, so the result of OLS must be heavily biased. In other words, the transaction, especially in the small regions, cannot be reproduced from the coefficients obtained in the OLS estimates.

From the specification of NLS and MLGT models, the coefficients are expected to be positive

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[7] $Prob(TRD_i^{kl}) = \dfrac{\exp \beta \ln\left(\frac{X_i^k}{\Sigma_k TRD_i^{kl}}\right) - \gamma_i \ln D^{kl}}{\sum_k \exp \beta_i \ln\left(\frac{X_i^k}{\Sigma_k^{10} TRD_i^{kl}}\right) - \delta_i \ln D^{kl}}$

[8] The variables represent the conditions of choices.

numbers. The significant coefficients in all sectors are obtained in NLS except for the agriculture, forestry, and fishery sectors. The result of the multinomial logit specification model implies that the choice model is not suitable for application in the tertiary sectors. The total fit of these two models is not as high as OLS or the maximum likelihood estimates in table 4. The results imply that the restrictions of parameter signs are strong.

Comparing the results of the TOBIT model with OLS estimates, basically the same tendencies of coefficient values are obtained (table 5). All estimates of manufacturing sectors are significant, and the signs meet economic conditions. The higher values of distance coefficients are obtained in the sectors of bulky commodities such as mining, refinery and coal, and cement, clay, and stone sectors.

The total fit of the TOBIT model differs little from the results of the OLS estimate in most manufacturing sectors under the AIC criteria. The estimate errors have improved in many sectors. For all tertiary sectors, the TOBIT model shows the better performance. All parameters are positive in the TOBIT model, while some coefficients are negative in the OLS model.

The above estimated results are summarized to show that the treatment of zero trade flows is a key issue to be solved in the selection of the 'best' trade model. So, we employ the result of the TOBIT model in table 5 to compose the trade coefficient matrix in our multiregional economic systems, because the zero flows are explicitly obtained in the model specification.

4. Sensitivity Analysis of Transportation Infrastructure

4.1. Assumptions of Simulation

The interregional transportation environments have changed dramatically recently (Figure 6). The interregional highway and super express railway systems were only installed in central large metropolitan regions in the early 1980s. Five new lines of super-express railways[9] were extended to connect the north eastern cities, and the extension of the highway network has more than doubled in the last two decades. All four major Japanese islands are now connected by ground transportation through tunnels and bridges.

[9]Tohoku, Joetsu, Akita, Yamagata, and Nagano Lines have been open since 1980.

Comparing the economic distances for 1980 and 2004, the average travel time of automobiles decreased more than 10 % in most of the regions. Particularly, Chugoku and Kyushu-Okinawa have become much closer to other regions due to the openings of new highways and bridges. The decreases in travel time for passengers, on the other hand, have different tendencies. The decreasing rates are much larger in the eastern regions. Especially in Shutoken, the average travel time decreased about 30% because new routes of super-express railways have opened, and the numbers of flights and express trains have doubled and tripled respectively. So the waiting duration has been reduced. Compared to Osaka in Kansai, the frequencies of flights and super-express trains have much increased on routes outbound from Tokyo in Shutoken.

The increased accessibility should have important impacts on the structure of interregional trade. In the following counter factual simulation, we examined the economic impacts of past investment in transport infrastructures on regional trade structures, economies, and income disparities. To examine the effects of improved accessibility, the interregional input-output coefficients are estimated under the actual transport systems prior to the counter factual simulations. This case is defined as the bases case.

The following sensitivity analysis assumes that the current transport network system of 2004 had already been constructed in 1981. However, the total Japanese final demands are fixed at the actual levels, so the investment share across regions would only change in the simulation.

4.2. Impacts on Trade Structure

The expectation would be that the decrease in interregional travel time of automobiles and passengers should change the trade structures. At this time, we are not sure that the change in trade structure has had positive or negative effects on output levels, as the change in purchasing pattern depends on the demand and industrial structure, and the geographical location. Comparing the technical coefficients of the base and the simulations cases (tables 7 and 8), substantial differences are observed. The intraregional purchasing ratios have decreased in all regions except in Shikoku. Most regions decreased the local purchases, and the demands were replaced by markets located in other regions. The larger decreases were estimated in North Kanto (-2.2%) and Hokuriku (-1.7%).

The great positive impacts of trade structure are observed in Tohoku, Shikoku, and Chugoku regions. These regions benefit by selling more of their products to other regions, while the purchases from the regions located in central Japan such as Chubu, Hokuriku, and Kansai have decreased. Our numerical example implies that the advantages of geographical location of these central regions are weakening since the location in terms of travel time has changed.

4.3. Impacts on Industrial Structure

The output differences of base and simulation cases of the initial year of 1981 are compared in figure 7. Opening of highways and super-express railways in the 1980s and 1990s had a tremendous impact on regional economies. The large positive effects are observed in Tohoku, North Kanto, and Shikoku. The effects on Tohoku and North Kanto are interpreted as benefits of the super-express railway and highways. Particularly in Shikoku, the new bridges connecting to Japan's main island completely changed the exogenous environment of industrial trade and passenger travel. Before the bridges were opened in Shikoku, the ferryboat was the only surface transportation method between Shikoku and rest of Japan. The intraregional highways in Shikoku also have contributed to increasing accessibility since Shikoku is a very mountainous region. On the other hand, the production level of the surrounding regions decreased.

Figure 8 shows the changes in regional disparities of labor productivity by sectors in terms of coefficient of variation. The new transportation facilities induced the concentration of production locations of textile and apparel, and material manufacturing sectors. The increases in the coefficient of variation for textile and apparel, and steel and nonferrous metal sectors are more than 10% of those of the base case. On the other hand, the regional differences in labor productivity of other manufacturing, primary, and tertiary sectors decreased. This is interpreted as the increase in accessibility inducing more interregional trade. In other words, the regional production process becomes more dependent on external sources of inputs and on demands in markets located in other regions.

Obviously the effect of transport infrastructures must be captured in the long term, and the investment time effect must be examined at the end of the simulation period. The advantage of our model is to calculate the cumulative effect of exogenous changes on trade environments. The interesting finding in this simulation is that the initial negative impacts of network environment changes in Chubu and Kyushu-Okinawa regions turn into positive effects at the later phase of the simulation period (figure 9). On the other hand, the large initial impacts in terms of labor productivity in Shikoku and Chugoku finally drop to a level slightly below the national average at the end of simulation period.

The coefficient of variation for per capita GDP gradually increased in the 1980s and decreased in the early 1990s (figure 10). After the mid 1990s, the level remained around 0.15, which is the level of the mid 1980s. The interregional income disparity also decreases if the transport facilities of 2004 had been installed at a previous period. The marginal effect of highway and railroad openings has been diminishing in recent years as the marginal improvement of accessibility is decreasing. It is a result that corresponds to those in the prior study (Yamano. 2002).

4.4. Implications and the Effects of Proposed Infrastructures

Although we observed a great change in trade structures in this sensitivity analysis, the improved accessibility in periphery regions has not necessarily increased the economic growth and labor productivities. It is interpreted that the final demand, especially the increasing rate of private consumption, has not increased in Shikoku and Tohoku regions because the population is starting to decrease in these regions. The existing industrial agglomeration has also influenced the differences in economic growth, and even the geographical advantages of the central regions have decreased.

Most inter-metropolitan highways have already been constructed in Japan, but the capacity of intraurban highways is extremely scarce in many metropolitan regions. Although the contribution of new highways is small in terms of shortening the interregional travel time, some proposed belt highways in the large metropolitans certainly reduce the congestion and contribute to stable supplies of commodity transportation.

5. Summary

Using our originally redefined interregional input-output tables, the multiregional economic forecasting model has been developed. The most significant feature of our model is that the interregional trade structure is endogenously determined within the model based on the actual transport networks. Using the economic distances and qualitative choice model for trade functions, the single region REIM system is revised as the multiregional system.

The estimate results of interregional trade flows show that the performances of TOBIT maximum likelihood estimators are better than OLS and NLS estimates. In the trade coefficient formulations, the economic travel distance of automobile and passengers are chosen as the interregional distance instead over Euclidean linear distance. Our travel time measure not only incorporates the actual duration of travel time, but also the actual frequencies of flights and trains services are considered.

The sensitivity analysis of exogenous change in the transportation network was also examined to evaluate the behavior of our model. By assuming that the current traffic network had already been introduced 20 years ago, the economic and trade structures in each region become similar to present structures, so it can be said that the practicality of our model is secured.

Important policy implications are also provided in the numerical examples. The routes opened at the initial stage of infrastructure investment had tremendous influences on production processes of regional economies, however the recently developed highways and super-express railway have made relatively small impacts on regional economies. This result arises from the fact that the recently opened routes are predominantly intraregional and inner cities routes. Therefore, the decreasing impacts of transport investment do not directly imply that economic effects or the marginal productivity of newly opened routes are necessarily diminished.

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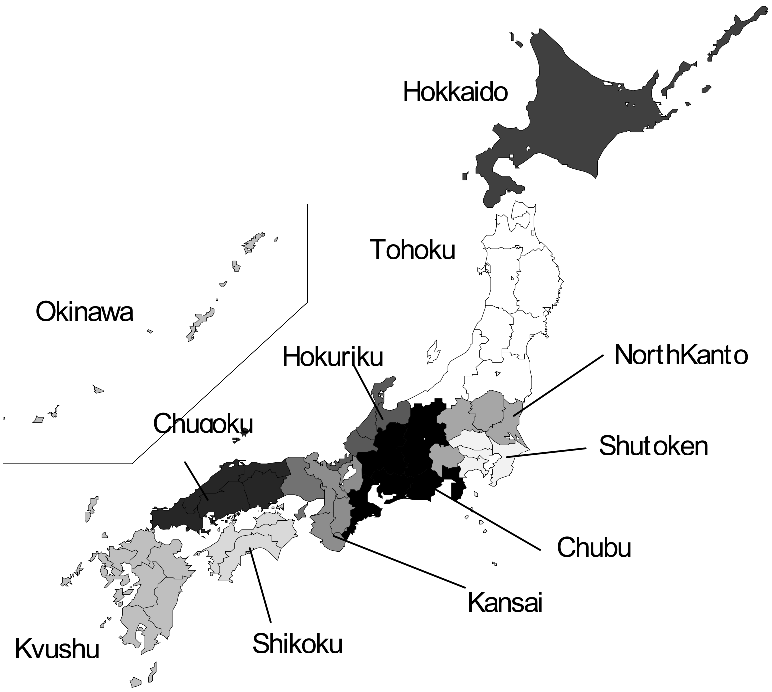


REGION	GDP Tril.Yen (2000)	Manuf. Ratio (%)	Population Thousand Oct. 2003
Hokkaido	21.5	(11.3)	5,659
Tohoku	46.0	(20.6)	12,207
NorthKanto	32.1	(35.6)	7,923
Shutoken	161.4	(18.7)	34,050
Chubu	76.7	(33.6)	17,139
Hokuriku	13.0	(26.1)	3,124
Kansai	87.7	(24.7)	20,900
Chugoku	30.3	(26.3)	7,707
Shikoku	14.6	(21.6)	4,127
Kyushu	46.6	(17.8)	13,436
Okinawa	3.7	(5.8)	1,349
Japan	533.6	(23.2)	127,621

(Note: Kyushu & Okinawa is aggregated in the model)

Figure 1: Japanese Regions

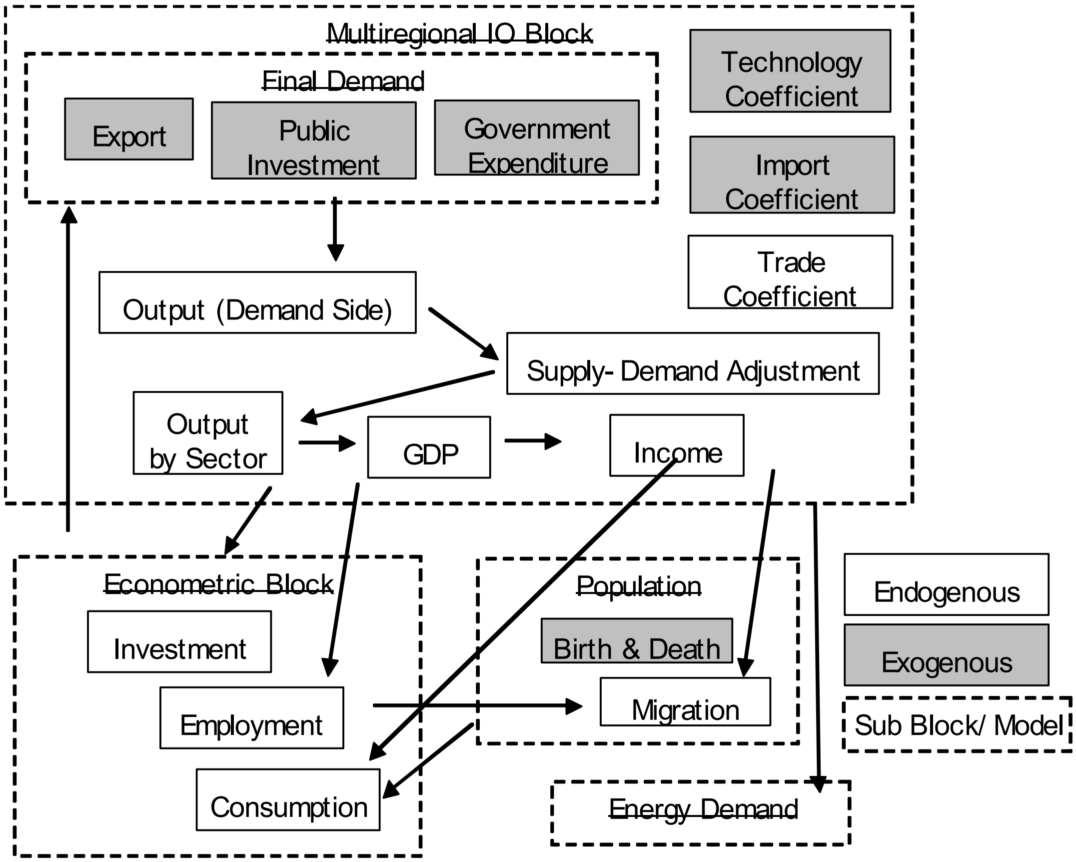


Figure 2: Multiregional Econometric Input-Output Model

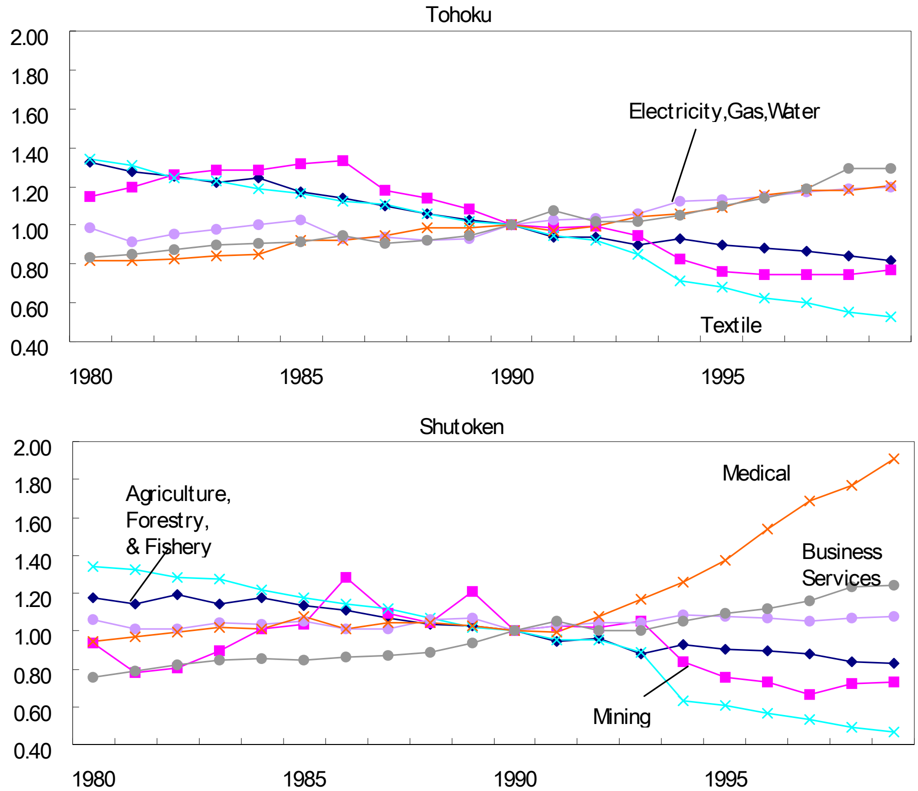
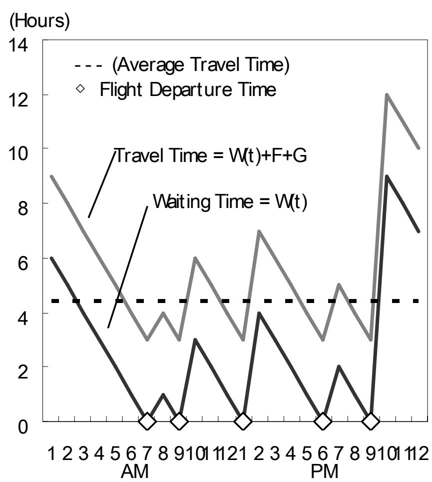
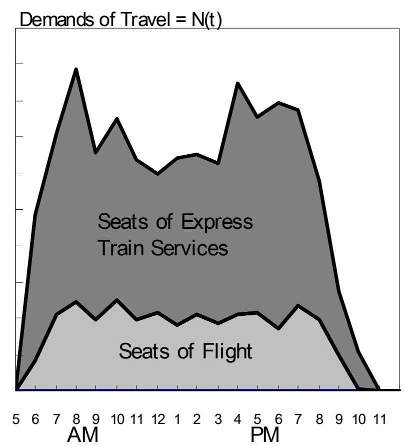


Figure 3: Actual Output and Demand Side Output





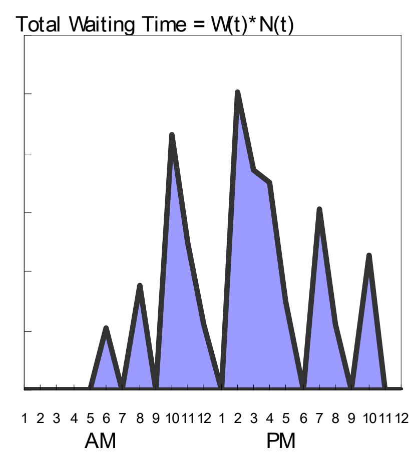
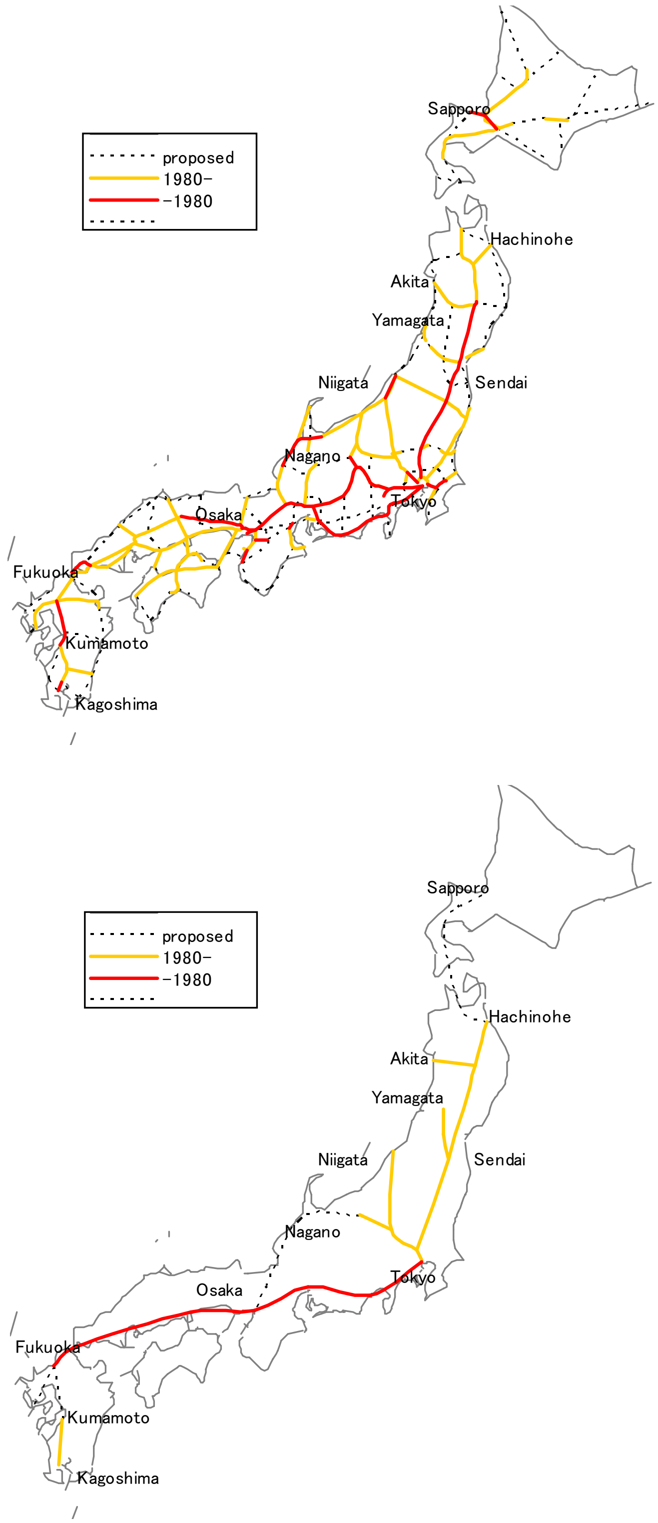


Figure 3: Waiting Time and travel time for passengers

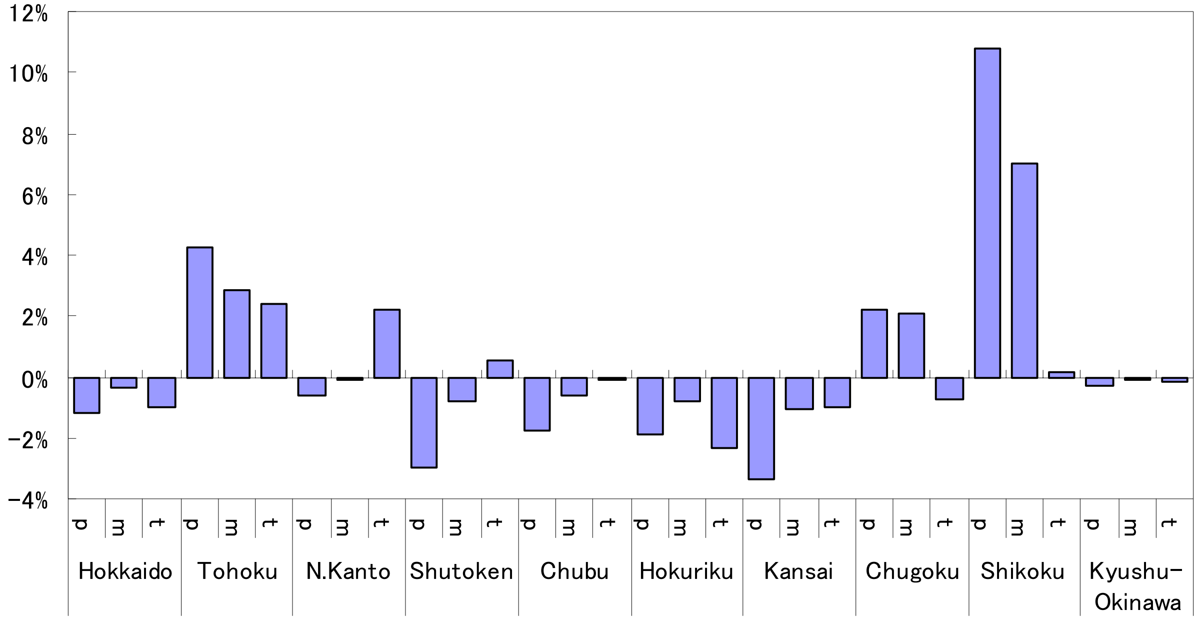
Figure 4: Travel demands by departing hour

Figure 5: Total waiting time for passengers



(Highways) (Super-Express Railway)

Figure 6: Current and Proposed Transport Infrastructure



p: primary sector, m: manufacturing, and t: tertiary

Figure 7: The Percentage Change in Output of Simulation Case (1981)

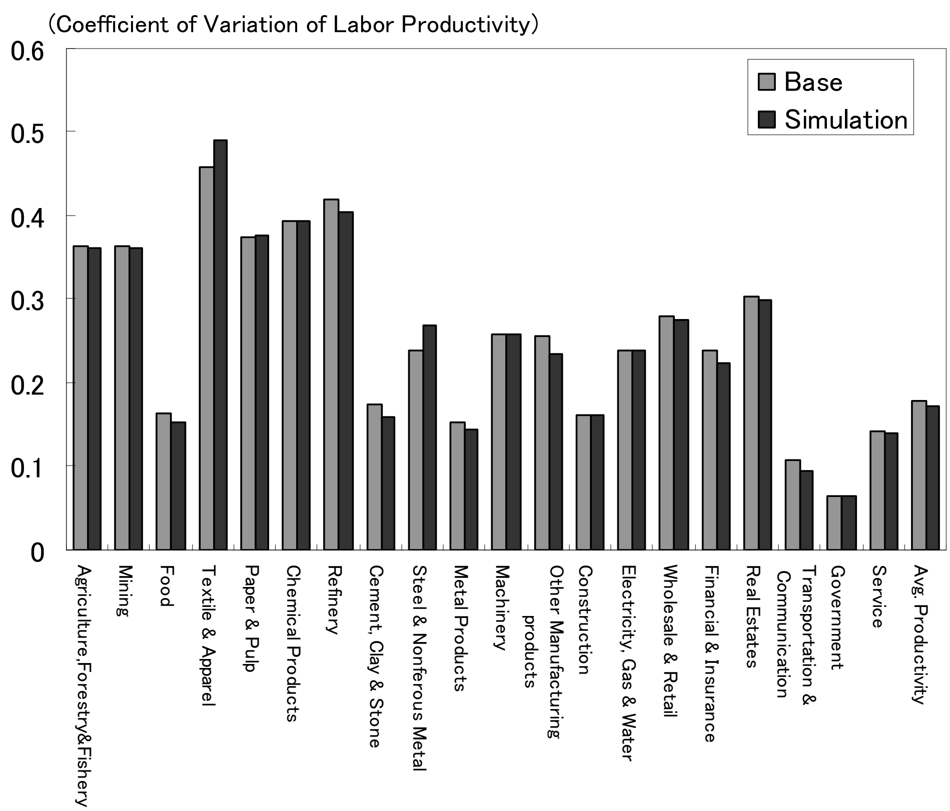


Figure 8: Regional Discrepancies of Labor Productivity by Sectors(1981)

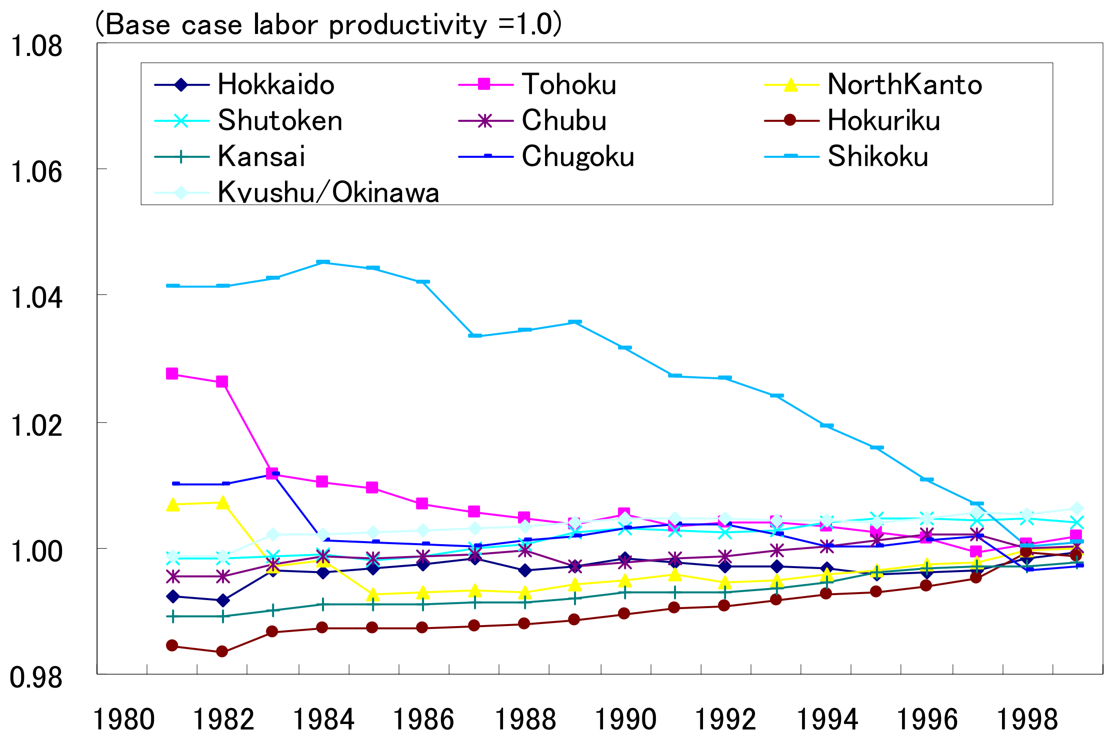


Figure 9: Cumulative Effects of Prior Introduction of Transport Infrastructure

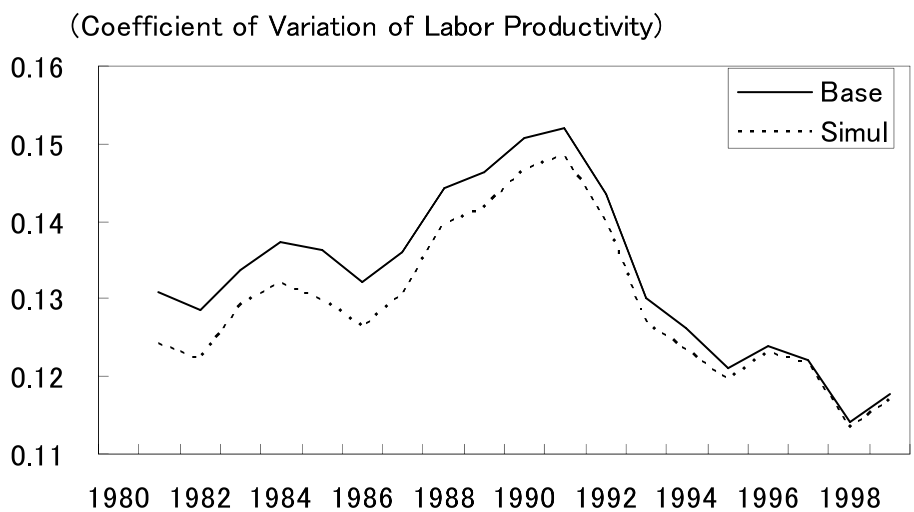


Figure 10: Income Disparities

Table 1: Sectors

Primary	Manufacturing & Construction	Tertiary
1 Agriculture, Forestry, & Fishery	3 Food	15 Electricity, Gas & Water
	4 Textile & Apparel	16 Wholesale & Retail
	5 Paper & Pulp	17 Financial & Insurance
2 Mining	6 Chemical Products	18 Real Estates
	7 Refinery & Coal	19 Transportation&Communication
	8 Cement, Clay & Stone	20 Government
	9 Steel & Iron Products	21 Educational Services
	10 Nonferrous Metal	22 Medical Services
	11 Metal Products	23 Other Public Services
	12 Machinery	24 Business Services
	13 Other Manufacturing products	25 Personal Services
	14 Construction	26 Miscellaneous

No interregional trade flows in sectors 14, 20, 22 and 26

Table 2: Estimate Results of Trade Functions (OLS)

Sector	β (Output)	γ (Demand)	δ (Dist-at)	δ (Dist-psg)	AIC	+ obs
1 Agriculture,Forestry&Fishery	0.762 *	0.181	-1.325 *	-	673.2	198
2 Mining	0.701 *	0.340 *	-2.493 *	-	867.5	197
3 Food	0.560 *	0.398 *	-1.417 *	-	697.3	195
4 Textile & Apparel	0.835 *	0.143	-1.459 *	-	638.5	179
5 Paper & Pulp	0.351 *	0.637 *	-1.525 *	-	595.6	189
6 Chemical Products	0.719 *	0.243 *	-1.337 *	-	680.6	200
7 Refinery	0.846 *	0.119	-1.649 *	-	765.8	193
8 Cement, Clay & Stone	0.608 *	0.357 *	-1.593 *	-	659.2	193
9 Steel and Iron Products	0.697 *	0.280 *	-1.655 *	-	661.6	197
10 Nonferrous Metal	0.576 *	0.403 *	-1.436 *	-	588.3	186
11 Metal Products	0.648 *	0.344 *	-1.558 *	-	603.0	192
12 Machinery	0.590 *	0.366 *	-1.434 *	-	731.6	200
13 Other Manufacturing products	0.454 *	0.512 *	-1.396 *	-	532.6	200
16 Wholesale & Retail	0.574 *	0.334 *	-	-1.517 *	491.1	200
17 Financial & Insurance	0.961 *	-0.037	-	-3.578 *	868.7	198
18 Real Estates	0.675 *	0.257	-	-4.992 *	1006.3	198
19 Transportation&Communication	0.489 *	0.446 *	-	-2.142 *	613.3	200
21 Educational Services	1.048 *	-0.114	-	-4.609 *	772.0	151
23 Other Public Services	-0.050	0.897 *	-	-3.297 *	930.2	198
24 Business Services	0.867 *	0.082	-	-3.115 *	783.7	200
25 Personal Services	0.603 *	0.366 *	-	-2.721 *	715.2	200

Samle size: 200(= 2yearsx10x10 region +obs: Observation of Non-zero trade flows *: Significant at 0.05 level

Dist-at: Automobile travel time Dist-psg: Passengers travel time

Table 3: Estimate Results of Trade Functions (NLS)

Sector	β^2(Output)	γ^2(Demand)	$-\delta^2$(Dist-at)	$-\delta^2$(Dist-psg)	AIC	+obs
1 Agriculture,Forestry&Fishery	1.037 *	0.001	-1.232 *	-	3762.3	198
2 Mining	0.390 *	0.688 *	-1.514 *	-	3550.5	197
3 Food	0.588 *	0.386 *	-1.185 *	-	4005.3	195
4 Textile & Apparel	0.377 *	0.557 *	-0.902 *	-	3524.5	179
5 Paper & Pulp	0.638 *	0.311 *	-1.064 *	-	3288.7	189
6 Chemical Products	0.500 *	0.440 *	-0.990 *	-	3589.4	200
7 Refinery	0.585 *	0.394 *	-1.316 *	-	3460.5	193
8 Cement, Clay & Stone	0.610 *	0.355 *	-1.201 *	-	3415.3	193
9 Steel and Iron Products	0.535 *	0.430 *	-1.174 *	-	3745.4	197
10 Nonferrous Metal	0.573 *	0.396 *	-1.161 *	-	3363.1	186
11 Metal Products	0.374 *	0.583 *	-1.220 *	-	3489.0	192
12 Machinery	0.542 *	0.408 *	-1.052 *	-	4317.0	200
13 Other Manufacturing products	0.429 *	0.538 *	-1.259 *	-	3906.9	200
16 Wholesale & Retail	0.491 *	0.492 *	-	-1.524 *	4264.8	200
17 Financial & Insurance	0.501 *	0.497 *	-	-1.756 *	4072.8	198
18 Real Estates	0.503 *	0.498 *	-	-1.776 *	4283.2	198
19 Transportation&Communication	0.469 *	0.518 *	-	-1.545 *	4137.0	200
21 Educational Services	0.490 *	0.509 *	-	-1.635 *	4081.1	151
23 Other Public Services	0.472 *	0.529 *	-	-1.667 *	3255.8	198
24 Business Services	0.487 *	0.507 *	-	-1.690 *	4214.4	200
25 Personal Services	0.484 *	0.509 *	-	-1.595 *	4191.7	200
26 Miscellaneous	0.522 *	0.487 *	-	-1.712 *	3587.8	50

Samle size: 200(= 2yearsx10x10 region +obs: Observation of Non-zero trade flows *: Significant at 0.05 level
Dist-at: Automobile travel time Dist-psg: Passengers travel time

Table 4: Estimate Results of Trade Functions (MLGT)

Sector	β (Output)	γ (Demand)	δ (Dist-at)	δ (Dist-psg)	AIC
1 Agriculture,Forestry&Fishery	-				
2 Mining	-				
3 Food	0.276 *	0.724 *	-1.719 *	-	626.6
4 Textile & Apparel	0.560 *	0.440 *	-1.380 *	-	664.2
5 Paper & Pulp	0.341 *	0.659 *	-1.515 *	-	587.5
6 Chemical Products	0.560 *	0.440 *	-1.202 *	-	708.0
7 Refinery	0.460 *	0.540 *	-1.749 *	-	522.9
8 Cement, Clay & Stone	0.309 *	0.691 *	-1.789 *	-	523.0
9 Steel and Iron Products	0.431 *	0.569 *	-1.752 *	-	555.9
10 Non-ferrous Metal	0.390 *	0.610 *	-1.513 *	-	593.6
11 Metal Products	0.405 *	0.595 *	-1.591 *	-	600.5
12 Machinery	0.538 *	0.462 *	-1.378 *	-	764.7
13 Other Manufacturing products	0.356 *	0.644 *	-1.607 *	-	645.6
16 Wholesale & Retail	0.159	0.841 *	-	-2.154 *	804.2
17 Financial & Insurance	-				
18 Real Estates	-				
19 Transportation&Communication	-				
21 Educational Services	-				
23 Other Public Services	-				
24 Business Services	-				
25 Personal Services	-				
26 Miscellaneous	-				

Samle size: 200(= 2yearsx10x10 region +obs: Observation of Non-zero trade flows *: Significant at 0.05 level
Dist-at: Automobile travel time Dist-psg: Passengers travel time
-: parameter condition is not satisfied or no converged solutions $\beta+\gamma=1$

Table 5: Estimate Results of Trade Functions (TOBIT)

Sector	α (Const)		β (Output)		γ (Demand)		δ (Dist-at)		δ (Dist-psg)		σ		AIC
1 Agriculture,Forestry&Fishery	-19.5	*	1.643	*	1.188	*	0.874	*	-		0.973	*	568.9
2 Mining	-15.2	*	1.296	*	1.165	*	1.066	*	-		1.625	*	698.7
3 Food	-24.2	*	1.684	*	1.387	*	0.564	*	-		1.175	*	641.8
4 Textile & Apparel	-16.6	*	1.539	*	1.002	*	0.870	*	-		2.080	*	823.7
5 Paper & Pulp	-19.8	*	1.434	*	1.568	*	0.960	*	-		1.291	*	673.8
6 Chemical Products	-17.7	*	1.306	*	1.180	*	0.218	*	-		0.880	*	527.7
7 Refinery	-11.1	*	1.329	*	0.661	*	1.003	*	-		1.596	*	746.7
8 Cement, Clay & Stone	-20.7	*	1.520	*	1.435	*	0.490	*	-		1.214	*	650.0
9 Steel and Iron Products	-13.8	*	1.162	*	0.966	*	0.547	*	-		0.956	*	557.5
10 Nonferrous Metal	-10.3	*	0.966	*	0.907	*	0.494	*	-		1.517	*	727.1
11 Metal Products	-20.1	*	1.494	*	1.352	*	0.535	*	-		1.279	*	671.9
12 Machinery	-10.5	*	0.904	*	0.896	*	0.964	*	-		1.297	*	680.7
13 Other Manufacturing products	-13.6	*	1.019	*	1.064	*	0.505	*	-		0.591	*	365.1
16 Wholesale & Retail	-5.1	*	0.726	*	0.493	*	-		0.335	*	0.529	*	320.8
17 Financial & Insurance	-5.8	*	1.155	*	0.108		-		1.605	*	1.481	*	723.7
18 Real Estates	-15.3	*	1.261	*	0.711	*	-		1.609	*	2.129	*	778.7
19 Transportation&Communication	-7.3	*	0.734	*	0.719	*	-		0.711	*	0.716	*	441.7
21 Educational Services	-17.2	*	2.488	*	0.169		-		1.226	*	2.295	*	681.8
23 Other Public Services	-9.0	*	0.279		1.185	*	-		0.448	*	1.778	*	718.5
24 Business Services	-8.7	*	1.141	*	0.400	*	-		1.152	*	1.176	*	640.9
25 Personal Services	-9.8	*	0.961	*	0.737	*	-		1.026	*	1.027	*	586.1
26 Miscellaneous	-3.7		0.331		0.148		-		0.912	*	0.551	*	86.3

Samle size: 200(= 2yearsx10x10 regions) *: Significant at 0.05 level

Dist-at: Automobile travel time Dist-psg: Passengers travel time

Table 6: Change in Interregional Accessibility

	Automobile Travel Time		Passenger Travel Time	
	1980	2004	1980	2004
Average trave time to other regions (hr)				
Hokkaido	20.7	19.2	8.3	6.7
Tohoku	10.4	9.1	9.0	6.8
NorthKanto	10.1	9.2	6.7	5.3
Shutoken	8.4	7.6	5.4	3.9
Chubu	8.1	7.3	6.0	4.8
Hokuriku	9.8	8.8	6.9	5.8
Kansai	8.2	7.5	5.1	4.3
Chugoku	11.8	9.9	7.0	6.3
Shikoku	11.1	9.9	7.7	6.4
Kyushu/ Okinawa	17.9	15.5	9.1	7.1
Japan	10.8	9.7	6.8	5.5
	Outbound Tokyo		Outbound Osaka	
	1980	2004	1980	2000
No. of bullet train services (weekday, express only)	56	199	100	210
No. of air flights (to prefecture capital only)	157	306	130	153

Table 7: Regional Technical Coefficients (Sector average, Base Case 1981)

	Hokkaido	Tohoku	N.Kanto	Shutoken	Chubu	Hokuriku	Kansai	Chugoku	Shikoku	Kyushu-Okinawa
Hokkaido	0.290	0.011	0.004	0.005	0.004	0.006	0.003	0.003	0.003	0.002
Tohoku	0.017	0.253	0.034	0.011	0.010	0.020	0.008	0.007	0.005	0.005
N.Kanto	0.007	0.020	0.227	0.017	0.012	0.013	0.009	0.008	0.007	0.006
Shutoken	0.045	0.047	0.111	0.303	0.050	0.034	0.028	0.033	0.033	0.029
Chubu	0.014	0.023	0.032	0.025	0.295	0.048	0.035	0.032	0.029	0.024
Hokuriku	0.005	0.008	0.005	0.004	0.007	0.247	0.005	0.004	0.002	0.002
Kansai	0.017	0.023	0.028	0.024	0.047	0.033	0.301	0.050	0.050	0.032
Chugoku	0.004	0.010	0.006	0.013	0.016	0.014	0.024	0.277	0.031	0.023
Shikoku	0.002	0.004	0.004	0.005	0.007	0.005	0.010	0.011	0.241	0.005
Kyushu-Okinawa	0.005	0.008	0.010	0.011	0.013	0.008	0.015	0.028	0.019	0.286
Total	0.405	0.406	0.462	0.418	0.462	0.429	0.437	0.452	0.419	0.414

The sector average output multiplier, $R(k,l)= \Sigma_i \Sigma_j z_{ij}^{kl}/x^l$, where z_{ij}^{kl} is the intermediate transaction.

Table 8: Percent Change in Technical Coefficients (Compared to the base case)

	Hokkaido	Tohoku	N.Kanto	Shutoken	Chubu	Hokuriku	Kansai	Chugoku	Shikoku	Kyushu-Okinawa
Hokkaido	-0.2%	-6.4%	-6.7%	-0.2%	2.1%	-1.3%	0.1%	-4.0%	-13.0%	4.1%
Tohoku	2.5%	-0.3%	6.3%	9.5%	6.5%	2.9%	3.7%	1.3%	-5.4%	3.1%
N.Kanto	-0.7%	1.5%	-2.2%	3.9%	2.8%	10.9%	0.8%	-0.3%	-0.5%	3.4%
Shutoken	-0.5%	7.1%	2.1%	-1.0%	1.9%	9.2%	2.1%	2.6%	-0.6%	1.5%
Chubu	2.1%	-0.9%	0.0%	2.4%	-0.8%	-1.3%	-0.9%	-0.5%	-6.0%	4.0%
Hokuriku	-1.1%	-4.9%	4.1%	1.7%	-2.4%	-1.7%	-2.2%	-0.6%	-4.0%	4.2%
Kansai	0.0%	-3.4%	-1.4%	0.2%	-1.4%	-1.3%	-1.0%	1.5%	-0.5%	1.5%
Chugoku	-0.3%	-3.8%	-2.7%	3.0%	2.0%	3.1%	5.5%	-0.2%	-0.9%	0.3%
Shikoku	-0.6%	-3.7%	3.3%	3.0%	2.6%	7.6%	10.7%	8.2%	2.2%	4.5%
Kyushu-Okinawa	3.3%	-6.7%	-1.2%	1.5%	4.3%	5.0%	2.3%	-2.5%	-7.6%	-0.8%
Total	0.0%	0.0%	-0.2%	0.0%	-0.1%	0.2%	0.1%	0.2%	0.1%	0.1%

Note: The column sum changes due to the change in the supply/demand adjustment coefficient (Ω).