A Study on Regional Economic Efficiency of Improving Transportation Facilities

By

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We have proposed in this study a new econometric model for estimation of the long-term and synthetic regional economic effects of improving transportation facilities. The principle of this study is based on the Expanded Inter-regional I-O Analysis.

We analyzed the variation of the inter-regional trade pattern coefficient and the input coefficient in the inter-regional I-O analysis according to the saving of transport cost between regions caused by improvement of transportation facilities, and proposed a mathematical model which explains this process. Then, using the econometric model, we showed that the variation of these structural coefficients changes the various present economic indexes and also the future final demand and inter-regional trade pattern coefficient, and that the effects of improving transportation facilities change the regional economic structure accumulatively year after year.

Additionaly, we applied this econometric model for the estimation of effects of the New Tokaido Line.

1. Introduction

Transportation facilities not only have the function of meeting the given traffic demand, but also have another function, that of changing the industrial and urban structures in regions over a long term.

Therefore, the establishment of the method measuring the effects in a long term is needed for the purpose of both improving future transportation facilities effectively and making use of the improvement successfully as the development strategy for leading the desirable regional structures.

This model is based on the nation-wide regional econometric model. Its direct objects are to measure the long-term and synthetic effects of improving transportation facilities, and to obtain some basic data for estimating the appropriateness of the improvement.

This model stands on the basis of the expanded-inter-regional I-O model and

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has five features as follows.

(1) The inter-regional trade pattern coefficient of each goods is changed endogenously. We developed econometric model for estimation of trade pattern coefficient which determines the trade pattern coefficient endogenously.

In this model three economic indexes are used as variations, namely capital stock, inter-regional transport cost and other locational conditions by region and industry.

(2) The variation of the input coefficient from the transport sector and the additional value rate in each region and industry affected by the saving of transport cost, is given endogenously by theoretical equation. While the time series variation of the other input coefficient is given exogenously every second year.

We have solved, by this model, the problem of inelasticity of the input coefficient and the trade pattern coefficient which is usually called the weak point in I-O analysis. And we utilized these two coefficients as policy variables for inducing the saving of transportation cost into the econometric model.

(3) The model is constituted so that vector of the regional final demands is determined endogenously by economic indexes in the last year. Thus we can give time series continuity to the model. Final demand of each year is not always decided by the previous values, but it can be allowed to combine economic indexes by sequential model, when economic growth is stable.

(4) We could increase the precision of this model using the inter-regional transaction sum calculated by inter-regional I-O analysis, to the estimation of inter-regional traffic volume and migration of population. Particularly in the freight traffic volume presumption model, the inter-regional transaction sum of each product is directly converted into the inter-regional freight traffic volume of each product. This point can be said to be one of remarkable advantages of our model which includes the inter-regional I-O analysis.

(5) Traffic capacity is checked endogenously, and it is assured that the estimated inter-regional traffic volume is not a latent demand but a real solution, and also transport cost between regions will be changed mechanically as a result of traffic capacity check.

2. The System Chart and Basic Organization of the Model

The system chart of the model is shown in Fig. 1. We can see in this figure, that the exogenous variables are the following four items, namely, the input coefficient, the import coefficient, the unit outlay vector of the final demand and the locational index but of the transport sector, excepting the saving of transport cost between regions and the increase of traffic capacity which are the policy coefficients.

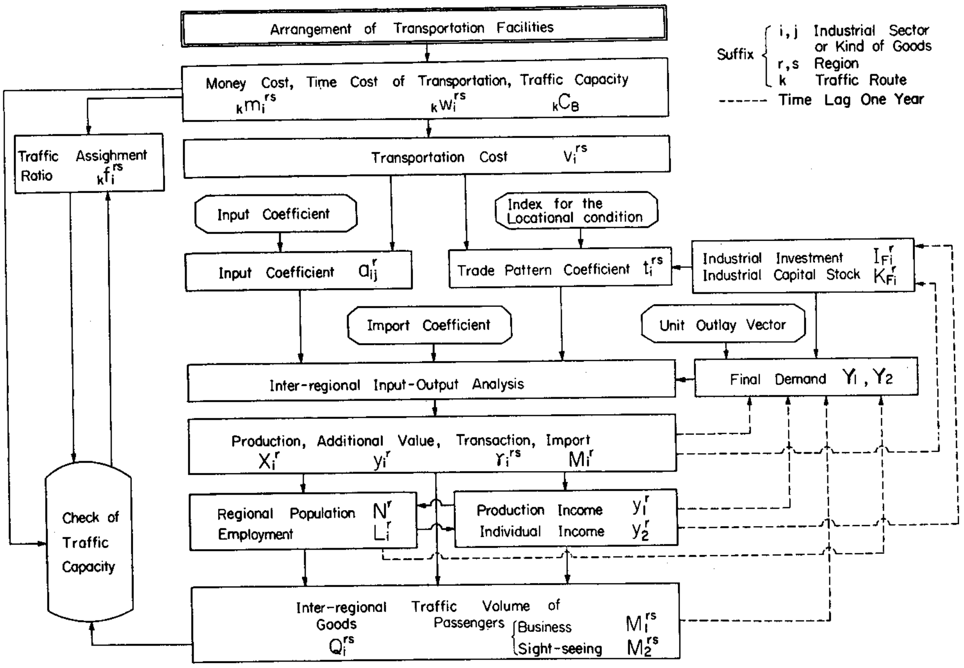


Fig. 1 The System Chart of the Proposed Model

We will explain the essentials of this model according to the system chart Fig. 1 as follows.

The concrete substance of improving transportation facillities is taken up by the direct effects, that is to say, the saving of transport money cost and time cost per unit freight and unit passenger and the increase of traffic capacity. The first problem is to presume how each user of the transportation facilities responds to the saving of money cost and time cost when traffic volume is below capacity.

i) Model for the Inter-regional Traffic Assignment Ratio by Goods

At first, cargo owners or carriers will select the most desirable route anew. As a result, the inter-regional traffic assignment ratio of each facility will be changed. This situation will be presumed by the following equation:

$$ {}_kf_i^{rs} = \frac{1}{n} + b_i\left(\frac{\sum_{k=1}^{n} {}_kw_i^{rs}}{n} - {}_kw_i^{rs}\right) + c_i\left(\frac{\sum_{k=1}^{n} {}_km_i^{rs}}{n} - {}_km_i^{rs}\right) \tag{1} $$

where

${}_kf_i^{rs}$: traffic assignment ratio of goods i by transportation facility k between region r and s

n : number of traffic routes between r and s

b_i, c_i : positive constant by goods
${}_kw_i^{rs}$: time cost of goods i by transport k between region r and s
${}_km_i^{rs}$: money cost of goods i by transport k between region r and s

That is to say, if some traffic routes exist between two regions, the traffic assignment ratio of each route will be determined as the function of the difference from both of average time cost and money cost.

ii) Model for Transport Cost by Goods between Regions

As a result, the inter-regional transport cost by goods, which is one of the most principal locational conditions, will be changed. This cost v_i^{rs} means the total cost or loss per unit goods, and is shown as follows:

$$\left.\begin{aligned} v_i^{rs} &= m_i^{rs} + \lambda_i w_i^{rs} \\ m_i^{rs} &= \sum_{k=1}^{n} {}_kf_i^{rs} \cdot {}_km_i^{rs}, \quad w_i^{rs} = \sum_{k=1}^{n} {}_kf_i^{rs} \cdot {}_kw_i^{rs} \end{aligned}\right\} \tag{2}$$

In this equation, λ_i is the exchange rate of time cost to money cost. Using b_i and c_i of the equation (1), we have

$$\lambda_i = \frac{b_i}{c_i} \tag{3}$$

The reason is as follows; each passenger or cargo owner will select the most desirable route which minimizes the total cost or loss of transportation, after comparing money cost and time cost of each traffic route. Supposing that the sum of assignment forms present traffic share, the partial derivative of the assignment ratio with respect to time cost is given as,

$$\frac{\partial_k f_i^{rs}}{\partial_k w_i^{rs}} = b_i\left(\frac{1}{n} - 1\right)$$

and that with respect to money cost as,

$$\frac{\partial_k f_i^{rs}}{\partial_k m_i^{rs}} = c_i\left(\frac{1}{n} - 1\right)$$

Thus, the ratio of them,

$$\frac{\partial_k f_i^{rs}/\partial_k w_i^{rs}}{\partial_k f_i^{rs}/\partial_k m_i^{rs}} = \frac{b_i}{c_i}$$

can be regarded as the ratio of values, time cost to money cost for cargo owners or carriers.

iii) Model for the Inter-regional Trade Pattern Coefficient

Each supplier and demander of goods will aim at his profit maximum. As a result, when some inter-regional transport cost is saved by improvement of transportation facilities, market share and trade pattern between regions must be changed. This situation has been presented by trade pattern coefficient in inter-regional I-O analysis, and can be determined by the following function:

$$ {}_t t_i^{rs} = \frac{{}_t K^r{}_{Fi} \cdot e^{-({}_t O_i^r + b_i \cdot {}_t v_i^{rs} + b_{0i} \cdot {}_t v_0^{rs})}}{\sum_{r=1}^{m} {}_t K^r{}_{Fi} \cdot e^{-({}_t O_i^r + b_i \cdot {}_t v_i^{rs} + b_{0i} \cdot {}_t v_0^{rs})}} \tag{4} $$

where

t_i^{rs} : Moses-Type trade pattern coefficient of goods i between region r and region s

$K^r{}_{Fi}$: capital stock of industry i in region r

O_i^r : index of the relative locational advantage of industry i in region r except transport cost of products

v_i^{rs}, v_0^{rs}: transport cost between r and s per unit goods i and unit business passenger

b_i, b_{0i} : positive constant

(Equation (4) will be explained in following chapter 3.)

iv) Model for the Input Coefficient from the Transport Sector and the Additional Value Rate

On the other hand, the saving of transport cost changes the input coefficient from the transport sector and the additional value rate of each industrial sector.

Assuming that selling price of goods does not vary, that is to say, the saving of transport cost of raw materials is wholly included in profit rate or additional value rate of the enterprises, they are calculated by the following equations:

$$ a'_{nj}{}^s = a_{nj}{}^s + \Delta a_{nj}{}^s \tag{5} $$

$$ a'_{0j}{}^s = a_{0j}{}^s - \Delta a_{nj}{}^s \tag{6} $$

$$ \Delta a_{nj}{}^s = \sum_{i=1}^{n} \sum_{r=1}^{m} k_i \cdot a_{ij}{}^s (t'_i{}^{rs} \cdot \Delta v_i{}^{rs} + v_i{}^{rs} \cdot \Delta t_i{}^{rs}) \tag{7} $$

$$ \Delta t_i{}^{rs} = t'_i{}^{rs} - t_i{}^{rs} \tag{8} $$

$$ \Delta v_i{}^{rs} = v'_i{}^{rs} - v_i{}^{rs} \tag{9} $$

where

$a_{nj}{}^s$, $a'_{nj}{}^s$: input coefficient from trasport sector n of industry i in region s before and after saving of transport cost

$t_i{}^{rs}$, $t'_i{}^{rs}$: trade pattern coefficient of goods i between region r and s before and after saving of transport cost

$a_{ij}{}^s$: input coefficient from industry i to sector j in region s

k_i : weight per unit sum of goods i

These equations are obtained as follows:
When X_j^s is produced in region s, assuming that $\bar{x}_{ij}^{rs}$ of goods i in weight are invested from region r, we have

$$\bar{x}_{ij}^{rs} = \bar{x}_{ij}^{s} t_i^{rs}$$

The transport cost required is

before saving : $\bar{x}_{ij}^{s} t_i^{rs} v_i^{rs}$

after saving : $\bar{x}_{ij}^{s} t'^{rs}_i v'^{rs}_i$

So, the saving of transport cost is written as

$$\Delta V_{ij}^{rs} = \bar{x}_{ij}^{s} t'^{rs}_i v'^{rs}_i - \bar{x}_{ij}^{s} t_i^{rs} v_i^{rs}$$

substituting $v'^{rs}_i = v_i^{rs} + \Delta v_i^{rs}$ into this equation, we have

$$\Delta V_{ij}^{rs} = \bar{x}_{ij}^{s} (v_i^{rs} \Delta t_i^{rs} + t'^{rs}_i \Delta v_i^{rs})$$

Therefore, Δx_{nj}^s which is the variation of total transport cost for producing X_j^s in region s, can be calculated by the following equation:

$$\Delta x_{nj}^s = \sum_{r=1}^{m} \sum_{i=1}^{n} \Delta V_{ij}^{rs}$$

According to definition, the input coefficient from transport sector of industry j in region s before the saving, is

$$a_{nj}^s = \frac{x_{nj}^s}{X_j^s}$$

and that after the saving is

$$\begin{aligned} a'^{s}_{nj} &= \frac{x_{nj}^s + \Delta x_{nj}^s}{X_j^s} \\ &= a_{nj}^s + \sum_{r=1}^{m} \sum_{i=1}^{n} \bar{a}_{ij}^s (v_i^{rs} \Delta t_i^{rs} + t'^{rs}_i \Delta v_i^{rs}) \\ &= a_{nj}^s + \Delta a_{nj}^s \end{aligned}$$

Ultimately, according to the assumption, the additional value rate after the saving is as follows:

$$a'^{s}_{0j} = a_{0j}^s - \Delta a_{nj}^s$$

If the saving of transport cost Δv_i^{rs} is negative, the input coefficient from the transport sector will decrease and the additional value rate of each industrial sector will increase.

v) Model for the Production

Variation of inter-regional trade pattern coefficeint and input coefficient caused by improvement of transportation facilities, changes the production of each goods in each region calculated by the inter-regional I-O analysis, even if the regional final demand is constant.

At first, we assume that imported goods are not sold between regions and only the products in self region are appropriated for export and net addition in stock. Then we define two inter-regional trade pattern coefficients anew, as follows:

$$t_i^{rs} = \frac{\gamma_i^{rs}}{R_i^s} \tag{10}$$

$$t'^{rs}_i = \frac{\gamma'^{rs}_i}{R'^s_i} \tag{11}$$

where

γ_i^{rs} : sum of domestic products i which region s purchases from region r, except that for export and net addition in stock

R_i^s : sum of domestic products i which region s purchases except that for export and for net addition in stock

γ'^{rs}_i: sum of goods i which region s purchases from region r including imports except that for export and for net addition in stock

R'^s_i : sum of goods i including imports which region s purchases except that for export and for net addition in stock

The trade pattern coefficeint t_i^{rs} defined above, shows the inter-regional transaction in domestic products i except that for export and for net addition in stock, and t'^{rs}_i means the same including imports.

Now we give a definition to the import coefficient as follows:

$$\left.\begin{aligned} {}_t\eta_i^s &= \frac{{}_tM_i^s}{{}_tR'^s_i} \\ {}_tR'^s_i &= R_{0i}^s - Y_{2i}^s \\ R_{0i}^s &= \sum_{j=1}^{n} a_{ij}^s X_j^s + Y_{1i}^s + Y_{2i}^s \end{aligned}\right\} \tag{12}$$

where

Y_{1i}^s : final demand of goods i in region s except that for export and for net addition in stock

Y_{2i}^s : final demand of goods i in region s for export and net addition in stock

M_i^s : import sum of goods i in region s

Thus, we have

$$\begin{aligned} &\text{if } r \neq s, \quad \gamma_i^{rs} = \gamma'^{rs}_i \\ &\text{if } r = s, \quad \gamma_i^{rs} = \gamma'^{rs}_i - M_i^s \\ &R_i^s = R'^s_i - M_i^s \end{aligned}$$

so that we obtain

$$\text{if } r \neq s, \quad t'^{rs}_i = t_i^{rs}(1-\eta_i^s) \tag{13}$$

$$\text{if } r = s, \quad t'^{ss}_i = t_i^{ss}(1-\eta_i^s)+\eta_i^s \tag{14}$$

The other side, the balance equation in the inter-regional I-O analysis of Moses Model is as follows:

$$X_i^r = \sum_{s=1}^{m} \sum_{r=1}^{n} t'^{rs}_i a_{ij}^s X_j^s + \sum_{s=1}^{m} t'^{rs}_i Y_{1i}^s + Y_{2i}^s - M_i^r \tag{15}$$

The fourth term in the right side of the equation (15), means balance term added to treat imports purchased by region r as goods produced in self region.

Substituting the equations (13) and (14) into (15),

$$X_i^r = \sum_{s=1}^{m} \sum_{j=1}^{n} t_i^{rs}(1-\eta_i^s) a_{ij}^s X_j^s + \sum_{s=1}^{m} t_i^{rs}(1-\eta_i^s) + Y_{2i}^s \tag{16}$$

Rewriting this equation with matrix, we obtain the following in the end.

$$_t\boldsymbol{X} = [\boldsymbol{I} - {_t\boldsymbol{T}}_t\boldsymbol{A}]^{-1} [_t\boldsymbol{T}_t\boldsymbol{Y}_1 + {_t\boldsymbol{Y}_2}] \tag{17}$$

where

$$\boldsymbol{X} = \begin{pmatrix} \boldsymbol{X}_1 \\ \boldsymbol{X}_2 \\ \vdots \\ \boldsymbol{X}_r \\ \vdots \\ \boldsymbol{X}_m \end{pmatrix}, \quad \boldsymbol{X}_r = \begin{pmatrix} X_1^r \\ X_2^r \\ \vdots \\ X_i^r \\ \vdots \\ X_n^r \end{pmatrix}, \quad \boldsymbol{Y}_1 = \begin{pmatrix} \boldsymbol{Y}_{11} \\ \boldsymbol{Y}_{12} \\ \vdots \\ \boldsymbol{Y}_{1r} \\ \vdots \\ \boldsymbol{Y}_{1m} \end{pmatrix}$$

$$\boldsymbol{Y}_{1r} = \begin{pmatrix} Y_{11}^r \\ Y_{12}^r \\ \vdots \\ Y_{1i}^r \\ \vdots \\ Y_{1n}^r \end{pmatrix}, \quad \boldsymbol{Y}_2 = \begin{pmatrix} \boldsymbol{Y}_{21} \\ \boldsymbol{Y}_{22} \\ \vdots \\ \boldsymbol{Y}_{2r} \\ \vdots \\ \boldsymbol{Y}_{2m} \end{pmatrix}, \quad \boldsymbol{Y}_{2r} = \begin{pmatrix} Y_{21}^r \\ Y_{22}^r \\ \vdots \\ Y_{2i}^r \\ \vdots \\ Y_{2n}^r \end{pmatrix}$$

$$\boldsymbol{T} = \begin{pmatrix} \boldsymbol{T}_{11} & \boldsymbol{T}_{12} & \cdots & \boldsymbol{T}_{1s} & \cdots & \boldsymbol{T}_{1m} \\ \boldsymbol{T}_{21} & \boldsymbol{T}_{22} & \cdots & \boldsymbol{T}_{2s} & \cdots & \boldsymbol{T}_{2m} \\ \vdots & \vdots & \ddots & \vdots & & \vdots \\ \boldsymbol{T}_{r1} & \boldsymbol{T}_{r2} & \cdots & \boldsymbol{T}_{rs} & \cdots & \boldsymbol{T}_{rm} \\ \vdots & \vdots & & \vdots & \ddots & \vdots \\ \boldsymbol{T}_{m1} & \boldsymbol{T}_{m2} & \cdots & \boldsymbol{T}_{ms} & \cdots & \boldsymbol{T}_{mm} \end{pmatrix}, \quad \boldsymbol{T}_{rs} = \begin{pmatrix} t_1^{rs}(1-\eta_1^s) & & & & 0 \\ & t_2^{rs}(1-\eta_2^s) & & & \\ & & \ddots & & \\ & & & t_i^{rs}(1-\eta_i^s) & \\ 0 & & & & \ddots \\ & & & & t_n^{rs}(1-\eta_n^s) \end{pmatrix}$$

$$A = \begin{pmatrix} A_1 & 0 & \cdots & 0 & \cdots & 0 \\ 0 & A_2 & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & & \vdots \\ 0 & 0 & \cdots & A_r & \cdots & 0 \\ \vdots & \vdots & & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 & \cdots & A_m \end{pmatrix}, \qquad A_r = \begin{pmatrix} a_{11}{}^r & a_{12}{}^r & \cdots & a_{1j}{}^r & \cdots & a_{1n}{}^r \\ a_{21}{}^r & a_{22}{}^r & \cdots & a_{2j}{}^r & \cdots & a_{2n}{}^r \\ \vdots & \vdots & \ddots & \vdots & & \vdots \\ a_{i1}{}^r & a_{i2}{}^r & \cdots & a_{ij}{}^r & \cdots & a_{in}{}^r \\ \vdots & \vdots & & \vdots & \ddots & \vdots \\ a_{n1}{}^r & a_{n2}{}^r & \cdots & a_{nj}{}^r & \cdots & a_{nn}{}^r \end{pmatrix}$$

Out of the structural coefficients, the trade pattern coefficient and the input coefficients from transport sector can be presumed by equation (4) and (5). And the other input coefficients are changed exogenously by means of time series tendency. For example, in our application, they are changed in every second year using the actual result in 1960 and the values in 1963, 1965 and 1971 calculated by the RAS-Method. And also the import coefficients are changed anually by means of time series using the actual result of the import coefficient in each region in 1960, the actual results of the national import sum of each goods in 1963, 1964 and 1966 and the presumed national import sum of each goods in 1971.

vi) Model for the Additional Value Sum, the Production Income and the Individual Income

It is due to the variations of the additional value sum, the production income and the individual income in each region, that the variation of production sum in each region and industry changes the final demand in each region in the next year.

At first, the additional value is obtained,

$$y_i{}^r = a_{0i}{}^r X_i{}^r \tag{18}$$

where

$y_i{}^r$: additional value of industry i in region r

$a_{0i}{}^r$: additional value rate of industry i in region r

Then, multiplying a constant ratio to the additional value, the proudction income is calculated as

$$\left.\begin{aligned} y_1{}^r &= ky^r \\ y^r &= \sum_{i=1}^{n} y_i{}^r \end{aligned}\right\} \tag{19}$$

where

$y_1{}^r$: production income in region r

k : positive constant

The regional individual income is the important economic index which shows expenditure in regional economy. Especially it is not the production income but the individual income that has direct relation to consumption demand out of regional final demand in the inter-regional I-O analysis. And the most adequate index for comparing the living level in regions is the individual income per person. This is given as follows:

$$\left.\begin{aligned} {}_t\bar{y}_2{}^r &= a_0 + a_1\frac{{}_ty_1{}^r}{{}_tN^r} + a_2({}_{t-1}\bar{y}_2 - {}_{t-1}\bar{y}_2{}^r) \\ {}_ty_2{}^r &= {}_tN^r \cdot {}_t\bar{y}_2{}^r \end{aligned}\right\} \tag{20}$$

where

$\bar{y}_2{}^r$: individual income per person in region r
$y_1{}^r$: production income in region r
N^r: population in region r
y_2 : national average of individual income per person

vii) Model for Regional Population

Future regional population is one of the most important variables for regional economy. For presuming the consumption demand, population is as important as the industrial capital for production. So, it's necessary to raise presumed accuracy as much as possible. Regional population can be presumed by natural increase in population and the difference between influx population and efflux population as a result of migration, as the following equation:

$$\left.\begin{aligned} {}_tN^r &= a \cdot {}_{t-1}N^r + ({}_tN_{\mathrm{in}}{}^r - {}_tN_{\mathrm{out}}{}^r) \\ {}_tN_{\mathrm{in}}{}^r &= \sum_{s=1}^{m} {}_tN^{sr} \\ {}_tN_{\mathrm{out}}{}^r &= \sum_{s=1}^{m} {}_tN^{rs} \end{aligned}\right\} \tag{21}$$

where

N^r : population in region r
$N_{\mathrm{in}}{}^r$: total influx population into region r
$N_{\mathrm{out}}{}^r$: total efflux population from region r
a : reproduction ratio in population
N^{rs}, N^{sr}: migration from r to s, from s to r

When we presume regional population in this equation, it is important to estimate the migration between regions.

We have established various migration models and examined their fitness.

In the end, we got the following model satisfactorily, concerning both the theoretical basis and presuming accuracy:

$$\left.\begin{aligned} N^{rs} &= a_0 + a_1 \frac{({}_{t-1}\bar{y}_1{}^s - {}_{t-1}\bar{y}_1{}^r)({}_{t-1}L_2{}^s + {}_{t-1}L_3{}^s)_{t-1}L_1{}^r}{d^{rs}} D_1 \\ &\quad + a_2({}_{t-1}\gamma^{rs} + {}_{t-1}\gamma^{rs}) + a_3 \sum_{l=t-1}^{t-5} {}_lN^{sr} \\ D_1 &= \begin{cases} 1 \ ; \text{ if } \ {}_t\bar{y}_1{}^s - {}_t\bar{y}_1{}^r > 0 \\ 0 \ ; \text{ if } \ {}_t\bar{y}_1{}^s - {}_t\bar{y}_1{}^r < 0 \end{cases} \end{aligned}\right\} \quad (22)$$

where

$L_2{}^s$, $L_3{}^s$: number of workers of the secondary and the tertiary industry in region s
$L_1{}^r$: number of workers of the primary industry in region r
γ^{rs}, γ^{sr} : transaction from r to s, from s to r
d^{rs} : distance by railway from r to s
a_0, a_1, a_2, a_3: constant

The second term of this equation means migration caused by income differential and employment, and it acts only when the income differential is positive. The third term means migration by the degree of economic connection such as transference, and it acts similarly to both directions. The fourth represents population coming back home. We applied this model to the transaction analysis of 1965, using the data of nine divided regions in Japan. As a result, we got the multiple

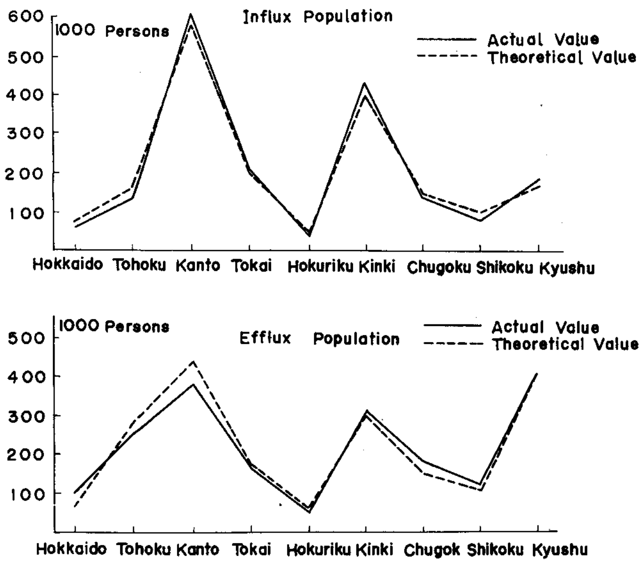


Fig. 2 Comparison between the Actual and Theoretical Values of Total Influx, Efflux Population

correlation coefficient, 0.940, and all of coefficients satisfactorily. Fig. 2 indicates the comparison between the actual results and the theoretical values of total influx population and efflux population, showing that both influx and efflux structures are steady.

viii) Model for Freight Traffic Volume between Regions

We can say that freight traffic volume between regions and transactions are dual expression, the former with weight unit and the later with the amount of money. As the dealings have been already calculated by the inter-regional I-O analysis, equation (17), in this model freight traffic volume can be obtained as follows:

OD Freight Traffic Volume

$$ {}_tQ_i^{rs} = a_{0i}^r + a_{1i}^r \cdot {}_t\gamma_i^{rs} \tag{23}$$

where

Q_i^{rs} : traffic volume of goods i from region r to region s

a_{0i}^r, a_{1i}^r: translating coefficient of transactions of goods i from region r, into freight volume

OD Freight Volume by Transportation Facility

$$ {}_{tk}Q_i^{rs} = {}_{tk}f_i^{rs} \cdot {}_tQ_i^{rs} \tag{24}$$

where

${}_kQ_i^{rs}$: OD freight volume of goods i from r to s on the transportation facility k

In this equation, ${}_kf_i^{rs}$ means the traffic assignment ratio gained in equation (1).

Traffic Volume of Passing Freight

$$ {}_{tk}H_{i\beta}^{rs} = {}_kq_\beta^{rs} \cdot {}_{tk}Q_i^{rs} \tag{25}$$

where

${}_kH_{i\beta}^{rs}$: out of the traffic volume of goods i from r to s on the transportation facility k, the volume passing the traffic seciton β

${}_kq_\beta^{rs}$: ratio of the traffic volume passing the traffic section β to the total volume from r to s on k

ix) Model for the Traffic Volume of Passengers between Regions

Passengers are divided into business and sight-seeing, then presumed separately. They are originated essentially from the different necessity, therefore it's necessary to classify passengers traffic according to their purpose if we expect to presume it accurately.

Traffic Volume of Passengers for Business

$$ {}_tM_1{}^{rs} = G\frac{\sum_{i=2}^{10}\frac{1}{2}({}_t\gamma_i{}^{rs} + {}_t\gamma_i{}^{sr})}{({}_tv_0{}^{rs})^{\alpha}} \tag{26} $$

where

$M_1{}^{rs}$: traffic volume of passengers for business between region r and region s
$v_0{}^{rs}$: time distance of passenger between r and s
G, α : positive constant

Traffic volume of passengers for business is presumed by transactions of secondary and tertiary industry and time distance by this equation, which assures enough conformity.

Traffic Volume of Passengers for Sight-seeing

$$ {}_tM_2{}^{rs} = \frac{1}{2}[G_0\cdot{}_tf_s\cdot{}_tN^r({}_t\bar{y}_2{}^r)^k({}_tv_0{}^{rs})^{\alpha_s} + G_0\cdot{}_tf_r\cdot{}_tN^s({}_t\bar{y}_2{}^s)^k({}_tv_0{}^{sr})^{\alpha_r}] \tag{27} $$

where

$M_2{}^{rs}$: traffic volume of passengers for sight-seeing between region r and s
f_r, f_s: "index for attractive potential" of sight-seeing in region r and s
G_0, k : positive constant
α_r, α_s : negative constant

Attractive potential in sight-seeing is formed by latent peculiarity of each region, and we have called it "index of regional attractive potential" of sight-seeing.

x) Model for Industrial Capital Investment and Stock

Industrial capital stock is an important variable because it changes directly the inter-regional trade pattern coefficient according to equation (4).

We presume sum of national industrial investment, I_F, by the following equation.

$$ {}_tI_F = a_0 + a_1\cdot{}_{t-1}y_1 + a_2t \tag{28} $$

We also examined acceleration model, but we prefer equation (28) on its better fitness.

Then sum of national investment by industry, ${}_tI_{Fi}$, is presumed using allocated national industrial investment by the sum of additional value by industry in the preceding year.

$$ {}_tI_{Fi} = {}_tI_F\left(a_0 + a_1\frac{{}_{t-1}y_i}{{}_{t-1}y}\right) \tag{29} $$

Then I_{Fi} is allocated into the investment by industry and region, $I_{Fi}{}^r$, by the following acceleration model.

$$ {}_tI_{Fi}{}^r = {}_tI_{Fi}\left(a_{i0}+a_{i1}\frac{{}_{t-1}y_i{}^r}{{}_{t-1}y_i}+a_{i2}\frac{\Delta_{t-1}{}^*X_i{}^r}{\Delta_{t-1}{}^*X_i}+a_{i3}\frac{\Delta_{t-2}{}^*X_i{}^r}{\Delta_{t-2}{}^*X_i}\right) \tag{30}$$

where

$$\Delta_t{}^*X_i{}^r = \begin{cases} {}_tX_i{}^r - {}_{t-1}X_i{}^r, & \text{if } {}_tX_i{}^r - {}_{t-1}X_i{}^r > 0 \\ 0 & , \text{ if } {}_tX_i{}^r - {}_{t-1}X_i{}^r < 0 \end{cases}$$

When production of each region increases by improving transportation facilities, both the sum of additional value, $y_i{}^r$, and the increase of production from the preceding year, $\Delta^*X_i{}^r$, will be increased. Thus the investment ratio of industrial capital by region will be changed. Therefore sum of capital stock by industry and region, $K_{Fi}{}^r$, is estimated by the following equation.

$$ {}_tK_{Fi}{}^r = (1-e_{Fi})_{t-1}K_{Fi}{}^r + {}_{t-1}I_{Fi}{}^r \tag{31}$$

where

e_{Fi}: annual elimination ratio of capital in industry i.

The inter-regional trade pattern coefficient is changed again by alteration of industrial capital stock by region through equation (4). Consequently improvement of any transportation facility changes the inter-regional trade pattern coefficient year after year accumulatively.

xi) Model for the Final Demand

The variation of economic indexes such as production, additional value, income and population influenced by improving transportation facilities, changes the demand for consumption and investment in the next term. Thus it changes also the final demand in each region.

We divided the final demand into nine sectors, i.e. household consumption expenditure, business consumption expenditure, general government consumption expenditure, industrial capital investment, housing investment, capital investment in transport, governmental general investment, net addition in stock and export. Then we formed econometric model for each sector respectively, and after calculating the nation-wide value, we allocated it to regions. Finally regional values are divided into final demands by goods using unit outlay vectors classified into nine sectors of final demand.

These vectors are changed exogenously every year with demand and supply tables by industry in 1960, 1963, 1965 and 1971. Final demand vectors in equation (17), $\boldsymbol{Y}_1$ and $\boldsymbol{Y}_2$, are writern as

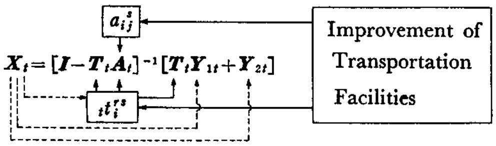
$$ {}_t\boldsymbol{Y}_1 = {}_t\boldsymbol{Y}_{c1}+{}_t\boldsymbol{Y}_{c2}+{}_t\boldsymbol{Y}_{c3}+{}_t\boldsymbol{Y}_{IF}+{}_t\boldsymbol{Y}_{IP}+{}_t\boldsymbol{Y}_{GT}+{}_t\boldsymbol{Y}_G \tag{32}$$

$$ {}_t\boldsymbol{Y}_2 = {}_t\boldsymbol{Y}_J+{}_t\boldsymbol{Y}_F \tag{33}$$

Where all of $\boldsymbol{Y}$ present final demand vectors of

$\boldsymbol{Y}_{c1}$: household consumption expenditure
$\boldsymbol{Y}_{c2}$: business consumption expenditure
$\boldsymbol{Y}_{c3}$: governmental general consumption expenditure
$\boldsymbol{Y}_{IF}$: industrial capital investment
$\boldsymbol{Y}_{IP}$: housing investment
$\boldsymbol{Y}_{GT}$: capital investment in transport
$\boldsymbol{Y}_{G}$: other investment by government
$\boldsymbol{Y}_{J}$: net addition in stock
$\boldsymbol{Y}_{F}$: export

A summary of the above-mentioned model is shown in the following figure



where

$\boldsymbol{X}$: output vector in objective regions
$\boldsymbol{I}$: unit matrix
$\boldsymbol{T}$: matrix of the regional input coefficients
$\boldsymbol{Y}$: vector of the regional final demands
$\dashrightarrow$: stands for the time lags

3. Model for the Inter-Regional Trade Pattern Coefficient

One of the most important structural coefficients in the inter-regional I-O analysis is the inter-regional trade pattern coefficient. But it has seldom or never been studied yet in spite of its importance. We will now propose a model for preceding presumption of the inter-regional trade pattern coefficient, and will present the result of inspecting its appropriateness.

3-1 Model for the Trade Pattern Coefficient

The trade pattern coefficeint in I-O analysis in Moses Model is defined as

$$t_i^{rs} = \frac{\gamma_i^{rs}}{R_i^s} \tag{34}$$

where

R_i^s : sum of goods i purchased by region s
γ_i^{rs} : sum of goods i purchased by region s from region r

The values of variables in equation(34) are in a cross-sectional term or year. So equation (1) is rewritten as

$$ {}_t t_i^{rs} = \frac{{}_t\gamma_i^{rs}}{{}_tR_i^s} \tag{35} $$

in which suffix t shows the value in term t. The inter-regional trade pattern coefficients defined by equation (34) and (35) are after going indexes, namely, we can get it after transaction in objective term is over.

What is necessary on applying to the inter-regional I-O analysis for economical forecast or planning is

$$ \{Y_i^r,\ a_{ij}^r,\ t_i^{rs}\} \longrightarrow \{X_i^r,\ \gamma_i^{rs},\ R_i^s\} $$

Therefore, it is not suitable to use directly the trade pattern coefficient defined in equation (34) for future planning. In order to use the coefficient defined in equation (35) for future planning, the value of the coefficient must be predictable, that is, it is required to know what conditions are necessary to be satisfied when the trade pattern coefficient is constant, and how the coefficient changes for the variation of these conditions. So we have to find the principle by which the trade pattern coefficient in equation (34) takes its present value.

In the perfect market a buyer will select freely out of the same commodities which many suppliers offer by their prices, and the commodities of the same quality will remain settled in same price.

For each enterprise, the supplier, a dominant factor of its business is the motive of profits. Therefore, whether a supplier offers his goods to market s or not, seems to depend on the difference.

$$ p_i^s - c_i^{rs} $$

where $\quad c_i^{rs} = p_{0i}^r + v_i^{rs}$

p_{0i}^r : production cost of goods i in region r

v_i^{rs} : transportation cost of the goods to region s

p_i^s : the price of the goods in market s

Since the price p_i^s appears to be determined afterwards by equilibrium both of demand and supply, it can be said that, in substance, dimensions of c_i^{rs} controls relative merits or competitive potential of each supplying region r to demanding region s.

Proceeds of sales within a definite period of time will be unestimated until the end of the period for each supplier. Supplier for a demanding region is usually not single but multiple, because they compete with one another. And in such a case, the larger the total cost c_i^{rs}, the fainter the relative competitive potential to region s. So the supplying share from region r to whole demand in region s, will be decreased. We will assume accordingly as follows:

$$t_i^{rs} \propto e^{-b_i c_i^{rs}} \tag{36}$$

That is to say, if all indexes except the total cost c_i^{rs} are equal in each region r, the supplying share will decrease through an exponential function according to c_i^{rs}. The reason why we assume this exponential function of that relative variance of c_i^{rs} is the matter in market competition as the function expresses it well, and that the function is suitable for various convenient calculations.

On the other hand, when competitive potential of each supplying region r to demanding region s is the same, that is to say, c_i^{rs} are equal to each other, the saled share from a supplying region to total demand in demanding region seems to be in proportion to productive capacity s_{0i}^{r} in the region. So we will suppose

$$t_i^{rs} \propto s_{0i}^{r} \tag{37}$$

This can be explained also by domain problem as follows. Assume that one domain r which has productive capacity s_{0i}^{r} is divided into two domains, $s_{0i}^{r_1}$ and $s_{0i}^{r_2}$. If these two domains have the same conditions except for productive capacity, it should be said that the trade pattern coefficients for a demanding region s are as follows.

$$t_i^{r_1 s} : t_i^{r_2 s} = s_{0i}^{r_1} : s_{0i}^{r_2}$$

provided that $t_i^{r_1 s} + t_i^{r_2 s} = t_i^{rs}$

We prefer sum of capital stock of industry i in the region at the beginning of the period as that which indicates productive capacity s_{0i}^{r}, in equation (37). Then, using equations (36) and (37), we have

$$t_i^{rs} = k_i^s \cdot K^r{}_{Fi} \cdot e^{-b_i c_i^{rs}} \tag{38}$$

Substituting $\sum_{r=1}^{m} t_i^{rs} = 1$, We obtain

$$k_i^s = \frac{1}{\sum_{r=1}^{m} K^r{}_{Fi} \cdot e^{-b_i c_i^{rs}}}$$

Thus the model for trade pattern coefficient is written as the following equation:

$$t_i^{rs} = \frac{K^r{}_{Fi} \cdot e^{-b_i c_i^{rs}}}{\sum_{r=1}^{m} K^r{}_{Fi} \cdot e^{-b_i c_i^{rs}}} \tag{39}$$

3-2 Modified Model for the trade pattern coefficient

It is so difficult to presume accurately the total cost c_i^{rs} in equation (39), that we will propose an expedient process for calculation in the following.

In equation (39) the total cost, c_i^{rs}, can be divided as

$$c_i^{rs} = p_{0i}^r + v_i^{rs}$$

where

p_{0i}^r: production cost per unit goods i in region r

v_i^{rs}: transport cost per unit goods i from region r to region s

Therefore,

$$e^{-b_i c_i^{rs}} = e^{-b_i(p_{0i}^r + v_i^{rs})} = e^{-b_i p_{0i}^r} \cdot e^{-b_i v_i^{rs}} \tag{40}$$

In this equation we rewrite as

$$e^{-b_i p_{0i}^r} = A_i^r \tag{41}$$

then A_i^r shows the value of productive locational factor in region r except for transport condition of manufactured goods.

Substituting equations (40) and (41) into (39), we have

$$_t t_i^{rs} = \frac{_tK^r{}_{Fi} \cdot {}_tA_i^r \cdot e^{-b_i v_i^{rs}}}{\sum_{r=1}^{m} {}_tK^r{}_{Fi} \cdot {}_tA_i^r \cdot e^{-b_i \cdot v_i^{rs}}} \tag{42}$$

In equation (42), A_i^r is not needed to take the absolute value as defined in (40), and it can be thought of as an index representing the relative locational conditions of region r to other regions except transport condition of manufactured goods.

In equation (42) the value of $A_i^{r_k}$ in a optional region r_k shall be fixed as

$$A_i^{r_k} \equiv 1$$

Calculating the coefficients b_i and A_i^r, by the regression analysis with the actual values of t_i^{rs}, $K^r{}_{Fi}$ and v_i^{rs}, this A_i^r comes to show the relative difference of the locational condition of each region to the region r_k except transport of manufactured goods. Now, when we calculate each x_i^r with obtained A_i^r, by

$$e^{-b_i x_i^r} = A_i^r \tag{43}$$

we can find the value of x_i^r, that is, the difference of production cost p_{0i}^r in equation (41) between region r and region r_k. We will call x_i^r "difference of the productive locational factor" to optional region, and it can be said that;

if $x_i^r > 0$ $(A_i^r < 1)$, locational conditions except transport of manufactured goods are worse than region r_k',

if $x_i^r < 0$ $(A_i^r > 1)$, the conditions are better than r_k'.

On the occasion that production cost p_{0i}^r in equation (41) changes as far as Δx_i^r, in future, we can presume the change of the trade pattern coefficient by suing

$$A'_i{}^r = A_i^r \cdot e^{-b_i \cdot \Delta x_i^r}$$

instead of A_i^r in equation (42). Then equation (42) enables us to presume the change of the trade pattern coefficient according to every change of locational conditions in addition to that of transport cost.

Equation (42) does not contain the change of the trade pattern coefficient by improving transportation facilities for business passengers.

As business passengers usually travel between trading regions before and after the inter-regional transaction of goods, improvement of transportation facilities must have some influence upon the pattern of inter-regional transaction.

We propose the following modified model for the trade pattern coefficient in case of considering the transportation of business passengers.

$$t_i^{rs} = \frac{K^r{}_{Fi} \cdot A_i^r \cdot e^{-(b_i v_i^{rs} + b_{0i} v_0^{rs})}}{\sum_{r=1}^{m} K^r{}_{Fi} \cdot A_i^r \cdot e^{-(b_i v_i^{rs} + b_{0i} v_0^{rs})}} \tag{44}$$

where

v_i^{rs}: transport cost between region r and region s per unit goods i

v_0^{rs}: transport cost between r and s per a passenger (considering both money cost and time cost)

Now,

$$A_i^r = e^{-o_i^r} \tag{45}$$

Substituting equation (45) into (44), we have

$$t_i^{rs} = \frac{K^r{}_{Fi} \cdot e^{-(O_i^r + b_i v_i^{rs} + b_{0i} v_0^{rs})}}{\sum_{r=1}^{m} K^r{}_{Fi} \cdot e^{-(O_i^r + b_i v_i^{rs} + b_{0i} v_0^{rs})}}$$

which has already been mentioned as equation (4).

3-3 An application of the Model for the Trade Pattern Coefficient

—Measurement of the short-term expansion effect and contraction effect by improving transportation facilities—

We will analyze, using the model, the short-term effect by means of changing the inter-regional transaction pattern by goods out of the expansion effect and the contraction effect which improvement of transportation facilities gives to each region. This short-term effect means the effect when production capacity and demand are stable.

At first, we will give the following definition; expansion effect is the effect which increases the supplying amount of the proper industry in the region, and contraction effect is that which decreases the supplying amount.

Now, we shall consider the effect on the occasion when transport cost between r_0 and s_0 is saved by improving transportation facilities. And let us suppose, for simplicity, that improvement of transportation facilities between r_0 and s_0 does not have an influence on the transport cost except between r_0 and s_0.

The transport cost between r_0 and s_0, $v_i^{r_0 s_0}$, changes the supplying amount of goods i from optional region r to s_0. And this ratio can be written as follows by equation (42) and the assumption that the demanding amount of each region is constant:

$$r \neq r_0\,, \quad \frac{\partial \gamma_i^{r s_0}}{\partial v_i^{r_0 s_0}} = \frac{\partial R_i^{s_0} t_i^{r s_0}}{\partial v_i^{r_0 s_0}} = R_i^{s_0} \frac{\partial t_i^{r s_0}}{\partial v_i^{r_0 s_0}} = b_i t_i^{r s_0} t_i^{r_0 s_0} R_i^{s_0} \tag{46}$$

$$r = r_0\,, \quad \frac{\partial \gamma_i^{r s_0}}{\partial v_i^{r_0 s_0}} = \frac{\partial \gamma_i^{r_0 s_0}}{\partial v_i^{r_0 s_0}} = R_i^{s_0} \frac{\partial t_i^{r_0 s_0}}{\partial v_i^{r_0 s_0}} = -b_i[t_i^{r_0 s_0} - (t_i^{r_0 s_0})^2] R_i^{s_0} \tag{47}$$

where

$\gamma_i^{r_0 s_0}$: transaction sum of goods i from r to s_0

$R_i^{s_0}$: demanding amount of goods i in region s_0

When transport cost $v_i^{r_0 s_0}$ is saved, $\varDelta v_i^{r_0 s_0}$ will become negative. So the change of supplying amount in regard to the transport in each region is given as

$$r \neq r_0\,, \quad \varDelta v_i^{r_0 s_0} b_i t_i^{r s_0} t_i^{r_0 s_0} R_i^{s_0} < 0 \tag{48}$$

$$r = r_0\,, \quad \varDelta v_i^{r_0 s_0} b_i [t_i^{r_0 s_0} - (t_i^{r_0 s_0})^2] R_i^{s_0} > 0 \tag{49}$$

Therefore, saving of transport cost from r_0 to s_0 gives the expansion effect to region r_0 and contraction effect to other regions. As variation of transport cost from r_0 to s_0 usually changes that from s_0 to r_0, total effect which each industry in each region is suffered consequently becomes

$$\begin{aligned} r \neq r_0, s_0\,, \quad & \varDelta v_i^{r_0 s_0} \frac{\partial \gamma_i^{r s_0}}{\partial v_i^{r_0 s_0}} + \varDelta v_i^{s_0 r_0} \frac{\partial \gamma_i^{r r_0}}{\partial v_i^{s_0 r_0}} \\ & = \varDelta v_i^{r_0 s_0} b_i t_i^{r s_0} t_i^{r_0 s_0} R_i^{s_0} + \varDelta v_i^{s_0 r_0} b_i t_i^{r r_0} t_i^{s_0 r_0} R_i^{r_0} \end{aligned} \tag{50}$$

$$\begin{aligned} r = r_0\,, \quad & \varDelta v_i^{r_0 s_0} \frac{\partial \gamma_i^{r_0 s_0}}{\partial v_i^{r_0 s_0}} + \varDelta v_i^{s_0 r_0} \frac{\partial \gamma_i^{r_0 r_0}}{\partial v_i^{s_0 r_0}} \\ & = -\varDelta v_i^{r_0 s_0} b_i [t_i^{r_0 s_0} - (t_i^{r_0 s_0})^2] R_i^{s_0} + \varDelta v_i^{s_0 r_0} b_i t_i^{r_0 r_0} t_i^{s_0 r_0} R_i^{r_0} \end{aligned} \tag{51}$$

$$\begin{aligned} r = s_0\,, \quad & \varDelta v_i^{r_0 s_0} \frac{\partial \gamma_i^{s_0 s_0}}{\partial v_i^{r_0 s_0}} + \varDelta v_i^{s_0 r_0} \frac{\partial \gamma_i^{s_0 r_0}}{\partial v_i^{s_0 r_0}} \\ & = \varDelta v_i^{r_0 s_0} b_i t_i^{s_0 s_0} t_i^{r_0 s_0} R_i^{s_0} - \varDelta v_i^{s_0 r_0} b_i [t_i^{s_0 r_0} - (t_i^{s_0 r_0})^2] R_i^{r_0} \end{aligned} \tag{52}$$

Thus it is able to judge which of the effects each industry in each region is suf-

fered by improving transportation facilities between r_0 and s_0 by the positive or negative of equation (50), (51) and (52).
While, equations (50), (51) and (52) indicate

$$\sum_r \frac{\partial \gamma_i^{rs_0}}{\partial v_i^{r_0 s_0}} \equiv 0 \tag{53}$$

$$\sum_r \frac{\partial \gamma_i^{rr_0}}{\partial v_i^{s_0 r_0}} \equiv 0 \tag{54}$$

then both of regions suffering expansion effect and contraction effect always exist, and the total effects become zero, when demands by region and goods are not changed.

More generally, if transport cost between regions is changed by improving transportation facilities as much as

$$\Delta v_i^{r_k s_l} \ (r_k = 1,\ 2,\ \ldots..\ m,\quad s_l = 1,\ 2,\ \ldots..,\ m)$$

the total effect which optional region r_j suffers, is given as follows:

$$\begin{aligned}
&\sum_i \sum_{k=1}^{m} \sum_{l=1}^{m} \Delta v_i^{r_k s_l} \frac{\partial \gamma_i^{r_j s_l}}{\partial v_i^{r_k s_l}} \\
&= \sum_i \sum_{l=1}^{m} \Delta v_i^{r_j s_l} \frac{\partial \gamma_i^{r_j s_l}}{\partial v_i^{r_j s_l}} + \sum_i \sum_{\substack{k=1 \\ k \neq j}}^{m} \sum_{l=1}^{m} \Delta v_i^{r_k s_l} \frac{\partial \gamma_i^{r_j s_l}}{\partial v_i^{r_k s_l}} \\
&= \sum_i \sum_{l=1}^{m} \{-\Delta v_i^{r_k s_l} b_i [t_i^{r_j s_l} - (t_i^{r_j s_l})^2] R_i^{s_l}\} \\
&\quad + \sum_i \sum_{k=1}^{m} \sum_{l=1}^{m} \Delta v_i^{r_k s_l} b_i t_i^{r_j s_l} t_i^{r_k s_l} R_i^{s_l}
\end{aligned} \tag{55}$$

4. Relation Between Improving Transportation Facilities and Economic Growth

4-1 Economic Growth Analysis and Input-output Analysis

The models mentioned above, have explained in detail the relative economic variation between regions by improving transportation facilities. But it can not explain yet the effect on the nation-wide economic growth caused by improving transport.

Essentially, the theory of I-O analysis is applied for estimating the productive amount by equality of final demand and income, which is

$$y_t = \boldsymbol{A}_{0t}\boldsymbol{X}_t = \boldsymbol{A}_{0t}[\boldsymbol{I}-\boldsymbol{A}_t]^{-1}\boldsymbol{Y}_t = Y_t \tag{56}$$

where

y : national sum of income
Y : national sum of final demand
$\boldsymbol{A}$: matrix of the input coefficients
$\boldsymbol{A}_0$: vector of the additional value rate
$\boldsymbol{X}$: vector of the production amounts
$\boldsymbol{Y}$: vector of the final demands

Therefore, no matter how the input coefficient $\boldsymbol{A}$ and the additional value rate $\boldsymbol{A}$ change by improving transportation facilities, income y is not changeable so long as final demand Y is constant. So it is required to elucidate on how much the improvement of transportation facilities changes final demand Y, for dealing with the problem of how much the improvement changes nation-wide income. But we cannot solve this problem using the simple models mentioned above for presuming final demand,formed by the principle that the sum of final demand in the present term Y_t is determined by the sum of income in the former term y_{t-1}. We propose anew the following model for expressing the actual economic activity more exactly:

$$\boldsymbol{X}_t = [\boldsymbol{I}-\boldsymbol{A}]^{-1}\boldsymbol{Y}_t \tag{57}$$
$$\boldsymbol{Y}_t = \boldsymbol{Y}_{1t}+\boldsymbol{Y}_{2t} \tag{58}$$
$$\boldsymbol{Y}_{1t} = \boldsymbol{f}_1(y_{t-1}) \tag{59}$$
$$\boldsymbol{Y}_{2t} = \boldsymbol{f}_2(y_t) \tag{60}$$
$$y_t = f(\boldsymbol{K}_t, \boldsymbol{L}_t, \boldsymbol{A}_t) \tag{61}$$

where

$\boldsymbol{K} = \{K_i\}$: vector of the industrial capitals
$\boldsymbol{L} = \{L_i\}$: vector of the labor powers
$\boldsymbol{A} = \{a_{ij}\}$: matrix of the input coefficients

The actual economic activities are transformed into these equations (57)–(61) hypothetically, that is to say, the final demand in the present term $\boldsymbol{Y}$ consists of element determined by income in the former term, $\boldsymbol{Y}_1$, and that in the present term, $\boldsymbol{Y}_2$. And the national average income in the present y, is determined by two vectors such as, the industrial capital $\boldsymbol{K}_0$, the labor power $\boldsymbol{L}$, and by matrix $\boldsymbol{A}$ of the technique coefficient (or input coefficient) which expresses the technique level of the national industry containing the effect of external economy. In this way, the products vector $\boldsymbol{X}$ which fulfils the final demands vector in the present term determined by both income in the present and former term, can be estimated by means of equation (57).

In this case, it is not always certain that distribution of industrial capital and labor power determined by (61) is in accord with distribution of those to satisfy the products vector $\boldsymbol{X}$ by (57). But this accordance may be considered to be achieved through adjustment of demand and supply in commodity market or through redistribution of capital and labor power (including redistribution of capital through the process of refundment and investment) so long as the whole economy is growing fairly stably. On the basis of this idea we proposed to transform the economic growth caused by improving transportation facilities as the folowing model.

4-2 Improvement of Transportation Facilities and Economic Growth

Improvement of transportation facilities is one way of improving exernal economy, and it changes the matrix of the technique coefficients $\boldsymbol{A}$ in equation (61). As we have mentioned in 1-iv), it decreases the input coefficient from transport sector, a_{nj}, and increases the additional value, a_{0j}.

Namely, the improvement of transportation facilities means progress of technique out of three factors stimulating economic growth, i.e. increase of capital, increase of labor power, progress of technique. This change of $\boldsymbol{A}$ by the technical progress raises the income level y in the present term. In order to presume how much the income level y will be changed by $\boldsymbol{A}$ practically, we may form a practical presumption equation equivalent to (61). But we prefered to adapt an idea on the I-O analysis in our model.

i) Increase of the Income Level y Influenced by Decrease of the Input Coefficient from Transport Sector a_{nj}.

We will, now, suppose that the solution for $\boldsymbol{X}=[\boldsymbol{I}-\boldsymbol{A}]^{-1}\boldsymbol{Y}$, i.e. $\boldsymbol{X}=\{X_i\}$, can be gained with the vector of the input coefficients from transport sector, $\boldsymbol{A}_n=\{a_{nj}\}$, and the constant final demand, $\boldsymbol{Y}_0=\{Y_{0i}\}$. Then, if $\boldsymbol{A}_n$ turns into $\boldsymbol{A}_n'=\{a_{nj}-\varDelta a_{nj}\}$ by improvement of transport, the variation of products of each industry resulting from the same final demand $\boldsymbol{Y}_0$ can be obtained as follows.

Before improving transportation facilities:

$$X_i=\sum_{j=1}^{n} a_{ij}X_j+Y_{0i} \tag{62}$$

After improving transportation facilities:

$$X_i'=\sum_{j=1}^{n} a_{ij}'X_j'+Y_{0i} \tag{63}$$

Making definition that X_i', X_j' and a_{ij}' are

$$X_i' = X_i - \varDelta X_i$$
$$X_j' = X_j - \varDelta X_j$$
$$a_{ij}' = a_{ij} - \varDelta a_{ij} \quad \begin{cases} \text{if} \quad i = n, & \varDelta a_{ij} = \varDelta a_{nj} \\ \text{if} \quad i \neq n, & \varDelta a_{ij} = 0 \end{cases}$$

and substitute them into (62) and (63), then we have the following equation:

$$\varDelta X_i = \sum_{j=1}^{n} a_{ij} \varDelta X_j + \sum_{j=1}^{n} \delta_{in} \varDelta a_{ij} X_j - \sum_{j=1}^{n} \delta_{in} \varDelta a_{ij} \varDelta X_j \tag{64}$$

where

$$\delta_{in} = \begin{cases} 1 & \text{for} \quad i = n \\ 0 & \text{for} \quad i \neq n \end{cases}$$

Neglecting the third term on the right side of this equation because it is the secondary minute amount, we can express equation (64) with vector as

$$\begin{pmatrix} \varDelta X_i \end{pmatrix} = [a_{ij}] \begin{pmatrix} \varDelta X_j \end{pmatrix} + \begin{pmatrix} 0 \\ \vdots \\ 0 \\ \sum\limits_{j=1}^{r} \varDelta a_{nj} X_j \end{pmatrix} \tag{65}$$

When the input coefficient from transport sector decreases in $\varDelta a_{nj}$ by improving transportation facilities, production of each industry ultimately decreases in $\{\varDelta X_i\}$, and this $\varDelta X_i$ is equal to the solution in case that saving of transport cost in intermediary goods, $\sum_{j=1}^{n} \varDelta a_{nj} X_j$, is regarded as the final demand for transport sector. This shows that capital and labor power is sufficiently less as much as $\{\varDelta K_i\}$ and $\{\varDelta L_i\}$ corresponding to $\{\varDelta X_i\}$ after improving transport facilities if the constant final demand $\boldsymbol{Y}_0$ is required. Substituting the total additional value corresponding to the total of $\varDelta X_i$ as $\varDelta Y$, it is said by equation (65) inevitably that $\varDelta Y = \sum_{j=1}^{n} \varDelta a_{nj} X_j$, so income of $\varDelta Y$ is produced by substituting these $\{\varDelta K_i\}$ and $\{\varDelta L_i\}$ into production functional equation (67). With equation (61), we have

$$y_t' = f(\boldsymbol{K}_t, \boldsymbol{L}_t, \boldsymbol{A}_t') = f(\boldsymbol{K}_t, \boldsymbol{L}_t, \boldsymbol{A}_t) + f(\varDelta \boldsymbol{K}_t, \varDelta \boldsymbol{L}_t, \boldsymbol{A}_t) = y_t + \varDelta y \tag{66}$$

$$\varDelta y = \sum_{j=1}^{n} \varDelta a_{nj} X_j = -\sum_{j=1}^{n} \varDelta a_{0j} X_j \qquad (\because \quad \varDelta a_{nj} = -\varDelta a_{0j}) \tag{67}$$

But production to satisfy the vector of final demands, $\varDelta \boldsymbol{Y} = \boldsymbol{f}_2(\varDelta y)$ equivalent to income $\varDelta y$ determined by (60) cannot always be done soon. It can be done after a definite period of time of redistribution of capital and labor power (redistribution through refundment and investment in the case of capital).

ii) Substantial Increase of the Final Demand According to Decrease of the Purchase Price of the Final Demand

Saving of the transport cost caused by improving transportation facilities raises the substantial final demand directly through the process of saving the transport cost which is necessary to purchase goods for the final demand, besides the above-mentioned reason.

Supposing that the transport cost per unit goods i between region r and region s, v_i^{rs}, is saved in Δv_i^{rs}, the total transport cost needed to purchase the final demand in region r, can be cut down as much as ΔY^r

$$\Delta Y^r = \sum_{i=1}^{n} \sum_{s=1}^{m} \Delta v_i^{sr} Y_i^r t_i^{sr} \tag{68}$$

So the demand for the transport sector decreases in ΔY^r. The decreased amount of transport cost required to purchase the final demand is equal to purchased price of final demand. If we define the price elasticity of final demand as 1, decrease of final demand for the transport sector, ΔY^r, becomes final demand for other goods. In this case, the total final demand in nominal amount does not change, but in substantial amount it increases in ΔY^r. Accordingly national substantial increase of final emand as

$$\Delta Y = \sum_{r=1}^{m} \Delta Y^r \tag{69}$$

will be achieved under the income level determined by equation (61).

On the conclusion of i) and ii), we suppose that increase of income as

$$\Delta y^r + \Delta Y^r = \sum_{j=1}^{n} \Delta a_{0j}^r X_j^r + \sum_{i=1}^{n} \sum_{s=1}^{m} \Delta v_i^{sr} Y_i^r t_i^{sr} \tag{70}$$

occurs in each region by improving transportation facilities, and so we propose to add this value to final demand of each region in the next term, so as to avoid repeating calculation.

5. Measurement of Economic Effect of the New Tokaido Line

We applied the above-mentioned model for forecasting the economic effect of the New Tokaido Line which is one of the biggest transport projects in recent Japan.

The New Tokaido Line is the superexpress railway for the exclusive use of passengers, and was established in Oct. '64. It is located, as shown in Fig. 3, along the Pacific coast of central Japan, where most of the population and many indus-

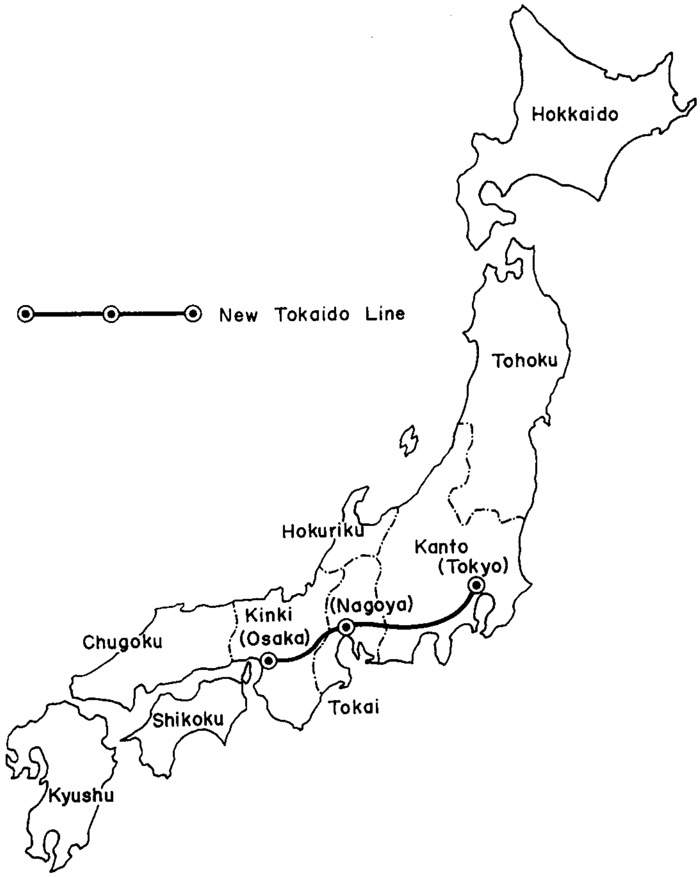


Fig. 3 Divided Nine Regions and the New Tokaido Line

tries are concentrated. Thus 600 km between Tokyo and Osaka is covered in speed of 200 km an hour. This railway has caused much influence upon the regional economy in Japan through the following direct effects, that is, the variation of the trade pattern coefficient caused by saving time for passengers and cut down of the inter-regional transport cost of goods accoring to the speed-up and increase of traffic capacity for freight train on the former Tokaido Line.

i) Estimation of Exclusive Effect of the New Tokaido Line

In order to extract the objective effect of the New Tokaido Line exclusively, we presumed regional economic effects applying our model in following cases,

Case 1..... various transportation facilities, incuding the New Tokaido Line, are improved actually

Case 2..... supposed condition that the New Tokaido Line is not constructed.

Differences in regional economic indexes, [(Case 1)-(Case 2)], are cosnidered to be the influence which the New Tokaido Line has produced exclusively.

ii) Conditions for Presuming

In this calculation national land has been divided into 9 regions and industry into 10 sectors. Starting with the inter-regional input-output table in 1960 made by Ministry of Trade and Industry, we calculated annualy till 1964, and then continued from 1965 to 1970 in Cacse 1 and Case 2 respetively. In this case, variation of time cost and money cost by improving inter-regional transport among each other 22 regions were given exogenously in 1961, 1965 and 1968 respectively.

iii) Electronic Computor and its Programming

The number of statesments in our programming of this model were 15,370 words, the number of steps were 2,200 and operating time in each forecasting year by case was 720 seconds by "Barrows 5,500".

Table 1 List of OUT-PUT Data

		region industry
1.	Capital stock by region and industry	10 × 11
2.	Final demand by region and sector	10 × 8 (demand sector)
3.	Industrial capital investment by region and industry	10 × 11
4.	Amount of export by region and industry	10 × 11
5.	Inter-regional traffic assignment ratio by industry	
6.	Change of transport cost between regions by goods	9×9 × 7
7.	Inter-regional trade pattern coefficient by goods	9×9 × 7
8.	Change of trade pattern coefficient by goods to 1960's	9×9 × 7
9.	Input coefficient and additional value rate from transport sector	9 × 10
10.	Production amount by region and industry	10 × 11
11.	Production amount by region and industry (3 groups)	10 × 3
12.	Increasing rate of production amount by region and industry to last year	9 × 10
13.	Additional value sum by region and industry	10 × 11
14.	Additional value sum by region and industry (3 groups)	10 × 3
15.	Inter-regional transaction amount by region	10 × 11
16.	Inter-regional migrating population	10×10
17.	Income by region	10 × 4 (income)
18.	Occupied population by region and industry (3 groups)	10 × 4
19.	Inter regional traffic volume of freight by transport facilities and goods	10×10× 4
20.	Inter-regional traffic volume of passengers by object	10×10× 3 (by object)
21.	Traffic volume of passing freight by section and traffic route	14 (section) × 3
22.	Traffic volume of departure and arrival by region and transport facilities	10 × 4

iv) Portion of Calculation Result and its Consideration

The items of out-put data of each case in every year are shown in Table 1. It points out that the calculated results of this model are extended to the global regional economic indexes, but we show in figures the essential effect of the New Tokaido Line.

(1) Change of the inter-regional trade pattern coefficient:

The inter-regional trade pattern coefficient of machinery into Kanto and Kinki region in 1966 and 1970 is shown in Fig. 4 as one of example. The coefficients and production sum in each case and target year are noted in fugure.

(2) Production sum by region and industry:

The difference of the production sum, [(Case 1)-(Case 2)], in each region in

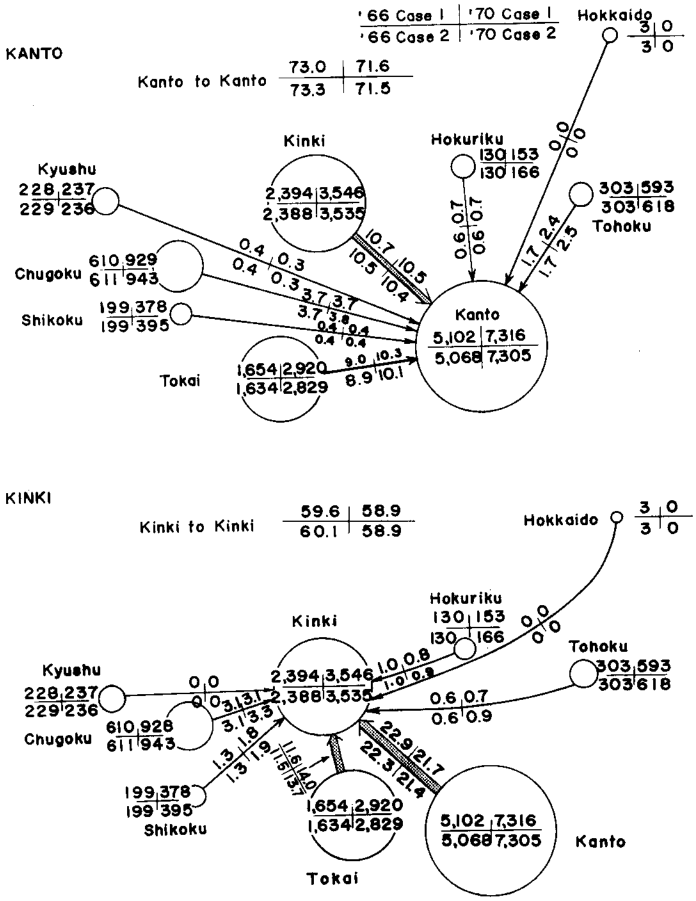


Fig. 4 Production and Inter-regional Trade Pattern Coefficient (Machinery)

Unit: Production ...... billion yen

Trade Pattern coeff. ...... %

Fig. 5

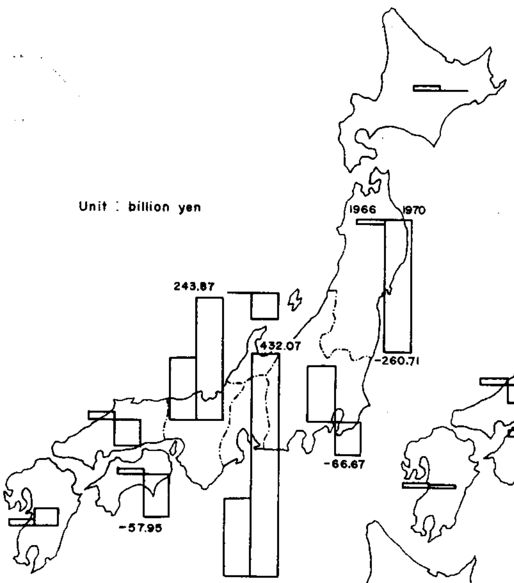
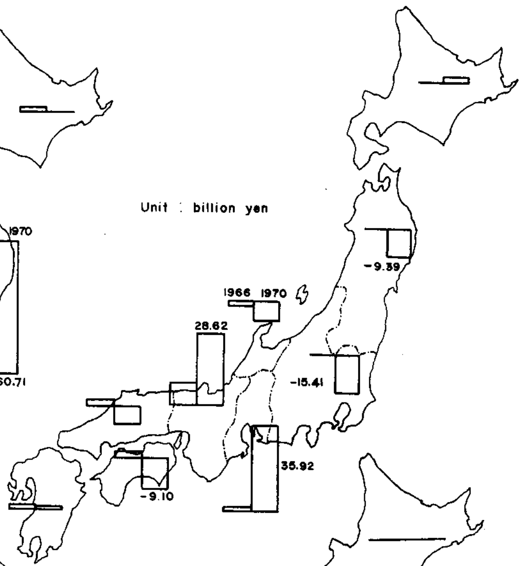
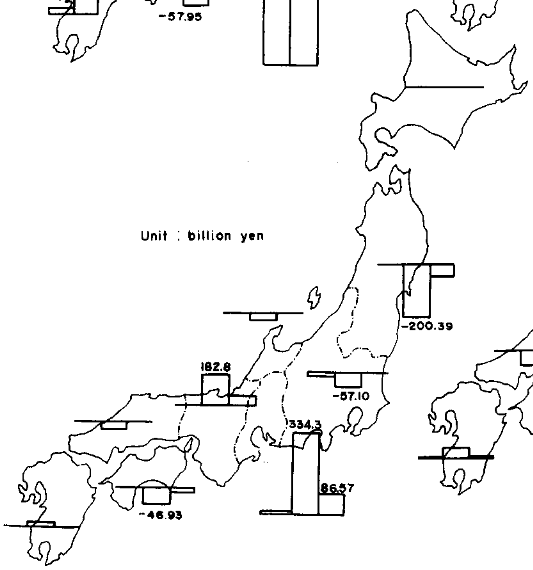


Fig. 6





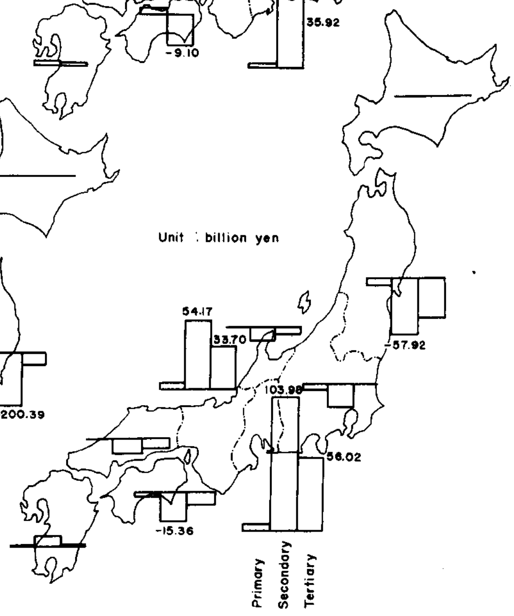


Fig. 7

Fig. 8

Fig. 5 Total Productions by Region (CASE 1-CASE 2) 1970

Fig. 6 Production of Chemical Industry by Region (CASE 1-CASE 2) 1970

Fig. 7 Production of Primary, Secondary and Tertiary Industry by Region (CASE 1-CASE 2) 1970

Fig. 8 Value Added by Region and Industry (CASE 1-CASE 2) 1970

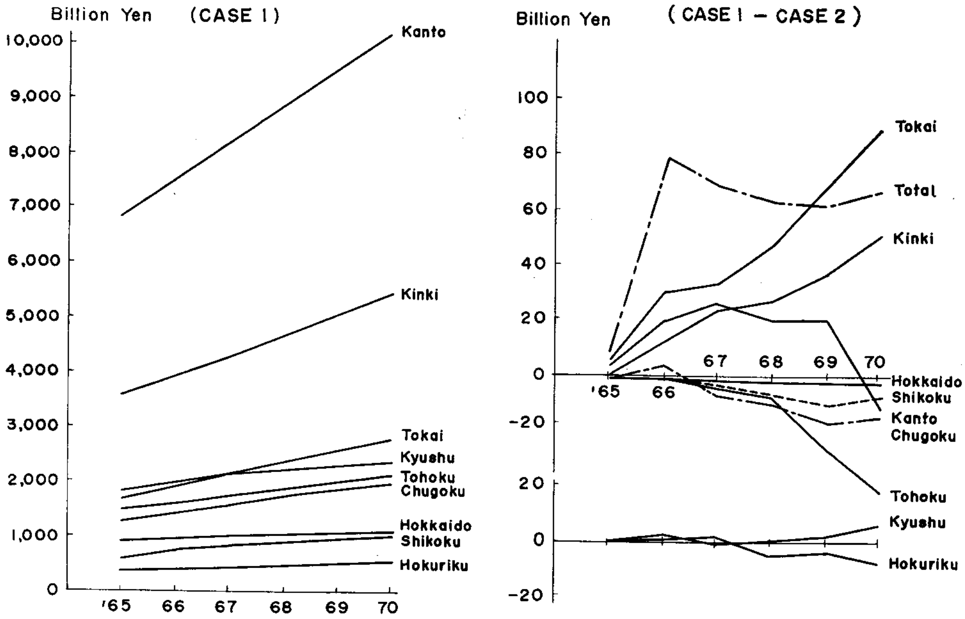


Fig. 9 Individual Income by Region and Year

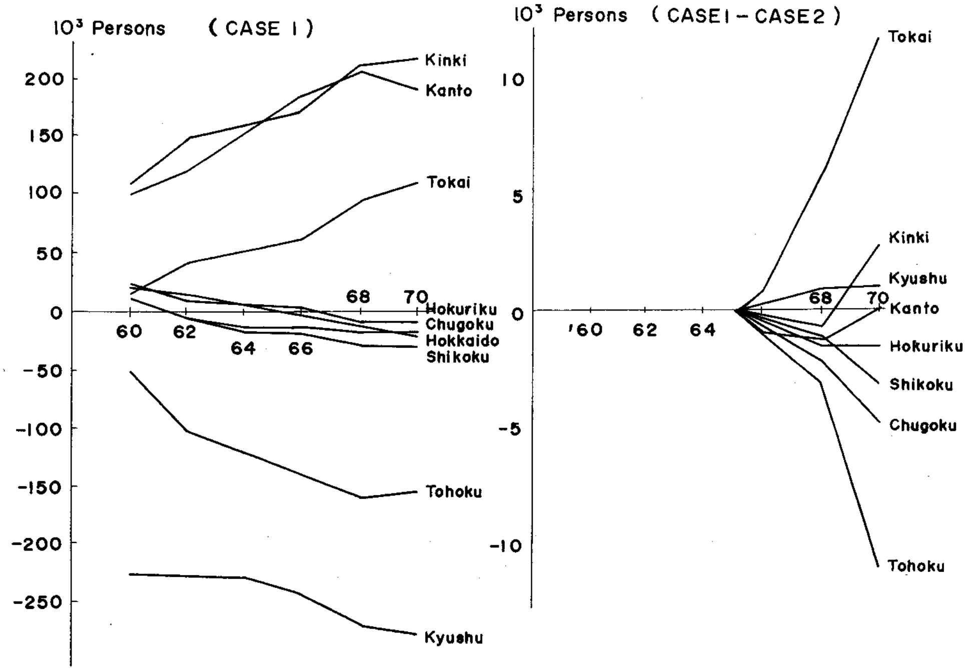


Fig. 10 Increased Population by Region and Year

1966 and 1970 is written in Fig. 5, and that of chemical production amount is in Fig. 6. It shows that production in the Tokai and Kinki regions will be much accelerated by the New Tokaido Line, while in the Kanto and Tohoku regions, it will go down. Increased effect of the national industrial production in 1970 is as much as 220 billion yen.

Fig. 7 shows the value of [(Case 1)-(Case 2)] of production in 1970 by primary, secondary and tertiary industry. In the national sum, decrease is 320 million yen in the primary industry, but increases are 163 billion yen in the secondary industry and 63 billion yen in the tertiary industry.

(3) Additional value by region and industry:

The result of [(Case 1)-(Case 2)] of additional value by primary, secondary

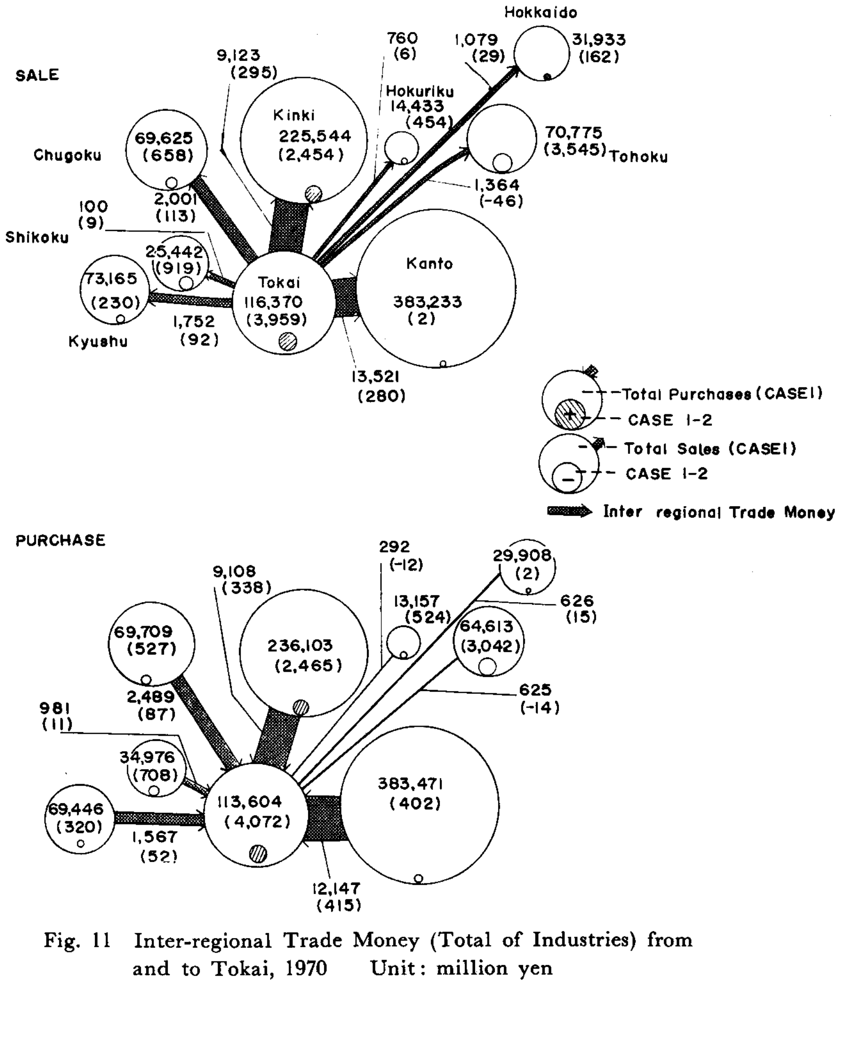


Fig. 11 Inter-regional Trade Money (Total of Industries) from and to Tokai, 1970 Unit: million yen

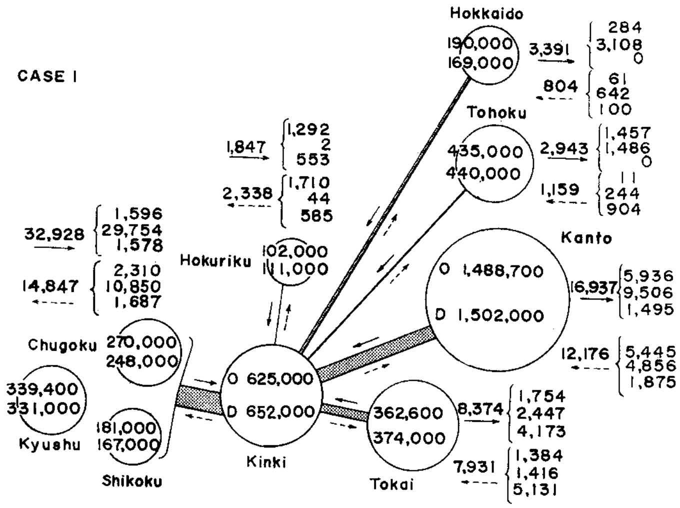


Fig. 12 Inter-regional Traffic Volume from and to Kinki, 1970
Unit: 10^3 ton/year

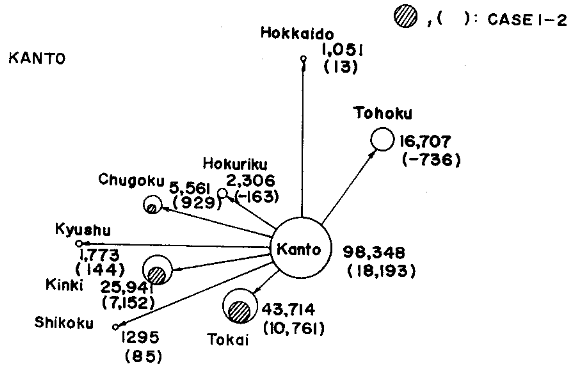


Fig. 13 Business Travellers (CASE 1) 1970 Unit: 10^3 Persons

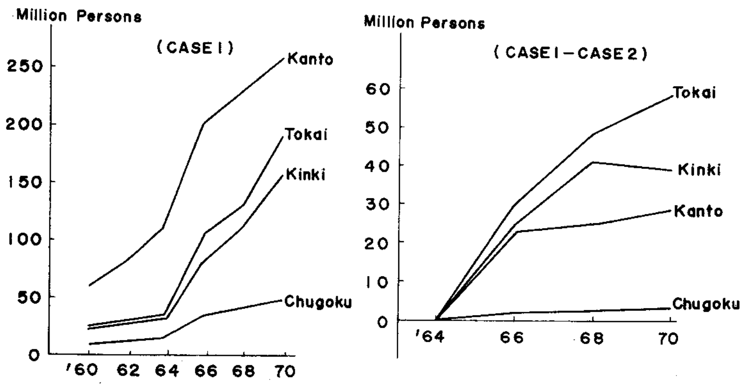


Fig. 14 Departing Travellers by Region and Year

and tertiary industry by region in 1970 is shown in Fig. 8. In the national sum, the decrease is 4 billion yen in the primary industry, but increases are 50 billion yen in the secondary industry and 411 billion yen in the tertiary industry.

(4) Individual income by region:

The accelerated sum of individual income by region is shown in Fig. 9.

(5) Population by region:

The increased population by region is shown in Fig. 10.

(6) Inter-regional transaction by goods:

Inter-regional transaction in 1970 is shown in Fig. 11.

(Tokai region as one of example)

(7) Inter-regional freight traffic volume:

Inter-regional total volume of goods is shown in Fig. 12.

(Kinki region as one of example)

(8) Inter-regional traffic volume of business passengers:

Fig. 13 shows a number of departing business passengers centering around the Kanto region.

(9) Total departing business passengers by region:

Fig. 14 shows the variation of total departing business passengers by region.

The conclusion through our presumption of the regional economic effect by the New Tokaido Line can be said as follows:

1. The effect of the New Tokaido Line in national sum in 1970 will increase 220 billion yen more in industrial production and increase 62 billion yen more in production income. Thus the construction of New Tokaido Line will continue to make a great contribution to the economic growth in Japan.

2. On the view-point of regional balance, construction of the New Tokaido Line will accelerate the concentration of population and industries to the central pacific coast, such as Tokai, Kinki and Kanto regions.

6. Conclusion

We have stated the essentials of our econometric model for presuming the long-term and synthetic regional economic effect caused by improving transportation facilities, mainly by means of the expanded inter-regional input-output analysis.

We should state about the other partial models such as checking traffic capacity etc. which we have proposed, and about the parameters in each function determined by actual indexes, but we had not enough pages.

Our model proposed in this study should be mended or modified in the future. But it can be said that the model is sufficiently applicable already to compare the effects of various improving transportation facillities relatively, as shown in example of application to the New Tokaido Line.