POST-EVALUATION OF THE IMPACT OF INFRASTRUCTURE IMPROVEMENT ON REGIONAL WELFARE DISPARITY: JAPANESE EXPERIENCE AFTER WORLD WAR II

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Abstract: In Japan, as a part of national land-use policy, a great deal of resources has been invested in the infrastructure of underdeveloped regions with the aim of reducing regional disparity. The objective of this paper is to post-evaluate the impact of such policies. First, we estimate the indirect utility function of households based on repeated cross-section data on consumption and interregional migration to evaluate the welfare attained in each region at each period. Second, we estimate the objective function of the central government assuming that public investment has been allocated among regions to maximize social welfare. From these results, we can know (i) that the utility-level in each region has been improved through the improvement of infrastructure and (ii) that Japanese central government has changed the policy objective to attach larger weight on equality than efficiency as for the improvement of community environmental infrastructure.

1. INTRODUCTION

In Japan, as a part of national land-use policy, a great deal of resources has been invested in the infrastructure of underdeveloped regions to reduce the regional disparity. Although a large number of studies have been conducted on the evaluation of such policies, there is little agreement as to its validity. The main reason, we think, is that only few attempts, which are both normative and empirical, have so far been made.

The researches on the interregional allocation of public investment can be divided into main two groups. First group are not normative, but empirical researches in static context. Yang (1997) and Tsukahara (1994) assumed that Japanese central government had allocated public investment or subsidy to maximize their objective function under the constraints of budget and production technology in each region. Following Berhman *et al.* (1984)'s model, they estimated the objective function of the central government and evaluated the degree of inequality aversion that was implicit in the allocation of public investment. (Note: In original researches, international allocation of foreign aids and intersectoral allocation of public expenditures were analyzed. See Behrman *et al.*, 1984, Behrman *et al.*, 1987 and Craig, 1987). Anderstig *et al.* (1989) investigated the same subject in almost the same way. Mera (1986) showed some hypothesis for the interregional allocation policy of public investment and empirically revealed the policy objective, which was consistent with actual public investment. Some researches related to the estimation of production functions can be included in this group (e.g. Ohkawara *et al.*, 1998). Most of studies, included in this group, discuss only on the interregional distribution of income. However, the roles of regional specific factors (e.g. local public goods) are not negligible

for human betterment and interregional gaps in prices also should not be disregarded. Therefore, we can say that the researches concentrating on income disparity have limitations for normative discussion and are not effective approaches to derive beneficial policy implications. Second group are normative, but not empirical researches in dynamic context. Many studies in this group take advantage of optimal control theory and discuss on the necessary conditions for optimal growth or on the stability of that path (e.g. Arrow *et al.*, 1971 in national economy model, Sakashita, 1967, Takayama, 1985 and Okuno *et al.*, 1990 in two-region model). As far as we know, this type of study has not been applied to empirical research.

This paper aims to post-evaluate the impact of infrastructure improvement on regional disparity in the case of Japan after WWII. In contrast with exsisting researches, we evaluate the impact of interregional allocation policy in both normative and empirical framework. We take the standpoint of welfarism and do not take into account the other kind of disparity than utility-level. Our tools for evaluation are indirect utility function and Bergson-Samuelson social welfare function.

The outline of the paper is as follows. In Section 2, we estimate the indirect utility function of household. This estimated indirect utility function is used as a measure of welfare. By implementing this, the trend of utility-level attained in each region at each period and the impact of infrastructure improvement on regional welfare and its disparity can be evaluated. In Section 3, we assume that central government has allocated public investment among regions to maximize social welfare in static context and the objective function (social welfare function) of the central government is estimated. As this objective function includes a parameter, which indicates the degree of aversion to inequality, we can know how central government has met with the trade-off between efficiency and equality at each period. Brief conclusion follows in Section 4.

2. EVALUATION OF WELFARE

2.1 The Model

We build a model with major the following assumptions.
(a) In each region, there are households with a homogeneous utility function.
(b) Households migrate in the direction of reducing interregional utility gap. Nonetheless, the utility gap is not adjusted instantaneously.

To begin with, we specify households' indirect utility function as transcendental logarithmic form in eq.(1). This form gives a second order approximation of general functions and is one of the flexible functional forms. Jorgenson (1997a,b) used this function to evaluate the welfare of consumers in U.S over the postwar periods 1947-1985, based on cross-section micro data and time-series macro data on consumption. Although Jorgenson interpret A_{ti} as demographic variables (e.g. age, family size), we interpret A_{ti} as regional specific factors to evaluate the impact of infrastructure improvement on standard of living.

$$\ln V_{ti} = \left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right)\alpha_{p} + \frac{1}{2}\left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right) B_{pp}\left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right) + \left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right) B_{pA}\left(\ln A_{ti}\right) + \left(\ln A_{ti}\right)' \gamma_{A} \qquad (1)$$

where

y_{ti}^{d} : expenditure of household in region i at period t

$\ln \frac{p_{ti}}{y_{ti}^{d}} = \left(\ln \frac{p_{ti}^{1}}{y_{ti}^{d}}, \cdots, \ln \frac{p_{ti}^{N}}{y_{ti}^{d}} \right)'$: vector of logarithms of ratios of prices to expenditure

$\ln A_{ti} = \left(\ln A_{ti}^{1}, \cdots, \ln A_{ti}^{m} \right)'$: vector of regional specific factors

$\alpha_p = \left(\alpha_p^{1}, \cdots, \alpha_p^{N} \right)'$, $B_{pp} = \begin{pmatrix} \beta_{pp}^{11} & \cdots & \beta_{pp}^{1N} \\ \vdots & \ddots & \vdots \\ \beta_{pp}^{N1} & \cdots & \beta_{pp}^{NN} \end{pmatrix}$, $B_{pA} = \begin{pmatrix} \beta_{pA}^{11} & \cdots & \beta_{pA}^{1M} \\ \vdots & \ddots & \vdots \\ \beta_{pA}^{N1} & \cdots & \beta_{pA}^{NM} \end{pmatrix}$, $\gamma_A = \left(\gamma_A^{1}, \cdots, \gamma_A^{M} \right)'$: parameters

By applying Roy's Identity to eq.(1), we obtain the k th expenditure share eq.(2) (cf. Jorgenson, 1997a,b). We examine both the cases with and without Lau's exact aggregation condition ($i'B_{pp}i = 0$ and $i'B_{pA} = 0$).

$$w_k = \frac{1}{D(p_{ti})} \left(\alpha_p + B_{pp} \ln p_{ti} - B_{pp} i \ln y_{ti}^{d} + B_{pA} \ln A_{ti} \right) \tag{2}$$

where

$$D(p_{ti}) = \begin{cases} -1 + i'B_{pp} \ln q_{ti} + i'B_{pA} \ln A_{ti} & \text{(without Lau's exact aggregation condition)} \\ -1 + i'B_{pp} \ln p_{ti} & \text{(with Lau's exact aggregation condition)} \end{cases} \tag{3}$$

$i = (1, \cdots, 1)'$: vector of ones

$\ln p_{ti} = \left(\ln p_{ti}^{1}, \cdots, \ln p_{ti}^{N} \right)'$: vector of logarithms of prices

Next, we specify the process of interregional migration as eq.(4). This process known as partial adjustment mechanism in investment theory. To keep consistency in the analysis, we should build location choice model that is derived from utility maximization hypothesis. However, it is well known that a large part of migrants in Japan are due to transference and we can't get the data on interregional migration with the reason for migration. So, even if we build a rational location choice model, as the reason for migration is not considered in the data, it is easily conjectured that we can't get good results. Therefore, in this paper, we utilize this migration model for convenience.

$$\Delta N_{ti} = a \left(\ln V_{ti} - \ln \overline{V}_t \right) \tag{4}$$

where

ΔN_{ti} : net social increase of households in region i at period t

$\overline{V}_t$: indirect utility when equilibrium is achieved at period t

a : parameter (which indicates the speed of adjustment process)

Finally, for statistical inference, we specify our model as eqs.(5) and (6). We employ the accessibility to urban agglomeration and the stock of community environmental infrastructure as regional specific factors. ACC_{ti} is the measure of accessibility to urban agglomeration and eq.(7) is the form used in competing destinations model (Fotheringham, 1985). Although eq.(7) is commonly used form, its economical meaning is not sufficiently clear. To replace eq.(7) with Morisugi *et al.* (1995)'s measure, the parameters in which can be estimated from the data on transportation market, is required (the economical meaning of general accessibility measure is given by Fujita *et al.* (1990)). $G_{ti}^{1} N_{ti}^{\theta}$ is the stock of community environmental infrastructure adjusted with the degree of congestion. Parameter

θ indicates the degree of congestion and is expected to become zero and minus one when community environmental infrastructure is pure public goods and private goods respectively.

$$w_{ti}^{k} = \frac{1}{D(p_{ti})}\left(\alpha_{p} + B_{pp} \ln p_{ti} - B_{pp} i \ln y_{ti}^{d} + B_{pA} \ln A_{ti}\right) + \varepsilon_{ti}^{k} \tag{5}$$

$$\Delta N_{ti} = a\left\{\left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right)\alpha_{p} + \frac{1}{2}\left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right) B_{pp}\left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right) + \left(\ln \frac{p_{ti}}{y_{ti}^{d}}\right) B_{pA} \ln A_{ti} + \left(\ln A_{ti}\right)' \gamma\right\} + b_{t} + \varepsilon_{ti}^{n} \tag{6}$$

where

$i = (Hokkaido, \cdots, Kagoshima)$: Japanese 46 prefecture except Okinawa

$t = (1965, \cdots, 1995)$

$k = (food,\ housing + fuel/light/water,\ others)$

$\ln A_{ti} = \left(\ln G_{ti}^{1} N_{ti}^{\theta}, \ln ACC_{ti}\right)$

G_{ti}^{1}: stock of community environmental infrastructure in region i at period t

N_{ti}: number of households in region i at period t

$ACC_{ti} = \sum_{j \neq i} \frac{N_{ij}}{d_{ij}}$: accessibility to urban agglomeration in region i at period t (7)

d_{ij}: distance between region i and j

θ, b_{t}: parameters

2.2 Data

Before we come to parameter estimation, we must draw attention to data used for statistical inference. The data on expenditures and disposal incomes are obtained from the Japan Management and Coordination Agency's Annual Household Expenditure Survey. It consists of a sample survey of households in 47 prefectural capital cities. The published data are average values. Each year, a total of approximately 5,400 observations are taken from 47 cities. The survey had covered five expenditure groups (foods, housing, fuel/light/water, clothing/footwear, miscellaneous) before 1979. In 1980 the design of survey was renewed and since then ten expenditure groups (continuous five groups plus furniture/household utensils, medical care, transportation/communication, education and reading/recreation) has been covered. The connection was however not smooth, so we have to combine five groups into less than four groups to keep intertemporal consistency of data. Finally, we set up three expenditure groups indicated above. Since housing expenditure in the HES does not include the imputed rent of home owners, we adjusted the figures by the data from the National Survey of Family Income and Expenditures (NSFIE), conducted in 1969, 74, 79, 84, 89, 94, combining the data on proportion of housing tenure types. The price indices corresponding to the above ten expenditure groups are obtained from the Consumer Price Index Report (CPIR). For each of the 47 prefectures, separate price indices are available for five groups in time series form (1990=100). To account for regional differences in prices, these indices are adjusted to the regional price difference indices obtained from National Survey of Prices (NSP) in 1967, 74, 77, 82, 87, 92.

The data on migration and population are obtained from Report on the Internal Migration in Japan (RIMJ). From the published report, we can know the net social increase of population in each prefecture at each period. The data on stock of community

environmental infrastructure are obtained from Economic Planning Agency's Japanese Infrastructure (JI) in monetary terms. JI divided infrastructures into 14 groups. We regard public rental housing, sewage, waste disposal, water supply, urban park and education as community environmental infrastructure. We should notice that road, which is occupying the largest part of the stock of infrastructure in Japan, is not included in our definition of community environmental infrastructure at all. The reason is that they are not classified into sub classes (e.g. highway, community road) in JI. The data on distance among prefectures (between the center of gravity) are obtained from Population Census (PC).

2.3 Estimation Procedures

In principle, all parameters in eqs.(5) and (6) can be estimated by applying non linear three stage least squares method (NL3SLS). However, as the fitness of our model (especially of (6)) is not good, even if we apply system estimation methods (including NL3SLS), the estimates often become unstable. So, we took the procedure below. Through this, we can obtain consistent estimates.

1. Apply NL3SLS to (8) and estimate α_p, B_{pp}.

$$w_{ti}^k = \frac{1}{D(p_{ti})}\left(\alpha_p + B_{pp} \ln p_{ti} - B_{pp} i \ln y_{ti}^d\right) + \varepsilon_{ti}^k \tag{8}$$

2. Apply non-linear ordinary least squares method (NLOLS) to (6) and estimate only a, b_t, γ, θ.

3. Apply NL3SLS to (5) and estimate α_p, B_{pp}, B_{pA}.

4. Apply NLOLS to (6) and estimate a, b_t, γ, θ again.

5. Go back to 3, unless estimates converge.

2.4 Estimation Results

The estimates are shown in Table 1. We estimated both cases with and without Lau's exact aggregation condition. It is clear from adjusted R squared at the bottom of Table 1 that the statistical significance of our model is not so good in anyway. To be sure, it may be preferable to modify our model at this stage. Nevertheless, it is also the fact that the constraint of data are very severe and there is no agreeable consumption and migration model. Moreover, as shown later, the results of our analysis is not far from our intuition and we believe that it is worth suggesting the issue. Now, understanding the limitation of our results, we want to go ahead to discuss on our main subject.

The asymptotic t-values of estimates suggest that almost all of them are significantly different from zero. Moreover, the signs of estimates are the same as expected before estimation. This result indicates that the improvement of community environmental infrastructure contributed to the improvement of utility-level attained in each region. Though θ is expected to be between minus one and zero, the estimate is less than minus one. The most likely explanation is that the community environmental infrastructure has characteristics close to private goods and the negative externality not relating to the consumption of the service from community environmental infrastructure (e.g. natural environment) affected the estimates of θ.

Table 1. Estimates of Indirect Utility Function

Parameter	Without Lau's exact aggregation condition			With Lau's exact aggregation condition		
	Estimate	Standard Error	asymptotic t-statistic	Estimate	Standard Error	asymptotic t-statistic
α^1_p	-0.3558	0.0141	-25.31	-0.7790	0.0244	-31.88
α^2_p	-0.2419	0.0061	-39.56	0.1770	0.0276	6.41
α^3_p	-0.4023	0.0153	-26.25	-0.3980	0.0369	-10.79
β^{33}_{pp}	0.0321	0.0044	7.29	—	—	—
β^{11}_{pA}	0.0110	0.0013	8.69	-0.0136	0.0016	-8.39
β^{21}_{pA}	0.0138	0.0014	10.20	-0.0016	0.0018	-0.86
β^{31}_{pA}	0.0348	0.0029	11.94	0.0152	0.0024	6.20
β^{12}_{pA}	0.0110	0.0018	6.03	0.0566	0.0008	67.94
β^{22}_{pA}	-0.0313	0.0049	-6.35	-0.0298	0.0009	-31.69
β^{32}_{pA}	0.0029	0.0032	0.92	-0.0267	0.0013	-21.27
γ^1_A	0.2538	0.0405	6.27	0.1939	0.0300	6.46
γ^2_A	0.2067	0.0557	3.71	0.1528	0.0416	3.68
θ	-1.1803	0.0680	-17.35	-1.2002	0.0702	-17.10
	w1	w2	w3 ΔN	w1	w2	w3 ΔN
Adj.R^2	0.716	0.379	0.624 0.326	0.781	0.410	0.385 0.344

As mentioned above, we estimated both cases with and without Lau's exact aggregation condition. When Lau's exact aggregation condition is imposed, eq.(1) can be converted into eq.(9), which indicate the minimum expenditure M_{ti} to achieve utility-level V_{ti} under the base price p_0 and the base regional specific factors A_0. This is called indirect money metric utility function and is useful to avoid the difficulties caused by ordinality of indirect utility functions. In the following analysis, we employ the parameter estimates with Lau's exact aggregation condition for convenience.

$$M_{ti} = \exp\left[\frac{1}{D(p_0)}\left\{(\ln p_0)'\left(\alpha_p + \frac{1}{2}B_{pp}\ln p_0 + B_{pA}\ln A_0\right) + (\ln A_0)'\gamma_A - \ln V_{ti}\right\}\right] \tag{9}$$

Figure 1 indicates the trend of money metric utility-level M_{ti} under the price and the regional specific factors of Tokyo in 1965. We can understand easily that there is an increasing trend. By carefully observing, the increasing rate before 1975 is a little steeper than after 1975. The most likely explanation is that this is caused by the structural change due to the oil shock happened in 1973. Turning to the regional welfare disparity, it is clear that the utility-level attained in metropolitan area (e.g. Tokyo, Kanagawa, Nara) is relatively high and that attained in Hokkaido, Aomori and Miyazaki is relatively low. Although we can't show the evidence for the lack of space, we can see that the regional disparity of utility-level is due to the difference of the level of consumption and accessibility to urban agglomeration by decomposing the indirect money metric utility into each component of consumption, accessibility to urban agglomeration, community environmental infrastructure and cross-effect of them,

Figure 2 indicates how much the improvement of consumption and the improvement of community environmental infrastructure contributed to the increase of money metric utility-level. It is clear that the improvement of consumption contributed to that of utility-level from '70 to '75 and from '80 to '85. The improvement of consumption declines next decade and became worse in some prefectures from '90 to '95. It is difficult to believe that consumption level became worse during last decade. The most likely explanation is that

mad increase of land price during bubble periods gave the bad impact. There is room for argument on this point. Turning to the impact of the improvement of community environmental infrastructure, we can see that this has contributed positively for all periods though its impact has been declining. Since the improvement of consumption level is almost zero from '90 to '95, we can say that the improvement of community environmental infrastructure was the unique engine to increase the utility-level during that period.

Although the results of our analysis suggest some interesting viewpoints, these are open to objection. For example, Figure 1 indicates that utility-level attained in Nagasaki in 1995 is not so different from that attained in Tokyo in 1965. Without doubt, this may be against the intuition of many people. As we mentioned above, the reliability of our analysis is not so good. Therefore, we don't hope only the figures become the subject of discussion. Of course, we believe that suggested framework for evaluating the regional welfare is the right way and the results shown above also are meaningful as basic material for discussion.

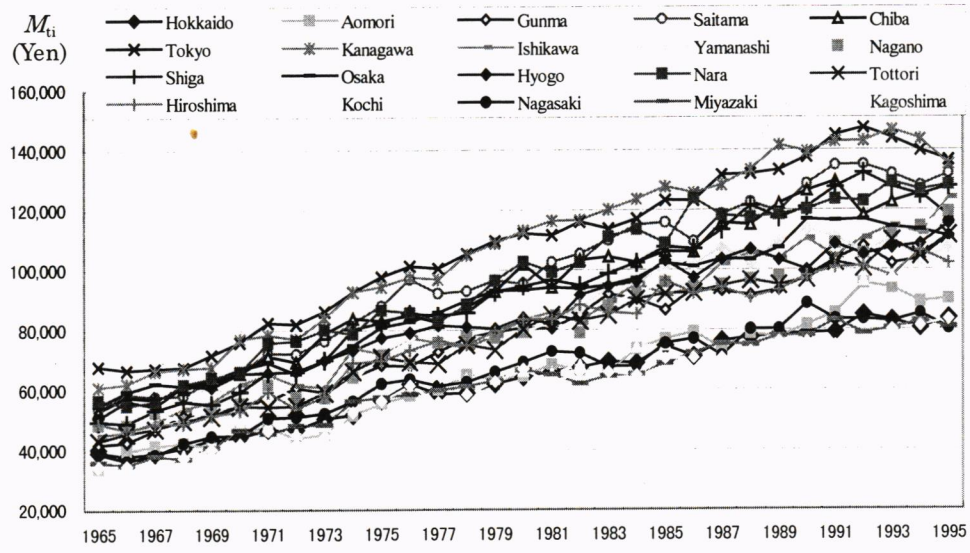

Figure 1. Trend of Indirect Money Metric Utility

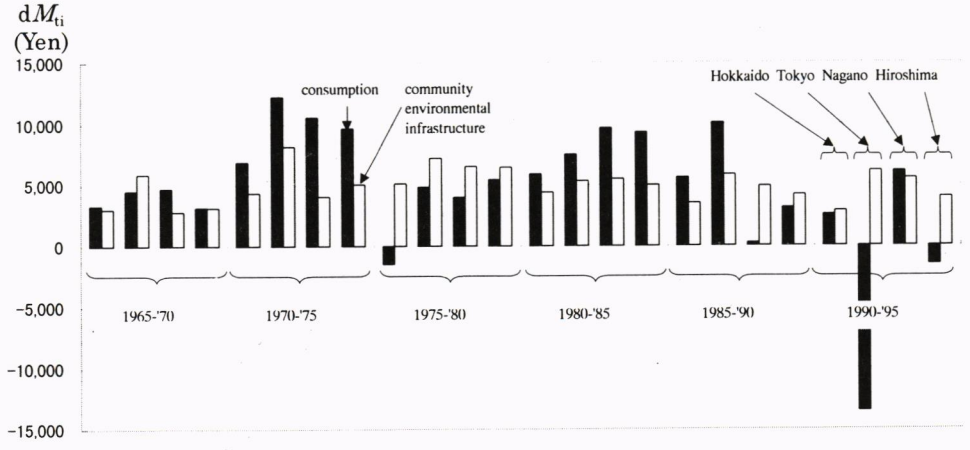

Figure 2. Decomposition of the Variation of Indirect Money Metric Utility

3. ANALYSIS OF INTERREGIONAL ALLOCATION POLICY

3.1 The Model

We build a model with major the following assumptions.

Central Government

(c) The central government allocates public investment to maximize their objective function.

(d) The central government expect that households' taste, number of households, production sectors' technology and equilibrium prices in each region are identical at period t and period $t+1$ (assumption of naïve expectation).

(e) Saving ratio is fixed and identical in every region.

(f) Income tax ratio is fixed and identical in every region.

Production Sector

(g) There is a production sector with the identical production function in each region.

3.1.1 Production Sector

At first, we specified the aggregate production function as simple Cobb-Douglas form. However, as a result of parameter estimation, the coefficient related to the productivity of infrastructure became significantly negative. These estimates suggest that the marginal productivity of infrastructure would be negative. It is however difficult to believe that the infrastructure has negative impacts on production. We therefore try another specification given by eq.(10) following Kanemoto, *et al.* (1996). Of course, we should apply other type of functional forms (e.g. transcendental logarithmic functional form) in further research.

$$Y\left(K_{ti}, G_{ti}^2, N_{ti}\right) = AK_{ti}^{\ c} N_{ti}^{\ 1-c} N_{ti}^{\ d \ln G_{ti}^2} \tag{10}$$

where

G_{ti}^2, K_{ti} : stock of industrial infrastructure and private capital in region i at period t

N_{ti} : number of households in region i at period t

A, c, d : parameters

3.1.2 Central Government

We assume that central government allocates the community environmental infrastructure and industrial infrastructure to maximize myopically their objective function consisted of the utility-level attained in each region. In this study, we specify this objective function $W(\cdot)$ as CES functional form given by eq.(11) and regard this objective function as a social welfare function. This idea is due to Behrman *et al.* (1984)'s model. But, we are different on the point of not discussing on the distribution of income but on that of utility. In eq.(11), ε indicates the degree of aversion to inequality. When ε is one, eq.(11) is the same with well-known utilitarianism (Benthamite) social welfare function. When ε approaches minus infinity, eq.(11) approaches the Rawlsian social welfare function. These facts indicate that eq.(11) is a flexible functional form and appropriate for the analysis of the trade-off between efficiency and equality. a_i indicates the weight on the households in region i. If a_i is larger than one, it means that region i is imposed larger importance than average. In the following research, we assume a_i for any i is one for the simplicity of the analysis.

$$W(V_{ti}, N_{ti}) = \left(\sum_i a_i N_{ti} V_{ti}^{\varepsilon}\right)^{\frac{1}{\varepsilon}} \tag{11}$$

where

V_{ti} : regional welfare in region i at period t

ε, a_i : parameters

In the following analysis, several cases, which are distinguished with the presumption on the mobility and the allocation mechanism of private capital, will be set up and analyzed. Of course, some of them may be unrealistic. Nonetheless, since recovering the objective function without enough information on the practice of decision-making is a kind of ill-posed inverse problem, we think that considering the same problem from several viewpoints would give a fruitful insight, especially into the reliability of our analysis. Therefore, we set up three typical cases shown in Table 2 and analyze each of them. In Table2, second column from the right indicates the presumption on the mobility of private capital. "Instantaneously" and "gradually" means that private capital mobile to other region instantaneously and gradually, responding to the difference of the marginal productivity of private capital. The extreme right column in Table 2 indicates the presumption on the allocation mechanism. "Decentralized" means that private capital is allocated to equalize the marginal productivity of private capital. "Centralized" means that central government allocates private capital to maximize their objective function. These three cases are formalized as below and the structures of the model in Case I and III are shown respectively as Figure 3 and 4.

Table 2. Outline of Set Up Cases

Case	tax system		saving ratio	private capital	
	type	ratio		mobility	allocation
I	income tax	fixed	fixed	instantaneously	decentralized
II	income tax	fixed	fixed	gradually	decentralized
III	income tax	fixed	fixed	instantaneously	centralized

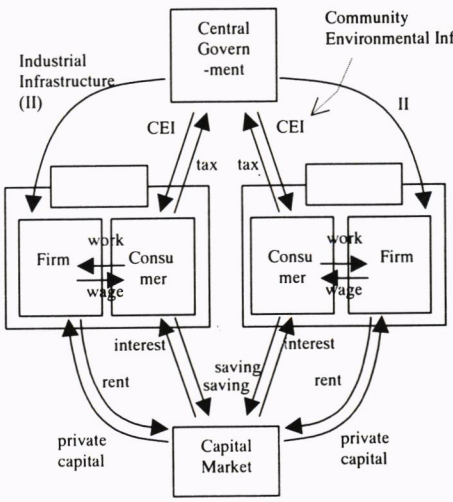

Figure 3. Model Structure of Case I

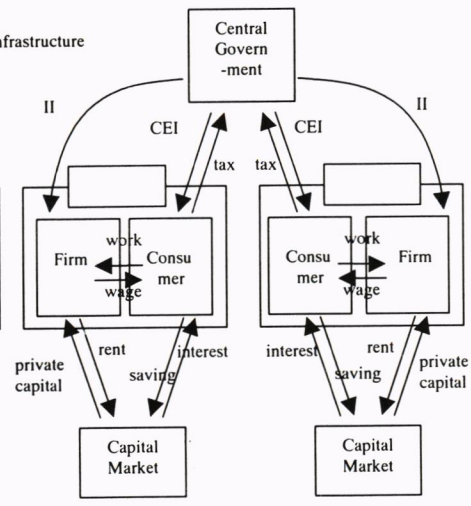

Figure 4. Model Structure of Case III

Case I

$$\max_{\theta_t,\alpha_{ti},\beta_{ti}} W\left(V\left(y^d_{t+1,i}, G^1_{t+1,i}, N_{t+1,i}\right), N_{t+1,i}\right) \tag{12}$$

$$s.t. \quad G^1_{t+1,i} - G^1_{ti} = \alpha_{ti}\theta_t \sum_i \tau Y\left(K_{ti}, G^2_{ti}, N_{ti}\right) - nG^1_{ti} \tag{13}$$

$$G^2_{t+1,i} - G^2_{ti} = \beta_{ti}(1-\theta_t)\sum_i \tau Y\left(K_{ti}, G^2_{ti}, N_{ti}\right) - nG^2_{ti} \tag{14}$$

$$z_{t+1,i} - z_{ti} = \frac{s}{1-s} y^d_{ti} - nz_{ti} \tag{15}$$

$$N_i y^d_{t+1,i} = (1-s)(1-\tau)\left\{Y\left(K_{t+1,i}, G^2_{t+1,i}, N_{ti}\right) - r_{t+1}K_{t+1,i} + r_{t+1}N_{ti}z_{t+1,i}\right\} \tag{16}$$

$$\frac{\partial Y\left(K_{t+1,i}, G^2_{t+1,i}, N_{ti}\right)}{\partial K_{t+1,i}} = r_{t+1} \tag{17}$$

$$\sum_i \alpha_{ti} = 1 \tag{18}$$

$$\sum_i \beta_{ti} = 1 \tag{19}$$

$$\sum_i N_{ti} z_{t+1,i} = \sum_i K_{t+1,i} \tag{20}$$

$$G^1_{ti} = \overline{G}^1_{ti} \tag{21}$$

$$G^2_{ti} = \overline{G}^2_{ti} \tag{22}$$

$$z_{ti} = \overline{z}_{ti} \tag{23}$$

Case II

$$\max_{\theta_t,\alpha_{ti},\beta_{ti}} W\left(V\left(y^d_{t+1,i}, G^1_{t+1,i}, N_{t+1,i}\right), N_{t+1,i}\right) \tag{12'}$$

$$s.t. \quad \text{(13)-(16), (18)-(19), (21)-(23)}$$

$$\frac{\sum_i K_{t+1,i}\left(\partial Y_{t+1,i}/\partial K_{t+1,i}\right)}{\sum_i K_{t+1,i}} = r_{t+1} \tag{24}$$

$$\frac{K_{t+1,i} - K_{ti}}{K_{ti}} = \rho \frac{\left(\partial Y_{ti}/\partial K_{ti}\right) - \sum_j \left(K_{tj}/\sum_l K_{tl}\right)\left(\partial Y_{tj}/\partial K_{tj}\right)}{\sum_j \left(K_{tj}/\sum_l K_{tl}\right)\left(\partial Y_{tj}/\partial K_{tj}\right)} + \frac{\sum_j K_{t+1,j} - \sum_j K_{tj}}{\sum_j K_{tj}} \tag{25}$$

Case III

$$\max_{\theta_t,\alpha_{ti},\beta_{ti},K_{ti}} W\left(V\left(y^d_{t+1,i}, G^1_{t+1,i}, N_{t+1,i}\right), N_{t+1,i}\right) \tag{12'''}$$

$$s.t. \quad \text{(13)-(16), (18)-(24)}$$

where

z_{ti} : capital owned by a household in region i at period t

α_{ti} (β_{ti}): proportion of the investment in community environmental infrastructure (industrial infrastructure) in region i to that in whole region at period t ($\sum_i \alpha_{ti} = \sum_i \beta_{ti} = 1$)

θ_t : proportion of the investment in community environmental infrastructure to that in community environmental infrastructure and industrial infrastructure at period t ($0 \le \theta_t \le 1$)

r_t, τ, s, n : interest rate at period t, income tax rate, saving rate, depreciation rate

ρ : parameter (which indicate the quickness of adjustment process)

Necessary conditions for the maximization problem of the central government can be induced easily by assuming interior solutions. For the lack of spaces, we show the procedure of estimating the objective functions only for the case I. By simple calculation, eqs.(26) and (27) can be given as necessary conditions. Each of them is related to the interregional allocation of public investment in community environmental infrastructure and industrial infrastructure.

$$\frac{\partial W}{\partial V_{t+1,i}}\frac{\partial V_{t+1,i}}{\partial G^1_{t+1,i}} = \lambda^G_t \tag{26}$$

$$\frac{(1-s)(1-\tau)}{N_{t+1,i}}\frac{\partial Y_{t+1,i}}{\partial G^2_{t+1,i}}\frac{\partial W}{\partial V_{t+1,i}}\frac{\partial V_{t+1,i}}{\partial y^d_{t+1,i}} = \lambda^G_t - \frac{\partial^2 Y_{t+1,i}/\partial K_{t+1,i}\partial G^2_{t+1,i}}{\partial^2 Y_{t+1,i}/\partial (K_{t+1,i})^2}\lambda^{Nz}_t \tag{27}$$

where

$\lambda^G_t, \lambda^{Nz}_t$: Lagrange Multiplier for eqs.(13) and (14) and for eq.(20)

$$r_{t+1} = \left\{\frac{\sum_j N_{t+1,j} z_{t+1,j}}{\sum_j \left(a_1 A N_{t+1,j}^{1-a_1} N_{t+1,j}^{a_2 \ln G^2_{t+1,j}}\right)^{\frac{1}{1-a_1}}}\right\}^{a_1-1} \tag{28}$$

$$K_{t+1,i} = \frac{\left(a_1 A N_{t+1,i}^{1-a_1} N_{t+1,i}^{a_2 \ln G^2_{t+1,i}}\right)^{\frac{1}{1-a_1}}}{\sum_j \left(a_1 A N_{t+1,j}^{1-a_1} N_{t+1,j}^{a_2 \ln G^2_{t+1,j}}\right)^{\frac{1}{1-a_1}}}\sum_j N_j z_{t+1,j} \tag{29}$$

$$y^d_{t+1,i} = \frac{1}{N_{t+1,i}}(1-s)(1-\tau)\left\{Y_{t+1,i} - r_{t+1}K_{t+1,i} + r_{t+1}N_{t+1,i}z_{t+1,i}\right\} \tag{30}$$

By substituting eqs.(10) and (11) into eqs.(26) and (27) and adding disturbance terms, eqs.(31) and (32) can be given. Since C_t, D_t and E_t can be regarded as constants in the analysis using cross-section data, we can estimate the inequality aversion parameter ε by applying NLOLS to each of them or generalized least squares method (GLS) to seemingly unrelated regression model.

$$\ln\left(N_{t+1,i}\frac{\partial V_{t+1,i}}{\partial G^1_{t+1,i}}\right) = C_t - \ln a_i + (1-\varepsilon)\ln V_{t+1,i} + u^1_{ti} \tag{31}$$

$$\ln\left[\frac{\partial V_{t+1,i}}{\partial y^d_{t+1,i}}\frac{\partial Y_{t+1,i}}{\partial G^2_{t+1,i}}\right] = \ln\left(D_t - \frac{\partial^2 Y_{t+1,i}/\partial K_{t+1,i}\partial G^2_{t+1,i}}{\partial^2 Y_{t+1,i}/\partial (K_{t+1,i})^2}E_t\right) - \ln a_i + (1-\varepsilon)\ln V_{t+1,i} + u^2_{ti} \tag{32}$$

where

$C_t = \ln \lambda^G_t + \ln W^{\varepsilon-1}$

$D_t = \ln \lambda^G_t + \ln W^{\varepsilon-1} - \ln(1-s)(1-\tau)$

$E_t = \ln \lambda^{Nz}_t + \ln W^{\varepsilon-1} - \ln(1-s)(1-\tau)$

3.2 Data

The data on the stock of private capital and labor capital is obtained from Doi (1998). The data on industrial infrastructure is obtained from JI. As noted before, JI divide infrastructures into 14 groups. We regard 8 groups, which are not grouped in community environmental infrastructure in Section 2 as industrial infrastructure. We must draw

attention again to the fact that road, which is occupying the largest part of the stock of infrastructure in Japan, is included in the group of industrial infrastructure because of the reason mentioned above. The data on annual private investment is obtained by handling the stock data in JI.

3.3 Estimation Results

3.3.1 Production Sector

We estimated the production function given by eq.(10), pooling the data from 1965 to '95. The results are shown in Table 3. The marginal productivity of industrial infrastructure calculated from the estimation results is positive and is consistent with existing researches.

Table 3. Estimates of Production Function

Parameter	Estimate	Standard Error	t-statistic
C	0.30905	0.00904	34.22
D	0.00198	0.00029	6.86
$\ln A$	-3.3984	0.04973	-68.34
Adj.R^2			0.959

3.3.2 Central Government

For three cases in Table 2, we estimated the inequality aversion parameter in eq.(11) from the data on annual private investment (we assumed that a_i is unity for any i). As for the periods of analysis, we set up four cases, 1965-'67, '70-'72, '77-'79, '87-'89, which correspond the first three years of Japan's Comprehensive National Development Plan (JCNDP) ever practiced except for first period (because of the data constraints, even though first JCNDP started at 1962, we must analyze the period after 1965). By comparing the estimates of each planning period, it is expected to be able to know the change of interregional allocation policy. The estimation results are given in Table 4 and Figure 5. From the figures of R-squared in Table 4, we must say that the reliability of the analysis related to CEI is not so good. Although the results are open to objection, we want to interpret them in anyway.

As for the interregional allocation of public investment in community environmental infrastructure, firstly, we can say that the difference of estimates between set up cases is negligible. Figure 5 indicates that it is most inequality loving in the second JCNDP. This result is consistent with our intuition and we can infer that the needs of investment for pollutant abatement in urban area of that time have an influence on our results. In addition to this, Figure 5 indicates that the interregional allocation policy changed around 1975 to attach larger weight on equality than efficiency. This result is also consistent with widely shared opinion and this point is the center of criticism against Japanese public investment policy nowadays.

As for the interregional allocation of public investment in industrial infrastructure, this is the same with community environmental infrastructure at the points that the direction of the change of that parameter is almost the same for all cases. It is however different at the point that the absolute values of inequality aversion parameter estimate in each case is

different. This fact indicates that our understanding of social system (in the case of our analysis, the assumption about the mobility and allocation mechanism of private capital) have an influence on the evaluation of the system. Further, we can know the needs of sensitivity analysis on the model structure. Turning now to the real subject, from Figure 5 we see that the estimates of inequality aversion parameter is almost the same through these 30 years in each case. As the share of public investment in local area where utility-level is relatively low is slowly increasing for these 20 years, at first glance, our results seem to be inconsistent with the fact. However, we also know the fact that the interregional difference of the marginal productivity of industrial infrastructure is slowly decreasing for these 30 years. Therefore, we can infer that the change of the share of public investment and that of the marginal productivity of industrial infrastructure balance out and the estimates of inequality aversion parameter take almost the same value for all periods.

Although much resources has been invested in the community environmental and industrial infrastructure of underdeveloped regions to reduce the regional welfare disparity for these 30 years, as the analysis in Section 2 indicates, the regional welfare disparity has not been diminishing clearly. From this result, we can conclude that the interregional allocation policy of public investment did not strongly contribute to reduce the regional disparity. Needless to say, there is a possibility that the interregional allocation policy contributed to prevent the regional welfare disparity from growing more serious.

Table 4. Estimates of inequality aversion parameter

	Period	Community Environmental Infrastructure		Industrial Infrastructure	
		Estimates	Adj. R^2	Estimates	Adj. R^2
Case I	'65~'67	0.765	0.07	0.731	0.97
	'70~'72	0.885	0.07	0.677	0.99
	'77~'79	0.772	0.03	0.695	0.99
	'87~'89	0.483	0.22	0.750	0.99
Case II	'65~'67	0.765	0.07	0.975	0.90
	'70~'72	0.885	0.07	0.888	0.93
	'77~'79	0.777	0.03	0.855	0.95
	'87~'89	0.487	0.22	0.858	0.97
Case III	'65~'67	0.816	0.03	0.908	0.94
	'70~'72	0.937	0.04	0.841	0.95
	'77~'79	0.780	0.03	0.821	0.97
	'87~'89	0.496	0.20	0.848	0.98

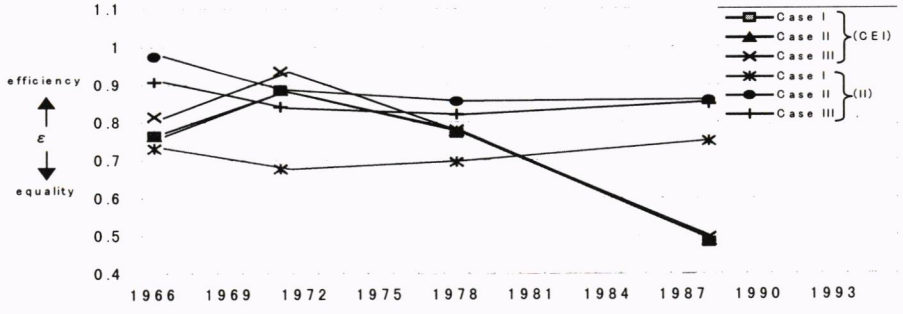

Figure 5. Trend of Inequality Aversion Parameter

4. CONCLUSION

In this paper, we indicated the framework for the post-evaluation of the impact of the infrastructure improvement on the regional welfare disparity. Our analysis makes the following points clear although the reliability of our analysis is not so high.

1) The improvement of community environmental infrastructure contributed to the increase of the welfare attained in each region, though there is little contribution to the reduction of the regional welfare disparity.
2) The interregional allocation of industrial infrastructure did not strongly contribute to reduce the regional disparity.
3) The interregional allocation policy of community environmental infrastructure changed from inequality loving to inequality aversion drastically.

Finally, re-examining the reason why we believe the empirical and normative post-evaluation of the interregional allocation of public investment is needed, we want to show the topics for further research. First, nowadays the reformation of the political system is the subject of discussion in Japan. It is easily imagined that the political system has made influences on the interregional allocation of public investment. We think that it is effective for the discussion on the political reformation to indicate the political impact on actual public investment and the welfare losses due to it. To discuss on the influence of the political system is one of further topics. Second, in economic growth theory, how should the central government meet the trade-off between efficiency and equality has been one of the important topics. Until now, Japan has been taken as a successful example generally. It is however difficult to know the degree of inequality aversion of the Japanese central government at each period even if we are given the list of raw data on annual public investment in each prefecture. (For example, in the case of our analysis, the information is shrunk from two panels of 31 by 46 to two time-series of 31 figures). Suggested framework help the work of post-evaluation by shrinking the information related to the interregional allocation of public investment. To discuss on the impact of interregional allocation policy of public investment on the economic growth with comparing the cases of other countries is also one of further topics. Third, we believe that for better planning, it is needed to measure the utility function precisely. We indicated one way to identify the utility function, but more strict measurement is required. In the case of our analysis, to treat the interregional migration and transportation market precisely is one direction for further research. Fourth, it is requested to analyze the behavior of central government under the hypothesis of the objective function maximizing in dynamic context. Although many hypothesis has been suggested for the behavior of central government, to the best of our knowledge, dynamically maximizing central government has not been empirically analyzed. Needless to say, this is a very difficult problem. However, we believe that to solve this problem would give us fruitful insight not only on the behavior of central government but also on the economic growth theory.

ACKNOWLEDGEMENTS

This research is partially supported by a Japan Ministry of Education Science Research Grant, number 10450188. We would like to thank Taka Ueda (Tokyo Institute of Technology) for helpful comments and suggestions. But responsibility for the text with any surviving errors rests entirely upon the authors.

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