Direct and Indirect Effects of Public Infrastructure on Regional Economic Growth in Japan: An Application of the Covariance Structure Model by Geographical Classification Area

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Abstract

The direct and indirect effects of public infrastructure (PI) were evaluated by a covariance structure model. Empirical results showed the positive indirect effect, crowding-in effect, as well as the direct effect as an input factor, differences of these effects by the geographical areas and periods.

Key words: public infrastructure, covariance structure model, crowding-in effect, geographical classification areas, economic bubble burst.

JEL Classification codes: H43, O18, Q18, R53, R58

Introduction

In the 1990's, public infrastructure (PI) has been increasingly constructed throughout Japan by issuing of national loans, especially in rural areas, to overcome economic recession and to solve regional income inequality problems. With consequent accumulation of deficit in the national budget, the progressive public investment policy now raises questions as to the effectiveness of PI investments by the government. Evaluation of the effects of PI is highly necessary to show the appropriateness of the investment paid by taxes in view of regional differences.

PI is expected to stimulate the regional economic growth in two ways. One is a direct effect of production processes as input factors and another is an indirect effect from crowding in or crowding out the private investment. Aschauer (1989a) measured the direct effects by the production function showing that contributions of PI to economic growth are significant in the US. Also he measured the indirect effect of PI by the estimation of private investment function showing that PI had a positive effect, crowding-in effect, to the private sector (Aschauer, 1989b). After his study, several empirical studies had been conducted to show the spill-over effect of PI (Munnell 1990a, 1990b), and to evaluate the effect from different function types and different data sets (Costa et al.; 1987, Pinnoi; 1994). Even in Japan, there are many previous studies using production function (Asako and Sakamoto; 1993, Kamata et al.; 1994, Mitsui et al.; 1995, Iwamoto; 1990, Hatano; 1998, Yoshino et al.; 1999). They indicate the contribution of PI to economic growth is significant and accounts for about 10% of the total economic growth in Japan. However, all previous studies in Japan used the data based on 47 prefectures, so that analyzing differences in effects between urban and rural areas is impossible by this prefectural data which include urban and rural areas together. Considering complicated topographic conditions, it is indispensable to take geographical features into consideration when production structure is analyzed. In addition, co-existence of the direct and indirect effects of PI causes several problems, such as multi-co-linearity in the estimation process, impossibilities for comparing both effects, and double count problems if the effects are estimated and summed.

This study aims to comprehensively evaluate the direct and indirect effects of PI by the covariance structure model (CSM) in view of differences in Japanese geographical areas classified into urban areas (UBA), flat farming areas (FFA), hilly and middle areas (HMA), and mountainous areas (MTA). To analyze the effects of the geographical classification areas, the data based on 3247 towns were estimated for PI and private capital stock by the perpetual inventory method, benchmark year method and physical stock value method.

In Sections 2 and 3, the empirical models and data are described in detail, respectively. Section 4 presents the results of analysis and Section 5 contains the summary and conclusions.

Model

The merits of CSM, which combines pass analysis and factor analysis, are that it treats several explanatory variables correlating them to each other, and is able to treat the correlation of errors under a simple structure. This method is used in psychology and sociology where complicated situations and mutual relations between variables are expected to exist in the system. Even in economics, CSMs have been built to show the economic effects of information technology (Nakayama et al., 2001) and the effects of public relations (Fujimi, 2001). In terms of PI in regional economies, we assumed the following relationships between the variables (Fig. 1).

- Considering the purpose and contents, PI was classified into two types, PI for production and

PI for basic human needs (BHN), to simplify the model structure. PI for production consisted of transportation infrastructure (roads and harbors) and agricultural infrastructure (irrigation and drainage facilities, reclaimed farmland and consolidated farmland). PI for BHN consisted of natural disaster protection infrastructure (flood and slide protection facilities), life line infrastructure (waterworks, public rental houses, rural life bases, parks and schools), and environmental protection infrastructure (urban and rural sewage systems, disposal treatment facilities). There are other kinds of public facilities, such as rail roads and telecommunication facilities, but they were ignored because of data limitation.

- PI for production can directly stimulate regional economic growth as an input factor in regional production and can also indirectly stimulate private activities. The indirect effect of PI is indicated by the coefficient, c, and can be either a positive effect, crowding-in effect, or a negative effect, crowding-out effect, in the regional economic growth. Which effect is dominant depends on the economic situations, so only the economic data can show the difference. By using the pass coefficients of the CSM, the effects of k-th PI can be calculated as follows.

  Direct effect of k-th infrastructure: $DE=a_k \times b$ (1).

  Indirect effect of k-th infrastructure: $IE=a_k \times c \times d$ (2).

- PI for BHN is passively stimulated by private activities instead of actively stimulating the regional economy. Under an improvement of private activities, this infrastructure is consolidated by the local governments to prevent social frictions and to satisfy the needs of the residents. The effects of PI for BHN to regional populations can be calculated by the coefficient of CSM as follows.

Passive effect of k-th infrastructure: $PE_k = a_k \times h$ (3).

If the value of PE_k is close to one in Eq. (3), the k-th infrastructure has been constructed in accordance with regional population and activities of the private sector. If the value of PE_k is low, the k-th infrastructure has been constructed under the leadership of the government away from domestic needs.

- Transportation infrastructure, natural disaster protection infrastructure, life line infrastructure and environmental protection infrastructure have mutual relations, because these kinds of infrastructure are subsidized under the same policies managed by the Ministry of Land and Transportation. On the other hand, agricultural infrastructure is constructed under a unique policy scheme showing no correlation to other kinds of infrastructure.

Fig. 1

Data

To estimate CSM in each geographical classification area, UBA, FFA, HMA and MTA, the data were calculated from 3247 towns for obtaining variances of data within each area. The geographical classification was determined by the Ministry of Agriculture, Forestry and Fishery (MAFF) after considering the rate of mountainous areas, residential areas and existence of the densely inhabited district. This classification has been used in many previous studies to represent the Japanese geographical topography. Also, town based data can represent differences in policy decisions on PI within the area, because the overall scheme of PI in each town was uniquely decided by the local government. Therefore, the suitable and minimum unit for analysis is a town, when the geographical differences are taken into account.

The stocks of PI, KG_{ijk}, were calculated from $KG_{ijk} = KG'_{jk} \times Q_{ijk} / \sum_{i=1}^{I} Q_{ijk}$ for each town. This equation was based on the perpetual inventory method, benchmark year method and physical stock value method (Kunimitsu et al.; 2003, Nakata et al.; 2003). Here and after, the suffix i indicates town, j indicates prefecture and k indicates the kind of PI. KG'_{jk} is the stock of PI in each prefecture calculated by the perpetual inventory method and published in the *Social Capital in Japan* (Cabinet Office of Japanese Government; COJG, 2002). Q_{ijk} is the physical value of the public facilities, such as length of roads, areas of public parks and numbers of schools, assuming that the stock of PI is in proportion to the physical value of the public facilities. In terms of the agricultural sector, Q_{ijk} was calculated from the *Investigation of Main Irrigation and Drainage Facilities* (MAFF) indicating the total assets of the irrigation and drainage facilities, *Research on Infrastructure for Agricultural Production Basis* (MAFF) indicating areas of consolidated farmland (paddy and dry field), and *Farm Road Survey* (MAFF) indicating the total length of farm roads, as the benchmark year value adding the annual consolidation area minus annual depreciation area published in *Statistics of Agricultural Construction Project* (MAFF). In other sectors, the statistical data published in *Public Facility Survey* (Ministry of Internal Affairs and Communications; MIC) every year were used for procuring the data of Q_{ijk}.

The private capital stock was calculated from $KP_{ij} = KPM_j \times \left(\frac{AM_{ij}}{\sum_i AM_{ij}} \right) + KPA_j \times \left(\frac{AA_{ij}}{\sum_i AA_{ij}} \right) + KPE_j \times \left(\frac{NS_{ij}}{\sum_i NS_{ij}} \right)$. Here, KPM_j, KPA_j and KPE_j are the private capital stock of manufacture industry, agriculture and other sectors, respectively, and they are published by COJG. This equation is assumed so that private capital stock in each town is in proportion to the share rate of the physical values, AM_{ij}, AA_{ij}, and NS_{ij}, in each town. AM_{ij} is the tangible fixed assets of the private manufacturing company published in *Statistics of Enterprises and Establishments* (Statistic Bureau of MIC). AA_{ij} is the farmland areas investigated by MAFF, and NS_{ij} is the number of offices and shops published in *Census of Manufactures* (Ministry of Economic, Trade and Industry).

Domestic income Y of each town was calculated from the taxable income (Japan Market Research Center) by $Y_{ij} = y_{ij} \times ND_{ij}$, where y_{ij} is a per capita taxable income and ND_{ij} is the number of day time population of each town. This equation was used for adjusting the data based on persons to the data based on the place. In general, the taxable income does not include profits of private companies, but Y_{ij} is considered the proxy of regional GDP.

The labor force was obtained from the numbers of employees published in the *National Census* (MIC) for each town. The labor force was revised to data based on the place by using the number of commuters to (and from) other towns.

The years of analysis were in 1985 and 1995. The former year was in the economic bubble period, and the latter was in the economic recession period after the economic bubble burst in 1990.

Results

Table 1 shows the changes in the main variables during 1985-90 and 1990-95 before and after the economic bubble burst. In the HMA and MTA, population seriously decreased during both periods and an increase of per capita income was not high as compared to other areas even after including the positive contribution of a decrease in population to the per capita value. The per capita value of private capital stock increased during these periods by almost the same amount in both periods and all areas, but an increase of per capita private capital stock depended considerably on the decrease of population in the HMA and MTA, so that regional differences in the effect of total private capital stock must have existed and its increase was low in these areas. On the other hand, the per capita values of PI, especially in PI for production, increased more rapidly in the HMA and MTA than other areas. This tendency became strong after the economic bubble burst showing a progressive policy in the public investment.

Table 1.

Figures 2 and 3 show the representative results of CSM in the UBA during the economic bubble period in 1985 and in the HMA during the economic recession period in 1995. The estimation was done by AIMOS ver. 5.1 (SPSS inc.). The most likelihood estimation (MLE) method and general least square (GLS) method were employed in the estimation process after comparing performances of the models between these methods. For the UBA and MTA in both years, the model performances calculated from GFI (goodness of fit index) and RMSR (root mean square residual) were low in the MLE method, so the GLS method was used to obtain the estimations. The performances indicated by the GFI and RMSR were suitable in all models showing GFI=0.855 and RMSR=0.097 (UBA), 0.902 and 0.030 (FFA), 0.968, 0.018 (HMA), and 0.926, 0.038 (MTA) in 1985, respectively, and GFI=0.825, RMSR=0.112 (UBA), 0.888, 0.037 (FFA), 0.950, 0.026 (HMA), and 0.921, 0.051 (MTA) in 1995 (Tanaka; 1987, Browne and Cudeck; 1993, Hu and Bentler; 1999). Since these models were estimated from cross-sectional data, it is acceptable that some cases indicated low GFI of less than 0.9 and high RMSR of more than 0.1.

Fig. 2

Fig. 3

Table 2 shows the direct and indirect effects of PI for production on the regional economic growth quantitatively calculated from Eq. (1) and (2). The following features can be found in this result.

First, the direct effect of PI was considerably low in all cases as compared to the indirect effect and to other input factors. Especially, the direct effect of the UBA was low in both years, but the effect was slightly higher in other areas, FFA, HMA and MTA, showing a direct contribution of PI to regional economic growth in these areas. Reversely, private capital stock and labor greatly affected the regional economic growth. Especially in the UBA, the contribution degrees of private capital stock and labor were remarkably high as compared to PI. These results indicate that the private sector led the economic growth in the UBA, but the public sector had higher influences on the regional economy in other areas.

Second, the direct effect of agricultural infrastructure was low, but as high as 50 to 80% that of transportation infrastructure except for in the UBA. This is because agricultural infrastructure tended to improve only agricultural income that accounts for less than 10% of the total regional income. If we calculated the model by agricultural income instead of total income[i], the direct effect of agricultural infrastructure was higher than the case of regional income and higher than the direct effect of transportation infrastructure (Fig, 4 and Table 3). Therefore, this indicates that the direct effect of agricultural infrastructure contributes more to agricultural production along with other kinds of capital as compared to its contribution to total regional income.

Third, the indirect effect of PI, which stimulates regional income via the private sector, was positive in all areas and during all periods (Table 2), indicating a crowding-in effect of PI. This result corresponds to the results of Aschauer (1989 b) in the USA. If we compare the effects between areas, the crowding-in effect is higher in the UBA in both years. In the UBA, the private sector led economic growth and accounted for a high portion of economic components as compared to other areas, so that the indirect effect rather than the direct effect of PI was high. In other areas, the indirect effect was positive but not as high as that of UBA. Also, the indirect effect of transportation infrastructure was higher in the UBA than other areas, FFA, HMA and MTA.

To compare above results to the effects without consideration of crowding-in effect, the CSMs were estimated by ignoring the arrow between the variables of "PI for Production" and "Vitarity of Private Sector" (Table 4). Results without consideration of crowding-in effect indicate that all values of coefficient *b* became higher showing higher direct effect of PI to regional income. These results, in some sense, represent the estimations of the production function, even though there are differences in the function type, such as linear function and exponential function. Hence, it can be said that the direct effect without consideration of crowding-in effect is displayed in higher value than that with consideration of this simultaneous effect, showing unavoidable biases in the production function approach.

Table 2

Table 3.

Table 4.

Table 5 shows the relation between PI for BHN and population, calculated from Eq. (3). The pass coefficients show that the effects of natural disaster protection infrastructure and life line infrastructure were higher than environmental protection infrastructure. Comparing effects between areas, the effect of PI tended to be higher in the UBA than other areas. This result indicates that PI in the UBA has been constructed along with the growth of the private sector, but PI in other areas has a weak relation to the private sector. As seen before, PI for production contributed to regional economic growth in the FFA, HMA and MTA, so that PI for BHN decreased in its contribution to the regional economy. In other words, stimulation of production was more necessary than BHN in the FFA, HMA and MTA.

Comparing effects between 1985 and 1995, the effect of life line infrastructure and environmental protection infrastructure increased in their contribution to the regional economy after the economic bubble burst. Hence, the linkage between PI for BHN and private sector was strengthened after the economic bubble burst.

Table 5.

Summary and Conclusions

In order to show the quantitative effect of PI, this study aimed to build the CSM around the regional economic growth by geographical classification areas in 1985 for the economic bubble period and 1995 for the economic recession period. The results obtained from the model show that the direct effect of PI for production was weaker than the indirect effects of PI and other input factors in every areas and both years. However, the direct effect was higher in the FFA, HMA and MTA than in the UBA showing higher direct contribution of PI in these areas. On the other hand, the indirect effect of PI for production, especially transportation infrastructure, was high showing a crowding-in effect. From these results, we can conclude that PI has direct and indirect effects which vary by geographic classification area and economic booming situations. The direct effect without consideration of crowding-in effect is displayed in higher value than that with consideration of this simultaneous effect, showing unavoidable biases in the production function approach. Therefore, considering geographical situations and mutual relations between public and private sectors is important in the evaluation for the effect of PI in the economy.

There are other effects of PI that remain to be investigated. Since the estimation period was in 1985 and 1995, using a newer analysis period is highly necessary to see the recent effects of PI. Also, PI has a spill-over effect expanding to neighboring cities, so consideration of the spill-over effect in the model may be important.

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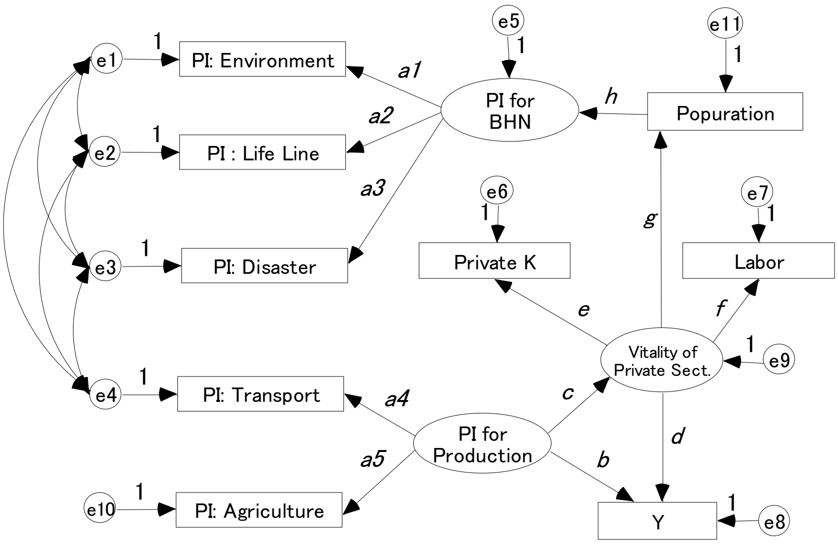

Figure 1. Covariance structure model for effects of public infrastructure.

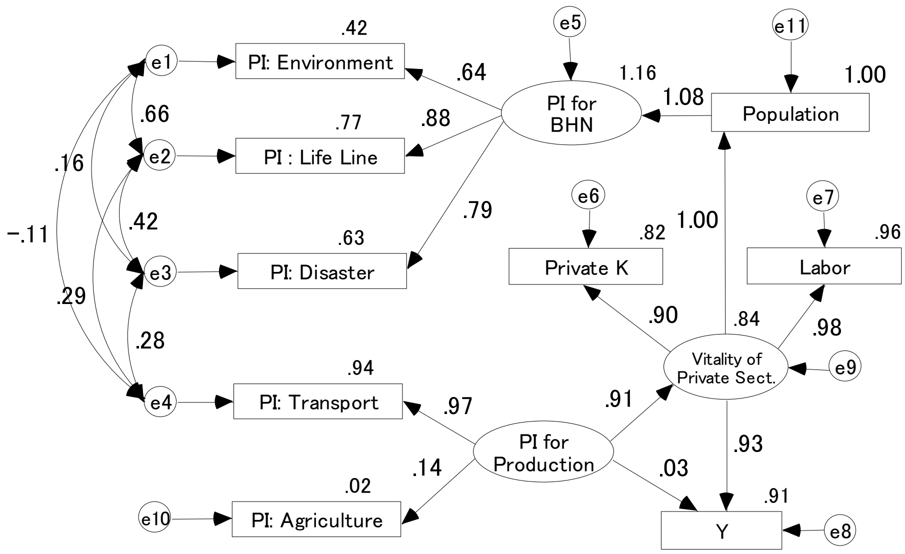

Figure 2. Estimations of CSM in the urban areas (UBA) 1985.

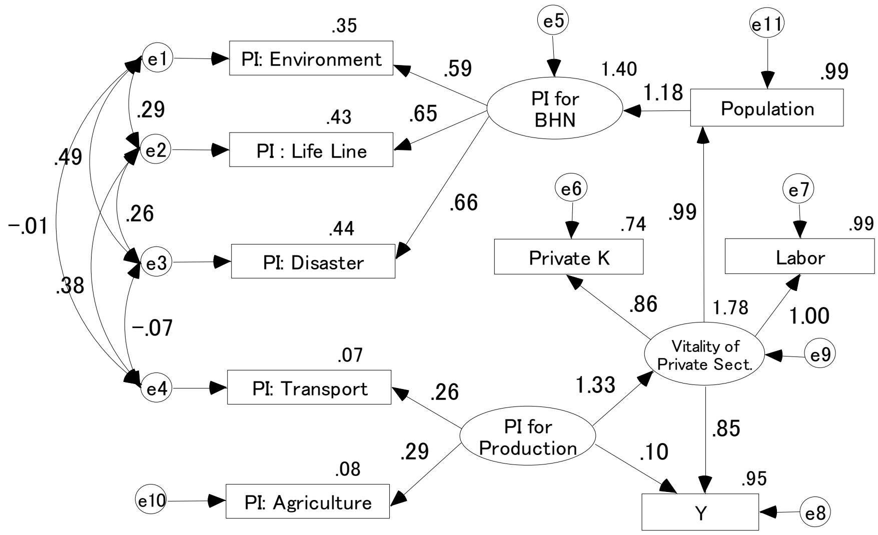

Figure 3. Estimations of CSM in the Hilly and Middle Areas (HMA) 1995.

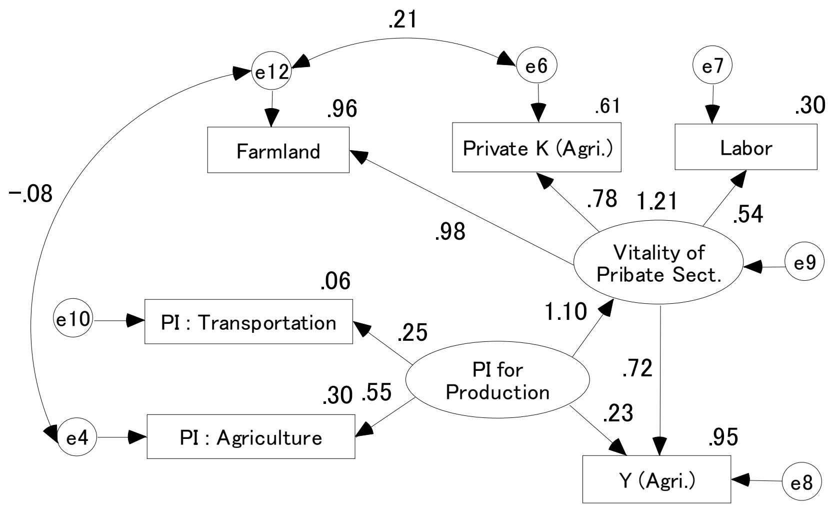

Figure 4. Estimations of CSM in the Hilly and Middle Areas (HMA) in 1995 for agricultural income

Table 1. Changes in population and per capita values of main variables during 1985-90 and 1990-95.

(persons, yen / person)

Items	UBA	FFA	HMA	MTA	Whole
1985–90					
Population	4,327	147	−246	−351	858
Per capita Income	1,236,624	869,935	807,893	779,447	913,144
Private capital	1,669	2,186	1,968	1,843	1,923
Public Infrastructure					
for Production	286	1,123	1,133	1,543	1,031
for BHN	328	350	383	478	384
1990–95					
Population	3,256	324	−100	−225	732
Per capita Income	190,662	227,540	226,367	221,648	217,484
Private capital stocks	1,705	2,237	2,027	1,609	1,909
Public Infrastructure					
for Production	336	1,181	1,327	1,815	1,178
for BHN	401	495	563	666	534

(Note) All variables were calculated by (value of start year)-(value of end year) and except for population have a unit as per capita value.

Table 2. Effects of public infrastructure for production and private capital stock in each geographical area

Items	1985				1995			
	UBA	FFA	HMA	MTA	UBA	FFA	HMA	MTA
Direct Effect								
Transport. PI	0.03	0.13	0.04	0.10	−0.03	0.07	0.03	0.08
Agricultural PI	0.00	0.06	0.03	0.06	0.00	0.03	0.03	0.05
Indirect Effect								
Transport. PI	0.82	0.42	0.39	0.39	0.90	0.42	0.29	0.37
Agricultural PI	0.12	0.18	0.30	0.26	0.12	0.19	0.33	0.24
Private Capital	0.84	0.58	0.73	0.64	0.90	0.68	0.73	0.60
Labor	0.91	0.75	0.84	0.76	0.96	0.81	0.85	0.77

Table 3. Effects of public infrastructure for production to agricultural income.

Item	1985				1995			
	UBA	FFA	HMA	MTA	UBA	FFA	HMA	MTA
Direct Effect								
Transport. PI	0.04	0.10	0.07	0.06	0.02	0.08	0.06	0.06
Agricultural PI	0.10	0.10	0.12	0.08	0.09	0.07	0.13	0.09
Indirect Effect								
Transport. PI	0.22	0.39	0.23	0.26	0.14	0.39	0.20	0.23
Agricultural PI	0.52	0.37	0.41	0.34	0.53	0.35	0.44	0.36
Private Capital	0.62	0.56	0.52	0.53	0.66	0.64	0.56	0.52
Farmland	0.83	0.69	0.69	0.70	0.90	0.77	0.71	0.70
Labor	0.02	0.81	0.70	0.83	0.01	0.63	0.59	0.73

Table 4. Effects of public infrastructure for production without consideration of indirect effect

Items	1985				1995			
	UBA	FFA	HMA	MTA	UBA	FFA	HMA	MTA
Direct Effect								
Transport. PI	0.78	0.56	0.44	0.47	0.80	0.49	0.34	0.45
Agricultural PI	0.10	0.22	0.32	0.35	0.11	0.22	0.34	0.29
Private Capital	0.79	0.74	0.85	0.77	0.78	0.82	0.85	0.80
Labor	0.89	1.01	0.97	0.97	0.89	1.00	0.99	0.97

Table 5. Effects of public infrastructure for basic human needs in each geographical area.

Items	1985				1995			
	UBA	FFA	HMA	MTA	UBA	FFA	HMA	MTA
DisasterProtec. PI	0.85	0.76	0.81	0.75	0.87	0.74	0.78	0.72
Life Line PI	0.95	0.89	0.66	0.89	0.95	0.92	0.77	0.86
Disposal Treat PI	0.69	0.60	0.60	0.54	0.67	0.74	0.70	0.59

< Foot Note>

[i] The megalopolis data, such as 23 wards in Tokyo, were excluded due to a lack of agricultural data in the megalopolis areas.