A Re-examination of the Method to Measure Economic Productivity of Public Expenditure and Technology*

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Abstract

This paper investigates the economic impact of the accumulation of transport capital taking technological progress into account. This analysis plays a role to respond author's former papers having researched the same target from cost approach. Since the concept of the duality is widely accepted within theoretical framework, hypothesis, that identical outcome might be obtained under the condition of production scope, must be tested. Unlike previous research in which technology is treated as a simple composite, the possibility of multi-composites in the process of estimation is accounted for.

The results show the productive characteristics of both social capital and technological progress, playing a contributory role onto the private economy. Furthermore, the analysis of disaggregated factors with multi-capital model shows unique influence for respective components, especially transport-related capital indicating positive and negative features.

キーワード：

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1. Introduction

Measuring the economic performance of public expenditure has been one of the most significant issues in not only economic but also political arena in Japan. This paper aims at proposing a different methodology from the traditional framework in which social capital is treated as a single variable. Unlike the analysis of Aschauer [1] having clarified "plus effect" of the publicly provided capital on the U.S. market, Arai [2] pointed out that its performance on Japan's private sector might be complicated in interpretation due to quite unstable characteristic in statistical sense. In other words, it is hard to conclude that economic performance of social capital plays a productive role in private market. Arai [3] proposed a cost-based analysis to the same target in order to research the possibility of the similar outcomes as the one by Aschauer to be observed. With the introduction of PCA (Principal Component Analysis) method, Arai made an attempt to create a new "composite" variable which is a substitute for current technological level. Those approaches mixed together has led the empirical result to be opposite from the one in former paper using macro-production function. For further research to be proceeded, Arai [4] tried a micro-level cost analysis with pooled data of private railroad companies in order to find the impact of both social capital and technological progress on specific private sector. The result has been quite identical with the one in macro-level cost analysis. Unlike the result of production approach, both technology and social capital as external factors seem to possess negative effect on cost structure. These outcomes seem to be acceptable in comparison with the one for the case of Sweden by Berndt & Hansson [5], and the one for U. S. case by Nadiri & Mamuneas [6].

What seems to be lacking in this particular point has been the response to the original discussion of the production function analysis which still remains questionable. Even though it is dangerous to simply accept the generalization that social capital and technological progress do contribute to the economic activity to some degree toward "plus" direction, we must test the performance of those elements before evaluation. To achieve the goal, the author applied Principal Component Analysis on Social Capital Variable. Then, regression to the macro-level production function is proceeded with the newly composed substitute variable. PC analysis has been applied not only on the social capital, but also on technological variable as the former trials. This approach might allow quite many kinds of data to be involved in the analysis. Furthermore, social capital variable is decomposed into several categories to see individual performance on private economy. Finally, economic performance of the model is evaluated with observed marginal productivity.

2. Principal Component Analysis on Social Capital Data

2.1 Analytical Framework for PCA

PCA is a method to extract respective characteristics from observed data, and at the same time, to change the vector to lower dimension. To describe, if the observation x consists of $(n \times p)$ elements, it can be converted to $(m \times p)$ factors as given by

$$z_1 = l_{11}x_1 + l_{12}x_2 + \cdots + l_{1p}x_p = \sum_{i=1}^{p} l_{1i}x_i$$

$$z_2 = l_{21}x_1 + l_{22}x_2 + \cdots + l_{2p}x_p = \sum_{i=1}^{p} l_{2i}x_i$$

$$\vdots$$

$$z_m = l_{m1}x_1 + l_{m2}x_2 + \cdots + l_{mp}x_p = \sum_{i=1}^{p} l_{mi}x_i$$

under the following condition

$$\sum_{i=1}^{p} (l_{ki})^2 = 1 \qquad (k = 1, 2, \cdots, m) \tag{1}$$

To summarize, coefficient (weight, in other words) to be calculated must satisfy the following conditions:

(a) l_{it} $(i=1, 2, \cdots, p)$ for the first component z_1 maximizes the variance of z_1

(b) z_2 also maximizes the variance of z_2 with the constraint that $V[z_1] > V[z_2]$

(c) z_2 must be orthogonal with respect to z_1

(d) the same procedure is applied to $z_3 \cdots z_m$

Then, let us describe the means to acquire respective l_{ki}. According to the condition (a) shown above, variance of Z_k

$$V[z_k] = \sum_{a=1}^{n} (z_{ak} - \overline{z}_k)^2/(n-1) = \sum_{a=1}^{n} \left\{ \sum_{i=1}^{p} l_{ki}(x_{ai} - \overline{x}_i \right\}^2/(n-1)$$

$$= \sum_{i=1}^{p} \sum_{i'=1}^{p} l_{ki}l_{ki'} \sum_{a=1}^{n} (x_{ai} - \overline{x}_i)(x_{ai'} - \overline{x}_{i'}/(n-1) = \sum_{i}\sum_{i'} l_{ki}l_{ki'}V_{ii'}$$

must be maximized under the equation (1). Thus,

$$\max Q=\sum_{i}\sum_{i'} l_{ki} l_{ki'} V_{ii'} \tag{2}$$

$$s.t. \sum_{i=1}^{p} (l_{ki})^2=1$$

Here we would like to focus upon the case of two variables in order to simplify the framework. In this case, the first principal component, being assumed to possess the largest variance, can be rewritten as

$$z_{\alpha 1}=l_1 x_{\alpha 1}+l_2 x_{\alpha 2} \quad (under \quad l_1^2+l_2^2=1) \tag{3}$$

From the framework discussed above, this case becomes a simple problem

$$(n-1)V[z_1]=\sum_{\alpha=1}^{n}(z_{\alpha 1}-\overline{z_1})^2=\sum_{\alpha}\{l_1(x_{\alpha 1}-\overline{x_1})+l_2(x_{\alpha 2}-\overline{x_2})\}^2$$
$$=l_1^2 S_{11}+l_2^2 S_{22}+2l_1 l_2 S_{12}$$

where S_{ij} is an expression for sum of squared. Finally, l_k^* can be obtained by maximizing the following:

$$\max Q=l_1^2 S_{11}+l_2^2 S_{22}+2l_1 l_2 S_{12}+\lambda(l_1^2+l_2^2-1) \tag{4}$$

From this process, we can extract the primary component from diverse data with the minimum loss of information.

2.2 Results and Analysis

In order to create the new composite, twenty three data have been applied in this analysis. These are described in the Table. 1, and obtained from Economic Planning Agency.

Table. 1

	Factors		Factors		Factors
1	Road Construction	9	Drain System	17	Shore Control
2	Port Investment	10	Waste System	18	Farm Control
3	Airport Construction	11	Water Supply	19	Forestry Control
4	National Railway	12	Park Construction	20	Fishery Control
5	Super Express	13	Academic Facilties	21	Postal Service
6	Subway Investment	14	Cultural Facilities	22	Woods (National Forest)
7	Tele-Communication	15	Riparian Control	23	Water (Industrial Use)
8	Public Housing	16	Afforestation Control		

First of all, single composite reflecting the information of all the data has been created. Its eigenvector can be observed in Figure. 2. Significant point here might be the quite large impact of road construction. In fact, it occupies the biggest portion of the amount within the social capital stock. Farm control, drain system, and public housing

Table. 2

Loading	PC 1	PC 2	Loading	PC 1	PC 2
Road	0.99962	-0.01558	Academic Facilty	0.99704	-0.00006
Port	0.99763	0.05117	Cultural Facility	0.99590	-0.05603
Airport	0.99615	-0.02922	Riparian	0.99986	0.00781
Railway	-0.17015	0.91852	Afforest	0.99805	0.05126
Express	0.97195	0.16432	Shore	0.98420	0.12993
Subway	0.99536	0.07645	Farm Investment	0.99596	0.07362
Tele-Com.	-0.01542	0.97305	Forestry	0.99575	0.07686
Pub. Housing	0.98771	0.13247	Fishery	0.99941	-0.00526
Drain System	0.99572	0.00885	Postal Service	0.99935	0.01528
Waste System	0.99460	0.04376	Woods (National)	0.96500	0.19667
Water Supply	0.99835	0.03995	Industrial Water	0.97039	0.21224
Park	0.97838	-0.16065			

may also be significant factors for the composite. Factor Loading for respective data can be recognized in Table. 2.

Second, these diverse data consisting of twenty three in number have been categorized into four groups; transport section, primary section (agriculture, forestry, and fishery), public services, and facilities for living. Through the categorization, we might be able to obtain newly created composites indicating respective type of investment.

Table. 3

Eigenvector	PC 1	PC 2
road	0.98544	0.01127
port	0.14298	0.06811
airport	0.02647	-0.00189
railway	-0.02733	0.99436
express	0.05167	0.06736
subway	0.06594	0.04406

As can be seen Figure. 2, similar characteristics for road investment can be recognized in the transport investment sector (Table. 3).

Table. 4

Eigenvector	PC 1	PC 2
farm	0.97846	-0.14948
forestry	0.13170	-0.07926
fishery	0.15899	0.98558

As to the agricultural investment, farm control seems to possess the highest amount of impacts among factors.

Public service section shows us quite understandable feature that investment on academic facilities seems to be the most significant.

Table. 5

Eigenvector	PC 1	PC 2
academy	0.74502	-0.60152
culture	0.17483	-0.06359
riparian	0.62337	0.61654
afforest	0.11268	0.21576
shore	0.06475	0.20457
post	0.02325	0.00780
woods	0.08040	0.35677
indust.wat.	0.04349	0.19560

Table. 6

Eigenvector	PC 1	PC 2
tele-com	0.01584	0.99483
housing	0.46815	0.07234
drain	0.64845	-0.05713
waste	0.10739	-0.00145
water sup.	0.58226	-0.01463
park	0.09764	-0.03998

Facilities for living seems to be different from other three sections on the ground that about half of the factors show us their impacts. It should be marked here finally is the remaining groups categorized as "others". Since those remaining take approximately 20 percent of the whole investment, PC analysis should also be applied for it. It; however, seems to be relatively hard at this time due to the data having not shown the expenditure in detail. Thus, newly composed variable for K_{gt} in this paper does not include whole information for the investment.

3. Estimation and the Result

3.1 Case of Social Capital as a Single Variable

The basic framework for the estimation has not changed from the former trial adopting both production and cost approach. Here in this point, social capital itself is treated as a single variable. Then, it is substituted by categorized composites as a next step. Technological factors are also based upon the same assumption that both innovative factor and economic environment surrounding the researchers are combined non-linearly. This variable has been assumed to play a quite significant role to amplify certain external effects onto the economy.

To be simple, let us first describe the models to be targeted in the process of estimation. For the first case that constant returns has been achieved to higher degree within the boundary of private sectors (case 1),

$$\log(Y_t/L_t)=\alpha_0+\beta_0 t+\phi\log T_{t-i}+\beta_1\log(K_{pt}/L_t)+\beta_3\log K_{gt}+\varepsilon_t \quad (5)$$

Then, for the second case that constant returns may have been achieved in whole sectors including both public and private sectors mixed (case 2),

$$\log(Y_t/L_t)=\alpha_0+\beta_0 t+\phi\log T_{t-i}+\beta_1\log(K_{pt}/L_t)+\beta_3\log(K_{gt}/L_t)+\varepsilon_t \quad (6)$$

Furthermore, for the third case in which public, private, and technological sectors are to be all necessary to achieve the constant returns (case 3),

$$\log(Y_t/L_t)=\alpha_0+\beta_0 t+\beta_1\log(K_{pt}/L_t)+\beta_3\log(K_{gt}/L_t)+\phi\log(T_{t-i}/L_t)+\varepsilon_t \quad (7)$$

Composite variable for the social capital K_{gt} is used here for those three models. T_{t-i}, representing technological level, is also substituted by composite variable involving diverse information of I_t and E_t in the framework of the following.

$$Y_t=e^{\theta t}E_t^{\delta}I_{t-i}^{\rho}K_{pt}^{\beta_1}L_t^{\beta_2}K_{gt}^{\beta_3} \quad (8)$$

Results of the estimation are described in Table 7. These are obtained by instrumental variable estimation since endogenous feature has been recognized in the process of preliminary estimation. Estimated value for K_{gt} is 0.16 and the estimates for private capital K_{pt} is 0.53. ϕ, indicating the estimated parameter for T_{t-i} is obtained to be 0.1. Those three have been positive numbers with relatively reliable t-statistics except case 3.

Table. 7

	Case 1	(Increase)	Case 2	(Constant)	Case 3	(Decrease)
Variables	Estimation	(t-statistics)	Estimation	(t-statistics)	Estimation	(t-statistics)
α_0	-2.5697	-2.9664	-1.5412	-2.1478	0.4214	2.8047
β_0	-0.0479	-6.9879	-0.2691	-6.9815	-0.3154	-6.3119
d_{74}	-0.1026	-5.6314	-0.098	-2.8948	-0.4178	-4.2581
ϕ	0.1021	2.6847	0.1145	3.2517	0.1261	2.8849
β_1	0.5367	5.6348	0.6013	4.2118	0.7224	5.1984
β_3	0.1613	2.3402	0.0514	2.1154	-0.0432	-1.2478

It should be marked that the social capital variable K_{gt} is found to possess statistically acceptable feature when technological level variable T_{t-i} has applied a lag of the second order T_{t-2} in this experiment. It seems to be relatively acceptable since it requires certain period of time to be extended and utilized.

3.2 Case for the Capital Consisting of Multi-Factors

As described in the previous section, the social capital variable is now disaggregated into four composites. K_{gt} can be considered to be

$$K_{gt}=\sum_{i=1}^{n} K_{igt} \tag{9}$$

where K_{gt} is divided into n number of sectors. The social production functional form is modified as

$$Y_t=e^{0t}E_t^{\delta}I_{t-i}^{\rho}\cdot f(L_t,K_{pt},K_{g1t},K_{g2t},\cdots,K_{gnt}) \quad (i=0,1,2,\cdots) \tag{10}$$

Models to be estimated are presented as following. Case 1 for increasing returns for the whole society, the functional form is given by

$$\log(Y_t/L_t)=\alpha_0+\beta_0 t+\phi\log T_{t-i}+\beta_1\log(K_{pt}/L_t)+\sum_{j=1}^{4}\gamma_j\log K_{gjt}+\varepsilon_t \tag{11}$$

The second case for constant returns to scale (Case 2), the model is also specified as

$$\log(Y_t/L_t)=\alpha_0+\beta_0 t+\phi\log T_{t-i}+\beta_1\log(K_{pt}/L_t)+\sum_{j=1}^{4}\gamma_j\log(K_{gjt}/L_t)+\varepsilon_t \tag{12}$$

Case 3 for decreasing returns indicates the following form:

$$\log(Y_t/L_t)=\alpha_0+\beta_0 t+\phi\log(T_{t-i}/L_t)+\beta_1\log(K_{pt}/L_t)+\sum_{j=1}^{4}\gamma_j\log(K_{gjt}/L_t)+\varepsilon_t \tag{13}$$

Results have been shown in Table 8. As can be seen, γ_3 and γ_4 for public services and facilities for living respectively have shown negative sign. This might not be questionable since those activities are not provided for just economic interest. It might be controversial; however, that the estimated parameter γ_1 for transport investment is found to be negative. This symptom is identical for all three cases. The negative impact of the

Table. 8

Variables	Case 4	(Increase)	Case 5	(Constant)	Case 6	(Decrease)
	Estimation	(t-statistics)	Estimation	(t-statistics)	Estimation	(t-statistics)
α_0	0.6314	2.3415	-0.5415	-3.2014	-1.2513	-2.1447
β_0	-0.2058	-1.9875	-0.4573	-1.9637	-0.4316	-2.001
ϕ	0.0875	2.0342	0.0743	1.9743	0.0325	1.6985
β_1	0.5127	8.7445	0.5528	8.1447	0.5716	10.254
d_{74}	-	-	-	-	-	-
γ_1	-0.2418	-7.5698	-0.3121	-9.2563	-0.4875	-6.3894
γ_2	0.3458	6.3478	0.4125	7.2541	0.6124	8.6417
γ_3	-0.1014	-2.3223	-0.0415	-2.0141	-0.0742	-1.7849
γ_4	-0.0542	-5.2543	-0.3141	-4.6537	-0.3874	-6.3527

variable seems to be high to some degree due to quite high level of t-statistics. One implication for this is the nature of road investment. It takes quite a large amount of portion in amount of money within the investment on transport-related project. Construction of the road; however, seems not to emit a high impact on economic scene except urban highway project. From this point of view, the author has recreated a transport composite by applying Principal Component Analysis again on the data in which road section is excluded. The result for it is shown in Table 9.

Now in this time, the result seems to be less questionable than the one for the former case. Estimated elasticities γ_1 for transport investment take a value in between 0.2 and 0.3 while β_1 for K_{pt} takes a value of 0.6 in average.

Table. 9 (No Road)

	Case 7	(Increase)	Case 8	(Constant)	Case 9	(Decrease)
Variables	Estimation	(t-statistics)	Estimation	(t-statistics)	Estimation	(t-statistics)
α_0	-5.6557	-3.8794	-3.2647	-2.5474	-3.0014	-6.3517
β_0	-0.3215	-3.2517	-0.1345	-2.5471	-0.0958	-2.0314
ϕ	0.0943	2.1367	0.0689	2.0317	0.0621	1.9875
β_1	0.5413	7.8987	0.6021	9.6337	0.7481	8.3264
d_{74}	-	-	-	-	-	-
γ_1	0.3004	2.4327	0.2415	2.1406	0.1989	1.7849
γ_2	0.2103	5.4872	0.2746	3.2531	0.7215	2.3457
γ_3	0.2531	2.6553	0.3052	1.678	-0.4213	-1.3624
γ_4	-0.3647	-3.1089	-0.4059	-2.6934	-0.1025	-1.9853

From what we have observed in trial of both single and multi-capital models, we have obtained several implications as follows.

(a) statistical features such as t-statistics seem to be more stable than the one of former analysis having adopted raw data

(b) technological variable tends to play a role to emphasize the impact of K_{gt}, K_{gjt} when lagged form is adopted

(c) K_{gt} shows unsatisfactory statistical symptoms when deflated by labor variable L_t

In fact, stability of the model itself has been improved to a greater degree when being compared with the one in former paper. Serial correlation has never been found in multi-sector models, for instance. This is quite different from the other models having faced multicollinearity due to the use of raw data. Statistical advantage of K_{gt}; however, tends to deteriorate when being deflated by labor variable. Hence, we would like to restrict the target case to be the increasing returns model, case 1, in both estimation.

3.3 Measured Productivity and Evaluation

In order to observe the transition of the economic performance including the social capital and technological variable, marginal productivities for K_{pt}, K_{gt}, and T_{t-i} have been measured respectively. The plotted result is shown in Figure 8. As can be seen from the plotted line, performance of private capital is higher than the one of public capital except in the decade of 1974 to 1984. This might be acceptable since Japan's economic activity in private sector has experienced a severe crisis of oil shock. The increase of the economic performance of public capital; however, tends to depend upon political decision. Thus, simultaneous estimation with investment function may be required for further analysis. Technological variable, on the other hand, has shown us the characteristic that its performance tends to deteriorate when economic cycle goes downward. This might be due to the data since most of the data for technological activity take forms of cost. Since financial assistance plays a quite significant role in technological research, the symptom found in this trial might be reasonable in some sense.

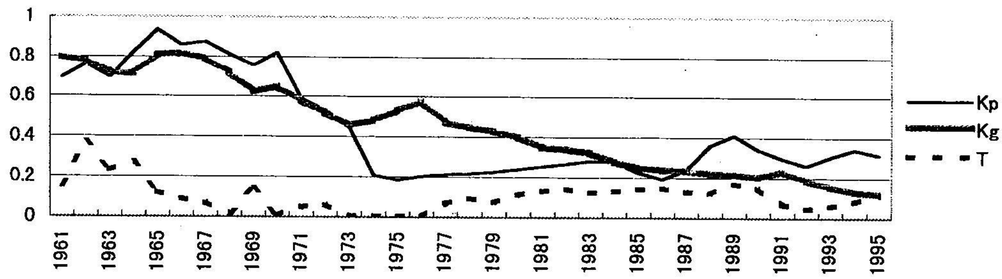
Then, aside from the broad tendency mentioned above, discussion should go further into the detail. The graph in Figure. 8 might imply that there are four phases for the publicly provided capital. These phases listed below show the periods when social capital K_{gt} increased or remained at relatively higher level. These are as following.

(a) First phase: quite higher amount of investment for social capital K_{gt} just after "Nixon shock".

(b) Second phase: increase in the amount of investment for social capital during 1975-1977 period of oil shock.

(c) Third phase: small increase for K_{gt} during the period of economic boom of 1990-1991.

Figure. 8 Marginal Productivity (Increasing Returns)



(d) Fourth phase: still remains higher level of K_{gt} investment in current period of severe economic recession.

Finally, for the whole tendency of K_{gt} in transition, marginal productivity of the social capital has continued to decrease since the early '60s up to the present. This feature might be able to justify that the accumulation of publicly provided capital has been achieved to relatively sufficient level to some degree.

4. Concluding Remarks

From what we have recognized from this analysis, we have faced the statistical advantage in applying created composite. It tends to possess relatively stable characteristics in model estimation. Technological variable, on the other hand, has indicated its role to assist the economic performance, especially in private economy, as the external element. The role of social capital is also recognized to affect the private economy to positive direction. Moreover, disaggreated factors for the social capital show quite acceptable performances, though transport category should be researched further. Finally, measured MP (marginal productivity) also shows acceptable transition for respective factors.

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Figure. 1 Respective Group Factors of Social Capital

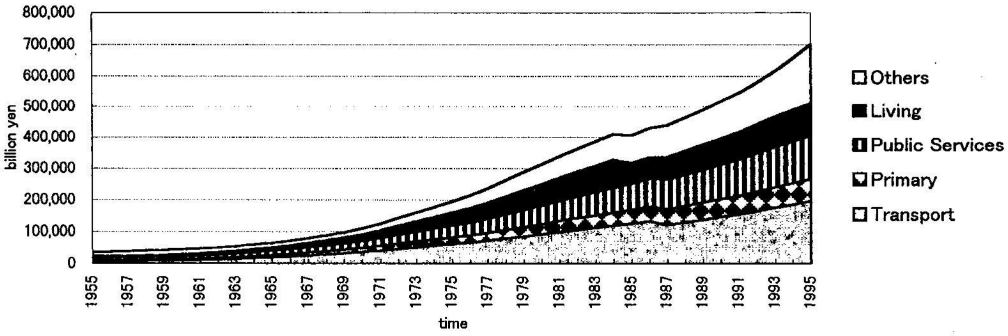

Figure. 2 Eigenvector for PC1 (Single Composite for Kg)

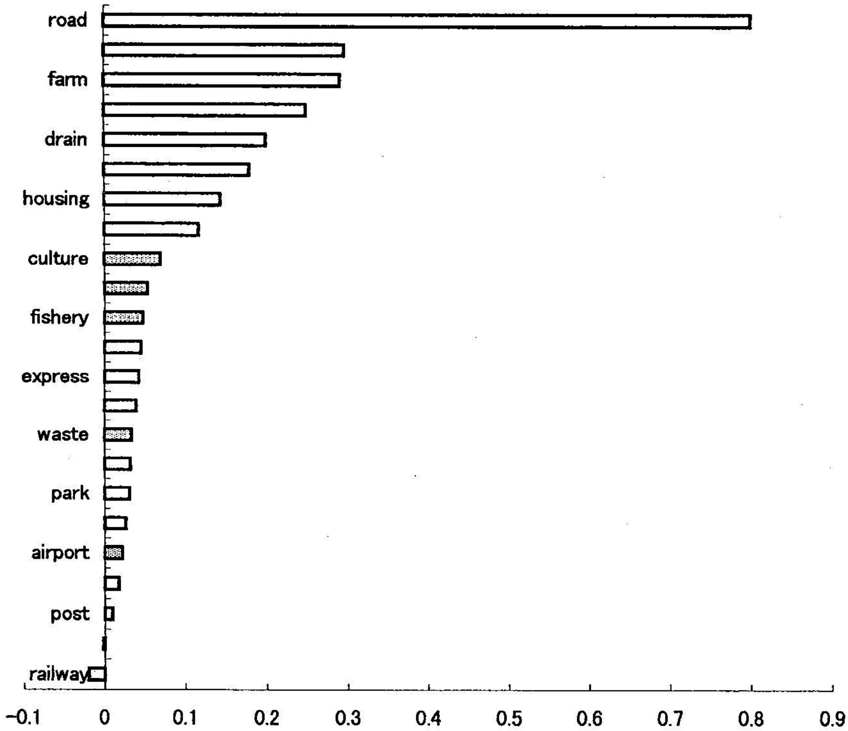

Figure. 3 Score of Single Composite for Kg

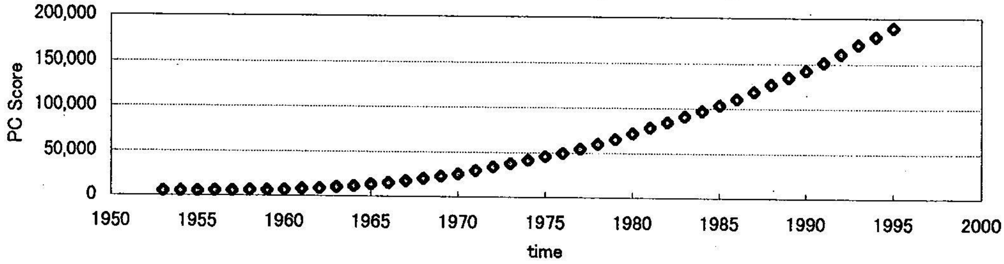

Figure. 4 Factor Loading for Transport Composite (Case of PC1)

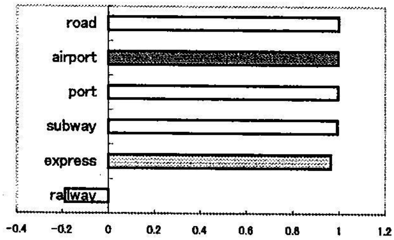

Figure. 5 Factor Loading for Primary Industry-Agriculture, Forestry, Fishery-(Case of PC1)

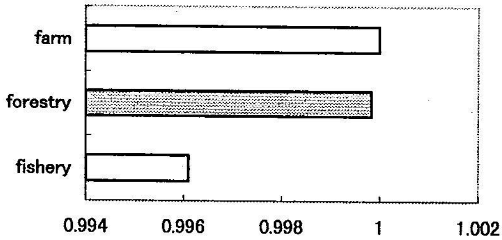

Figure. 6 Factor Loading for Public Services (Case of PC1)

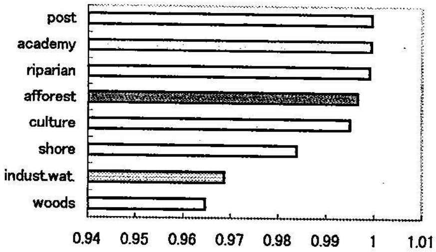

Figure. 7 Factor Loading of Facilities for Living (Case of PC1)