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Efficiency of Disaggregate Public Capital Provision in Japan

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Abstract

We investigate the efficiency of disaggregated public capital provision for the Japanese economy. We estimate the optimality conditions based on simultaneous Euler equations by using GMM. Our results suggest that public capital productivities have been relatively high and divergent among several public capital goods. The allocation of public works is not optimal yet in Japan.

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1. Introduction

Spending on public works has been very high in Japan among developed countries. The ratio of general government fixed capital formation to GDP amounted to 8% in 1998, compared with 1 to 3% in other industrial countries. In recent years, it is widely believed in Japan that the aggregate level of public capital is sufficiently provided. However, it is also well recognized that there may be a shortage of public capital in some areas such as public works in the urban area. This paper intends to provide some empirical evidence of such conjectures. Namely, this paper is a first attempt to investigate the optimality of disaggregated public capital for Japan by estimating and testing the efficient allocation conditions using Hansen (1982)'s generalized method of moments (GMM).

There are many empirical studies on the productivity effect of public capital infrastructure, (Aschauer, 1989), (Munnell, 1990), (Macmillan and Smyth, 1994) and (Batina, 1998) for the U.S. economy and (Iwamoto, 1990), (Asako et.al, 1994), (Mitsui and Ohta, 1995), (Akagi, 1996), (Yoshino and Nakano, 1996), (Doi, 1998) and (Ida and Yoshida, 1999) for the Japanese economy. Aschauer (1989), Munnell (1990), Iwamoto (1990) and Mitsui and Ohta (1995) estimated the aggregate production function using aggregate time series data of public capital. Asako et.al (1994), Yoshino and Nakano (1996) and Ida and Yoshida (1999) employed several panel data of public capital for Japan. Macmillan and Smyth (1994) estimated the VAR model in first differences. Batina (1998) found evidence of multiple cointegration properties among aggregate output, labor, private capital and social capital for the US.

From the normative point of view, it is crucial to judge whether public capital is efficiently provided. Iwamoto (1990) and Mitsui and Ohta (1995) calculated the marginal productivity of public capital based on the estimated production function and concluded that the public capital stock was too small in Japan until the early 1980s compared with the optimal level. Akagi (1996) studied the optimality of public capital for the living environment and found that it was not well founded in Japan. Ihori and Kondo (1998) and Kondo and Ihori (1999) evaluated the Japanese public investment policy by estimating the response of private consumption to public works.(1) Otto and Voss (1998) and Kitasaka (1999) characterized the efficient allocation conditions of both private and public capital and examined whether these conditions were rejected by the data in Australia and in Japan respectively using Hansen(1982)'s generalized method of moments.(2) Kitasaka (1999) concluded that the stock of Japanese public capital goods was efficiently provided at the aggregate level. However, even though public capital has been sufficiently provided in the aggregate level, it does not necessarily mean that optimality is attained at the disaggregated level. Whether the efficient allocation of various types of public capital goods has been attained consistently is not empirically verified yet for Japan.

The approach we pursue is as follows. We derive efficient provision conditions of private capital goods and various types of public capital goods. We estimate the parameters in these conditions using GMM and examine whether the hypothesis of the optimal provision is rejected by an overidentification test statistic. This procedure provides useful information about which types of capital goods are efficiently provided and the estimates of the productivities related to such capital goods. However, it does not provide information about whether the other public capital goods are too small or not compared with the efficient level. Therefore, we estimate an aggregate production function, too. We can thus calculate the productivities of all types of disaggregated public capital goods. Gramlich (1994) criticized this approach in the sense that it tended to overestimate productivities of public capital goods.(3) However, the results may provide some information about the allocation of the public capital goods, some of which are judged to be inefficiently provided by the GMM estimates.

Our empirical results suggest that some public capital goods are not optimally provided although public capital productivities have been very high in Japan. Especially, public capital goods related to railways, infrastructures for telephone networks, telegraph, and postal services are still too low compared with the efficient level.

2. The Model

We consider a standard neoclassical growth model with productive public capital. The aggregate production function of the economy is given by

$$Y_t = F(\mathbf{GK}_t, PK_t, L_t), \tag{1}$$

where Y, $\mathbf{GK}$, PK and L denote aggregate output, a vector of public capital stocks, the private capital stock, and the labor input, respectively. The public capital vector represents n types of public capital goods:

$$\mathbf{GK}_t = (GK_t^1 \, GK_t^2 \Lambda \; GK_t^n).$$

We assume that the production technology exhibits the constant-returns-to-scale property with respect to private inputs PK and L, and that public capital $\mathbf{GK}$ raises the productivities. In each factor market, as the result of the optimization of competitive firms, the factor price is determined as the marginal productivity, which is a function of the aggregate factor endowments:

$$1 + r_t = \partial F(\mathbf{GK}_t, PK_t, L_t) / \partial PK_t + (1 - \delta_{PK}), \tag{2}$$

$$w_t = \partial F(\mathbf{GK}_t, PK_t, L_t) / \partial L_t, \tag{3}$$

where δ_{PK}, r_t and w_t denote the depreciation rate of private capital, interest rate and wage rate respectively. The total factor payments just exhaust the aggregate output.

Each individual wishes to maximize a time separable expected lifetime utility functional,

$$E_t\left[\sum_{\tau=t}^{\infty}\left(\frac{1}{1+\rho}\right)^{\tau-t} u(C_\tau)\right], \tag{4}$$

where ρ denotes the discount rate and C_t denotes private consumption. $u(\;)$ is the instantaneous utility function. We assume that $u(\;)$ is increasing in C_t and concave. The budget constraint for the individual is

$$A_{t+1} = (1 + r_t)A_t + w_t L_t - C_t - T_t, \tag{5}$$

where A_t, L_t and T_t denote asset, labor supply, and lump-sum taxes respectively. The individual chooses a consumption path and an asset accumulation path in order to maximize utility in (4) subject to the constraint in (5). In our model, the labor/leisure preference is not taken into account. In such a case, the individual supplies the full amount of the labor endowment inelastically. The first order condition with respect to the asset accumulation path satisfies

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left\{\frac{u'(C_{t+1})}{u'(C_t)}\right\}(1+r_{t+1})-1\right]=0\,. \tag{6}$$

This condition is the standard Euler equation.

The public capital stock vector and the lump sum taxes are taken as given for the firms and the individuals in the economy. The government's budget constraint must satisfy:

$$T_t=\sum_{i=1}^{n}GK_{t+1}^{i}-(1-\delta_{GK})\sum_{i=1}^{n}GK_t^{i}\,, \tag{7}$$

where δ_{GK} denotes the depreciation rate of public capital.

We are now able to present the structure of a dynamic equilibrium by combining the characteristics of the production function and the optimizing behavior of the individuals. In our closed economy model, the private capital stock is entirely owned by domestic residents. Namely, the asset owned by individuals equals the private capital stock:

$$A_t=PK_t\,. \tag{8}$$

From (2), (3), (7), (8) and the fact that the factor payments just exhaust the aggregate output, we can transform (5) into the resource constraint equation for the overall economy:

$$PK_{t+1}+\sum_{i=1}^{n}GK_{t+1}^{i}=F(\mathbf{GK}_t,PK_t,L_t)+(1-\delta_{PK})PK_t+(1-\delta_{GK})\sum_{i=1}^{n}GK_t^{i}-C_t\,. \tag{9}$$

Substituting (2) into (6), we get

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{u'(C_{t+1})}{u'(C_t)}\right)\left(\frac{\partial F(\mathbf{GK}_{t+1},PK_{t+1},L_{t+1})}{\partial PK_{t+1}}+(1-\delta_{PK})\right)-1\right]=0\,. \tag{10}$$

Equations (9) and (10) describe the dynamic behavior of the equilibrium.

The first best economy is the economy where $\{\mathbf{GK}_t\}$ as well as $\{PK_t\}$ is chosen to maximize (4) subject to (9). Consequently, in addition to (10), the following conditions are also satisfied:

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{u'(C_{t+1})}{u'(C_t)}\right)\left(\frac{\partial F(\mathbf{GK}_{t+1},PK_{t+1},L_{t+1})}{\partial GK_{t+1}^{i}}+(1-\delta_{GK})\right)-1\right]=0$$

$$i=1,2,\Lambda\,,n \tag{11}$$

These $n+1$ conditions imply, roughly, that in each period there should be no differences among the returns of all the capital goods and that in the long run they should be equal to the individual's discount rate, too, as discussed by Arrow and Kurtz (1970).

Thus far the relative prices for investment goods to output or consumption goods are assumed to be constant. However, as we will see later, that is not the case in Japan. The public investment goods have become more expensive than aggregate output over time. This reflects the adjustment costs associated with the installation of capital goods. Including relative prices for investment goods in our model, we modify the conditions (10) and (11) as

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{u'(C_{t+1})}{u'(C_t)}\right)\left(\frac{1}{p_t}\right)\left(\frac{\partial F(\mathbf{GK}_{t+1}, PK_{t+1}, L_{t+1})}{\partial PK_{t+1}}+(1-\delta_{PK})p_{t+1}\right)-1\right]=0, \qquad (12)$$

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{u'(C_{t+1})}{u'(C_t)}\right)\left(\frac{1}{p_t^i}\right)\left(\frac{\partial F(\mathbf{GK}_{t+1}, PK_{t+1}, L_{t+1})}{\partial GK_{t+1}^i}+(1-\delta_{GK})p_{t+1}^i\right)-1\right]=0,$$

$$i = 1,2,\Lambda\ ,n \qquad (13)$$

where p_t and p_t^i are relative prices for private and public investment goods to aggregate output respectively. In period t, one unit of output can be transformed into $1/p_t^i$ units of the investment good and in the next period it increases output and capital stock by $\partial F/\partial GK_{t+1}^i$ and $(1-\delta_{GK})p_{t+1}^i$ respectively.

3. Empirical Evidence

3.1 Data

The data sources of public capital goods we use are fairly standard in this literature. In Japan, disaggregated data for the 20 types of public capital goods for the sample period FY1953-1993 at prices in CY1990 are available from "Social Capital in Japan" (Economic Planning Agency, 1998). These data are calculated by employing PI method (Perpetual Inventory Method) or BY method (Benchmark Year Method). The original flow data for the 20 types of public investment are defined and calculated by the same way as public fixed capital formation is in the SNA, "Annual Report on National Account" (Economic Planning Agency). We use gross domestic product and private final consumption expenditure for the sample period FY1955-1993 at market prices in CY1990 from "Annual

Report on National account". Therefore, disaggregated public capital goods data in "Social Capital in Japan" are suitable for our empirical investigations. These 20 types of public capital goods can be classified into two large groups, public capital goods for the production infrastructure and the ones for the living environment.

We pick up the 13 kinds of public capital goods that belong to the former group and sum them up to the following five components:

Group 1: Roads, harbors and airports
(consists of 3 types of public capital goods)

Group 2: Railways
(consists of 3 types of public capital goods)

Group 3: Postal service, telephone and telegraph
(consists of 2 types of public capital goods)

Group 4: Agriculture-related public capitals and fishing ports
(consists of 2 types of public capital goods)

Group 5: Erosions of flood control and conservation of forests
(consists of 3 types of public capital goods).

As for private capital goods, we use the gross capital stock data of all enterprises in "Gross Capital Stock of Private Enterprises" (Economic Planning Agency) times operating ratio in "Statistics on Japanese Industries" (Ministry of International Trade and Industry). It must be noted that some public companies were privatized in 1980s. Nippon Telegraph and Telephone Public Corporation and Japan National Railways (JNR) were privatized in 1985 and in 1987 respectively. They were newly named as Nippon Telegraph and Telephone Company (NTT) and Japan Railways (JR) respectively. The capital stock data of JR and NTT are included in gross capital stock data of all enterprises in "Gross Capital Stock of Private Enterprises". In this paper, they are derived from the private capital stock data and added to Group2 and Group3 respectively.

As for the prices of aggregate output and private sector investment goods, we use deflators of GDP and private sectors gross domestic fixed capital formation for plant and equipment in "Annual Report on National account" respectively. We can use the deflators of investment goods of 20 types of public sectors, NTT and JR from "Social Capital in Japan". Weighting them with the real values of the investment goods included in that group, we calculate each price of public investment goods for the 5 groups.

Output-capital ratios and relative prices of investment goods are presented in Figure 1 and Figure 2 respectively. Their time series properties will be discussed in the following subsection.

In estimating the efficiency conditions, we use per capita consumption data divided by the total population in “Monthly Report on Current Population Estimates” (Management and Coordination Agency).

As for labor supply, we use employed labor force in “Labor Force Survey” (Management and Coordination Agency) times total hours worked indices in manufacturing in “Final Report of Monthly Labor Survey” (the Ministry of Labor).

Figure 1: Output-Capital Rations

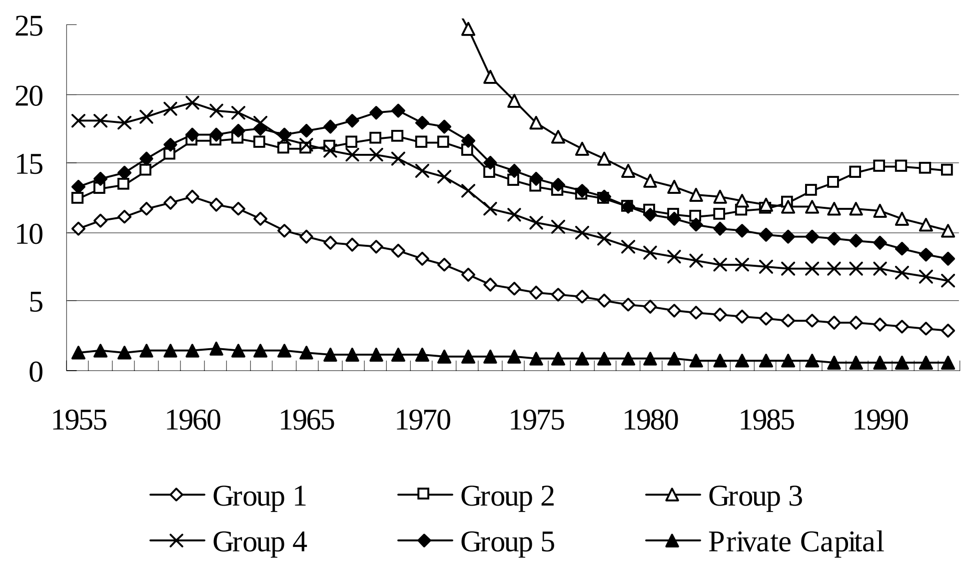
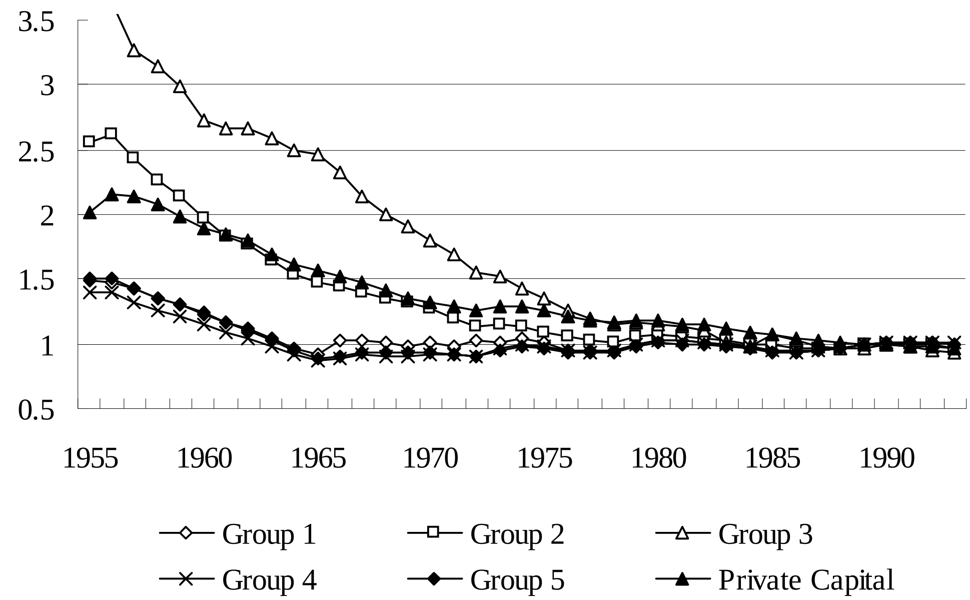


Figure 2: Relative prices of Investment Goods



In this section, we intend to estimate and test the efficient allocation conditions by GMM.

First of all, we must specify the production function and utility function to transform (10)-(13) into testable equations. We specify the production function as

$$Y_t = PK_t^{\beta} GK_{1t}^{\gamma_1} GK_{2t}^{\gamma_2} GK_{3t}^{\gamma_3} GK_{4t}^{\gamma_4} GK_{5t}^{\gamma_5} L_t^{\phi}. \tag{14}$$

We use the constant relative risk aversion (CRRA) utility function specified as

$$u(C_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} \quad , \tag{15}$$

where σ is the coefficient of relative risk aversion and non-negative.

With these specifications, we can rewrite (10) and (11) as

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\beta\frac{Y_{t+1}}{PK_{t+1}} + (1-\delta_{PK})\right) - 1\right] = 0 \ , \tag{16}$$

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\gamma_i\frac{Y_{t+1}}{GK^i_{t+1}}+(1-\delta_{GK})\right)-1\right]=0$$

$$i=1,2,\Lambda\ ,5\,, \qquad (17)$$

and we can rewrite (12) and (13) as

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{p_t}\right)\left(\beta\frac{Y_{t+1}}{PK_{t+1}}+(1-\delta_{PK})p_{t+1}\right)-1\right]=0\ , \qquad (18)$$

$$E_t\left[\left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{p^i_t}\right)\left(\gamma_i\frac{Y_{t+1}}{GK^i_{t+1}}+(1-\delta_{GK})p^i_{t+1}\right)-1\right]=0$$

$$i=1,2,\Lambda\ ,5\ . \qquad (19)$$

These conditions mean that the 6 dimension random vector defined as

$$u_{t+1}=\begin{pmatrix}\left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\beta\frac{Y_{t+1}}{PK_{t+1}}+(1-\delta_{PK})\right)-1\\ \left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\gamma_1\frac{Y_{t+1}}{GK^1_{t+1}}+(1-\delta_{GK})\right)-1\\ \mathrm{M}\\ \left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\gamma_5\frac{Y_{t+1}}{GK^5_{t+1}}+(1-\delta_{GK})\right)-1\end{pmatrix}$$

or

$$u_{t+1}=\begin{pmatrix}\left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{p_t}\right)\left(\beta\frac{Y_{t+1}}{PK_{t+1}}+(1-\delta_{PK})p_{t+1}\right)-1\\ \left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{p^1_t}\right)\left(\gamma_1\frac{Y_{t+1}}{GK^1_{t+1}}+(1-\delta_{GK})p^1_{t+1}\right)-1\\ \mathrm{M}\\ \left(\frac{1}{1+\rho}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{p^5_t}\right)\left(\gamma_5\frac{Y_{t+1}}{GK^5_{t+1}}+(1-\delta_{GK})p^5_{t+1}\right)-1\end{pmatrix}$$

should be uncorrelated with any information available at time t:

$$E(u_{t+1} \otimes I_t) = 0\,, \tag{20}$$

where I_t is the l dimension information set. These $6 \times l$ unconditional moment conditions are suitable for generalized method of moments (GMM) developed by Hansen(1982). Therefore, with GMM we can estimate the parameters. However, we will focus on the estimation of only the production parameters: $\theta = (\beta, \gamma_1, \Lambda\ , \gamma_5)$.

The GMM estimator of θ denoted $\hat{\theta}_{GMM}$ is given by

$$\hat{\theta}_{GMM} = \arg\min Q(\theta) \text{ where } Q(\theta) = g_T(\theta)' W_T^{-1} g_T(\theta)\ . \tag{21}$$

In (21), $g_T(\theta)$ is the $6l$ dimension sample average vector of $u_{t+1} \otimes I_t$ and W_T is symmetric positive-definite matrix that converges in probability to the asymptotic variance-covariance matrix of $u_{t+1} \otimes I_t$. Under the hypothesis that the condition (20) is correct, the test statistic $T \times Q(\hat{\theta}_{GMM})$ is distributed as $\chi^2(6l - 6)$. This statistic is called Hansen's J-statistic and can be used to test the validity of the model.

A plausible conjecture is that not all capital goods are efficiently provided. It may be nearer the truth to say that private capital goods and some types of public capital goods may be optimally provided, while other types of public capital goods may not be. Namely, our conjecture is that (16) and only some of (17) will hold (or, (18) and only some of (19) will hold). Therefore, we analyze which public goods are efficiently provided changing the combinations of the public capital goods put into the GMM.

It seems that the model without adjustment costs of investments is less realistic than the model with adjustment costs. Figure 2 shows that investment goods have been more expensive than aggregate output. It contradicts the theoretical precondition of no installation costs. Moreover, the GMM estimators will not consistent and asymptotically normal unless the series Y/PK and Y/GK^i $(i = 1, \Lambda\ , 5)$ are covariance stationary. Figure 1 shows that these series may exhibit nonstationary behavior.(4) Therefore, we focus on the efficiency conditions (18) and (19) derived from the model with adjustment costs.

Before turning to GMM, we examine whether the variables included in equations (18) and (19) have unit roots by the Augmented-Dickey-Fuller (ADF) unit root test. We estimate the regression

$$\Delta x_t = \lambda + \mu\ t + \phi_0 x_{t-1} + \sum_{j=1}^{m} \phi_j \Delta x_{t-j}\ ,$$

where x_t is a variable included in the efficiency conditions. Then we test the null hypotheses of a unit root that $\phi_0 = 0$ and that $\mu = 0$ and $\phi_0 = 0$. The results are presented in Table1. For $Y_{t+1} / GK_{t+1}^2 / p_t^2$ and $Y_{t+1} / GK_{t+1}^3 / p_t^3$ the null hypotheses of a unit root cannot be rejected. It is well known that the GMM will not provide efficient estimates when nonstationary series are included. In such a case, we cannot say that such capital goods are efficiently provided from a theoretical point of view as discussed earlier. The returns of the capital goods are expected to converge to the households' discount rate in the long run as long as they are on the optimal accumulation path. The returns of the capital goods with unit roots violate such a condition. Therefore, we estimate (18) and (19) with respect to the three types of public capital ($i = 1,4,5$).

Table 1: Univariate Statistics and the Results of the Unit Root Tests

x_t	Mean	Std. Dev.	Maxi -mum	Mini -mum	t -statistics	F -statistics
C_{t+1}/C_t	1.048	0.028	1.097	0.999	-3.422*	5.930*
$Y_{t+1}/PK_{t+1}/p_t$	0.730	0.081	0.866	0.610	-3.480*	8.338**
$Y_{t+1}/GK^1_{t+1}/p^1_t$	6.430	2.663	10.636	2.854	-3.307*	6.016*
$Y_{t+1}/GK^2_{t+1}/p^2_t$	11.670	2.275	14.930	5.536	-2.633	4.069
$Y_{t+1}/GK^3_{t+1}/p^3_t$	15.107	3.654	22.899	10.893	-2.669	3.569
$Y_{t+1}/GK^4_{t+1}/p^4_t$	12.077	4.290	18.538	6.478	-3.252*	5.789*
$Y_{t+1}/GK^5_{t+1}/p^5_t$	13.663	3.870	20.214	8.016	-3.073	6.308*
p_{t+1}/p_t	0.978	0.017	1.022	0.946	-4.767***	11.436***
p^1_{t+1}/p^1_t	0.991	0.038	1.117	0.925	-3.553**	6.337*
p^2_{t+1}/p^2_t	0.975	0.029	1.039	0.922	-4.255***	9.202**
p^3_{t+1}/p^3_t	0.966	0.037	1.105	0.913	-4.997***	12.548***
p^4_{t+1}/p^4_t	0.993	0.030	1.053	0.936	-3.521*	6.298*
p^5_{t+1}/p^5_t	0.991	0.032	1.052	0.928	-3.610**	6.598*

Notes: Sample is 1957-1993. The 1, 5 and 10% critical values are indicated by ***, ** and * respectively.

We set the discount rate, the coefficient of relative risk aversion and the depreciation rates at some particular rates.(5) Namely, we set the discount rate ρ and the coefficient of relative risk aversion at 0.04 per annum and 2, respectively. We also set the depreciation rate of private capital goods δ_{PK} and that of public capital goods δ_{GK} at 0.06 and 0.04 per annum, respectively.

We include one and two lags of the following,
C_{t+1}/C_t , $Y_{t+1}/PK_{t+1}/p_t$, $Y_{t+1}/GK^1_{t+1}/p^1_t$, $Y_{t+1}/GK^4_{t+1}/p^1_t$, $Y_{t+1}/GK^5_{t+1}/p^5_t$
and a constant in instrumental variables set. The estimation results are presented in Table 2.

Table 2: GMM Results for Efficiency Conditions

	(i)	(ii)	(iii)	(iv)
β	0.2956*** (16.8525)	0.2909*** (16.7039)	0.2837*** (16.1723)	0.2877*** (16.5800)
γ_1	0.0278*** (18.9323)			0.0269*** (18.0375)
γ_4		0.0145*** (17.1886)		0.0141*** (16.4010)
γ_5			0.0123*** (10.8789)	
J-statistics	46.8082	42.4020	41.5363	68.4726*
p-value	0.107	0.214	0.242	0.089

Notes: Sample is 1957-1992. The 1, 5 and 10 % critical values are indicated by ***, ** and * respectively. Hansen’s J-statistics obeys χ^2 under the null hypothesis that the capital goods included in the estimation are efficiently provided.

Table 2 (continued): GMM Results for Efficiency Conditions

	(v)	(vi)	(vii)
β	0.2767*** (15.7841)	0.2705*** (15.7772)	0.2673*** (15.7888)
γ_1	0.0262*** (17.5288)		0.02535*** (16.8233)
γ_4		0.0133*** (15.6698)	0.01295*** (15.0224)
γ_5	0.0116*** (10.2963)	0.0111*** (10.2855)	0.0108*** (10.0921)
J-statistics	67.4896	62.3072	85.8559
p-value	0.103	0.205	0.127

For each of the cases (i)-(vi), the efficiency conditions imposed by the model are only rejected for case (iv). We obtain a positive and significant estimate of the capital output elasticity parameters. For case (vii), the efficiency condition imposed by the four equations is supported by Hansen's J-statistic. In addition, we obtain a positive and significant estimate of the parameters that are similar to the results in cases (i)-(vi).

With the estimates in case (vii), we calculate the returns of capital goods:

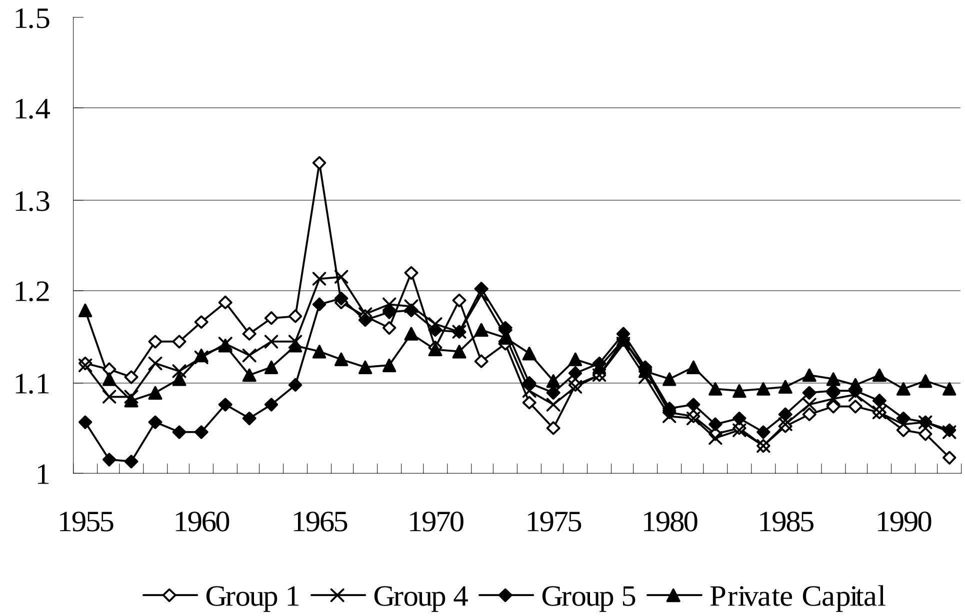
$$(1/p_t)(\hat{\beta}Y_{t+1}/PK_{t+1}+p_{t+1}(1-\delta_{PK}))$$

and

$$(1/p_t^i)(\hat{\gamma}_i Y_{t+1}/GK_{t+1}^i+p_{t+1}^i(1-\delta_{GK})) \text{ for } i=1,4,5 .$$

The results are presented in Figure 3. There are no significant differences between them as Hansen's J-statistic supports statistically.

Figure 3: Investment Returns



We conclude that private capital and the public capital goods of groups 1, 4 and 5 are efficiently provided. However, we cannot judge whether the other public capital good stocks are too small or too large compared with the efficient level since we cannot estimate the capital output elasticities for these public capital goods by GMM.

3.3 Public Capital Productivity

To consider whether the public capital goods of groups 2 and 3 are too small or too large compared with the optimal level, we calculate the returns of disaggregated public capital goods and compare them with each other. To obtain the parameters needed in the calculations, we estimate an aggregate production function. Gramlich (1994) criticized such an approach in the sense that it tended to overestimate the productivities of public capital goods. However, in comparing the returns of disaggregated public capital goods with each other, they provide some useful information. We examine whether the returns of the public capital goods of groups 2 and 3 are lower or higher than the others that are judged to be efficiently provided in the last subsection.

Table 3: Regression Results for an Aggregate Production Function

	(i)	(ii)	(iii)
Constant	0.010 (0.530)	0.022 (1.082)	-0.020 (-1.364)
Labor	0.322 (1.632)		
Private capital	0.173** (2.355)	0.101 (1.282)	0.087 (1.247)
Roads, harbors and airports	0.094 (0.424)	0.346 (1.491)	0.014 (0.058)
Railways	-0.523** (-2.159)	-0.303 (-1.152)	-0.712*** (-2.864)
Postal service, telephone and telegraph	0.511*** (3.343)	0.711*** (4.512)	0.524*** (3.175)
Agriculture-related public capitals and fishing ports	0.778* (1.739)	0.073 (0.168)	0.981** (2.062)
Erosions of flood control and conservation of forests	-0.974*** (-3.221)	-1.069*** (-3.138)	-0.497* (-1.969)

Notes: Sample is 1957-1994. The 1, 5 and 10 % critical values are indicated by ***, **, and * respectively.

We incorporate a trend term into (14):

$$Y_t = Ae^{\alpha_0+\alpha_1 t} PK_t^{\beta} GK_{1t}^{\gamma_1} GK_{2t}^{\gamma_2} GK_{3t}^{\gamma_3} GK_{4t}^{\gamma_4} GK_{5t}^{\gamma_5} L_t^{\phi}, \tag{22}$$

where $\alpha_0 + \alpha_1 t$ denotes a trend term. Taking the natural logarithm of (22), we get

$$\ln Y_t = \ln A + \alpha_0 + \alpha_1 t + \beta \ \ln PK_t + \sum_{i=1}^{5} \gamma_i \ln GK_t^i + \phi \ln L_t \,. \qquad (23)$$

To cope with the serial correlation problem, we estimates the following first difference linear regression model:

$$\Delta \ln Y_t = \alpha_1 + \beta \, \Delta \ln PK_t + \sum_{i=1}^{5} \gamma_i \Delta \ln GK_t^i + \phi \ \Delta \ln L_t \,. \qquad (24)$$

In Table 3, case (i) is the result of OLS estimation without restrictions among coefficients. Cases (ii) and (iii) are the results under the constant-returns-to-scale (CRS) restriction with respect to private inputs and with respect to all inputs respectively.

Obviously the results may face a serious multicollinearity problem. To cope with it, we use a principal components regression. First, using the eigenvalues and eigenvectors of the correlation matrix of explanatory valuables, we compose principal components. Next, we regress $\Delta \ln Y$ on a constant and some principal components. The results are reported in Table 4. Substituting the estimated parameters and their variance covariance matrix into the relationship between the components and the explanatory variables, we finally obtain the estimator of the parameters in equation (24) and their variance covariance matrix. The results are reported in Table 5. The restrictions imposed in cases (i), (ii) and (iii) in Table 4 and 5 are the same as those imposed in Table 3 respectively. We can say that all types of public capital goods have positive effects on aggregate output to some extent.

Table 4: The Results of Regressions on Principal Components

	(i)	(ii)	(iii)
Constant	0.003 (0.225)	-0.002 (-0.207)	0.002 (0.209)
1st Principal Components	0.301*** (5.793)	0.279*** (5.214)	0.257*** (5.579)
2nd Principal Components	0.142 (1.532)	0.030 (0.250)	-0.144 (-1.548)

Notes: Sample is 1957-1994. The 1, 5 and 10 % critical values are indicated by ***, ** and * respectively. In (i), (ii) and (iii), cumulative contribution of these two principal components are 0.904, 0.917 and 0.925 respectively.

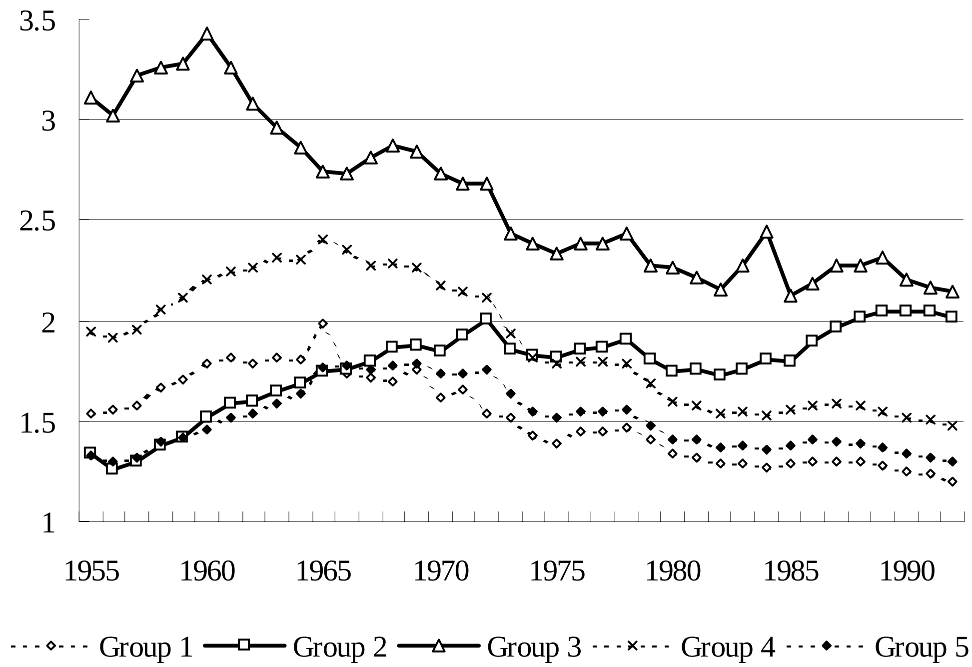
Table 5: Regression Results for an Aggregate Production Function

	(i)	(ii)	(iii)
Constant	0.003 (0.225)	-0.002 (-0.207)	0.002 (0.209)
Labor	0.054* (1.983)		
Private capital	0.274*** (3.485)	0.108 (1.016)	0.214** (2.421)
Roads, harbors and airports	0.086*** (3.506)	0.109*** (4.811)	0.095*** (4.429)
Railways	0.074** (2.176)	0.122*** (2.834)	0.084*** (2.974)
Postal service, telephone and telegraph	0.109** (2.552)	0.164*** (3.337)	0.131*** (4.753)
Agriculture-related public capitals and fishing ports	0.077*** (3.206)	0.103*** (3.512)	0.078*** (3.657)
Erosions of flood control and conservation of forests	0.041*** (3.249)	0.053*** (4.375)	0.038* (1.770)

Notes: Sample is 1957-1994. The 1, 5 and 10 % critical values are indicated by ***, ** and * respectively.

Next, using the estimates in (i) in Table 5, we calculate the return of each public capital: $(1/p_t^i)(\hat{\gamma}_i Y_{t+1}/GK_{t+1}^i + p_{t+1}^i(1-\delta_{GK}))$ for $i = 1, \Lambda, 5$. Figure 4 shows the results. The differences among the returns of the public capital goods of groups 1, 4 and 5 have been relatively small. On the other hand, in recent years, the returns for groups 2 and 3 have been diverging upwards from those of the former groups. Provided that the public capital goods of the groups 1, 4 and 5 are efficiently accumulated, the result here indicates that the public capital goods of the groups 2 and 3 are still inadequate compared with the optimal level.

Figure 4: Investment Returns



4. Conclusion

We have investigated the productivity of disaggregated public capital for the Japanese economy. We estimated the efficiency conditions given as simultaneous Euler equations and tested the validity of the model by GMM. We also calculated the productivity of public capital by estimating an aggregate production function.

We can conclude that some types of public capital are not being accumulated efficiently. From the estimation of the aggregate production function, we see that there still exist large differences among the marginal productivity levels for some types of disaggregate public capital goods.

We may conclude that the allocation of public capital goods is not optimal in Japan. Especially, infrastructures for railways, telephone networks, telegraph, and postal services are not being accumulated at efficient levels.

Spending on public works should be priority-allocated to projects to improve allocation efficiency among various areas. There are some attempts for such a direction in Japan. For example, an effort is being made to put an additional priority on infrastructure investment to improve the people's lives and the environment in urban area. At the same time, seeking to enhance both efficiency and transparency, the efforts to reduce costs and to utilize cost-benefit analysis will be complemented by a new re-assessment system in the near future. These changes are desirable but the speed of structural reform is not so high. A further determined effort is needed to reform public works in a more efficient way.

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Notes

(1) In these papers we develop the theoretical relationship between public capital productivity and private consumption by employing the conventional infinite horizon neoclassical framework. It is shown that private consumption responds to an unexpected change in the public investment policy as long as people are concerned with the overall costs and benefits of public works.

(2) Such an approach has often been employed to estimate and test the conditions for intertemporal efficiency in the asset pricing literature (e.g Hansen and Singleton, 1982 and Cochrane, 1991). In recent years, it is applied to examine the dynamic efficiency of public investment policy.

(3) The estimation of an aggregate production function contains many econometric problems such as common trend data and simultaneous bias. Gramlich pointed out that the estimated returns of public capital are very

high even though these problems are taken into consideration.

(4) For these series the hypotheses of a unit root can not be rejected even at the critical value of 20%.

(5) We focus on the production parameters. Thus, as Otto and Voss (1998), we set the particular values for the other parameters. The estimators of the parameters do not yield economically sensible results unless we develop individual's consumption behavior more carefully. For example, non-separability of preferences and the existence of non-durables consumption goods must be taken into consideration.

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