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Productivity Effects and Determinants of Public Infrastructure Investment*

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[Abstract]:

This study aims to investigate two important issues: whether or not public infrastructure contributes to production in the private sector, and whether or not political economy factors such as political situations, lobbying factors, and the availability of national grants for investment affect the allocation of public infrastructure investment. We estimate simultaneous equations by using a panel data set of 46 prefectures in Japan for 5 time periods from 1975 to 1990. From the empirical results, we conclude the following: (1) public capital contributes to productivity, (2) the investment behavior of the national government is efficiency-oriented for private productivity but equity-oriented for the capital stock level, (3) the complementarity of public capital investment between the national and the prefectural government could hold, (4) there is no clear political factor in the national government's public investment function, and (5) the availability of national government grants for the construction of infrastructure boosts investment among prefectural governments.

[JEL Classification] H50, H54, R53

[Key Words] Public Capital, Public Capital Investment, Infrastructure, Political Factors for Investment

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Productivity Effects and Determinants of Public Infrastructure Investment

Fumitoshi Mizutani and Tomoyasu Tanaka

1. Introduction

Inefficient use of public money is a policy issue of concern in Japan. Some contend that spending towards the formation of public capital does not promote economic growth, one reason being that such investment is concentrated in underdeveloped regions which have a low impact on the growth of economic activity. Investment in underdeveloped regions might be the result of political misallocation or simply the fact that public capital no longer contributes to private productivity. Our study addresses these two important issues: whether or not public infrastructure contributes to production in the private sector, and whether or not political economy factors such as political situations, lobbying factors and the availability of national grants for investment affect the allocation of public infrastructure investment. If the political economy factors indeed affect the allocation of public capital investment, what factors are the most deterministic?

There are three distinguishing characteristics of our study. First, we will analyze public capital's effect on private productivity, considering the regional allocation of the national government's public capital investment. Although there have been many studies evaluating public capital's private productivity, there has not been much research considering public investment while also estimating public capital's productivity effects. Studies by Duffy-Deno and Eberts (1991) and Kemmerling and Stephen (2002) analyze the determinants of public

investments as well as the private production process by using simultaneous equations. Our study may be characterized secondly by our consideration of both the national and the prefectural governments' public investment. Although our approach is similar to that of Kemmerling and Stephen (2002), they do not include both kinds of government. Third, we consider several factors for the determinants of public capital investment: efficiency/equity reason for private productivity and capital stock level, lobbying factors, political factors, and fiscal conditions. Several previous studies investigate the determinants of public capital investment and/or the formation of public capital. For example, Crain and Oakley(1995) investigate political factors. Kemmerling and Stephen (2002) consider lobbying factors as well as political factors. Kamada, Okuno and Futagami (1998) try to investigate how socio-economic conditions such as income growth rate per capita and population growth rate affect the regional allocation of public capital investment. We hope that our approach, with its three characteristics, answers some of the main questions.

The structure of this paper consists of four parts after the introduction. In the second section, we will describe previous published studies related to this topic. In this section we will explain the empirical evidence on private productivity related to public capital, the simultaneous approach of considering both private production and public capital investment, and determinants for public capital investments. In the third section, the whole structure of the model will be explained. For methodology, as we take a simultaneous approach to examine these issues, we will explain the structure of four equations: private production, public capital formation, the national government's public capital investment and the prefectural government's public capital investment functions. Empirical analysis will be done in the fourth section,

where we will, first, describe the empirical models and hypotheses to test and, second, explain the data set for public infrastructure and related variables. Public capital in this study is limited to public infrastructure such as roads, ports, airports, banks and dams. Railroads and electric power plants are excluded because these were built by the private sector in Japan. In this study, we plan to use a panel data set covering 46 prefectures and 5 time periods for every 5 years from 1975 to 1995 in Japan, making the total sample size in this study 230. Last, we will estimate simultaneous equations regarding regional production function, public capital formation function, and both governments' infrastructure investment functions. By using these estimated functions, we evaluate whether or not public capital contributes to production and what kind of political factors affect the allocation of public infrastructure investment. In the conclusion, we will summarize the major points.

2. Previous Studies on Productivity Effects and Allocation of Public Capital

There have been many studies on whether or not public capital contributes to production in the private sector. In this section, we will summarize previous studies which focus on public capital's productivity while considering the allocation of public capital (as for an overview on public capital, see Gramlich (1994)). First, using time-series data for the whole country, it is commonly shown that public capital contributes to private production. For example, Ratner (1983), Aschauer(1989) and Vijverberg et al. (1997) for the U.S. and Iwamoto (1990) for Japan show the positive contribution of public capital. However, if the regions and kinds of public capital are divided into smaller categories, then the estimation results of public capital on productivity vary among studies. For example, Munnell (1990) and Garcia-Mila

and McGuire (1992), by analyzing U.S. data, find that some components of public capital such as Highway, Water Supply and Disposal, and Education contribute positively to private production. However, Evans and Karras (1994) show a quite different result: while the public capital of education is productive, there is no evidence that other government stock is productive. In Japan, empirical results are not consistent. Mitsui et al. (1995) show that core infrastructure of public capital makes a positive contribution but that there is no clear evidence that non-core infrastructure does so. Ida and Yoshida (1999) show that public capital such as industry, living and environment are positive but that others such as education and land security make a negative contribution.

There are several studies which consider public capital investment and its allocation among regions. For example, Duffy-Deno and Eberts (1991) consider the linkage between public investment and personal income, arguing that public investment influences personal income through the regional production process, while maintaining that the determination of the level of public infrastructure is a consumption good in the median household's utility function. Therefore, Duffy-Deno and Eberts believe that public investment and personal income should be estimated simultaneously. They estimate these two simultaneous equations by using a data set of 28 SMSAs in the U.S. from 1980 to 1984. Their results show that public investment and public capital stock have a positive effect on personal income and that personal income has a positive effect on public investment.

Kemmeling and Stephan (2002) also consider both regional production and public investment. Their study is characterized by the fact that the simultaneous equations consist of the regional production function, the public investment function and the grant allocation

function. Kemmeling and Stephan consider the political factors which affect public investment and grant allocation. They estimate these three equations simultaneously by using a data set of 87 German cities for 1980, 1986 and 1988. The results they obtained are the following. First, local public capital contributes positively to private production. Second, political affiliation is decisive in explaining the distribution of investment grants across cities. Third, there is no evidence of a complementary relationship between matching investment grants and infrastructure spending.

Although Kemmeling and Stephan's (2002) is the most recent study of how political factors affect public investment, Crain and Oakley (1995) and Kamada, Okuno and Futagami (1998) have also investigated several factors affecting public investment. By using data from U.S. states from 1978 to 1988, Crain and Oakley (1995) investigate how political institutions and processes affect public capital and public investment. They find that institutions such as term limits, citizen initiative, and budgeting procedures were significant determinants of state public capital stocks and public investment.

Kamada, Okuno and Futagami (1998) investigate the factors underlying public decisions on regional allocation of public investments. They take for observation and analyze ten regions of Japan for the time periods from 1955 to 1986, using the following as explanatory variables: population growth rate, growth rate of per capita income, and regional income inequality index. They find that regional income inequality is an important factor in determining public investment.

3. Whole Structure of Models

In this study, our models consist of four simultaneous equations: (i) production function, (ii) public capital formation function, (iii) national government's public capital investment function, (iv) prefectural government's public investment function.

(1) Production Function

The production function defined here is specified as a function of private capital (K_{it}), labor input (L_{it}) and public capital stock (G_{it}) in prefecture i in year t . In this study, we specify the dependent variable as a productivity measure, which is defined by dividing output (Y_{it}) by labor input (L_{it}). Therefore, the production function is described as follows:

$$Y_{it}/L_{it} = f(K_{it}/L_{it}, G_{it}, t). \quad (1)$$

(2) Public Capital Formation Function

The public capital formation function expresses how the public capital stock is formatted. This function is specified as a function of the previous year's capital stock level ($G_{i,t-1}$), the national government's public capital investment (Ig^C_{it}) and the prefectural government's public capital investment (Ig^P_{it}). Therefore, the public capital formation function is expressed as follows:

$$G_{it} = g(G_{i,t-1}, Ig^C_{it}, Ig^P_{it}). \quad (2)$$

(3) The National Government's Public Capital Investment Function

The national government's public capital investment function is explained by several factors. The first factor is the productive efficiency/equity reason for public capital investment.

That is, the national government invests public capital in the prefecture which has regions more productive in private economic activity. The national government tries to promote more economic activity by investing more public capital. Thus, if a prefecture has higher private productivity (Y_{it}/L_{it}), the prefecture tends to have more public capital investment. Therefore, if the coefficients of these variables have a positive sign, then the national government invests more based on the productivity efficiency criteria. On the other hand, if the government cares greatly about the equity reason in this measure, the sign of the coefficient could be negative.

The second factor is the capital stock efficiency/equity reason. The government's investment behavior is also affected by the stock level of public capital ($G_{i,t-1}/POP_{i,t-1}$). If the government cares greatly about efficiency in this measure, then a prefecture which has more stock of public capital receives more investment. On the other hand, if the national government invests more public capital in order to reduce regional inequalities, then the prefectures with less public capital would receive more public investment. In this case, the relationship between the national government's investment and the stock of public capital could be negative.

The third factor is intergovernmental relationships. As each prefectural government also invests public capital in itself, the prefectural government's investment behavior could affect the national government's behavior. Although strictly speaking, it is an empirical question as to whether or not the national government's investment is complementary, substitutive or neutral in relation to the prefectural government's investment, we assume that the coefficient of this variable might be positive. The main reason is that in many cases public investment is done cooperatively by the national government and the prefectural government.

Therefore, we include the prefectural government's investment (Ig_{it}^P).

The fourth factor is lobbying from industries related to public capital investment. Because more investment in public capital increases total revenues and job opportunities for the industries related to public capital, the industries have incentives to promote lobbying. The percentage of the primary industry in number of employees (RAG_{it}) and the percentage of the construction industry in number of employees (RCN_{it}) can be considered as related to this factor.

Finally, there is the political factor, in which politicians could use to their advantage the degree of public capital investment. Clearly, politics is one important factor in attracting public investment, with one well-known job of politicians being to promote big national infrastructure construction projects in their home districts. Historically, regions with influential politicians tend to have more big projects. Among several other factors related to politics, one interesting question is whether or not political stability tends to have positive relationship with public capital investment. In order to test this factor, we include the ratio of majority vote to minority vote in the House of Representatives (RLS_{it}).

Therefore, the national government's public capital investment function is expressed as follows.

$$Ig_{it}^C = h_N(G_{i,t-1}/POP_{i,t-1}, Y_{it}/L_{it}, Ig_{it}^P, RAG_{it}, RCN_{it}, RLS_{it}) \quad (3)$$

(4) The Prefectural Government's Public Investment Function

The prefectural government's public capital investment function is generally explained by the same kinds of factors as the national government's capital investment function. The first and the second factor are the efficiency/equity reason in both private productivity and

the capital stock level for public capital investment. Private productivity (Y_{it}/L_{it}) and the stock of public capital per capita ($G_{i,t-1}/POP_{i,t-1}$) can be explained as related to these factors. If the coefficients of these variables have a positive sign, then the prefectural government invests more based on the efficiency reason. On the other hand, if these have a negative sign, then the prefectural government invests more based on the equity reason.

The third factor is the intergovernmental relationship. To test whether or not the prefectural government's investment has a complementary, substitutive or neutral relation to the national government's investment, we include the national government's investment (Ig_{it}^C).

The fourth factor is lobbying from industries related to public capital formation. In this function, the percentage of the primary industry in number of employees (RAG_{it}) and the percentage of the construction industry in number of employees (RCN_{it}) are included as in the National Government's investment function.

The fifth factor is political. In order to test this factor, we include the percentage of votes for the Liberal Democratic Party in prefectural congress (PLD_{it}).

The last is the fiscal factor of the prefectural government. Most prefectural governments in Japan have been facing financial difficulties. In many cases, prefectural expenditures exceed tax revenues. We seek to test how the prefectural government's public capital investment would be affected by the fiscal situation. Therefore, prefectural government's prefectural budget constraints affect public capital investment. With regard to this factor, national government grants for the construction of infrastructure (NTG_{it}) and Revenues-expenditures ratio in prefectural budget (BAL_{it-1}) are included. Therefore, the prefectural government's public capital investment function is expressed as follows.

$$Ig_{it}^P = h_N(G_{i,t-1}/POP_{i,t-1}, Y_{it}/L_{it}, Ig_{it}^C, RAG_{it}, RCN_{it}, PLD_{it}, NTG_{it}, BAL_{it-1}) \quad (4)$$

4. Empirical Analysis

4.1 Empirical Models

The empirical models for these functions are generally specified as log-log form. Although the original form of the production function is specified as the Cobb-Douglas form, production function in this study is expressed as private productivity by dividing by labor (L_{it}). These functions are specified as equation (5) to (8). We estimate these four equations simultaneously.

Production Function:

$$\ln(Y_{it}/L_{it}) = \alpha_t + \alpha_K \ln(K_{it}/L_{it}) + \alpha_G \ln G_{i,t} \quad (5)$$

where Y_{it} : Output of the private sector,

L_{it} : Labor input,

K_{it} : Private capital,

G_{it} : Public capital,

Public Capital Formation Function:

$$\ln G_{it} = \beta_t + \beta_1 \ln G_{i,t-1} + \beta_2 \ln Ig_{it}^C + \beta_3 \ln Ig_{it}^P \quad (6)$$

where Ig_{it}^C : National government's public capital investment for each prefecture,

Ig_{it}^P : Prefectural government's public capital investment for each prefecture.

National Government's Public Capital Investment Function:

$$\ln Ig_{it}^C = \gamma_t + \gamma_1 \ln(G_{i,t-1}/POP_{i,t-1}) + \gamma_2 \ln(Y_{it}/L_{it}) + \gamma_3 \ln Ig_{it}^P + \gamma_4 \ln RAG_{it} + \gamma_5 \ln RCN_{it} + \gamma_6 \ln RLS_{it}, \quad (7)$$

where $G_{i,t-1}/POP_{i,t-1}$: Public capital stock per population in the previous year,
 RAG_{it} : Percentage of employees in the first industry,
 RCN_{it} : Percentage of employees in the construction industry,
 RLS_{it} : Ratio of majority vote to minority vote in the House of Representatives.

Prefectural Government's Public Capital Investment Function:

$$\ln Ig_{it}^P = \delta_t + \delta_1 \ln(G_{i,t-1}/L_{i,t-1}) + \delta_2 \ln(Y_{it}/L_{it}) + \delta_3 \ln Ig_{it}^C + \delta_4 \ln RAG_{it} + \delta_5 \ln RCN_{it} + \delta_6 \ln PLD_{it} + \delta_7 \ln NTG_{it} + \delta_8 \ln BAL_{it}, \quad (8)$$

where PLD_{it} : Percentage of vote for the Liberal Democratic Party in the prefectural congress,
 NTG_{it} : National government grants for the construction of infrastructure,
 BAL_{it-1} : Stand-alone revenues-expenditures ratio of prefectural budget.

Endogenous variables are private sector's productivity(Y_{it}/L_{it}), stock of public capital(G_{it}), national government's public capital investment for each prefecture(Ig_{it}^C), prefectural government's public capital investment for each prefecture(Ig_{it}^P) and nine other variables which are exogenous. Parameters $\alpha_t, \beta_t, \gamma_t, \delta_t, t = 1, 2, 3, 4, 5$ refer to fixed effects for time periods. The estimation method is the three stage least square (3SLS) method. The

expected sign for these variables is summarized in Table 1.

Table 1 Expected Sign of Coefficients for Regression Analysis

Production function	$\ln(K_{it}/L_{it})$	$\ln G_{it}$						
	+	+						
Public capital formation function	$\ln(G_{i,t-1})$	$\ln g_{it}^C$	$\ln g_{it}^P$					
	+	+	+					
Public capital investment (national)	$\ln(G_{i,t-1}/POP_{i,t-1})$	$\ln(Y_{it}/L_{it})$	$\ln g_{it}^P$	$\ln RAG_{it}$	$\ln RCN_{it}$	$\ln RLS_{it}$		
	?	?	?	+	+	?		
Public capital investment (prefecture)	$\ln(G_{i,t-1}/POP_{i,t-1})$	$\ln(Y_{it}/L_{it})$	$\ln g_{it}^C$	$\ln RAG_{it}$	$\ln RCN_{it}$	$\ln PLD_{it}$	$\ln NTG_{it}$	$\ln BAL_{i,t-1}$
	?	?	?	+	+	?	+	+

(Note): The notation “?” refers to the empirical questions in the regressions.

4.2 Hypothesis

In this study, we will investigate whether or not the following eight hypotheses are held, the details of which will be explained.

Hypothesis 1: Public capital contributes to productivity.

As we mentioned earlier, previous studies do not have consistent results. In this study, we will investigate why the estimation results of public capital on productivity are quite different among previous studies. For example, some studies in the U.S., such as Munell (1990), Merriman (1990) and Garcia-Mila and McGuire (1992), find that some components of public capital such as Highway, Water Supply and Disposal, and Education contribute positively to private production. On the other hand, Evans and Karras (1994) show a different result: public capital, except for education, does not aid private production. Holtz-Eakin (1994) also

shows that public capital does not contribute private production. In Japan, Mitsui et al. (1995) show that core infrastructure of public capital makes a positive contribution but non-core infrastructure is not significant. Yamano and Ohkawara (2000) and Ida and Yoshida (1999) show that public capital such as industry, living and environment are positive but public capital such as education and land security have negative effects. In summary, we assume that public capital contributes to private productivity. Therefore, $\alpha_G > 0$ (i.e. for $\ln G_{it}$) holds.

Hypothesis 2: The government invests more public capital based on efficiency in private productivity.

As we explained before, public capital investment is made according to the productive efficiency/equity reason in private production. If the government tries to promote more economic activity, then the government invests more public capital. In this case, the prefecture with higher productivity tends to have more public capital investment. Therefore, if the coefficients of these variables have a positive sign, then the national government invests more based on productivity efficiency criteria. We assume that both the national and the prefectural government's behavior is based on the efficiency reason in private productivity. Therefore, $\gamma_2 > 0$ (i.e. for $\ln(Y_{it}/L_{it})$) and $\delta_2 > 0$ (i.e. for $\ln(Y_{it}/L_{it})$) hold.

Hypothesis 3: The government's public capital investment is made to solve the regional imbalance of stock of public capital.

As we explained previously, the government's investment behavior is also affected by the stock level of public capital. If the national government invests more public capital in

order to reduce regional inequalities, then the prefectures with less public capital would receive more public investment. Because in general the government considers both efficiency and equity criteria, we assume that the government behaves based on the equity reason in this measure. Therefore, in this case, the relationship between the government's investment of the both the national and the prefectural government and stock of public capital could be negative. Therefore, $\gamma_l < 0$ (i.e. for $\ln(G_{i,t-1}/POP_{i,t-1})$) and $\delta_l < 0$ (i.e. for $\ln(G_{i,t-1}/POP_{i,t-1})$).

Hypothesis 4: Public capital investment is complementary between national and prefectural governments.

As for the intergovernmental relationship in investment behavior, there are three possibilities: complementary, substitutive and neutral. Although this is an empirical question, we assume that the coefficient of this variable could be positive, because in many cases the public investment is made cooperatively by the national government and prefectural government. Therefore, $\gamma_3 > 0$ (i.e. for $\ln Ig_{it}^P$) and $\gamma_3 > 0$ (i.e. for $\ln Ig_{it}^P$).

Hypothesis 5: Public capital investment is promoted by lobbying activities.

As for the lobbying factor, because more investment in public capital increases total revenues and job opportunities for the industries related to public capital, industries have incentives to promote lobbying. The percentage of the primary industry in number of employees and the percentage of the construction industry in number of employees can be considered as related to this factor. Therefore, $\gamma_4 > 0$ (i.e. for $\ln RAG_{it}$), $\gamma_5 > 0$ (i.e. for $\ln RCN_{it}$) and $\delta_4 > 0$ (i.e. for $\ln RAG_{it}$), $\delta_5 > 0$ (i.e. for $\ln RCN_{it}$).

Hypothesis 6: Public capital investment is promoted if the majority-minority difference becomes smaller in a political election.

As explained above, politicians could use their influence to affect the degree of public capital investment. Among several factors in politics, one interesting question is whether or not political stability tends to have a positive relationship with public capital investment. In order to test this factor, we include in the national government's investment function the ratio of majority vote to minority vote in the House of Representatives. Therefore, $\gamma_6 > 0$ (i.e. for $\ln RLS_{it}$).

On the other hand, in the case of the prefectural government's investment function, the percentage of vote for the Liberal Democratic Party in prefectural congress is assumed to be positive. Therefore, $\delta_6 > 0$ (i.e. for $\ln PLD_{it}$).

Hypothesis 7: The public capital investment of the prefectural government is halted if the prefectural government's tax revenues are tight.

Most prefectural governments in Japan have been facing financial difficulties. In many cases, prefectural expenditures exceed tax revenues. In order to test how a prefectural government's public capital investment would be affected by the fiscal situation, we assume that prefectural government's budget constraints have an effect on public capital investment. If the stand-alone revenues become large, then the government invests more. Therefore, there is a positive relationship between public investment and the revenues-expenditures ratio in prefectural budget. Therefore, $\delta_8 > 0$ (i.e. for $\ln BAL_{it}$).

Hypothesis 8: The public capital investment of the prefectural government is promoted by grants from the national government.

Similar to the case for hypothesis 7, the more government grants a prefectural government has for the construction of infrastructure, the more investment there will be by the prefectural government. Therefore, $\delta_7 > 0$ (i.e. for $\ln NTG_{it}$).

4.3 Data

We use a panel data set of 46 prefectures for 5 time periods (1975, 1980, 1985, 1990, 1995). Although there are 47 prefectures in Japan, we use 46 prefectures, excluding Okinawa because it is located about 700km southeast of Kyushu, one of Japan's main islands. Furthermore, as Okinawa remained under U.S. occupation until May of 1972 and many U.S. military bases are located there, we would have been required to consider many unusual political factors. Therefore, we exclude Okinawa prefecture in this study. As a result, the total sample size used here is 230 observations.

4.4 Variables

All variables used in this study are based on prefectures in Japan and they are defined as follows. The statistical information for the variables is summarized in Table 2. First, the output of private sector (Y_{it}) is the gross prefecture products of the private sector, obtained from the item "industry" in the statistical data sources, *Annual Report on Prefectural Accounts* (*Kenmin Keizai Keisan Nenpo*) and *Report on Prefectural Accounts from 1955 to 1974* (*Chouki*

Sokyu Suikei Kenmin Keizai Keisan Hokoku) issued by the Economic Planning Agency.

Table 2 Statistics of Used Variables

	unit	Mean	Standard deviation	Minimum	Maximum
Y_{it}	Million yen	7,210,133	10,542,663	899,232	86,741,390
L_{it}	Ten thousands man-hours	281,468	289,280	67,853	1,889,678
K_{it}	Million yen	11,374,169	15,594,515	828,060	141,558,711
G_{it}	Million yen	3,099,763	2,966,615	460,516	28,809,711
$G_{i,t-1}$	Million yen	2,231,690	2,225,680	282,190	22,106,394
$POP_{i,t-1}$	person	2,473,132	2,210,007	581,694	11,639,293
Ig^C_{it}	Million yen	182,803	213,536	23,963	1,636,055
Ig^P_{it}	Million yen	280,228	203,102	44,106	1,697,881
RAG_{it}	%	13.54	7.45	0.37	34.79
RCN_{it}	%	9.71	1.27	6.90	13.38
RLS_{it}	-	1.19	0.63	0.26	3.75
PLD_{it}	%	48.96	9.58	25.40	70.30
NTG_{it}	Million yen	322,967	197,371	99,994	1,526,205
$BAL_{i,t-1}$	-	0.29	0.15	0.10	0.78

Labor input (L_{it}) defined here is total working hours, calculated by multiplying the number of total employees in the private sector and the total annual working hours per person.

Private capital (K_{it}) is defined as the sum of the capital stock of ten private industries: (1)agriculture, forestry and fishing, (2)mining, (3)construction, (4)manufacturing, (5)public utilities (electric power, gas, water supply and heat supply, (6)transport and telecommunications, (7)wholesale and retail, (8)banking and insurance, (9)real estate, and (10) service industry. However, these data are available only for the years 1953 to 1963, compelling us to estimate the capital stock of the private sector based on limited available data. Generally, the estimation of

each prefecture's capital stock is allocated from the national capital stock of the private sector according to the weight of the prefecture. The weight of the prefecture is obtained according to the amount of investment.

Public capital (G_{it}) used here is the sum of the public capital stock of four industries: (1)roads, (2)ports and airports, (3)agriculture (e.g. agriculture, forestry and fishing facilities), (4)land security (e.g. dams and banks). Most data is obtained from *the Infrastructure of Japan (Nihon no Shakai Shihon)* by the Economic Planning Agency, and *Annual Statistics of Construction of Public Works (Kokyo Koji Chakko Tokei Nendoho)* by the Ministry of Construction. Public capital in the previous time period ($G_{i,t-1}$) is the same as above.

Investment of the national government (Ig_{it}^C) and investment of the prefectural government (Ig_{it}^P) are the total amount of investment in four categories: (1) roads, (2) ports and airports, (3) agriculture, fishing and forestry, (4) land security. The figures for these investments are reported by distinguishing national government and prefectural government in the Ministry of Construction's *The Annual Statistical Report on the Public Works Construction Started (Kokyo Koji Chakko Tokei Nendoho)*.

As for lobbying, because there are no data on how often lobbying activities have been carried out, we use two kinds of variables as proxy variables: the percentage of employees in the first industry (RAG_{it}) and the percentage of employees in the construction industry (RCN_{it}). The first industry consists of agriculture, fishing and forestry. Public capital as defined in our study is related to the infrastructure of these industries. Therefore, if the percentage of these industries becomes higher, we assume that pressure on policymakers becomes stronger to build more infrastructure. These variables are defined as the number of employees in each industry

divided by the total number of employees in all industries.

As for the political factor, two variables are used: (1) the ratio of majority vote to minority vote in the House of Representatives (RLS_{it}) and (2) the percentage of votes for the leading party (Liberal Democratic Party) in the prefectural congress (PLD_{it}). First, the ratio of majority vote to minority vote is used for the investment of the national government. A ratio of significantly more than one indicates a stable political situation. As the ratio approaches one, the political situation becomes unstable. For example, in the case of political stability in which the majority(minority) vote is 70%(30%), then the ratio is about 2.33. On the other hand, in an unstable political situation in which the majority (Minority) vote is 50.1%(49.9%), the ratio becomes about 1.00. Thus, this variable represents political stability. The percentage of votes for the leading party in the prefectural congress is used for the investment of the prefectural government. In general, in many cases, especially prefectures with large metropolitan areas, the Liberal Democratic Party is the majority but in prefectures without large metropolitan areas it is not. Furthermore, in the prefectural congress, we can see many cases where the minority party in the House of Representatives joins the majority. However, it is often observed that the leading party in the House has had a strong political influence on investment decisions by prefectural governments. Therefore, we define this variable for the investment of the prefectural government.

Finally, as for the fiscal factor, two variables such as national government grants for the construction of infrastructure (NTG_{it}) and the stand-alone revenues-expenditures ratio of prefectural budget (BAL_{it-1}) are defined here. First, the figures on national grants to prefectural governments are obtained from the Ministry of Home Affairs' *Annual Statistics on Local*

Government Finance (Chiho Zaisei Tokei Nenpo). The stand-alone revenues-expenditures ratio of a prefectural budget is how much of its own revenue the prefectural government has. Most prefectural governments, except for large prefectures such as Tokyo, have been getting a significant amount of money, such as the distribution of local allocation tax from the national government. Prefectural officials sometimes claim that their own revenues, such as local tax and user charges, comprise only 30% of total revenues. In this study, as we would like to know the effect of prefectural budget constraints on the investment of public capital, we define the stand-alone revenues-expenditures ratio by dividing total prefecture revenues less the distribution of local allocation tax (i.e. local tax revenues and user charges) by the total expenditures of the prefectural budgets.

4.5 Results

Selected estimation results are summarized in Table 3. Although most cases are estimation results of the 3SLS for the four simultaneous equations, we also present the result of the fixed effect model by the estimation of equation-by-equation. Overall results seem to be reasonable: the fit of the four equations is pretty high with R^2 ranging from 0.664 to 0.999. From the estimation results, the following conclusions can be drawn.

First, the coefficient of public capital stock (G_{it}) in the production function is stable with respect to the different specifications, even if the estimate for the coefficient of public capital does not vary much between single equation and simultaneous equation. The coefficient of public capital in the production function is about 0.05 to 0.06 with statistical significance. Therefore, Hypothesis 1, which predicts that public capital contributes to

productivity, holds. However, the value of the coefficient seems a bit smaller than that of the equivalent public capital in the previous studies. For example, the coefficients of public capital in the previous studies are 0.240(core-infrastructure) in Aschauer(1989), 0.060(highway) in Munnell(1990), 0.044-0.045(highway) in Garcia-Mila and McGuire(1992), 0.172 (core-infrastructure) in Mitsui et al.(1995), 0.152-0.347 (industry) in Ida and Yoshida(1999).

Second, as for the relationship between public investment(Ig_{it}^C , Ig_{it}^P) and private productivity(Y_{it}/L_{it}), the results are different between the central government and the prefectural government. The coefficient of private productivity in the public investment function of the national government is about 0.76 to 1.14. On the other hand, the coefficient of private productivity in the public investment function of the prefectural government shows the negative sign: about -0.854 to -0.965 in the simultaneous model. These results show that the national government invests more based on the efficiency reason but that the prefectural government invests more based on the equity reason.

The relationship between public investment(Ig_{it}^C , Ig_{it}^P) and public capital per capita($G_{i,t-1}/POP_{i,t-1}$) is the opposite of results regarding private productivity. The coefficient of public capital per capita in the national government's public investment function shows the negative sign, which varies about -0.367 to -0.528 . On the other hand, in the case of the prefectural government's investment function, the public capital per capita shows the positive sign, ranging from about 0.282 to 0.392. Compared with a variable which shows economic flow (i.e. private productivity), the contribution of public capital to public investment is not large. As for this variable, the national government invests more based on the equity reason but the prefectural government invests more based on the efficiency reason.

Fourth, the complementarity of public capital investment (Ig_{it}^C, Ig_{it}^P) between the national and the prefectural government could hold because the coefficients of public investment of both the national and the prefectural government show the positive sign. However, the degree of the effects varies: the prefectural government's investment effect on the national government's investment is much larger. This result coordinates with the reality of public investment because the national government's big projects often coordinate with the local government's.

As for the lobbying factor, we were unable to get consistent results. In the national government's public investment function, the coefficient of the percentage of employees in the construction industry (RCN_{it}) shows the positive sign but the percentage of employees in the first industry (RAG_{it}) shows negative. On the other hand, in the prefectural government's public investment function, only the percentage of employees in the first industry is significant but the effect of that variable is not large. These results show that the lobbying factor might be effective in stimulating public investment by the national government.

As for the political factor, first the ratio of majority vote to minority vote in the House of Representatives does not show a clear effect on the national government's investment function. According to the results of simultaneous equations, this factor is not significant. On the other hand, in the case of the prefectural government's investment function, the percentage of votes for the Liberal Democratic Party in prefectural congress shows the positive sign, varying from 0.166 to 0.181.

Table 3 Estimation Results of Regressions

Function	Variables	Exp. sign	Equation-by-equation	3SLS	3SLS	3SLS	3SLS
Production function $\ln(Y_{it}/L_{it})$			Model-PR1	Model-PR2	Model-PR3	Model-PR4	Model-PR5
	$\ln(K_{it}/L_{it})$	+	0.721 (0.047)	0.712 (0.046)	0.710 (0.046)	0.716 (0.046)	0.714 (0.046)
	$\ln G_{it}$	+	0.050 (0.016)	0.058 (0.017)	0.052 (0.016)	0.061 (0.017)	0.052 (0.016)
	adj.R ²		0.798	0.798	0.798	0.798	0.798
Public capital formation Function $\ln G_{it}$			Model-PC1	Model-PC2	Model-PC3	Model-PC4	Model-PC5
	$\ln G_{i,t-1}$	+	0.695 (0.008)	0.630 (0.021)	0.639 (0.022)	0.612 (0.027)	0.614 (0.025)
	$\ln I_{it}^C$	+	0.112 (0.004)	0.149 (0.012)	0.149 (0.012)	0.155 (0.015)	0.159 (0.014)
	$\ln I_{it}^P$	+	0.191 (0.006)	0.216 (0.011)	0.207 (0.011)	0.228 (0.013)	0.223 (0.013)
	adj.R ²		0.999	0.999	0.998	0.998	0.998
National government's investment function $\ln I_{it}^C$			Model-NI1	Model-NI2	Model-NI3	Model-NI4	Model-NI5
	$\ln I_{it}^P$	+/-	1.013 (0.063)	1.043 (0.066)	1.177 (0.064)	1.187 (0.064)	1.174 (0.067)
	$\ln(G_{i,t-1}/POP_{i,t-1})$	+/-	-0.316 (0.101)	-0.367 (0.100)	-0.452 (0.097)	-0.378 (0.095)	-0.528 (0.099)
	$\ln(Y_{it}/L_{it})$	+/-	0.692 (0.272)	0.761 (0.327)	1.032 (0.255)	1.144 (0.263)	1.037 (0.260)
	$\ln RAG_{it}$	+	-0.116 (0.067)	-0.151 (0.069)	-	-	-
	$\ln RCN_{it}$	+	1.072 (0.320)	1.243 (0.308)	0.667 (0.245)	-	1.130 (0.308)
	$\ln RLS_{it}$	+/-	-0.155 (0.074)	-0.032 (0.066)	0.005 (0.055)	0.002 (0.046)	0.040 (0.054)
	adj.R ²		0.701	0.696	0.679	0.664	0.677
Prefectural government's investment function $\ln I_{it}^P$			Model-PI1	Model-PI2	Model-PI3	Model-PI4	Model-PI5
	$\ln I_{it}^C$	+/-	0.128 (0.027)	0.289 (0.214)	0.436 (0.039)	0.618 (0.109)	0.498 (0.044)
	$\ln(G_{i,t-1}/POP_{i,t-1})$	+/-	0.255 (0.046)	0.282 (0.046)	0.282 (0.043)	0.283 (0.050)	0.392 (0.044)
	$\ln(Y_{it}/L_{it})$	+/-	-0.389 (0.154)	-0.854 (0.259)	-0.878 (0.272)	-0.965 (0.249)	-0.897 (0.274)
	$\ln RAG_{it}$	+	0.131 (0.030)	0.087 (0.034)	0.041 (0.025)	-	-
	$\ln RCN_{it}$	+	0.008 (0.141)	-0.127 (0.290)	-	-	-0.446 (0.163)
	$\ln PLD_{it}$	+/-	0.196 (0.074)	0.175 (0.103)	0.181 (0.059)	0.166 (0.068)	-
	$\ln NTG_{it}$	+	0.902 (0.044)	0.709 (0.228)	0.499 (0.053)	0.284 (0.131)	0.419 (0.056)
	$\ln BAL_{it}$	+	0.486 (0.075)	0.467 (0.223)	0.333 (0.100)	0.172 (0.096)	0.234 (0.115)
	adj.R ²		0.906	0.885	0.840	0.743	0.805

Finally, as for the relationship between public capital investment and the financial difficulties, according to the regression results the revenues-expenditures ratio shows a positive relationship, varying from 0.172 to 0.467. And the availability of the national government grants for the construction of infrastructure further boosts the prefectural government's investment.

5. Concluding Remarks

The main goals of our study is to clarify two important issues: whether or not public infrastructure contributes to production in the private sector, and whether or not political economy factors such as political situations, lobbying factors and the availability of national grants for investment affect the allocation of public infrastructure investment. If the political economy factors indeed affect allocation of public capital investment, what kinds of factors are the most deterministic? In order to investigate these questions, we estimate simultaneous equations and evaluate them. We obtain the following empirical results.

(1) The coefficient of public capital stock (G_{it}) in the production function is stable with respect to the different specifications. Therefore, the hypothesis that public capital contributes to productivity, could hold.

(2) As for the relationship between public investment(Ig_{it}^C, Ig_{it}^P) and private productivity(Y_{it}/L_{it}), the results are different between the national government and the prefectural government. Empirical results show that the national government might invest more based on the efficiency reason but the prefectural government might invest more based on the equity reason.

(3) The relationship between public investment (Ig_{it}^C, Ig_{it}^P) and public capital per capita ($G_{i,t-1}/POP_{i,t-1}$) is the opposite to the case of private productivity. The national government invests more based on the equity reason but the prefectural government invests more based on the efficiency reason.

(4) The complementarity of public capital investment (Ig_{it}^C, Ig_{it}^P) between the national and the prefectural government could hold. However, the degree of the effects is different: the prefectural government's investment effect on the national government's investment is much larger.

(5) As for the lobbying factor, we could not get consistent results. Empirical results show that the lobbying factor regarding the construction industry might be effective in stimulating investment by the national government.

(6) We cannot find a clear political factor in the national government's public investment function but in the case of the prefectural government's investment function, the factor has a positive effect on investment.

(7) The availability of national government grants for the construction of infrastructure further boosts investments by prefectural governments.

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