Long-Term Effects of Fiscal Policy Generated through Changes in Productivity*

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Abstract

With the low birth rate and aging population, the scale of public investments has shrunk in Japan since the beginning of the 2000s because infrastructure development has almost been completed. In this situation, the aging of infrastructure has emerged as a problem. In order to study the future needs for infrastructure in Japan, this paper conducts an industry-by-industry analysis of the economic effects of public investments—particularly, those may occur on private investment through changes in the productivity of capital—based on a long-term stock equilibrium approach. The results make clear that at least in the private service industry, an increase in public capital stock has consistently increased the productivity of private capital and has the effect of increasing the optimal level of private capital stock. In order to ensure that the productivity of the private sector in Japan will be sustained in the future, it is essential, at least, to maintain public capital stock.

Keywords: public investment, public capital stock, private-sector investment, private capital stock

JEL Classification: C23, C26, D22, H54

I. Introduction

Public investment, which is a fiscal policy measure, has two economic effects: creating demand and improving productivity through an increase in factor productivity. In the latter, there are many studies on promoting economic growth through public capital in the endogenous economic growth model (Allow and Kurz 1970; Baxter and King 1993; Aschauer 2000).

The expenditure on public investment in Japan increased exponentially after the high-economic growth period, and at the same time, public capital stock increased quantitatively. After the 2000s, when public capital was almost complete, the amount of public investment began to decrease, and now, the share of public investment to GDP in Japan is the

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same as that in other OECD countries.

Japan's infrastructure faces aging problems. This problem has been discussed in the Ministry of Infrastructure, Land, and Transportation since 2000. After the collapse of ceiling boards in the Sasago Tunnel on the Chuo Expressway in Japan in December 2012, policies for road maintenance have been promoted in full swing; for example, inspections in bridges, tunnels, and equipment with roads are legally mandated every five years.

If public capital contributes to improving productivity, the aging of public capital causes a qualitative decrease in public capital and, consequently, decreases productivity in the private sector. If the decrease in public investment is insufficient to improve public capital built in the past, it may be that while the quantitative level of public capital is high, the qualitative level of public capital is decreasing.

This study analyzes the effect of public investment on private investment through the change in factor productivity in Japan based on changes in capital stock. In particular, through our analysis, under emerging aging infrastructure, we would like to clarify the necessity of maintaining the quality of public capital.

The remainder of this paper proceeds as follows. Section II reviews previous studies on the effect of public investment on private investment and shows the contribution of our analysis. In Sections III and IV, we explain our model and the data, respectively. Section V discusses the results of our analysis, and in Section VI, we present our conclusions.

II. Previous Studies and Analysis Framework

Various empirical studies have recently been conducted on the economic effects of public expenditure. The existence and magnitude of the effect of public investment on private investment is crucially important in terms of its effect on economic growth. Abiad et al. (2016) compare the economic effect of public investment financed by public debt with that financed by tax. Malizard (2015) clarifies whether an increase in military expenditure lowers private investment, using cointegration analysis in France.

In Japan, Miyazaki (2018) analyzed the effect of public investment on public investment by the industrial sector and showed that its effect is positive in mining, transport equipment, and transport and communication sectors and is negative in the finance, insurance, and service sectors. Funashima and Ohtsuka (2019) analyze the spillover effect of various kinds of public expenditure, including public investment on economic variables with spatial autocorrelation among prefectures. They indicate that public investment has neither a crowding-in nor a crowding-out effect on economic variables.

In addition to the above, studies have been conducted on the effect of public investment on private investment, using the relationship between public and private capital stock. Hatano (2010) hypothesizes that, in the long run, there is a relationship between public and private capital stock—and not between public and private investment—and provides evidence of a positive cointegrated relationship in Japanese macroeconomic data. Dreger and Reimers (2016) also show that, using cointegration analysis, there is an equilibrium in the stock level between private capital stock and public capital stock, and there is a positive relationship between them in Eurozone countries.

From the above studies, we can see that regarding the effect of public investment on private investment, there is an extreme difference between studies using investment data and those using stock data. Hatano (2010) points out the problem of a lack of long-run equilibrium and dynamic factors. To be sure, it is possible that the long-run equilibrium can be expressed using investment data by considering the adjustment cost of capital. However, if the aging of capital stocks and technological obsolescence change over time, the relationship expressed by the investments may be unstable.

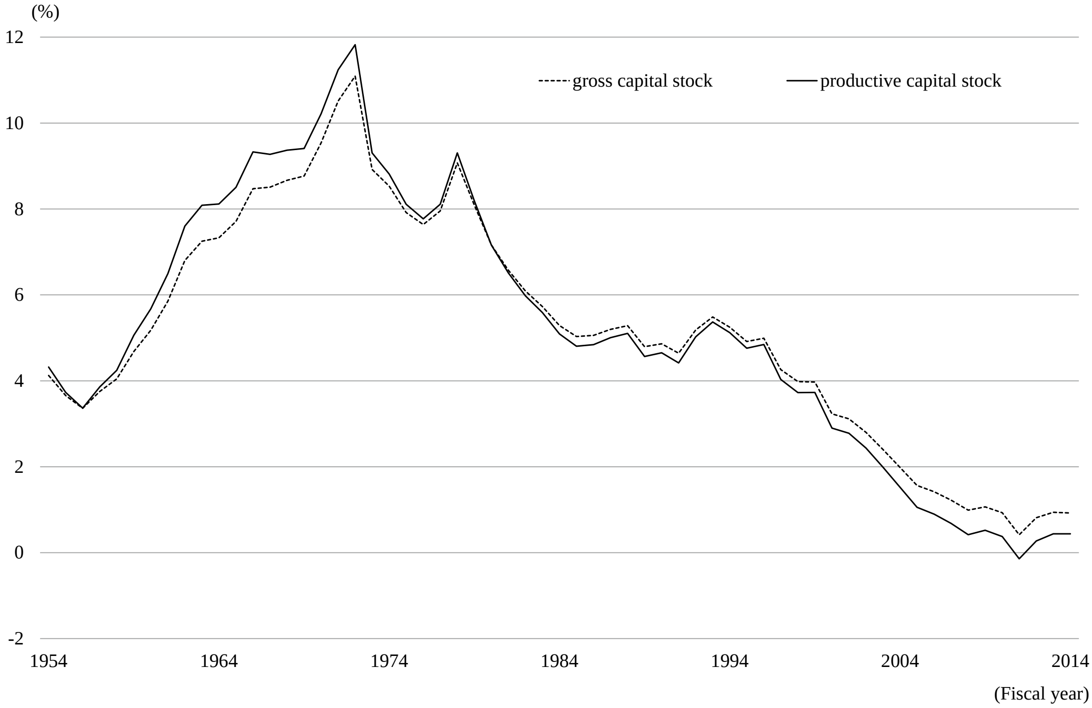
To illustrate the situation of aging infrastructure in Japan, Figure 1 shows the growth rate of gross public capital stock and that of productive public capital stock, using “Measuring Infrastructure in Japan 2017” (IOJ 2017) estimated by the Cabinet Office of Japan. The quantity of gross public capital stock represents the quantity of public capital without considering aging, and the quantity of productive public capital stock shows the quantity of public capital services with consideration of aging. Expenditures for new construction, updating, and preservation increase the gross public capital stock as well as the productive public capital stock, but the quantity of increase is different because of the aging of public capital stock. The decrease in gross public capital stock with aging is caused by disposal, such as corruption of public capital stock; the decrease in productive public capital stock with aging, however, is caused by functional decline as well as disposal. Therefore, in general, the quantity of increase in productive public capital stock is smaller than that in gross public capital stock. Furthermore, when increasing in capital stock exponentially, the growth rate of productive capital stock is higher than that of gross capital stock. However, when increasing in capital stock gradually, the growth rate of productive capital stock is smaller than that of gross public capital stock.

Figure 1 shows that in 1980, the growth rate of gross public capital stock and the growth rate of productive public capital stock were reversed. This reflects the rapidly improving infrastructure until 1980, as well as the appearance of aging infrastructure built in the past after 1980. After 2000, the divergence between the growth rate of these capital stocks gradually increased and represented the effect of aging infrastructure built in the past.

The aging of infrastructure in Japan may not coincide with the change in public capital stock and public investment because the optimal level of private capital services changes by reducing the actual level of public capital services even if the input–output relationship in production is stable. This may also lead to the increasing importance of the perspective in the long-run equilibrium of stock levels, as pointed out by Hatano (2010).

We clarify the effect of public investment on private investment by seeing public investment as a change in public capital stock and private investment as a change in private capital stock, based on the equilibrium at the stock level in accordance with Hatano’s (2010) idea. Although, in terms of analysis and data, our analysis is the same as that of Miyazaki (2018), its result may differ because the effect is measured by a change in stocks, not by an investment.

Figure 1. Growth rate of gross public capital stock and productive public capital stock



Source: Director General for Economic, Fiscal and Social Structure, Cabinet Office "Measuring Infrastructure in Japan 2017"

III. Model

Our model differs from previous studies in two ways. One is that the effect of public investment on private investment is captured at the industrial level rather than at the macroeconomic level. To be sure, it is important to clarify its effect at the macroeconomic level, but as shown in previous studies such as in Yoshino and Nakajima (ed) (1999), the effect of public investment on economic variables differs at the industrial level; hence, we analyze its effect by industry. Second, investment is captured by a change in stock.

III-1. Theoretical model

We assume that region *i*'s private producers determine the private capital service K_i and labor inputs L_i given public capital services G_i and under the following production function:

$$Y_i = f(K_i, L_i; G_i),$$

where we assume that the production function is a constant return to scale with respect to labor input and capital input, that is, increase returns to scale with respect to all inputs, which is the same as Yoshino and Nakajima (ed) (1999) and Nakahigashi and Yoshino (2016). In addition, we assume that private producers determine the amount of factor inputs to minimize costs under factor prices. Under this assumption, producers determine the factor inputs to satisfy the following equation:

$$\frac{r}{w_i}=\frac{\partial Y_i}{\partial K_i}\bigg/\frac{\partial Y_i}{\partial L_i}$$

We also assume that wages differ according to region because of travel cost. The price of capital service r and the price for output p, on the other hand, are the same across regions. Under these assumptions, private producers determine the amounts of private capital service K_i^* and labor input L_i^* as follows:

$$K_i^*=k_i(Y_i;\,G_i,\,w_i,\,r,\,p),\qquad L_i^*=l_i(Y_i;\,G_i,\,w_i,\,r,\,p)$$

Assuming the return to scale, the ratio of optimal private capital to output is as follows:

$$\frac{K_i^*}{Y_i}=k_i^*(G_i,\,w_i,\,r,\,p) \tag{1}$$

This equation reflects the change in factor productivity of private capital through the change in public capital stock, which is a part of the indirect effect shown in Yoshino and Nakajima (ed) (1999) and Nakahigashi and Yoshino (2016).

III-2. Specifications of the model

When estimating equation (1), we face the problem that the amount of capital services cannot be measured directly. We know that the amount of flow variables is measured within a given length of time, whereas the amount of stock variables is measured at some point in time. When using the quantity of stock as a proxy variable of the quantity of capital service, we need to construct an estimated model that includes flow variables as well as stock variables, recognizing that these variables are measured by different time concepts.

Then, we assume that the quantity of capital service in period t is proportional to the quantity of capital stock at the end of period $t-1$. Under this assumption, the production function in our analysis is as follows:

$$Y_{i,t}=f\,(K_{i,t-1},\,L_{i,t};\,G_{i,t-1})$$

where $Y_{i,t}$ is the quantity of product in region i in period t, $K_{i,t-1}$ is the quantity of private capital stock in region i at the end of period $t-1$, and $G_{i,t-1}$ is the quantity of public capital stock in region i at the end of period $t-1$. Based on these settings, the optimal quantity of private capital stock at the end of period t depends on the predicted quantity of the product, and is as follows:

$$\frac{K_{i,t}}{Y_{i,t+1}}=k_i^*(G_{i,t},\,r,\,w_i,\,p)$$

Furthermore, we assume that the quantity of $Y_{i,t+1}$ is expected to be based on $Y_{i,t}$, which is the actual quantity of product in period t, and then

$$\frac{K_{i,t}}{Y_{i,t}}=k_i^*(G_{i,t},\,r,\,w_i,\,p) \tag{2}$$

Furthermore, we assume that the factor demand functions can be expressed by log-linear, and that private investment is adjusted to optimize the private capital service in each period. Our estimated model called the "one-difference model," which takes the difference between equations in the current period and one period ago, is as follows:

$$\frac{K_{i,t}-K_{i,t-1}}{K_{i,t-1}} \Big/ \frac{Y_{i,t}-Y_{i,t-1}}{Y_{i,t-1}} = \beta_G \left(\frac{G_{i,t}-G_{i,t-1}}{G_{i,t-1}} \right) + \beta_W \left(\frac{w_{i,t}-w_{i,t-1}}{w_{i,t-1}} \right) + \alpha_i + \mu_t + \epsilon_{i,t}\,, \tag{3}$$

where α_i is the region-specific effect that captures regional characteristics unchanged over time, μ_t is the year-specific effect that represents common regional effects at the same time, and $\epsilon_{i,t}$ is the error term that represents elements other than region-specific and year-specific effects. In our settings, the price of capital service (r), price for product (p), and technological progress are included in the year-specific effect μ_t.

In addition, we introduce another model that relaxes the assumption of equation (3), which is derived under the strict assumption that capital service adjusts to the optimal level for each year. Because our data are measured in years, in industries with small-scale devices, this assumption may have little effect on the results of our estimation. However, in industries with large-scale devices, models may be needed considering the need for time to adjust to the optimal level of capital, such as the cointegrating relationship adopted by Hatano (2010) and Dreger and Reimers (2016).

In our paper, we introduce the "five-difference model," which assumes that private capital service adjusts to the optimal level in a long time, and which takes difference between equations in the current period and five years ago, is as follows:

$$\frac{K_{i,t}-K_{i,t-5}}{K_{i,t-5}} \Big/ \frac{Y_{i,t}-Y_{i,t-5}}{Y_{i,t-5}} = \beta_G \left(\frac{G_{i,t}-G_{i,t-5}}{G_{i,t-5}} \right) + \beta_W \left(\frac{w_{i,t}-w_{i,t-5}}{w_{i,t-5}} \right) + \alpha_i + \mu_t + \epsilon_{i,t} \tag{4}$$

III-3. Endogeneity

Our model is a partial-equilibrium model by private producers, and public capital is treated exogenously in private producers' decision-making.

However, in Japan, Yoshino and Yoshida (1988) focus on the regional allocation of public investment and show that regional differences in income level affect the regional allocation of public investment. Nagamine and Katayama (ed) (2001), Kondo (2013), and Goto (2015), who consider the regional allocation of road investment, show that the lower the regional income, the greater the regional allocation of public investment. If this is correct, because private producers and public sectors make decisions simultaneously, our explanatory variables are not strictly exogenous. In particular, in the service industry, which has a large share of economic activity, and the main industries in each region, the change in the value-added in the denominator of the dependent variable in each industry is highly related to the change in income. As a result, the parameter estimates of our model were biased.

To overcome the problems in estimating our model of endogenous decisions in the change in public capital stock, the instrumental variable (IV) method is introduced. From previous studies, there are many users of instrumental variables; for example, Miyazaki (2018) uses not only the change in the dependent variable but also the lagged dependent variable. Kameda et al. (2019) used treasury disbursement for education and public investment as instrumental variables. We introduce a new instrumental variable that reflects the results of previous studies on the regional allocation of public investment in Japan; a high amount of public investment is allocated to low-income regions.

The instrumental variable in estimating equation (3) is constructed as follows:

$$\frac{1}{s_{i,t-1}}\frac{G_t^A - G_{t-1}^A}{G_{t-1}^A},$$

where G_t^A is the total public capital stock of Japan at time t, $s_{i,t}$ is the share of the quantity of public capital stock, which reflects that the growth rate of public capital stock is high in the region with low per capita income relative to per capita income in all of Japan Y_{t-1}^A.

The instrumental variable in estimating equation (4) is used as follows:

$$\frac{1}{s_{i,t-5}}\frac{G_t^A - G_{t-5}^A}{G_{t-5}^A},$$

which estimates the difference between current variables and variables that existed five year ago.

IV. Data

Our analysis uses panel data to aggregate prefectural data into 11 regions as shown in Table 1. This is to internalize the spillover effect of public capital, which is similar to the analyses of Yoshino and Nakajima (ed) (1999) and Nakahigashi and Yoshino (2016). Our regional classification, however, is slightly different from that of Nakahigashi and Yoshino (2016). Okinawa Prefecture, which was not included in Nakahigashi and Yoshino (2016), is included in the South Kyushu region. Ibaraki Prefecture, which is included in the northern Kanto region by Nakahigashi and Yoshino (2016), is included in the Southern Kanto region. This is because cities in Ibaraki Prefecture belong to the Tokyo Metropolitan Area in the urban employment area proposed by Kanemoto and Tokuoka (2002), and there is a spillover effect of public capital in nearby prefectures in the Southern Kanto region.

Private capital stock, wage rate, and real Gross Regional Product (GRP) are based on the “Regional-Level Japan Industrial Productivity Database” (R-JIP) constructed by Tokui et al. (2013). In our analysis, public capital stock is the productive capital stock of IOJ 2017.

Our industrial classification is slightly different from the R-JIP data based on data availability. The industrial classification of R-JIP is based on similarities in the production process; R-JIP’s industries include the private sector as well as the public sector. In addition, in some industries, capital is treated as public capital in IOJ 2017. To match the range of public and private capital, in our analysis, our public capital includes only five of 16 sectors: roads, urban parks, forest conservation, flood management, and coastal maintenance[1]. Furthermore,

Table 1. Regional classification in our paper

Region	Prefectures
Hokkaido	Hokkaido
Tohoku	Aomori, Akita, Iwate, Miyagi, Yamagata, Fukushima
Northern Kanto	Tochigi, Gunma, Nagano
Southern Kanto	Ibaraki, Saitama, Chiba, Tokyo, Kanagawa, Yamanashi
Hokuriku	Niigata, Toyama, Ishikawa, Fukui
Tokai	Shizuoka, Gifu, Aichi, Mie
Kinki	Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
Chugoku	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi
Shikoku	Kagawa, Tokushima, Ehime, Kochi
Northern Kyushu	Fukuoka, Saga, Nagasaki, Oita
Southern Kyushu	Kumamoto, Miyazaki, Kagoshima, Okinawa

electricity, gas, water, transportation and communications, and service (government) industries in R-JIP are excluded from our analysis because their stocks are treated as public capital stocks in IOJ 2017. The electric machinery industry is excluded and the "mechanical industry," which combines general machinery with electrical machinery, transportation machinery, and electrical machinery, is included because there are prefectures with negative GRP.

Our estimated period is from 1972 to 2012, which is the capital stock in the R-JIP database by prefecture, including Okinawa.

V. Results

V-1. Estimate of the Basic Model

Table 2 shows the results of equation (3) using OLS. The regional fixed effect was tested, and the existence of a regional fixed effect was confirmed in three industries: electrical machinery, construction, and real estate industries. In addition, in other industries, estimated models containing only time effects were used to ensure the degree of freedom. Furthermore, considering the economic impact of the Great Hanshin-Awaji Earthquake in the Kinki region and the Great East Japan Earthquake in the Tohoku region, dummy variables are set in the year the earthquake occurred and the following year.

Our estimated results indicate that the coefficient of public capital is significantly posi-

[1] The share of productive public capital stock of 5 sectors to that of all 18 sectors is about 51 percent at the end of 2014 and the share of road stock to that of our public capital stock is about 72 percent at the end of 2014.

Table 2. Results of one-difference model by OLS

	Agriculture, forestry and fishing		Mining		Food and beverages		Textile mill products		Pulp and paper	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.397	(0.502)	-0.909	(0.666)	-0.011	(0.410)	-0.289	(0.282)	-0.410	(0.545)
Wage	—		—		-0.051	(0.120)	-0.375 **	(0.077)	-0.052	(0.094)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		×		×		×		×	
Time effect	○		○		○		○		○	
Coef. of determination	0.697		0.768		0.610		0.687		0.495	
Sample size	440		440		440		440		440	

	Chemicals		Petroleum and coal products		Ceramics, stone and clay		Basic metal		Processed metal	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	0.312	(0.455)	0.824	(1.273)	-0.413 **	(0.155)	0.055	(0.615)	0.350	(0.551)
Wage	-0.009	(0.151)	-0.634	(0.620)	0.161 *	(0.080)	0.373	(0.528)	-0.080	(0.185)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		×		×		×		×	
Time effect	○		○		○		○		○	
Coef. of determination	0.677		0.115		0.632		0.429		0.670	
Sample size	440		440		440		440		440	

	General machinery		Electrical machinery		Transport equipment		Other manufacturing		Construction	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.009	(0.470)	-1.212 *	(0.560)	2.064 *	(1.125)	1.067 ***	(0.273)	-0.198	(0.432)
Wage	-0.090	(0.192)	0.054	(0.158)	0.102	(0.258)	0.103	(0.076)	0.015	(0.023)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		○		×		×		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.669		0.705		0.312		0.768		0.790	
Sample size	440		440		440		440		440	

	Wholesale and retail trade		Finance and insurance		Real estate		Service (private)		Machinery	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	0.694	(0.395)	0.973 **	(0.348)	1.779 ***	(0.389)	1.642 ***	(0.348)	0.833	(0.526)
Wage	0.052	(0.056)	-0.073	(0.044)	—		0.014	(0.038)	-0.005	(0.147)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		×		○		×		×	
Time effect	○		○		○		○		○	
Coef. of determination	0.734		0.738		0.816		0.673		0.705	
Sample size	440		440		440		440		440	

Note 1: The coefficient of determination with regional fixed effect represents the coefficient of determination of within-estimate. The standard error in each estimation is cluster-robust estimate clustering by region.
Note 2: *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Note 3: In mining and real estate industries, the wage rate is excluded from our explanatory variables because it is the same in all regions.

tive in other manufacturing, finance and insurance, real estate, and services (private) sectors. This specification is included in the endogenous effect, and the interpretation of our results must be withheld.

V-2. Estimated Result Considering Endogeneity

Next, the results of applying the IV method are shown to consider the simultaneity included in the estimated equation. Table 3 shows the results of the first-stage estimation of the IV method, that is, the results of regressing the change rate of public capital stock on instrumental and exogenous variables in our model. Table 3 also shows the F statistics of the null hypothesis that all coefficients in the first-stage estimation are zero. To use the second step of estimation, we estimate separately with and without the regional fixed effect. The results show that the F statistics and the coefficient of determination are very large regardless of the existence of regional fixed effects, and that there is no problem with the weak instrument variable using the statistical table of Stock and Yogo (2005).

Table 3. Result of first-stage estimation of one-difference model

	With regional effect		Without regional effect	
	estimate	(std. err.)	estimate	(std. err.)
Instrumental variable	0.672 ***	(0.083)	0.606 ***	(0.042)
Earthquake dummy	○		○	
Time effect	○		○	
F-statistic	141.140		134.770	
Coef. of determination	0.937		0.938	
Sample size	440		440	

Note: *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4 shows the results of equation (3) using the IV method based on the first-stage estimation in Table 3. As shown in Table 2, the existence of regional fixed effects is tested, indicating that there is a regional fixed effect in the electrical machinery and real estate industries.

Our estimated results show that the parameter estimate of public capital is significantly positive only in other manufacturing and service (private) industries. Our results show that the scale of parameter estimates in these industries is larger than that in Table 2, and then OLS estimates are endogenously affected. In these industries, improving public investment increases optimal private capital, and aging infrastructure makes private producers decide investments to decrease private capital and thus have a negative effect on the economy. These results are consistent with those reported by Yoshino and Nakajima (ed) (1999) and Nakahigashi and Yoshino (2016), which have the largest indirect effects in tertiary industries.

In textile mill products and construction industries, our results show that an increase in public capital reduces optimal private capital. If this result is correct, improving public capi-

Table 4. Result of one-difference model by IV

	Agriculture, forestry and fishing		Mining		Food and beverages		Textile mill products		Pulp and paper	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.724	(0.491)	-1.137	(0.744)	-0.329	(0.508)	-0.573 **	(0.242)	-1.308	(0.827)
Wage	—		—		-0.056	(0.108)	-0.379 ***	(0.071)	-0.070	(0.078)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		×		×		×		×	
Time effect	○		○		○		○		○	
Coef. of determination	0.726		0.768		0.609		0.686		0.492	
Sample size	440		440		440		440		440	

	Chemicals		Petroleum and coal products		Ceramics, stone and clay		Basic metal		Processed metal	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.659	(1.007)	-0.932	(1.397)	-0.671 *	(0.405)	-0.690	(0.618)	0.986	(0.707)
Wage	-0.033	(0.122)	-0.633	(0.531)	0.156 **	(0.072)	0.363	(0.475)	-0.068	(0.166)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		×		×		×		×	
Time effect	○		○		○		○		○	
Coef. of determination	0.674		0.114		0.670		0.429		0.668	
Sample size	440		440		440		440		440	

	General machinery		Electrical machinery		Transport equipment		Other manufacturing		Construction	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.050	(0.765)	-2.313 *	(1.215)	0.900	(0.650)	1.503 ***	(0.434)	-1.437 **	(0.609)
Wage	-0.091	(0.177)	0.029	(0.157)	0.087	(0.235)	0.111	(0.074)	0.020	(0.023)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		○		×		×		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.669		0.704		0.311		0.766		0.776	
Sample size	440		440		440		440		440	

	Wholesale and retail trade		Finance and insurance		Real estate		Service (private)		Machinery	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	0.441	(0.537)	0.669	(0.437)	0.894	(1.256)	2.441 ***	(0.773)	0.252	(0.375)
Wage	0.053	(0.051)	-0.072 *	(0.040)	—		0.006	(0.036)	-0.020	(0.134)
Earthquake dummy	○		○		○		○		○	
Regional effect	×		×		○		×		×	
Time effect	○		○		○		○		○	
Coef. of determination	0.733		0.737		0.809		0.663		0.704	
Sample size	440		440		440		440		440	

Note: Same as Table 2.

tal reduces the factor productivity of private capital. However, considering the production process of these industries, it is difficult to imagine that the two above occur, so there may be factors that have not been considered in the equation.

V-3. Estimated Result of the Five-Difference Model

For the five-difference model, which considers adjusting the private stock to the optimum level over a certain period of time, Table 5 shows the results of the OLS estimation, Table 6 shows the results of the first-stage estimation of the IV method, and Table 7 the re-

Table 5. Result of the five-difference model by OLS

	Agriculture, forestry and fishing		Mining		Food and beverages		Textile mill products		Pulp and paper	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.223	(0.621)	-0.485	(0.778)	0.133	(0.490)	-0.666	(0.567)	0.099	(0.664)
Wage	—		—		0.075	(0.233)	0.631 *	(0.289)	0.196	(0.191)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		○		○		○		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.649		0.704		0.543		0.862		0.559	
Sample size	396		396		396		396		396	

	Chemicals		Petroleum and coal products		Ceramics, stone and clay		Basic metal		Processed metal	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	0.313	(0.506)	1.290 *	(0.579)	-0.164	(0.394)	-0.285	(0.561)	-0.003	(0.360)
Wage	-0.441	(0.267)	0.694	(0.904)	0.192	(0.261)	0.008	(0.915)	-0.225	(0.197)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		×		○		×		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.810		0.186		0.549		0.526		0.780	
Sample size	396		396		396		396		396	

	General machinery		Electrical machinery		Transport equipment		Other manufacturing		Construction	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	0.396	(0.523)	-1.031	(0.586)	0.351	(0.461)	0.937 **	(0.309)	0.140	(0.449)
Wage	-0.169	(0.182)	0.327	(0.312)	-0.372	(0.508)	0.105	(0.099)	-0.018	(0.059)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		○		×		○		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.710		0.703		0.269		0.762		0.817	
Sample size	396		396		396		396		396	

	Wholesale and retail trade		Finance and insurance		Real estate		Service (private)		Machinery	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	0.535	(0.400)	1.351 **	(0.449)	2.058 ***	(0.319)	0.907 ***	(0.045)	0.838	(0.611)
Wage	0.128	(0.151)	-0.060	(0.090)	—		-0.008	(0.042)	-0.224	(0.242)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		○		○		○		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.736		0.842		0.926		0.972		0.784	
Sample size	396		396		396		396		396	

Note: Same as Table 2.

sults of the IV method. In addition, the existence of a regional fixed effect is tested in advance, indicating that there are regional fixed effects, except for petroleum and coal products, primary metals, and transportation machinery.

OLS estimates in Table 5 show positive coefficients of public capital in four other industries: manufacturing, finance and insurance, real estate, and services (private).

Table 6 shows the results of the first-stage estimation of the IV method, which regresses the growth rate of public capital stock on instrumental variables and exogenous variables. In estimating the first-stage estimation, we estimate the equation with a regional fixed effect and without a regional fixed effect separately. In the five-difference model, regardless of the

Table 6. Result of the first-stage estimation of the five-difference model by IV

	With regional effect		Without regional effect	
	estimate	(std. err.)	estimate	(std. err.)
Instrumental variable	0.782 ***	(0.297)	0.561 ***	(0.131)
Earthquake dummy	○		○	
Time effect	○		○	
F-statistic	43.860		42.620	
Coef. of determination	0.826		0.828	
Sample size	396		396	

Note: Same as Table 3.

regional fixed effect, F statistics and the coefficient of determination are very large, which is the same as the one-difference model. From these results, it can be judged that there is no problem with the weak instrument variable from the statistical table shown in Stock and Yogo (2005).

Table 7 shows the results of the IV method, indicating that the coefficient of public capital is statistically positive only in the service (private) industry. Although the results change, it can be said that, at least in the service (private) industry, improving public capital increases the productivity of private capital and, as a result, increases the optimal level of private capital. In particular, we can imagine that the road stock, which accounts for about 70% of our public capital, causes an agglomeration economy through networking among economic agents, as shown in Bernard et al.'s (2019) analysis of a high-speed rail network. Therefore, it seems natural that the coefficient of public capital is statistically positive in the service (private) industry.

VI. Conclusion

Our study clarifies the economic effect of public investment on private investment through productivity change by changing capital stock. This is because it is necessary to maintain a substantial level of public capital service in Japan with a low birth rate and an aging population.

Although the results differ between the model and analytical methods, at least in the service (private) industry, improving public capital affects private capital, and its effect is statistically positive. It can be seen from our results that the aging infrastructure will reduce the productivity of the private sector by reducing the real quantity of public capital services. Therefore, appropriate maintenance of public capital is indispensable for maintaining productivity in Japan.

Finally, we present the future issues of our study. Our results vary greatly when changing the estimation method. In particular, the difference between coefficient estimates by the

Table 7. Result of the five-difference model by IV

	Agriculture, forestry and fishing		Mining		Food and beverages		Textile mill products		Pulp and paper	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-2.168	(1.169)	1.734	(2.763)	-0.369	(1.183)	-1.543	(2.373)	0.827	(2.757)
Wage	—		—		0.046	(0.206)	0.578 *	(0.326)	0.256	(0.304)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		○		○		○		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.509		0.677		0.533		0.855		0.551	
Sample size	396		396		396		396		396	

	Chemicals		Petroleum and coal products		Ceramics, stone and clay		Basic metal		Processed metal	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.486	(1.968)	0.555	(0.681)	-0.281	(2.704)	-1.252 **	(0.493)	1.138	(1.010)
Wage	-0.523 ***	(0.179)	0.669	(0.803)	0.188	(0.228)	-0.053	(0.827)	-0.166	(0.199)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		×		○		×		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.805		0.184		0.549		0.519		0.759	
Sample size	396		396		396		396		396	

	General machinery		Electrical machinery		Transport equipment		Other manufacturing		Construction	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	1.644	(1.279)	-1.149	(1.694)	-1.612	(1.107)	1.510	(1.225)	0.209	(0.429)
Wage	-0.069	(0.144)	0.316	(0.305)	-0.393	(0.477)	0.136	(0.089)	-0.019	(0.060)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		○		×		○		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.691		0.703		0.239		0.751		0.817	
Sample size	396		396		396		396		396	

	Wholesale and retail trade		Finance and insurance		Real estate		Service (private)		Machinery	
	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)	estimate	(std. err.)
Public capital	-0.875	(1.006)	2.522	(1.823)	1.489	(1.247)	1.597 **	(0.686)	1.369	(1.355)
Wage	0.188 **	(0.156)	-0.102	(0.103)	—		0.066	(0.104)	-0.173	(0.274)
Earthquake dummy	○		○		○		○		○	
Regional effect	○		○		○		○		○	
Time effect	○		○		○		○		○	
Coef. of determination	0.669		0.826		0.922		0.876		0.781	
Sample size	396		396		396		396		396	

Note: Same as Table 2.

IV method and OLS is inconsistent, so it is necessary to research for more desirable instrumental variables. In addition, this study presumes that private producers adjust private capital to the optimum level, but it can be considered that the correction of long-term relationships is included in the investment model, as in Hatano (2010).

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