The Role of Infrastructure in Economic Development * †
(Preliminary Version)

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November 22, 2000

*This project is supported by the Center of Excellence(COE)(Ministry of Education) affiliated to Keio University.

†You can obtain all the data used in this paper (from December 14, 2000 onward) from http://www2c.biglobe.ne.jp/~m_naka/official/research/

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1 Introduction

Infrastructure is the capital stock that provides public goods and services. It produces various effects, including those on production activities and quality of life for the households, which thus permeate the entire society.

To measure the effect of the infrastructure on production activities, the previous studies have estimated a production function that incorporated infrastructure as one of factors of production or a model of utility and production functions that incorporated infrastructure in the context of growth theory. To measure the effect on quality of life, qualitative, theoretical analyses have been made, using a growth model that incorporated infrastructure as an argument in the utility function (e.g. Arrow and Kurz(1970)), while empirical analyses have been conducted, among others, by governments which applied the cost-benefit analysis.

Despite an accumulation of numerous studies on infrastructure, empirical analyses have focused on the industrial countries, due largely to constraints on the availability of data. In such analyses, we have been very careful in scrutinizing the obtained results before applying them to the developing economies because in the industrial countries infrastructure had already been developed to a certain degree even in the early segment of the estimation period. Such an example may be seen in (2) of Table 3. This was reproduced from Yoshino and Nakahigashi(2000), which studied Japan in the period after World War II. It shows the effect of infrastructure on productivity since 1951. One can observe that the effect on productivity was very large in the postwar years, turned around in 1970, and has been declining since. One thing we should note carefully is the period before 1970 when productivity was very high. To figure out the relationship between infrastructure and production before and after World War II, see the average productivity of infrastructure in Figure 1. The graph reveals that productivity was gradually falling before World War II, and that after the war it stayed at very low levels before returning to the pre-war level in 1960. Moreover, it is common knowledge that the damage on infrastructure during the war was not very large. This suggests that after the end of the war, output, as represented by GNP, started from an extraordinarily low level. In other words, compared with developing countries today, Japan already had the groundwork for high economic growth right after World War II. This point will be made clear if we compare Figure 1 with Figure 2, which plotted the average productivity of infrastructure over time in Thailand.

Recently there has been growing interest in the relationship between poverty and economic growth. However, the literature dealing with this subject is still not abundant. Infrastructure will provide benefits to rich and poor equally because of the non-exclusionary nature of the consumption of public goods and services it provides. To the extent that infrastructure improves the quality of life for the poor, the development of infrastructure is likely to alleviate poverty.

The purpose of this paper is to analyze the effect of infrastructure on productivity and the relationship between infrastructure and poverty in Southeast Asian countries in the context of studying the relevance of infrastructure in economic development for the developing economies. Southeast Asian countries were selected due to the availability of time series data for tracing the process of transition from a developing to medium-income economy. Specifically, we used macroeconomic data from pre-war Japan and Thailand, and studied the effects of infrastructure in agriculture and the manufacturing industry on the productivity. We also examined the cross-section data of the entire world to study the relationship between infrastructure and poverty.

The paper consists of four sections. The Section 2 gives a survey of the literature on the relationship between economic development and infrastructure, and estimates the effect of infrastructure on productivity in pre-war Japan and Thailand. The Section 3 looks at the relationship between poverty and infrastructure from the medium to long-term perspective. The Section 4 summarizes the results.

2 The Effect of Infrastructure on Productivity

Although early studies on the effect of infrastructure on macroeconomic productivity may date back to Ratner(1983), Aschauer(1989) and, more recently, Mitsui and Inoue (1995) as well as chapter 2 of Yoshino and Nakajima (ed.) (1999). All these studies found infrastructure as an effective factor of production. And there are many empirical studies using economic growth theory, for example, Easterly and Rebelo (1993), Devarajan, Swaroop and Zou (1996), Barro (1997), and Nakazato(1999).

However, as shown by Figure 1, it seems difficult to regard the fact in Japan as the one in developing countries. This is because high economic growth occurred in Japan after the end of World War II against the backdrop of relative abundance in infrastructure in relation to the levels of real GDP.

In the following section, We will estimate the effect of infrastructure on productivity in post-war Japan (1905–1940) and Thailand (1970–1996).

2.1 Estimation Method

The estimation method sketched out below follows Yoshino and Nakajima(ed.) (1999). The effect of infrastructure on productivity is defined here as an increase in the potential productive capacity of the private sector. The private sector is assumed to engage in production activities given infrastructure and based on profit maximization.

The production technology of the private sector is represented by the following production function.

$$Y = f\left(K_P, L, K_G\right) \tag{1}$$

where Y denotes output (in value added) in the private sector. The output is produced by combining private capital stock, K_P, labor input, L, and infrastructure stock, K_G.

In this paper, we assume the translog production function.

$$\begin{aligned} \ln Y \;=\;& \alpha_0 + \alpha_K \ln K_P + \alpha_L \ln L + \alpha_G \ln K_G \\ & + \beta_{KK}\frac{1}{2}(\ln K_P)^2 + \beta_{KL}\ln K_P \ln L + \beta_{KG}\ln K_P \ln K_G \\ & + \beta_{LL}\frac{1}{2}(\ln L)^2 + \beta_{LG}\ln L \ln K_G + \beta_{GG}\frac{1}{2}(\ln K_G)^2 \end{aligned} \tag{2}$$

There are instances where models derived from the production function such as the cost function and total factor productivity have been used in the literature. [1] However, we adopted the production function approach. The reasons are: unlike other methods, the model does not require additional assumptions; there is a significant likelihood that other methods may not be applicable because of limited data availability. Estimation of the production function may give rise to multicollinearity due to the nature of time series data. Since we used the translog production function, multicolinearity is likely to pose a serious problem.

[1] For example, Lynde and Richmond (1992) and Shah (1992) estimate the effect of infrastructure on productivity using cost function. Takenaka and Ishikawa (1991) estimate the one using total factor productivity (TFP)

For this reason, we resorted to the estimation method used by Kamada et al.(1994), where the production function and factor share functions(the private capital share function and the labor share function) under perfect competition were simultaneously estimated.

Assuming that the production function is linear homogeneous in private capital and labor, and that factor prices and infrastructure are given, the profit maximization of private firms leads to:

$$\frac{\partial Y}{\partial K_P} = \frac{r}{p}, \quad \frac{\partial Y}{\partial L} = \frac{w}{p} \tag{3}$$

where r denotes the cost of capital, w the wage, and p the price of product.

Multiplying each equation by K_P/Y and L/Y respectively,

$$\frac{\partial Y}{\partial K_P}\frac{K_P}{Y} = \frac{\partial \ln Y}{\partial \ln K_P} = \frac{rK_P}{pY}, \quad \frac{\partial Y}{\partial L}\frac{L}{Y} = \frac{\partial \ln Y}{\partial \ln L} = \frac{wL}{pY} \tag{4}$$

If we assume the translog production function for equation (2), the left hand side of each equation above is obtained by taking partial derivative of equation (2) with respect to $\ln K_P$ and $\ln L$ respectively.

$$s_K = \alpha_K + \beta_{KK} \ln K_P + \beta_{KL} \ln L + \beta_{KG} \ln K_G \tag{5}$$

$$s_L = \alpha_L + \beta_{KL} \ln K_P + \beta_{LL} \ln L + \beta_{LG} \ln K_G \tag{6}$$

These are directly derived from equation (2) and are useful for estimating parameters in the simultaneous equation system.

We assume here that there is no distribution of income generated from production to infrastructure even if it is a factor of production. To put another way, profits generated from production activities are assumed to be distributed between private capital and labor. Given that the production function is homogenous of degree one in private capital and labor, the system equations for estimating is:

$$\begin{aligned} \ln Y - \ln L \quad = \quad & \alpha_0 + \alpha_K(\ln K_P - \ln L) + \alpha_G \ln K_G \\ & + \beta_{KL}\left(\ln K_P \ln L - \frac{1}{2}(\ln K_P)^2 - \frac{1}{2}(\ln L)^2\right) \\ & + \beta_{KG}(\ln K_P \ln K_G - \ln L \ln K_G) + \beta_{KG}\frac{1}{2}(\ln K_G)^2 \end{aligned} \tag{7}$$

$$s_L = (1 - \alpha_K) - \beta_{KL}(\ln K_P - \ln L) - \beta_{KG} \ln K_G \tag{8}$$

Equations (7) and (8) are simultaneously estimated by Seemingly Unrelated Regression(SUR).

Next, in estimating how much production will increase in the private sector when infrastructure increases by one more unit, we followed Yoshino and Nakano(1994) and divided this overall effect into direct and indirect effect to make an explicit account of the relationship between a variation in factor input and production. The *direct effect* is an additional output due to an increase in marginal productivity which occurs as a result of an increase in infrastructure. The *indirect effect* is an additional output due to increased labor input and private capital input based on an increase in infrastructure.

Assuming the production function represented by equation (1), and that factor prices and infrastructure are given for producers in the private sector, the effect of infrastructure on productivity is expressed as:

$$\frac{dY}{dK_G} = \frac{\partial Y}{\partial K_G} + \frac{\partial Y}{\partial K_P}\frac{\partial K_P}{\partial K_G} + \frac{\partial Y}{\partial L}\frac{\partial L}{\partial K_G} \tag{9}$$

Here, the effect of infrastructure is divided into three parts; the first term on the right hand side of equation (9) represents *direct effect*; the second term is the *indirect effect* on output with respect to the resulting change in the input of private capital and the third term is the *indirect effect* on output with respect to the resulting effect on labor input.

The equation (9) is graphically represented in Figure 3, which illustrates the relationship between private capital and output, given fixed labor input in the private sector. The similar graph may be obtained for the relationship between labor input and output, given fixed private capital. The bottom panel shows in terms of marginal productivity the same relationship shown in the top panel.

At point A, the private firm produces the optimal output under profit maximization, given factor prices and the level of infrastructure, K_G^0. Output corresponding to the optimal private capital, K_P^0, is indicated by A. Now, suppose that infrastructure is increased from K_G^0 to K_G^*. If infrastructure has a positive effect on productivity, then the production function in the top panel will shift upward, and so will the marginal productivity curve shift from MP^0 to MP^* in the bottom panel. The corresponding point on the new curve above Point A is indicated by Point B. The direct effect is the difference between output Y^0 and Y'. If we note that the factor price ratio $(r/p)^0$ (r: the cost of capital, p: product price) is given, since marginal productivity at Point B is higher than the factor price ratio, the private firm can increase profit by increasing more private capital. The firm can maximize profit by increasing private capital from K_P^0 to K_P^*. By increasing private capital, the private firm produces more output. This move is shown by a shift from Point B to C. Accordingly, output is increased from Y' to Y^*, the difference between them being the indirect effect.

In the following section, these direct effect and the indirect effect will be obtained.

2.2 Estimation Procedure

Before discussing the results of estimation, we first describe the procedure for estimating the production function that has incorporated infrastructure as a factor input.

1. **Estimation of the labor share function**

   (a) A stepwise Chow test is done on the labor share function to examine whether there is a structural change. If the test finds a statistically significant structural shift for a particular segment of the estimation period, it is dealt with by adding a dummy variable to the equation for that period.

   (b) The parameters of the labor share function are determined by statistical tests (t-test and F-test).

2. **Modeling and estimating the production function**
   Both production function and the labor share function are simultaneously estimated. In doing so, it should be noted that constraints are imposed on the parameters from the assumption of linear homogeneity in private capital and labor. The parameters of the variables not used in the labor share function are tested by t-test and F-test, and estimates with good statistic values are accepted.

The estimation method for Thailand and Japan requires further explanation. Since it is largely family-based enterprises that engaged in agriculture, forestry and fisheries, we found it difficult to accurately identify compensation for labor in this sector. Thus in these industries, we did not resort to simultaneous estimation for the labor share function, and only estimated the production function. Similarly, difficulties in obtaining data on labor share in the Japanese manufacturing industries [2] led to the single-handed estimation of the production function as in the case of agriculture, forestry and fisheries.

2.3 Effect of Infrastructure on Productivity in Japan

The estimated results of the sectoral translog production function and the labor share function are shown in Table 1 and Table 2 for agriculture, forestry and fisheries and for manufacturing. The estimation results with respect to the effect of infrastructure on productivity in Japan are shown in (1) of Table 3.

The following is a summary of findings with respect to the effect of infrastructure on productivity.

1. The effect of infrastructure in the manufacturing industries on the productivity was very large, with an estimate of 0.711 for the effect of infrastructure that exists in the overall economy during the high economic growth period in Japan.

2. When we examined the chronological movement, the effect of infrastructure in the manufacturing industry on productivity was large during the decade from the Russo-Japanese War in 1906 to World War I. It rose even higher in the second half of 1930s.

3. Infrastructure in agriculture did not have a large effect on productivity (0.050). The estimated value was not different from found in chapter 3 of Yoshino and Nakajima (ed.) (1999) for the post-World War II period in Japan.

4. The effect of infrastructure in agriculture on productivity was clearly declining over time, reaching to almost zero in 1930s.

5. During post-war period, infrastructure in agriculture sectors is the smallest productivity (0.029), then the infrastructure in industrial sector is the next (0.440), and the effect of service sector indicate the highest economic effect productivity effect (0.452).[3].

[2] The mining industry is included in the Japanese manufacturing sector because of data constraint.

[3] These values are reprinted from Yoshino and Nakajima(ed.) (1999).

6. According to (3) of Table 3, productivity effect of infrastructure was large after the World War II untill 1970 (from 0.648 to 0.816); however, it has been declined sharply afterward (0.080 in 1970-1974).

7. Productivity effect of the service sector infrastructure is higher in large cities compared to the rural area. In large cities, the indirect effect due to an increase in infrastructure is much larger than rural area.

2.4 Effect of Infrastructure on Productivity in Thailand

The estimation period is from 1971 to 1996. The results are shown in Table 4 and Table 5 for agriculture and manufacturing industry respectively. The estimation results with respect to the effect of infrastructure on productivity in Thailand are shown in the top panel of Table 6.

Notable findings with respect to infrastructure in the manufacturing industry are:

1. Structural shift occured in 1992, and the indirect effect resulted in a negative impact on the indirect effect of private capital.

2. Throughout the period under analysis, the direct effect as well as the indirect effect resulting from a change in labor input did not very significantly.

Notable findings with respect to infrastructure in agriculture are:

1. In terms of value, infrastructure in agriculture had a larger effect on overall productivity than the one in the manufacturing industry.

2. Effects on demand for factor inputs were: the indirect effect had (a) a negative impact on private capital and (b) a positive impact on private labor.

2.5 Difference between Thailand and Pre-war Japan

The effect on macroeconomic productivity of infrastructure in the manufacturing industry and in agriculture, forestry and fisheries were estimated respectively for Japan before World War II and Thailand, and the results were given. This section compares the results of Thailand and Japan.

The following characteristics were found through the comparison of Thailand and Japan in terms of the effect of infrastructure on overall productivity.

1. Infrastructure in agriculture, forestry and fisheries had a small productivity in Japan but a large in Thailand.

2. The corresponding effect with respect to infrastructure in the manufacturing industry was small in Thailand but was large in Japan.

These characteristics may be explained in terms of different share of infrastructure. Table 7 shows the share of infrastructure in pre-war Japan and Thailand.

In Table 7, the share of agricultural infrastructure to total capital stock in Thailand is constant, but in Japan that is decreasing. However, the share of infrastructure with respect to transportation and communication is increasing in Japan, but is decreasing in Thailand. This is why there is the difference between the effect of infrastructure on productivity in Japan and that in Thailand.

3 Poverty and Infrastructure

Since infrastructure is the capital stock that provides public goods and services, it contributes to production activities. At the same time, it improves the living conditions of the general public. Every citizen can consume the same amount of public goods and services. This means that the poor as well as the rich can enjoy the benefits it provides. Thus the development of infrastructure may be considered a prescription we need for reducing poverty.

Recently Deininger and Squire (1996) and Ravallion and Chen(1997) have made available the data related to the Gini coefficient. As a result, such empirical studies as Benabou (1996) and Li, Squire and Zou (1998) made a reassessment of the proposition of Kuznets (1955) on the relationship between economic development and inequality. [4] Dollar and Kraay (2000) went further and examined what policies might be helpful to reduce poverty.

This section focuses on the possibility that public services provided by infrastructure may reduce disparities in income, and makes an empirical analysis on infrastructure and income inequality.

[4]Persson and Tabellini(1994) conducted a theoretical study on inequality and economic growth.

We turned to Deininger and Squire (1996) for much of data on income distribution, including Gini coefficient, which provide a measure of income inequality. Other sources of data are Penn World Table (Summers and Heston (1991)) and the World Development Indicator of the World Bank. Since not all the countries have developed good data bases on infrastructure, we use as an approximation the average over the longest period possible of the ratio of gross domestic fixed capital formation to GDP, which is available from the World Development Indicator. The data on the proportion of private capital in gross domestic fixed capital formation were used to calculate nominal public investment, which was then divided by nominal GDP to obtain the ratio of infrastructure to GDP.

3.1 Analytical Framework

In this section, we examine the relationship between infrastructure and income disparities in two steps.

STEP1 Data Analysis

The data is examined by statistical analysis, using scatter diagrams.

STEP2 Regression Analysis

In general, multiple factors are responsible for income disparities. Here we follow the regression analysis of Li, Squire and Zou (1998), where Gini coefficient is used for the dependent variable and factors causing income disparities are explanatory variables, and examine various factors that may be responsible. We included factors that were found statistically significant in Li, Squire and Zou (1998) as explanatory variables. It should be noted that we included the public spending on education and the extent the financial markets are developed in addition to infrastructure in order to measure the effect of infrastructure on improving income disparities.

So, the regression is:

$$\mathrm{Gini}_i = \alpha + \beta_G \left(\frac{I_G}{Y}\right)_i + \beta_E \mathrm{E}_i + \beta_F \left(\frac{\mathrm{M2}}{\mathrm{GDP}}\right)_i + u_i \tag{10}$$

where Gini_i denotes the Gini Coefficient in the country i, I_G/Y the Government investment per GDP, E the public spending on education per GNP, M2/GDP the M2 per GDP.

Data analysis in STEP 1 found the following results. Figure 4 is the scatter diagram of Gini coefficient and per capita GDP, and Figure 5 plots Gini coefficient and the government investment per GDP in a similar diagram. They seem to suggest that there is no direct link between Gini coefficient and these variables. However, considering that multiple causes may be intertwined, we believe it is possible that apparent lack of relationship in the graphs may be a spurious result. Thus in STEP 2, compounding factors that may have muddled up the relationship between infrastructure and income disparities are excluded.

Case 1 of Table 8 shows the results of regression analysis in STEP 2 using all the data available. They indicate that, like Li, Squire and Zou (1998), the larger the percentage of people with higher education and the more developed the financial markets are, the larger are income disparities. However, it turned out that infrastructure was not statistically significant.

However, One may argue that these findings may be attributable to a substantial difference in the absolute level of infrastructure between the industrial and developing economies. Case 2 of Table 8 also show the results of estimation excluding the data from developed countries. They indicate that the percentage of people with higher education(β_E) and the more developed the financial markets(β_F) are statistically significant but government investment per GDP(β_G) is not.

4 Conclusion

Infrastructure has various effects on the economy. To shed light to the relationship between infrastructure and economic development, this study focused on its effect on production activities, and estimated the effect of infrastructure on productivity, using the data from Thailand, a medium income country, and pre-war Japan, as there is a relative paucity of the empirical literature that examined such country and period. Moreover, infrastructure is the capital stock that provides public goods and services. Therefore, it may lead to reduction in income disparities. To evaluate this effect, we also analyzed data to see whether infrastructure is a significant factor in reducing income disparities.

First, infrastructure did have an effect on productivity in both Thailand and Japan, but it differs, depending on particular infrastructure in different industries. However, when we interpret the difference in estimated values, we cannot determine whether a particular value that came up was appropriate without taking into account the historical background of the respective estimation period. Second, to examine the effect of infrastructure on income disparities, we used the Gini coefficient and tried to find the relationship between per capita income level and infrastructure. The evidence points toward no direct relationship.

We have gained the following insights from the analysis in this study. Infrastructure also affects production activities in the developing countries, implying a close relationship between infrastructure and economic development. Growth theory has often argued that the development of infrastructure is not an effective tool. Our analysis has shown, however, that this is because much of the existing literature has focused on industrial economies (e.g. Kochelakota and Yi (1996) and Nakazato (1999)). Such an approach may be prone to biased results. On the other hand, we were unable to show that infrastructure directly reduced income disparities. Whereas infrastructure does provide public goods and contributes to greater equality in economic opportunity, that does not necessarily imply its direct linkage with economic development. In recent years, there has been growing recognition that investment in education and the development of financial markets for financing large-scale production activities are factors that stimulate economic growth. By contrast, less attention is given to infrastructure as a fundamental factor behind economic growth. This study has shown its long-enduring significance.

References

[1] Arrow, Kenneth J. and Mordecai Kurz (1970) *Public Investment, the Rate of Return, and Optimal Fiscal Policy*, The Johns Hopkins Press, London.

[2] Aschauer, David Alan (1989) "Is Public Expenditure Productive?," *Journal of Monetary Economics* 23 pp.177-200.

[3] Barro, Robert J.(1997) *Determinants of Economic Growth - Cross-Country Empirical Study*, The MIT Press, London.

[4] Benabou, Roland (1996) "Inequality and Growth," in Ben Bernanke and Julio Rotemberg ed. *National Bureau of Economic Research Macroeconomics Annual*, Cambridge: MIT Press pp.11-74.

[5] Canning, David(1998) "A Database of World Infrastructure Stocks, 1950-1995," *World Bank Economic Review* 12 pp.529-547.

[6] Canning, David (1999) "Infrastructure's Contribution to Aggregate Output," *World Bank Policy Research Working Papers* No.2246.

[7] Canning, David and Peter Pedroni (1999) "Infrastructure and Long Run Economic Growth," Consulting Assistance on Economic Reform II Discussion Paper No.57 Harvard Institute for International Development.

[8] Dalamagas, Basil. (1995) "A Reconsideration of the Public Sector's Contribution to Growth," *Empirical Economics* 20, pp.385-414.

[9] Deininger, Klaus and Lyn Squire (1996) "A New Data Set Measuring Income Inequality," *The World Bank Economic Review* 10(3) pp.565-591.

[10] Devarajan, Shantayanan, Vinaya Swaroop and Heng-fu Zou(1996) "The Composition of Public Expenditure and Economic Growth," *Journal of Monetary Economics* 37 pp.313-344.

[11] Dollar, David and Aart Kraay (2000) "Growth is Good for the Poor," March 2000 Working Paper by the World Bank's Development Research Group.

[12] Easterly, William and Sergio Revelo (1993) "Fiscal Policy and Economic Growth," *Journal of Monetary Economics* 32 pp.417-458.

[13] Kamada, Kimiyoshi, Makoto Kawamura, Shinjin Takeuchi and Akio Mizuno (1994) "Public Investment and Fiscal Balance – Empirical Analysis about Excess Employment–", *Economic Research* 45(1) pp.31–40.(in Japanese)

[14] Kocherlakota, Narayama R. and Kei-Mu Yi (1996) "Simple Time Series Test of Endogenous VS. Exogenous Growth Models: an Application to the United States," *Review of Economics and Statistics* 78(1) pp.126-134.

[15] Kuznetz, Simon (1955) “Economic Growth and Income Inequality,” *The American Economic Review* 45 pp.1-28.

[16] Li, Hongyi, Lyn Squire and Heng-fu Zou (1998) “Explaining International and Intertemporal Variations in Income Inequality,” *The Economic Journal* 108 pp.26-43.

[17] Lynde, Catherine and J. Richmond (1992) “The Role of Public Capital in Production,” *Review of Economics and Statistics* 34 pp.37-45.

[18] Mitsui, Kiyoshi and Jun Inoue (1995) “Productivity Effect of Infrastructure,” in Mitsui, Kiyoshi and Kiyoshi Ohta(ed.) *Productivity of Infrastructure and Public Finance*, Nihon-Hyoron-sya Chapter 3.(in Japanese)

[19] Nakazato, Toru (1999) “Infrastructure and Economic Growth,” *Financial Review* pp.67-84.(in Japanese)

[20] Persson, Torsten and Guido Tabellini(1994) “Is Inequality Harmful for Growth?,” *American Economic Review* 84 pp.600-621.

[21] Ratner, J.B. (1983) “Government Capital and the Production Function for U.S. Private Output,” *Economic Letters* 13 pp.213-217.

[22] Ravallion, Martin and Shaohua Chen (1997) “What Can New Survey Data Tell Us about Recent Changes in Distribution and Poverty,” *The World Bank Economic Review* 11(2) pp.357-382.

[23] Shah, Anwar (1992) “Dynamics of Public Infrastructure, Industrial Productivity and Profitability,” *Review of Economics and Statistics* 74(1) pp.28-36.

[24] Summers, R and A. Heston(1991) “The Penn World Table(Mark 5): An Expanded Set of International Comparisons, 1950-1988,” *Quarterly Journal of Economics* 106 pp.327-336.

[25] Takenaka, Heizo and Tatsuya Ishikawa (1991) “Infrastructure in Japan and Supply Side,” *Monthly Report in Nissei Fundamental Research Institute* pp.19–35.(in Japanese)

[26] World Bank(1994) *World Development Report, Infrastructure for Development*, Washington D.C.

[27] Yoshino, Naoyuki and Hideo Nakano (1994) "Allocation of Public Investment in the Metropolitan Area," in Hatta, Tatsuo ed. *Economic Analysis of the Concentration in Tokyo*, Nihon Keizai Shinbunsya, Chapter 6.(in Japanese)

[28] Yoshino, Naoyuki and Masaki Nakahigashi (1999) "Empirical Analysis about Production Effect of Infrastructure from High Economic Growth Period to now," *Japan Economic Research Center Report in research meeting about infrastructure* Sep.1999.(in Japanese)

[29] Yoshino, Naoyuki and Masaki Nakahigashi(2000) "Economic Effect of Infrastructure – Experience in Japan after World War II," *Journal of Research Institute for Development and Finance* Special Issue Nov.2000.(in Japanese)

[30] Yoshino, Naoyuki, Masao Nakata and Masaki Nakahigashi (1999) "The Production Effect of Infrastructure in Each Field and the Simulation of Public Investment," Ono, Yoshiyasu and Hiroshi Yoshikawa ed. *Correct Way of Thinking about Economic Policy*, Toyo Keizai Shinposya, Chapter 5.(in Japanese)

[31] Yoshino, Naoyuki and Takanobu Nakajima (ed.) (1999) *Economic Effect of Public Investment*, Nihon Hyoronsya.(in Japanese)

Table 1: Estimation of Production Function in Japan (Agriculture)

Parameter Estimate

Parameter	Variable	Estimate	t-stat
α_K	$\ln K_P$	0.631	1.540
$\alpha_L(= 1 - \alpha_K)$	$\ln L$	0.369	—
α_G	$\ln K_G$	0.044	0.391
β_{KK}	$1/2\,(\ln K_P)^2$	—	—
β_{KL}	$\ln K_P \ln L$	—	—
β_{KG}	$\ln K_P \ln K_G$	-0.101	-1.065
β_{LL}	$1/2\,(\ln L)^2$	—	—
$\beta_{LG}(= -\beta_{KG})$	$\ln L \ln K_G$	0.101	—

Notes: * statistically significant at 5% level
** statistically significant at 1% level

$\bar{R}^2$	0.809
D.W.	1.367

Table 2: Estimation of Production Function in Japan (Manufacturing)

Parameter Estimate

Parameter	Variable	Estimate	t-stat
α_K	$\ln K_P$	0.181	1.020
$\alpha_L (= 1 - \alpha_K)$	$\ln L$	0.819	—
α_G	$\ln K_G$	0.573	4.868**
β_{KK}	$1/2\,(\ln K_P)^2$	—	—
β_{KL}	$\ln K_P \ln L$	—	—
β_{KG}	$\ln K_P \ln K_G$	0.202	3.402**
β_{LL}	$1/2\,(\ln L)^2$	—	—
$\beta_{LG} (= -\beta_{KG})$	$\ln L \ln K_G$	-0.202	—

Notes: * statistically significant at 5% level
** statistically significant at 1% level

$\bar{R}^2$	0.954
D.W.	0.517

Table 3: Effect of Infrastructure on Productivity in Japan

(1) Infrastructure Effect on Productivity in Pre-war Japan

Effect	Pre-war Period (1905–1940)	
	Agriculture	Manufacturing
Direct Effect	0.025	0.237
Indirect Effect (Capital)	−0.056	0.188
Indirect Effect (Labor)	0.081	0.286
Total Effect*	0.050	0.711

Note(*): Total effect equals the sum of direct effect, indirect effect (capital) and indirect effect (labor)

(2) Effect of Infrastructure (Yoshino and Nakahigashi(2000))

Effect	Post-war Period (1951–1975)				
	1951-55	1956-60	1961-65	1966-70	1971-75
Direct Effect	0.114	0.170	0.236	0.270	0.246
Indirect Effect (Capital)	0.085	0.123	0.162	0.175	0.156
Indirect Effect (Labor)	0.425	0.611	0.871	1.077	1.115
Total Effect*	0.624	0.904	1.268	1.522	1.517

Source: Computation using the result of Yoshino and Nakahigashi (2000) Figure 2-5.

(3) Effect of Infrastructure (Yoshino and Nakajima(ed.)(1999))

Period	1955-59	1960-64	1965-69	1970-74
	0.648	0.801	0.816	0.080
Period	1975-79	1980-84	1985-89	1990-94
	0.040	0.059	0.253	0.225

Source: Yoshino and Nakajima (ed.) (1999) Table 2-4 (p.32)

Table 4: Estimation of Production Function in Thailand (Agriculture)

Parameter Estimate

Parameter	Variable	Estimate	t-stat
α_K	$\ln K_P$	0.615	12.042**
$\alpha_L(= 1 - \alpha_K)$	$\ln L$	0.385	—
α_G	$\ln K_G$	0.415	33.456**
β_{KK}	$1/2\,(\ln K_P)^2$	—	—
β_{KL}	$\ln K_P \ln L$	—	—
β_{KG}	$\ln K_P \ln K_G$	−0.373	−5.465**
β_{LL}	$1/2\,(\ln L)^2$	—	—
$\beta_{LG}(= -\beta_{KG})$	$\ln L \ln K_G$	0.373	—
β_{GG}	$1/2\,(\ln K_G)^2$	−0.087	−3.603**

Notes: * statistically significant at 5% level
** statistically significant at 1% level

$\bar{R}^2$	0.986
D.W.	1.342

Table 5: Estimation of Production Function in Thailand (Manufacturing)

Parameter Estimate

Parameter	Variable	Estimate	t-stat
α_K	$\ln K_P$	0.869	43.301**
$\alpha_L (= 1 - \alpha_K)$	$\ln L$	0.131	—
α_G	$\ln K_G$	0.098	6.855**
α_T	$\ln T$	0.020	4.232**
β_{KK}	$1/2\,(\ln K_P)^2$	−0.081	−2.286**
β_{KL}	$\ln K_P \ln L$	—	—
β_{KG}	$\ln K_P \ln K_G$	−0.033	−2.732**
β_{LL}	$1/2\,(\ln L)^2$	−0.061	−3.825**
$\beta_{LG} (= -\beta_{KG})$	$\ln L \ln K_G$	0.033	—
β_{KT}	$\ln K_P \ln T$	−0.048	−6.018**
$\beta_{LT} (= -\beta_{KT})$	$\ln L \ln T$	0.048	—

Dummy(including after 1992)

Parameter	Variable	Estimate	t-stat
β_{KG}	$\ln K_P \ln K_G$	−0.078	−7.916**

Notes: * statistically significant at 5% level
** statistically significant at 1% level

Coefficient of determination
(adjusted for the degree of freedom)

Equation	$\bar{R}^2$
Production Function	0.974
Labor Share Function	0.968

Table 6: Effect of Infrastructure on Productivity in Thailand

Effect	Thailand (1971–1996)	
	Agriculture	Manufacturing
Direct Effect	0.119	0.032
Indirect Effect (Capital)	−0.085	0.014
Indirect Effect (Labor)	0.330	0.037
Total Effect*	0.364	0.083

Note(∗): Total effect equals the sum of direct effect, indirect effect (capital) and indirect effect (labor)

Effect	Pre-war Period (1905–1940)	
	Agriculture	Manufacturing
Direct Effect	0.025	0.321
Indirect Effect (Capital)	−0.056	0.422
Indirect Effect (Labor)	0.081	0.077
Total Effect	0.050	0.820

Note: This table is the same in (1) of Table 3.

Table 7: Government Stock in Japan and in Thailand

(1) Japan

Period	Facilitating Industry*	Primary Industry**
1905-1909	0.365	2.550
1910-1914	0.460	1.829
1915-1919	0.514	1.467
1920-1924	0.549	1.213
1925-1929	0.575	0.947
1930-1934	0.594	0.785
1935-1939	0.606	0.658

Note:(*) Facilitating industry consists of transportation, communication and public utility sector.
(**) Primary Industry consists of agriculture, forestry and fisheries.
Source: Ohkawa, Kazushi, Nobukiyo Takamatsu and Yuzo Yamamoto (1974) *National Income* Toyo Keizai Shinposha.(in Japanese) Table 7.2(2)[p.110] and Ohkawa, Kazushi, Shigeru Ishiwatari, Saburo Yamada and Hiromitsu Ishi (1966) *Capital Stock* Toyo Keizai Shinposha.(in Japanese) Table 2[pp.152-153]

(2) Thailand

Period	Agriculture	Transportation & Communication	Electricity & Water Supply
1970-1974	0.129	0.421	0.131
1975-1979	0.128	0.410	0.143
1980-1984	0.125	0.369	0.195
1985-1989	0.128	0.345	0.236
1990-1994	0.133	0.332	0.260

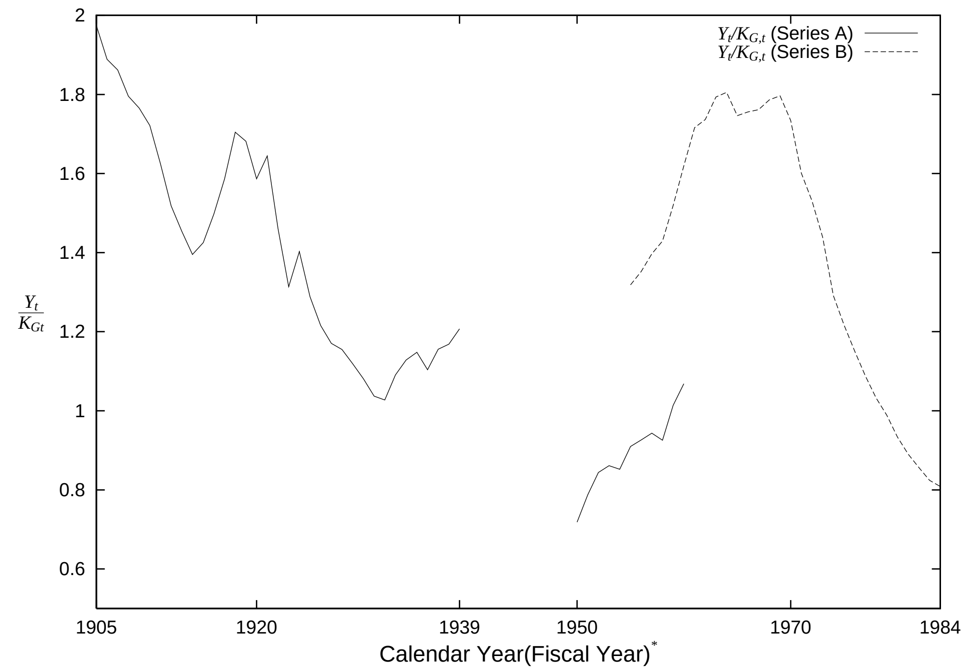
Source: These values are devided by total government capital stock. All the data are received from the Office of the National Economic and Social Development Board (NESDB) (http://www.nesdb.go.th)

Table 8: Regression of Gini Coefficient

Parameter	Case 1		Case 2	
	Estimate	t-stat.	Estimate	t-stat.
α	40.941	6.917***	9.795	2.263**
β_G	0.180	0.476	0.679	1.280
β_E	-1.179	-1.269	3.323	2.380**
β_F	0.145	1.730*	0.347	3.270***
R^2	0.127		0.633	
F-stat	1.456		17.283***	

Notes(1):	Case 1:	regression including all available data
	Case 2:	regresion excluding developed countries
Notes(2):	$***$	statistically significant at 1 % level
	$**$	statistically significant at 5 % level
	$*$	statistically significant at 10 % level
Notes(3):	F-stat:	the test all of the slope parameters are zero or not

Figure 1: Ratio of real GNP(GDP) to Infrastructure in Japan (1905-1984)



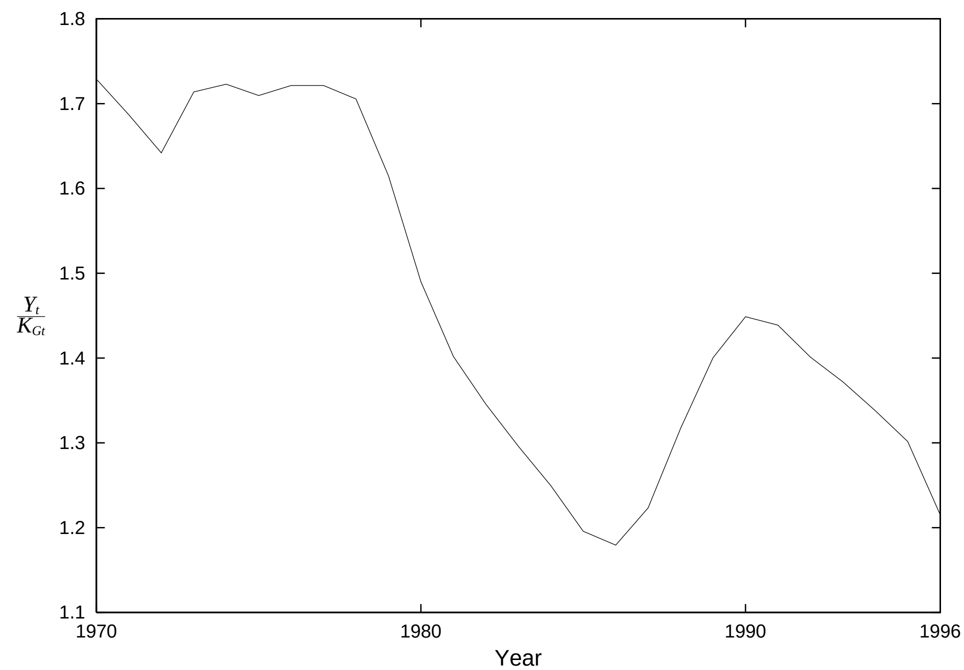
Note(∗): "Calendar Year" begins in January and ends in December. "Fiscal Year" begins in April and ends in March. The figures of Series A are based on "Calendar Year" and the figures of Series B are based on "Fiscal Year" because of data constraint.

Source:

Series A: Ohkawa, Kazushi, Nobukiyo Takamatsu and Yuzo Yamamoto (1974) *National Income* Toyo Keizai Shinposha.(in Japanese) Table 23 [p.225] (GNP from 1905 to 1939), Public History Sector in Ministry Finance (ed.) *Public Finance History in Showa era* (in Japanese) No.19 Table 8.(GNP from 1950 to 1960) and Ohkawa, Kazushi, Shigeru Ishiwatari, Saburo Yamada and Hiromitsu Ishi (1966) *Capital Stock* Toyo Keizai Shinposha.(in Japanese) Reference Table 3[pp.262] (government capital stock)

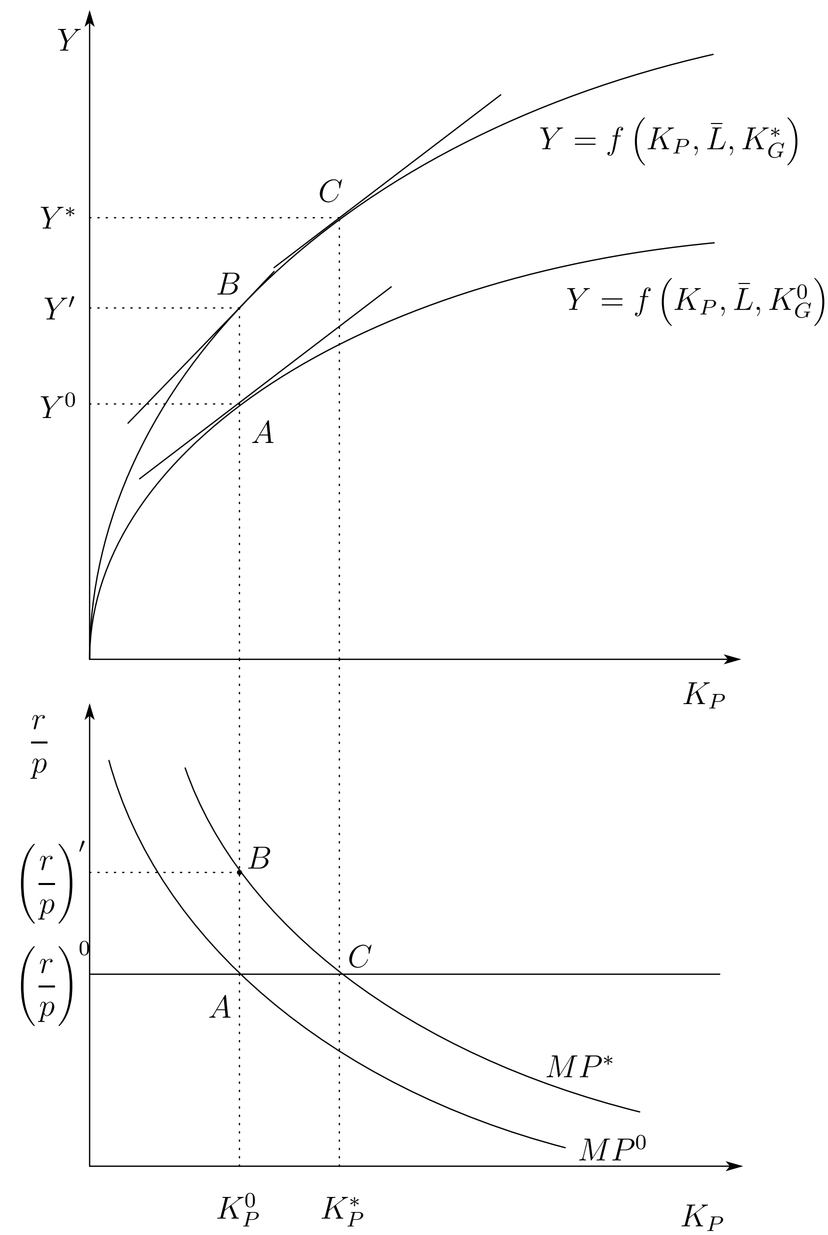
Series B: Economic Planning Agency *Annual Report on National Account* (real GDP) and General Planning Sector in Economic Planning Agency (ed.) (1998) *Social Capital in Japan*, Toyo Keizai Shinposya.(in Japanese) Table 3-14 (p.208) (government capital stock)

Figure 2: Ratio of real GDP to Infrastructure in Thailand (1970-1996)



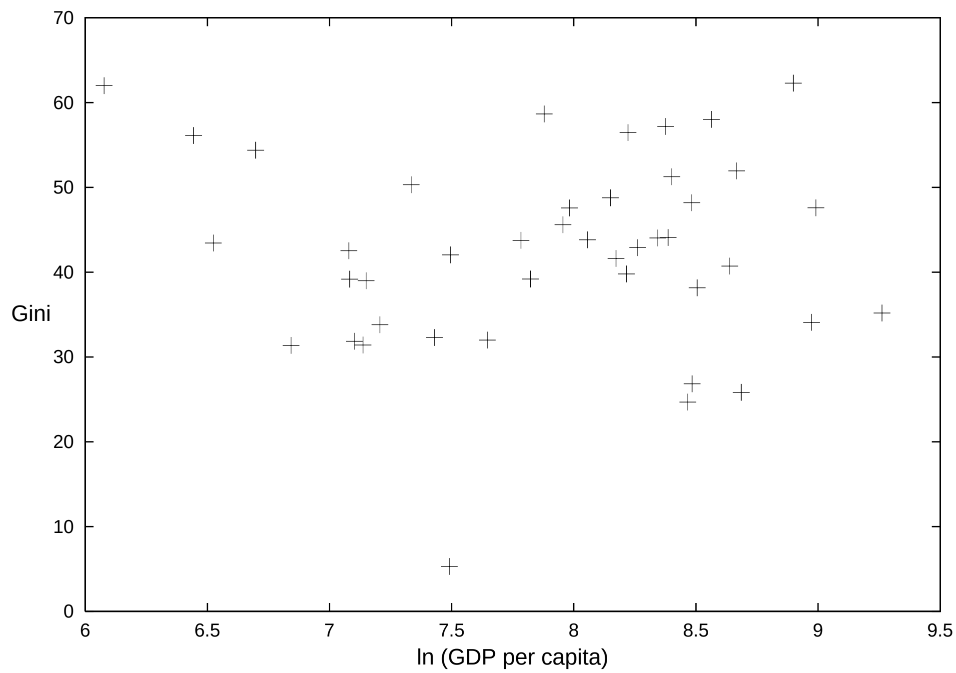
Source: Office of the National Economic and Social Development Board (NESDB) (http://www.nesdb.go.th/)

Figure 3: Direct Effect and Indirect Effect



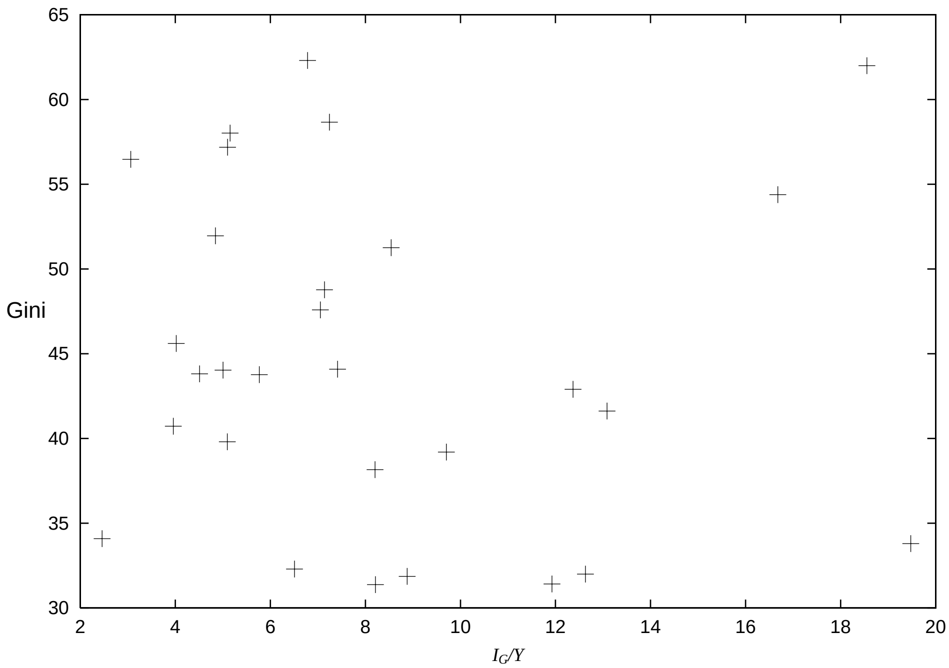
Source: Yoshino and Nakajima(ed.)(1999) Figure 3-3

Figure 4: Gini Coefficient and GDP per capita



Source: ln(GDP per capita) is the log of GDP per capita (PPP) and is based on World Bank *World Economic Indicators*. However, we exclude countries that there are not the private investment data (the share of private fixed capital formation to GDP). Gini Coefficient is taken from Deinger and Squire(1996)

Figure 5: Gini Coefficient and Government Investment per GDP



Source: We substitute government capital to government investment ratio to GDP (I_G/Y) taking average between 1985 and 1994. Gini Coefficient is taken from Deinger and Squire(1996)