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Do Public Capital Investments have an impact on Economic Growth?

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Introduction

In October 2019, the International Monetary Fund (IMF) trimmed its global growth expectation to 3.0% – the lowest since 2009 – down from 3.6% in 2018 (IMF, 2019a; 2019b). As global growth continues to slow amidst issues such as trade tensions and falling commodity prices, the need to identify key drivers of growth has intensified. In the search for these drivers, the benefits and importance of infrastructure may have been overlooked despite its strong potential to support higher economic growth as identified in several studies (Aschauer (1989, 2000); Calderón et al. (2004); Röller, L., & Waverman, L. (2001) etc.).

The link between infrastructure and growth will be of particular interest to the APEC region. Many economies have yet to invest adequately in infrastructure although their needs have increased significantly due to aging capital stock as well as to meet current and future demands of society. For instance, the Global Infrastructure Hub estimates APEC's regional infrastructure needs to have increased each year from USD 1.3 trillion in 2010–2015 to almost USD 2.5 trillion in 2030–2035 (APEC, 2018).

Several studies have examined the relationship between infrastructure and growth, but they are largely carried out using data from a limited sample of economies. This policy brief attempts to complement the existing literature by evaluating the connection between capital investment and economic growth using a global dataset.

Literature Review

Infrastructure plays an important role in supporting and creating new opportunities for economic growth and development. For instance, roads, bridges and ports provide firms with increased market access and business opportunities and allows for the expansion of their operations regionally and globally to reach new customers.

Historically, infrastructure has largely been provided by the government as it is regarded to have positive externalities and is often non-excludable[1] (to some extent), which reduces the ability of private firms to reap profits from it. These public good characteristics result in infrastructure often being synonymous with 'public capital' as governments have been largely responsible for both building and regulating these facilities. This is in contrast to 'private capital', which includes private assets such as factories and other industrial facilities and equipment. Notwithstanding, private participation has increasingly been channelled towards infrastructure investment through the public-private partnership (PPP) framework. In constant 2011 international dollars, APEC economies [2] have invested approximately 601.97 billion in PPPs between 2010 and 2015 (IMF, 2017).

[1] Relating to public goods, positive externality refers to a benefit that is enjoyed by a third-party as a result of an economic transaction, and non-excludable means it is not possible to exclude others from using the goods or services.

[2] Data was available for 10 APEC economies namely: Chile; China; Indonesia; Malaysia; Mexico; Peru; the Philippines; Russia; Thailand; and Viet Nam

There are several studies on the impact of infrastructure on economic growth. Seethepalli et al. (2008) using the regression analysis method estimates that infrastructure sub-sectors (telecommunications, electricity, roads, sanitation and water) generally have a positive and significant impact on growth in East Asia, with elasticities of GDP between 0.6 (roads) to 5.5 (telecommunications). Calderón et al. (2014) estimates the long-run output elasticity[3] of infrastructure to be between 0.07 and 0.10. Similarly, Stephan (1997) estimates output elasticities of road infrastructure to range from 0.33 to 1.13; while Aschauer (1989) predicts an output elasticity of 0.24 for core infrastructures, which include highways, mass transit, airports, electrical and gas facilities, water and sewers.

Apart from the direct effects of infrastructure on economic growth, there are indirect effects as well. For instance, Zou et al. (2008) finds an improvement in the mobility of labour, capital and information when transport bottlenecks are reduced, thereby supporting stronger economic growth and poverty alleviation in poor areas. Likewise, Munnel (1990) finds an increase in public infrastructure investment to raise labour productivity by between 0.31 and 0.39 percent.

When capital investment is disaggregated based on ownership, investment by the private sector is found to have a positive and significant impact on economic growth. The estimation by Aschauer (2000), when debt and efficiency is excluded, shows private capital investment to register a higher output elasticity at 0.27 as compared to public capital at 0.24. When public debt is considered however, a one percentage point increase in external public debt is estimated to reduce growth by 0.69% over two decades. This implies that should public capital be financed by the government budget, it is likely to further dampen the impact on economic growth.

Table 1: Production function estimates of the output elasticity of public capital by level of geographic aggregation

Author	Level of Aggregation	Specification	Output elasticity of public capital
Holz-Eakin (1988)	Economy-wide	Cobb-Douglas; Log levels	0.39
Aschauer (1989)	Economy-wide	Cobb-Douglas; Log levels	0.39
Munnel (1990a)	Economy-wide	Cobb-Douglas; Log levels	0.34
Ford and Poret (1991)	Economy-wide	Cobb-Douglas; Log levels	0.39*
Tatom (1991b)	Economy-wide	Cobb-Douglas; Log levels	Not significant
Mamatzakis (1997)	Economy-wide	Cobb-Douglas; Log levels	0.25
Costa et al (1987)	States	Translog; Levels	0.20
Eisner (1991)	States	Cobb-Douglas; Log levels	0.17
Mera (1973)	Japanese regions	Cobb-Douglas; Log levels	0.20
Munnel (1990b)	Districts States	Cobb-Douglas; Log levels	0.15
Duffy-deno and Eberts (1989)	Metropolitan areas	Log levels	0.08
Eberts (1986, 1900)	Metropolitan areas	Translog; Levels	0.03

Note: * refer to the elasticity in United States. Ford & Peret (1991) studied several other OECD economies.
Source: Adapted from Tom Björkroth & Anders Kjellman, 2000. "Public capital and private sector productivity - a Finnish perspective," Finnish Economic Papers, Finnish Economic Association, vol. 13(1), pages 28-44, Spring

[3] Output elasticity refers to the impact of infrastructure on output growth. The higher the number, the more sensitive growth will be to changes in infrastructure.

A study by Ligthart and Suárez (2011) finds substantial variation across output elasticities of public capital:

- 80% of the estimates took on values between −0.15 and 0.40, with the largest elasticity reported in Denmark (1.26) and the smallest in Portugal (-0.57).
- Approximately 21% of estimates evaluated had a negative sign, out of which 75% were significant (at the 5% level).

Table 1 provides a summary of some estimates of the output elasticity of public capital. As mentioned earlier, substantial research has been carried out to examine the relationship between infrastructure and growth, yielding different estimates on the impact of public capital on the economy. The current literature often only covers either the domestic economy level or includes just a few economies. This policy brief attempts to complement the existing literature; it evaluates the impact of capital investment on growth by replicating the study by Aschauer (2000), but with a larger sample of economies and over a longer time period.

Methodology and Data

Drawing from the estimation by Aschauer (2000) on the positive impact that public capital investment has had on growth for 46 low- and middle-income economies, this study carries out a similar analysis for 139 economies over the period 1970 – 2014. A concern of the Aschauer (2000) model is the upward bias in the estimated returns to public capital due to possible endogeneity: public capital affects productivity and output; on the other hand, stronger economic growth will also increase the demand and supply of public capital. Romp (2007) explains several methods to deal with this 'feedback' causality problem but they are beyond the scope of this paper.

This study also uses the Cobb-Douglas production function to relate output to capital and labour (Aschauer, 2000). Three types of capital are considered as inputs to the production process: (1) private physical capital, (2) human capital, and (3) public physical capital. This production function, written in labour intensive form, is:

$$Y_t = A \cdot \prod_{j=1}^{n} k_j^{a_j} \quad (1)$$

The definitions are:

Y_t = Output per worker

k_j = Type j capital per worker

a_j = Output elasticity of capital j

A = Other unspecified factors that may contribute to the production process

In a steady-state[4] log form, the Cobb-Douglas equation in (1) can be converted to the equation shown in (2) below:

$$\log\frac{Y_{2014}}{Y_{1970}} = b_0 \log Y_{1970} + b_1 \log\left(\frac{i_1}{\gamma+\lambda+\delta}\right) + b_2 \log\left(\frac{i_2}{\gamma+\lambda+\delta}\right) + b_3 \log\left(\frac{i_3}{\gamma+\lambda+\delta}\right) + c \quad (2)$$

The dataset evaluates the period 1970 – 2014 and covers 139 economies. The definitions and sources of data are:

y_t = Gross domestic product per capita, in billions of constant 2011 international dollars. Data from the IMF Investment and Capital Stock Dataset, 2017

i_1 = 1970 – 2014 average ratio of private investment (gross fixed capital formation) to GDP, in billions of constant 2011 international dollars to output. Data from the IMF Investment and Capital Stock Dataset, 2017

[4] In the steady state, where capital stocks stabilises, the level of gross investment in each of the various types of capital is given by $i_j \cdot y = (\gamma + \lambda + \delta) \cdot k_j$ where i_j = share of output devoted to gross investment in type j capital. (Aschauer, 2000, p.392). This equation is based on the law of motion for capital from the Solow (1956) growth model.

i_2 = 1970 – 2015 average gross secondary enrolment rates. Data from Lutz, Goujon, KC, Stonawski, and Stilianakis (Eds.) (2018)

i_3 = 1970 – 2014 average ratio of general government investment (gross fixed capital formation) to GDP, in billions of constant 2011 international dollars to output. Data from the IMF Investment and Capital Stock Dataset, 2017

$\gamma + \delta$ = rate of technological progress plus depreciation assumed to be constant at 5% per year following Aschauer (2000)

λ = average annual growth rate of population. Data from the Penn World Table Version 9.1

c = constant

Following Aschauer (2000), the coefficients b_j representing the effect of changes in the steady state levels of type j capital on the transitional growth rate, are given by:

$$b_j = -\frac{a_j \cdot b_0}{1 - \sum_j a_j}, \quad j = 1, 2, \ldots, n \qquad (3)$$

The following equation can be derived to calculate the output elasticities of capital:

$$a_j = \frac{b_j}{\sum_j b_j - b_0}, \quad j = 1, 2, \ldots, n \qquad (4)$$

Estimation – Descriptive Statistics

Table 2 provides the summary statistics for the variables used in the regression. As expected, the average output in 2014 (USD 18.2 trillion) is markedly higher than that in 1970 (USD 11.4 trillion). However, in terms of standard deviations, the latter is higher, indicating that the output of economies differs from the mean output more extensively in 1970 than 2014. In the case of capital investment, human capital has the largest standard deviation of 0.16, indicating that human capital is the most dispersed among the three types of capital.

When disaggregated by development levels, the sample of 139 economies is composed primarily of emerging market economies, followed by low-income developing and advanced economies (Table 3). In terms of average output level, those of advanced economies in 1970 is lower than that of emerging market economies, which indicates signs of catching up by some economies. In the case of capital investments, the advanced economies register the highest average output for both private capital investment and human capital investment. However, they trail the low-

Table 2: Summary statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Y_{2014}	139	18200.61	20502.76	606.51	149378.10
Y_{1970}	139	11351.73	29654.84	381.58	238519.60
i_1	139	0.14	0.07	0.02	0.34
i_2	139	0.22	0.16	0.01	0.66
i_3	139	0.06	0.04	0.01	0.20

Table 3: Sample statistics based on developmental level (mean)

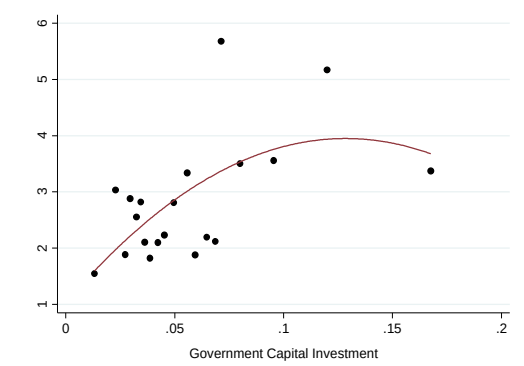
Development Level	Proportion of Sample	Y_{2014}	Y_{1970}	i_1	i_2	i_3
Low-income developing economies	33.8%	2852.48	1837.18	0.09	0.09	0.06
Emerging market economies	45.3%	19129.67	16350.68	0.14	0.23	0.06
Advanced economies	20.9%	41056.89	15912.07	0.20	0.42	0.05

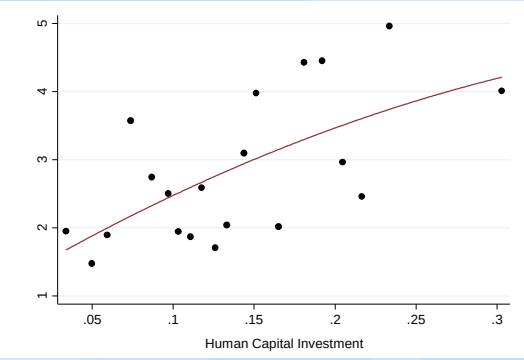
income developing and emerging market economies in public capital investment.

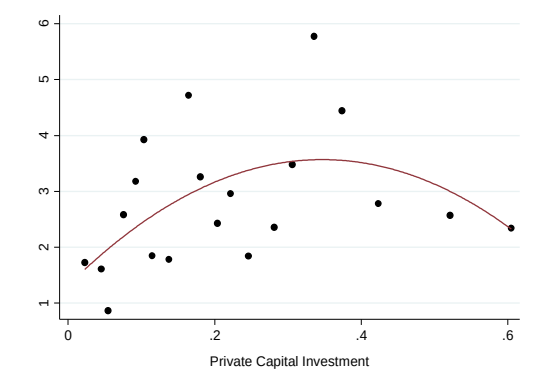
Multi-collinearity has been tested for and is not found to be an issue within this model.

Figure 1 illustrates binned scatterplots of the capital variables used in the regression against the change in output. In general, all three types of capital show a positive relationship with output at low levels of investment. At higher levels of investment, public and private capital may experience diminishing returns with the predicted trend in both graphs concaving downwards. Human capital investment on the other hand, continues to trend upwards although the data is found to be more dispersed.

Figure 1: Relationship between output and capital investment







Source: APEC Secretariat – Policy Support Unit Calculations
Notes: The graphs above illustrate binned scatterplots that group data points into bins before calculating an aggregate statistic to summarize each bin. A best fit quadratic line is then fitted based on these data points.[5]

Estimation – Regression Results

Table 4 illustrates the regression analysis investigating the impact of capital investment on output based on the three models explained below; showing the coefficients of b_j and a_j from equations (3) and (4). The results are as expected: the coefficients of capital investment register positive signs while that of the 1970 level of output displays a negative sign. This shows that economies with relatively low levels of output per capita in 1970 grow at a relatively faster rate (i.e. the convergence hypothesis).

Model 1, consisting of only private capital (as measured by i_1) as an explanatory variable, finds a 10% increase in private capital stock ratio to correspondingly increase output per capita by 6.7% over four decades. The implied output elasticity of private capital is 0.71. With the addition of human capital (i_2) in **Model 2**, a similar 10% increase in private capital will increase output per capita by only 3.6% over four decades; with an implied output elasticity of 0.30. Among the regression models, **Model 3** includes public capital (i_3) and has the highest explanatory power which is estimated to be 50% (Table 4)[6]. Model 3 shows that human capital (i_2) exerts a stronger influence on output per capita than private (i_1) and public capital (i_3). A 10% increase in human capital is

[5] More explanation on binned scatterplots is available at: https://michaelstepner.com/binscatter/

[6] The term R^2 is a statistical measures meant to serve as an indicator for the degree of fit.

Table 4: Impact of capital investment on output, 1970 – 2014

	All Economies			Only low income developing and emerging market economies
VARIABLES	**Model 1**	**Model 2**	**Model 3**	**Model 4**
y_{1970}	-0.271***	-0.418***	-0.410***	-0.393***
	(0.0414)	(0.0506)	(0.0497)	(0.0517)
$\log(\frac{i_1}{\gamma+\lambda+\delta})$	0.671***	0.358***	0.291***	0.235**
	(0.0814)	(0.0964)	(0.0914)	(0.0989)
Output elasticity	0.712	0.297	0.219	0.187
$\log(\frac{i_2}{\gamma+\lambda+\delta})$		0.430***	0.440***	0.439***
		(0.0636)	(0.0597)	(0.0597)
Output elasticity		0.357	0.331	0.350
$\log(\frac{i_3}{\gamma+\lambda+\delta})$			0.188**	0.189*
			(0.0932)	(0.0983)
Output elasticity			0.141	0.150
Constant	2.662***	3.700***	3.728***	3.592***
	(0.359)	(0.407)	(0.398)	(0.417)
Observations	139	139	139	110
Adjusted R-squared	0.342	0.481	0.500	0.476

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

expected to increase output per capita by 4.4%, while a similar change in private and public capital will increase output by 2.9% and 1.9%, respectively. Further comparison can be carried out in terms of output elasticity. Model 3 shows human capital to have the highest return with an output elasticity of 33.1%, followed by private capital (21.9%) and public capital (14.1%).

To better compare with the results by Aschauer (2000) which covers low – and middle-income economies, Model 4 restricts the dataset to only low-income developing and emerging market economies.

The results are as expected and similar to earlier results: human capital has the largest impact on output per capita. However, Aschauer (2000) finds private capital to be the most important form of investment contributing to economic growth, while our regression find it to be important but less so in comparison to human capital. Nevertheless, both studies find positive returns for all three types of capital.

Concluding Remarks

The results from this study highlight some key takeaways for policymakers to consider, specifically the following:

- **Human capital investment is an important component of economic growth**

The regression results show that human capital investment has the largest impact on economic growth across the 139 economies. It is estimated that a 10% increase in human capital investment is likely to boost growth by between 4.3% and 4.4%. In the 2017 APEC Economic Policy Report, the region was identified to have significant gaps in human capital development with a third of the region's economies registering net secondary enrolment rates below 60%. One of its recommendations was to improve access to and quality of education and training. (APEC, 2017). Likewise, economies have responded well to these gaps by

increasingly capitalising on this growth booster through skill development programmes to upgrade their workforce. Some examples in the APEC region include the Youth Employment and Skills Strategy by Canada to equip youths with relevant skills and help them gain paid work experience (Government of Canada, 2019) and Malaysia's Talent Corp initiative to diversify the skill sets of recent graduates (Tan & Tang, 2016).

- **Private and public capital investments have positive and significant impact on economic growth**

In recent years, there has been an increased attention on the decay of public infrastructure in advanced economies, which has been associated with the slowdown in infrastructure investment. Within the sample of economies covered in this study, public capital investment levels are low across the low-income developing, emerging market and advanced economies, with values ranging around 5% and 6% of GDP. On the other hand, private capital investment levels can reach 20% of GDP in advanced economies, 14% of GDP in emerging market economies, and 9% of GDP in low-income developing economies.

Private capital ownership can be seen as a complement to public capital. This is evident from the growing importance of PPPs in the provision of public infrastructure, which shows how private sector involvement could help governments to deliver infrastructure more efficiently. Additionally, focusing on 'core' infrastructures, such as highways, water and sewer lines and mass transit (Braun, 1998), will strengthen private investment productivity in other sectors that benefit from these core infrastructures. In short, core infrastructure capital can create an environment to facilitate private production (Berndt & Hansson, 1991).

This study finds that a 10% increase in investment in private and public capital will boost economic growth by 2.9% and 1.9%, respectively, from 1970 to 2014. It seems plausible that the impact of public infrastructure on growth could be stronger if the efficiency of public investment procurement is strengthened.

- **Measuring efficiency in infrastructure provision**

In 2014, then United States treasury secretary Larry Summers proposed that economies should embark on higher infrastructure investments to avoid long-term economic slump in the global economy, i.e. the secular stagnation hypothesis (Summers, L., 2014). Nevertheless, Ansar et al. (2016) cautions that scarce public resources should only be committed to infrastructure investment after considering risks such as potential cost overruns and benefit shortfalls. Flyvbjerg (2009) argues that ex ante estimates of costs and benefits are often overly optimistic compared with actual ex post costs and benefits. This is since large infrastructure projects often suffer from cost overruns, benefit shortfalls, and underestimation of risks, which ultimately result in 'survival of the unfittest'.

In terms of future scope of research, there may be value in evaluating the impact of different capital investment (i.e. 'core' infrastructures such as highways, telecommunications, and primary school education) on economic growth. Should such disaggregated data be available for the APEC region, more in-depth evaluations can be carried out to provide detailed sectoral analysis.

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