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Evidence of public capital spillovers and endogenous growth in Taiwan

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ABSTRACT

This study reaffirms the empirical evidence of public capital spillovers and endogenous growth by using data for the period 1966Q3–2012Q3 in Taiwan. Avoiding the use of a 100% depreciation rate for generating public and private capital stock series that is applied in some related studies, this study estimates these series by using disaggregate data of various investment assets and applying their individual depreciation rates, as calculated by Jorgenson and Stiroh (2000). The results show that, first, (per capita) output, private capital stock, and public capital stock cointegrated in the sample period. Second, the contribution of private capital to output is 50% higher than that of public capital. Third, in the presence of significant and sizeable public capital spillover effects, growth in Taiwan is strictly endogenous. Finally, the dynamic model with a cointegration equation helps in studying some sensible short-run properties of the model and bi-directional effects among variables.

1. Introduction

Economics profession as early as Arrow and Kurz (1970) had noticed that the role of public capital has different nature from private capital in fostering economic growth. In the series of studies collectively known as public capital debate, the seminal work of Aschauer (1989) conducted the first empirical testing for this hypothesis by estimating a single aggregate production function with factor inputs of private and public capital stock. Aschauer's study estimated a significantly large elasticity of output, 0.4, with respect to public capital in the United States. Otto and Voss (1994) and Kam and Wang (2008) found a similar estimation of a large share of public capital in Australia. The findings in this series of empirical studies are intuitive to our general knowledge of public capital, particularly when infrastructure capital—such as highways, sewage systems, electricity generating plants, and airports—is likely to be complementary to private capital in the production process.

To provide a theoretical foundation for the empirical estimation, Kam and Wang (2008) extended the deterministic growth model of Glomm and Ravikumar (1994) to a stochastic version with conventional private capital accumulation and public capital spillovers. Under the strict assumption that both private capital and public capital depreciate completely at the end of the period, they derived some testable equations and used data from Australia to conclude that the growth in Australia is strictly exogenous in the presence of significant and sizeable public capital spillover effects. Their theory-consistent empirical testing was similar to that conducted by Lau and Sin (1997), who investigated a similar issue for the United States.

However, this study differs from the existing series of studies in terms of the empirical relaxation of the assumption of a 100% depreciation rate in creating public and private capital stock series. Although this assumption is very unrealistic, previously mentioned studies such as Lau and Sin (1997) and Kam and Wang (2008) adopted it not only for mathematically solving the stochastic growth model with microfoundations but also for enabling the construction of a capital stock series directly from investment flow data. This unrealistic assumption seriously underestimates real capital stock series in both public and private sectors. Therefore, this study estimates public and private capital series by using disaggregate data on various investment assets and applying their individual depreciation rates, as calculated by Jorgenson and Stiroh (2000). This modification helps in obtaining some convincing evidence of public capital spillover effects and endogenous growth in Taiwan. In the process of economic development in Taiwan, the accumulation of government investment in the formation of public capital stock has played a crucial role in stimulating private investment and accelerating production efficiency. After the establishment of substantial infrastructure in the 1970s, the rapid growth experienced by this small open economy was said to be a “Taiwan miracle.” In addition, Taiwan differs from the United States and Australia in terms of the standard of living and geographic area. Therefore, examining the relationship between public capital spillovers and endogenous growth in Taiwan will add value to relevant literature, not only by facilitating a comparison of the empirical results obtained in this study with the evidence in large developed countries but also by serving as a reference for

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future empirical analysis in similar small open economies such as Hong Kong and Singapore.

The remainder of this paper is organized in the following manner. Section 2 reviews the theory-consistent empirical model derived from the stochastic growth model of Glomm and Ravikumar (1994), which motivates the time-series basis of the cointegration growth-accounting framework. Section 3 describes the aggregate data from Taiwan and how both series of private and public capital are estimated using the perpetual inventory method with the depreciation rates calculated by Jorgenson and Stiroh (2000). Section 4 presents the empirical analyses—including cointegration tests, Granger causality test, and the study of the short-run and impulse response analysis—using the structural model based on long-run parameter estimates. Section 5 concludes the paper.

2. Theory-consistent empirical model

Under a decentralized economy, the stochastic growth model of Kam and Wang (2008) sequentially solved the dynamic optimization problem for both private and public sectors. A representative household optimizes lifetime consumption paths by accumulating private capital stock with a given (exogenous) fiscal policy (such as the tax rate and the stock of public capital). In contrast, in the public sector, a benevolent social planner takes into account the household's optimization paths of consumption and private capital accumulation to implement an optimal tax rate path and accumulation of public capital stock. Their model begins from the following Cobb–Douglas aggregate production function:

$$Y_t = AK_t^{\alpha}\left[(1+x)^t L_t\right]^{1-\alpha}\widetilde{G}_t^{\theta}\epsilon_t^P; \alpha, \theta \in (0,1) \tag{1}$$

where Y_t, K_t, and L_t denote aggregate output, private capital stock, and labor input, respectively. $\widetilde{G}$ represents the congestion-adjusted public capital stock, which will be defined subsequently. x is the exogenous Harrod-neutral rate of technological progress; $A > 1$ is the total factor productivity; and the uncertainty of the production process is captured by the stochastic process that follows a normal distribution, denoted by $\epsilon_t^P \sim N(1, \sigma_P^2)$. This production process has increasing returns to scale with public capital stock as the input; thus, the magnitude of the spillover effects from the public sector depends on the size of its own share of capital stock, θ.

The congestion-adjusted public capital stock is different from non-rival and non-excludable public goods. Its contribution to the production process suffers from the use of factor inputs such as private capital and labor force. For example, a highway will be less productive if it is full of trucks (physical capital) and vehicle drivers (labors). To adjust for such congestion effects, the real public capital stock G is set in the following manner:

$$\widetilde{G}_t = \frac{G_t}{K_t^{\varphi}\left[(1+x)^t L_t\right]^{1-\varphi}}; \varphi \in (0,1) \tag{2}$$

where φ is the congestion parameter. $\varphi > 0.5$ when the level of rivalry and excludability of public capital from private capital is higher than that from labor input. Combining Eqs. (1) and (2) and dividing both sides of Eq. (1) by L_t, the following per-worker representation of the output equation is obtained:

$$y_t = A(1+x)^{\{1-[\alpha+(1-\varnothing)\theta]\}t} k_t^{\alpha-\theta\varphi} g_t^{\theta} \epsilon_t^P, \tag{3}$$

where the lower-case variables, y_t, k_t, and g_t, denote per-worker output, private capital stock, and public capital stock, respectively.

Capital accumulation with a 100% depreciation rate is unrealistic; however, it was initially assumed by Glomm and Ravikumar (1994) and also adopted by Kam and Wang (2008) for a solvable mathematical derivation (Glomm and Ravikumar, 1994) in both private and public sectors. Therefore, at every time point, private capital stock equals private investment flow (disposable income net of tax payment) in the previous period and is subject to a stochastic shock $\epsilon_t^K \sim N(1, \sigma_K^2)$ in the current period. Similarly, public capital stock equals total tax collected in the previous period and is also subject to a normalized shock $\epsilon_t^G \sim N(1, \sigma_G^2)$ in the current period. With an additional assumption that a representative household maximizes a log-linearized utility function by choosing optimal consumption paths, Kam and Wang (2008) demonstrated that a benevolent government will choose a time-invariant tax rate, τ_t, in this stochastic system[1]:

$$\tau_t = \beta\theta, \forall t, \text{ where } \beta \text{ is a discount factor.} \tag{4}$$

Let $\hat{k}_t = k_t/(1+x)^t$ stand for private capital per efficiency unit of labor; its law of motion with optimal tax rate from Eq. (4) can be expressed as

$$\hat{k}_{t+1} = [(1-\beta\theta)\,(\alpha-\theta\varphi)]^{1-\theta}\,\theta^{\theta}\beta A\hat{k}_t^{\alpha+(1-\varphi)\theta}\epsilon_t^p. \tag{5}$$

Eq. (5) implies that an economy can grow endogenously without relying on the exogenous Harrod-neutral rate of technological progress x if the following two conditions can be satisfied: $\alpha + (1-\varphi)\theta = 1$ and $[(1-\beta\theta)\,(\alpha-\theta\varphi)]^{1-\theta}\theta^{\theta}\beta A > 1$. With the satisfaction of the first condition and assuming $\epsilon_t^P = 1$; $\forall t$, the entire system exhibits a perpetual and constant growth rate in the following manner:

$$\gamma_y = \gamma_k = \gamma_g = x + [(1-\beta\theta)\,(\alpha-\theta\varphi)]^{1-\theta}\,\theta^{\theta}\beta A - 1 \tag{6}$$

where γ_z represents the growth rate of variable z. Assuming that there is no exogenous technological progress (i.e., $x = 0$) and $[(1-\beta\theta)\,(\alpha-\theta\varphi)]^{1-\theta}\theta^{\theta}\beta A > 1$, strict endogenous growth due to public capital spillovers is supported in this economy. For example, if $x = 0$, $\alpha - \theta\varphi = 0.7$, $\theta = 0.3$, $A = 2.5$, and $\beta = 0.95$, then the growth rate is roughly equal to 2% for each time period.

On the other hand, if the sum of the shares of k and g is less than one (that is, $\alpha + (1-\varphi)\theta < 1$), an economy can only rely on a positive rate of exogenous technological progress to foster economic growth. In this case, Eq. (3) exhibits decreasing returns to scale; moreover, the output per worker will converge to a steady state without perpetual growth if $x = 0$.

The linearization of Eq. (3) yields theory-consistent regression for empirical estimation:

$$\ln y_t = \ln A + (\alpha-\theta\varphi)\ln k_t + \theta \ln g_t + \{1-[\alpha+(1-\varphi)\theta]\}xt + \ln\epsilon_t^P. \tag{7}$$

Thus, one can estimate Eq. (7) with any time-series data to determine a country's growth scenario. Table 1 summarizes four variants of the steady-state scenario, depending on the empirical estimates of the parameters in the system.

Existing studies barely found the scenario of strict endogenous growth. For example, Lau and Sin (1997) used data from 1925 to 1989 for the United States and found that the estimate of $(\alpha - \theta\varphi) + \theta$ is approximately 0.54. Otto and Voss (1994) found this estimate to be 0.34 by using data from Australia, and Kam and Wang (2008) found it to be 0.50 by using more updated Australian data. Although these two countries have ever-accumulating public capital stock, their economic growth rates rely solely on exogenous technological progress. A large geographic area may be a possible explanation; thus, taking into account the geographic scope of a country, the theory-consistent approach described in this section may obtain a more desirable result in which public capital spillovers create strict endogenous growth in a

[1] This optimal tax rate path was solved by Glomm and Ravikumar (1994) in their deterministic growth model. Similarly, in the first endogenous growth model proposed by Barro (1990) that nested the public sector, government investment was treated as a flow variable with non-excludability and non-rivalry. In Barro's Ramsey solutions, the optimal tax rate for financing government expenditure was its own share in the production process in both decentralized and social planning economies.