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Is public capital really productive? A methodological reappraisal ☆

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ABSTRACT

We present an evaluation of the main empirical approaches used in the literature to estimate the contribution of public capital stock to growth and private factors' productivity. Based on a simple stochastic general equilibrium model, built as to reproduce the main long-run relations observed in US post-war historical data, we show that the production function approach may not be reliable to estimate this contribution. Our analysis reveals that this approach largely overestimates the public capital elasticity, given the presence of a common stochastic trend shared by all non-stationary inputs.

1. Introduction

Economists and political leaders generally consider public infrastructure investments as a way of sparking economic development over the forthcoming decades. The basic idea is that these investments may enhance the productivity of private factors, and thereby stimulate private investment expenditure and production. However, if this view seems to be broadly accepted, the conclusions are not so clear-cut when it comes to measuring these effects. Two methodological approaches were widely used for estimating the productive contribution of infrastructures (see Romp and De Haan, 2007 for a survey). The first and most popular consists in estimating an expanded production function, including the public capital stock as input, specified in *levels*. Applied to aggregate series (Aschauer, 1989; Munnell, 1990), this method leads to strikingly high estimates of public capital elasticity, and consequently to implicit rates of return much higher than those observed on the private capital.

The second approach consists in estimating the same type of production function, but with a specification in *first differences*. Indeed, several empirical studies on American data (Aaron, 1990; Tatom, 1991; Sturm and De Haan, 1995; Crowder and Himarios, 1997), highlighted the absence of a cointegrating relationship between output and (public and private) inputs. Such an outcome implies that the total productivity of private factors is non-stationary (as most macroeconomic series), and thus the technological function can not be considered as a long term relationship. However, when this issue is tackled by estimating the production function in first differences, the estimated elasticity of public capital is often not significantly different from zero. This not only challenges the validity of Aschauer's (1989) findings, but also casts doubt on the existence of a macroeconomic productive effect of public infrastructures (Tatom, 1991).

This large range observed in the empirical results leads us to suggest a sensitivity analysis of these approaches. More precisely, the aim of this paper is to identify the bias sources which could affect the estimates of public capital elasticity and to assess the magnitude of these biases.[1] To this end, we consider a theoretical Data Generating Process (DGP) in line with the standard theoretical representations of growth and public capital productivity. The DGP consists of a very usual dynamic stochastic general equilibrium (DSGE) model directly derived from the growth model coined by Barro (1990). This model was built such as to reproduce, under an appropriate calibration, the dynamics of the US economy, as this

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[1] Our general approach that consists in evaluating both theoretically and empirically the main empirical approaches generally used to estimate the efficiency of public capital is in line with recent works that aim at evaluating the efficiency of public good provision in general. For example, in another context, De Witte and Geys (2013) show that citizens' coproduction of public services requires a careful reassessment of how we approach the measurement of productive efficiency in public service delivery, as using observable outcomes (e.g., library circulation, school results, *etc.*) as output indicators is inappropriate and leads to biased estimates.

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was the case in the early DSGE literature. However, contrary to the moment-based strategy adopted in the DSGE literature, we give special attention to a particularly crucial neglected dimension, namely the stationarity (non-stationarity/cointegration) properties of the series.[2]

We proceed as follows. First, we show that our DGP (i.e. our DSGE model) has a reduced form that simply corresponds to a constrained *VARIMA*. Next, given this *VARIMA* form, we derive the exact asymptotic distribution of the estimators of the public capital elasticity for various regression models usually used in the empirical literature. This analysis allows deriving the asymptotic bias of the estimators, and more interestingly, explaining the source of this bias. To the best of our knowledge, it constitutes the first attempt to provide a theoretical explanation of the empirical puzzle of the public capital productivity estimates. Finally, we investigate the finite sample bias, using Monte Carlo simulations, by comparing the estimators on simulated data and the calibrated value of public capital elasticity.[3]

Our results are the following. It first appears that the standard approach, relying on the direct estimate of the production function specified in levels, leads to an overestimation of the productive contribution of public infrastructures. Given the long-run properties of the theoretical model, we prove that this asymptotic bias is due to the presence of a stochastic common trend between private and public capital stocks, which imposes a fallacious asymptotic constraint forcing the public capital elasticity to be equal to the labor elasticity.[4] Second, the finite sample analysis based on Monte Carlo simulations confirms our theoretical findings. Even for relatively small sample sizes, the estimation on levels leads to a positive bias of the public capital elasticity and the estimation on first differences leads to a downward bias and to a reduction in the power of standard tests. Consequently, our analysis shows that first differencing the data leads to spurious inferences about the public capital elasticity.

These findings imply that the correct strategy to estimate the public capital elasticity consists in withdrawing the common stochastic trends from the non-stationary regressors (and only for these regressors). On the contrary, the approach based on first differences, proposed by Tatom (1991), leads to differentiate the dependent variable and all the regressors. Our paper suggests that this transformation has not to be done for the dependent variable and for all the regressors, but only for the regressors that share the common stochastic trend.

The paper is organized as follows. Section 2 surveys the empirical puzzle on the infrastructure returns. Section 3 presents the DSGE model, which is then written in an econometric form in Section 4. Section 5 is devoted to characterizing the analytical properties of estimators, while Section 6 provides finite sample results based on Monte Carlo simulations, and Section 7 concludes.

2. The empirical puzzle

During the late 1980s and the 1990s, a huge empirical literature has been devoted to the estimation of the rate of return on public capital (see Gramlich, 1994, for a survey). If we stick to the most influential studies, namely those based on time series, two methodological approaches were employed. First, the direct estimate of a production function expanded to the stock of public capital. Applied to aggregate data, with a specification in *level* of the production function, this method generally tends to prove the existence of an important productive contribution of public infrastructures. Indeed, since the seminal article of Aschauer (1989), many empirical studies embraced this methodology and outlined statistically significant estimated elasticities, on American data as well as on OECD data sets (see Table 1).

However, it should be noticed that in these estimations the productive contributions of private factors are generally lower than the share of their respective remuneration in added value. Besides, in Aschauer (1989); Eisner (1994); Vijverberg et al. (1997) or Sturm and De Haan (1995), the elasticity of private capital is lower than that of public capital or equal to it, while the elasticity of labor is even negative under some specifications considered by Munnell (1990) or Sturm and De Haan (1995). Furthermore, if we accept such estimates as relevant, the implied annual marginal yield of public capital is strikingly high. For example, Tatom (1991) or Gramlich (1994) computed, on the basis of elasticities estimated by Aschauer (1989), that the annual marginal productivity of public infrastructures would lie between 75% in 1970 and more than 100% in 1991, meaning that "*one unit of government capital pays for itself in terms of higher output in a year or less, which does strike one as implausible*" (Gramlich, 1994, page 1186).

In an attempt to explore the robustness of these findings, several authors, including Tatom (1991) or Gramlich (1994), highlighted two bias sources which could partly explain them. First, the potential presence of an endogeneity bias, stemming from the simultaneous determination of the level of production factors and the total productivity of these factors (Gramlich, 1994). The second source of misspecification could come from the absence of a cointegrating relationship. Indeed, with the exception of Lau and Sin (1997), most empirical studies based on American data fail to find a cointegrating relationship for the aggregated production function extended to public capital (see, for example, Tatom, 1991; Sturm and De Haan, 1995; or Crowder and Himarios, 1997). In this context, the "spurious regression" configuration can lead to a fallacious inference about the estimated parameters of the production function and particularly about the estimate of public capital elasticity, and could also induce second order biases when innovations of integrated processes are correlated.

An alternative to the level specification is to consider the production function in the *first difference*. However, the use of first differenced data, justified in the case of non-stationary and non-cointegrated series, generally leads to opposites findings, namely the rejection of the hypothesis of positive effects of public infrastructures on the productivity of private factors (see evidence in Table 2). Although the use of this specification seems to clearly indicate important biases in Aschauer's (1989) estimates, several authors, including the influential work of Munnell (1992), suggested that first differencing is not, in this case, the suitable method because it destroys all long-term relations that may exist among the production function variables.

These observations lead us to question the specification of the production function. If the production function is a cointegrating relationship, then the total factor productivity (TFP) is, by definition, covariance stationary. However, there is no reason to believe *a priori* that the Solow's residual can be represented as a stationary process (namely, contrary to most macroeconomic series), all the more that standard models of stochastic growth typically attribute the non-stationarity of the economy to the exogenous process of Solow's residual. In these models, the cointegration between factors and output results from the balanced growth hypothesis and

[2] According to Crowder and Himarios (1997), these properties are: (i) all series, except employment, are integrated I (1), but (ii) the ratios of these integrated series are stationary. In other words, production, public and private investment, public and private capital stocks are non stationary, but all these couples of series are cointegrated with a cointegrating vector defined by $(1, -1)$. Since our DGP reproduces these properties, it can be considered as an accurate representation of the US economy (due to our calibration) and can be extended to other economies (using appropriate calibration).

[3] We would like to thank the Referees for this suggestion.

[4] In addition, we emphasize a second bias source, namely the traditional endogeneity bias due to the simultaneous determination of public capital and private factor productivity.