Theoretical approaches and empirical results on the economic effects of public investment

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Abstract

This paper presents an extensive discussion of the literature on the economic impact of public investment on infrastructures both for the US and internationally. The paper expands the focus of previous surveys by concentrating on empirical econometric studies about the effects of public investment as well as on the evolution of the methodological issues motivated by criticisms.

From the empirical results reported in the literature, there is a general evidence that suggests that nonmilitary public investment contributes significantly to output growth and production costs reduction, not only as a direct input to production function, but also by its influence on private factors of production. This evidence raises the importance of the endogeneity of private inputs and also public investment, as well as the direction of causality. The studies performed at sectoral and regional levels show very often unbalanced effects from public investment. Moreover, as the geographic focus narrows, the estimated elasticities with respect to public capital become smaller, which suggests the existence of spillover effects.

Keywords: public investment, production function, cost function, VAR models.

Resumo

O artigo é um "survey" da literatura sobre o impacto económico do investimento público em infra-estruturas nos Estados Unidos e noutros países. O artigo expande a análise de "surveys" anteriores ao centrar a análise nos resultados dos estudos econométricos aplicados, bem como ao enfatizar a trajectória que a investigação seguiu em resultado da identificação de problemas metodológicos de base.

De uma forma geral, os resultados empíricos sugerem que o investimento público não militar contribui significativamente para o crescimento do produto e para a redução dos custos de produção, quer como factor produtivo, quer através da influência que exerce nos restantes factores. Esta evidência reforça a importância da endogeneidade dos factores de produção privados e do investimento público e ainda a questão da direcção da causalidade. Os estudos realizados aos níveis sectorial e regional apresentam, frequentemente, efeitos heterogéneos do investimento público. Acresce ainda que quanto maior a desagregação geográfica da análise, menores tendem a ser a elasticidades estimadas. Tal situação sugere a existência de efeitos de "network".

Palavras-chave: investimento público, função de produção, função de custo, modelos VAR.

1. Introduction

In the US, the slowdown of output growth in the 70s was justified by the slowdown of public investment in infrastructures. In several African countries, the absence of infrastructures network seems to condemn the entire continent to poverty. In the Eastern European countries, the economies recovery seems to depend, in large scale, from the reconstruction of obsolete infrastructures. In the particular case of Germany, the unification process that followed the Berlin Wall fall down, motivated the interest for the investigation about the effects of public investment in infrastructures since about 70% of the infrastructures in the former East Germany was obsolete. It is not surprising that in the European Union, the development strategy, in the last two decades, of the countries evolved in a process of real convergence, like Spain, Greece, Ireland and Portugal, has been based on the execution of public investment projects in infrastructures.

By all these reasons, the last two decades have witnessed a fast growing body of literature focusing on the role of public investment in infrastructures. In this literature, the debate has centered around four major issues. The first is the issue of the possible existence of an infrastructure deficit, reflecting a slowdown in infrastructure spending in the recent past. The second issue is the determination of the relevance of infrastructure spending on economic performance, and, in particular, on the determination of whether or not public capital is productive. The third issue pertains to the relationship between the productivity of private and public capital and, in particular, on the determination of whether or not public capital is more productive than private capital. Finally, the fourth issue has to do with the feasibility and desirability of using infrastructure spending as a counter-cyclical tool to promote short-term economic policies. These very pertinent questions raise many controversial and complex issues (see Hulten and Schwab (1993) for a detailed discussion of these four issues).

In this paper we focus on the empirical literature addressing the second issue, i.e., the econometric determination of the effects of public investment on private sector performance. This means that we focus exclusively on econometric studies. We consider studies on the contribution of both aggregate and disaggregate public capital to private economic sector performance; that is, studies that analyze the question of whether public capital is productive, which types of public capital are more productive, and the transmission channels. Two important surveys on the effects of infrastructure investment in the U.S. are Munnell (1992) and Gramlich (1994). In surveying this empirical literature we follow the methodological econometric debate that successively has led to the estimation of production functions, cost functions and, more recently, VAR models including public capital variables.

The comparison of the results in the empirical literature on the determination of the impact of infrastructure spending is a rather difficult matter. There are three main reasons for that. First, the literature has used a variety of econometric techniques, which makes similar terms, like elasticity or marginal product not always comparable. Also, most of the literature on the effects of public infrastructures focuses on the effects of public

investment on private output and is not designed to address its impact on private inputs. Second, the definitions of public investment used in the literature vary wildly. This difficulty assumes larger proportions in international comparisons. Finally, the focus of the analysis is not always on the private sector. Often it is a regional or an industrial focus.

This survey is organized as follows. We start by analyzing results for the U.S. economy, by level of data aggregation and then we review other international literature on this subject. The present discussion ends with the enumeration of the main conclusions of the literature, highlighting the consensual and non-consensual features still in debate.

2. Empirical Evidence for the U.S.

Recently, we have witnessed a fast growing body of literature devoted to the investigation of the impact of public infrastructure on the performance of the private sector. This explosion of research has yielded a variety of estimates providing supporting and non-supporting evidence on public capital's role. However, most of the literature can be traced back to the work of Aschauer (1989a, 1989b) on the relation between public sector capital accumulation and private sector performance. The key message of Aschauer's papers is that the stock of public infrastructure, as well as the stock of private capital, may be a key in explaining changes in the U.S. private sector output.

Before Aschauer's work, and in a different context, Arrow and Kurz (1970), Eisner (1980) and Schultze (1981) had already suggested that the apparent slowdown in U.S. productivity growth in the 1970s might be attributed to the slowdown in the growth of government capital relative to private capital. This conjecture was later confirmed by several studies (see Holtz-Eakin (1988), and Ram and Ramsey (1989)) which suggest a significant impact of public capital on private sector productivity. The reason why Aschauer's and not other's findings had a greater impact and stimulated much of the subsequent research, was the unexpected result contained in his paper (Aschauer (1989a)) that the elasticity of private output with respect to private capital was between 0.34 and 0.39. These estimates imply an annual marginal productivity of public capital of about 70 cents on the dollar, which is approximately three times as great as the estimated return to private capital. It is also much greater than previous estimates of the marginal products of public capital. The work of Aschauer generated immediately a large body of supporting literature (see Munnell (1990), Holtz-Eakin (1989) and Eisner (1991)).

This early body of literature follows in one way or another the terms of the debate and the methodological approach set forth in Aschauer's seminal contributions. In fact, the debate on whether public capital is productive has focused on the size of the elasticity of output with respect to public capital as implied by estimates, in a univariate and static framework of production functions relating labor, private capital and public capital, to output.

In practice, this relation may be expressed as:

$$Y_{it} = A_{it}^{*} \cdot F\left(L_{it}, K_{it}, G_{it}\right), \qquad (2.1)$$

where Yit represents the level of private output of a country, region or sector i in period t; Lit represents the level of employment; Kit is the stock of private capital; Git represents the stock of public capital; and Ait* is an index intended to reflect factors that affect output like the productive capacity utilization rate, the evolution of technology and other non observable factors, like geographic localization, climate and natural resources. By this index it is possible to capture all deviations of output from its equilibrium level, which are related to the intensity of demand.

Although the general implication of the results about the role of public capital to production accords with economic theory, the magnitude of the effects emerged from aggregated time series studies has generated a raft of criticisms. On one side there are the arguments that the estimated impact of public capital on private sector output is implausible high. This issue is even more serious since those studies conclude that the stronger effects come from state and local infrastructure and, in particular core infrastructure, which was, in 1988, about one half of the total state and local nonmilitary public capital. Furthermore, it is hard to accept that public capital's impact on private output is greater than that of private capital, considering that part of the effects goes to social and welfare goals, not reflected in output variations. This skepticism is also reinforced by the large difference of results magnitude between aggregate and regional studies. The last studies provide lower and more acceptable estimates. Munnell (1992) recognizes that the coefficients for public capital tend to be smaller as the geographic area decreases in size, from the national level to regional and state levels. This situation tends to suggest that the spillover benefits from infrastructure investment are not completely captured when tested in a region smaller than the national area.

In a different vein, several studies raised several econometric problems that could have justified those incredible high estimates in the aggregate studies. A first problem has to do with stochastic trends. Jorgenson (1991) shows that after correcting for non-stationarity there is conflicting evidence on the effects of public capital on output.

A second problem has to do with misspecification due to missing variables that might be correlated with the stock of public capital, like energy and investment and development investments. In this context, some papers (Aaron (1990) and Tatom (1991)) provide a comparative analysis by re-estimating Aschauer's specification with the inclusion of other variables. These authors conclude that the earlier empirical results which are based on the production function approach are built on "fragile statistical foundations" and should be viewed with extreme skepticism. The advice is toward the importance of undertake careful analysis with other functional forms and other variables when the results seem outlandish, as was the case of previous studies.

A third econometric problem concerns the direction of causality between the growth rate of infrastructure capital and the growth rate of private output. The general conclusion is that causation may be more from output to infrastructure capital.

From all this discussion, on methodological issues, there are two main open aspects for which the production function approach is not able to give an answer. First, there is the question of the potential simultaneity of private sector variables. In a related vein, the potential endogeneity of public capital, being affected by the private sector variables is also a concern. Second, the production function approach is static in nature, accounting only for the contemporaneous relations between inputs levels and the output level. The past values of variables, being ignored, are considered not relevant to explain current variations, which is a priori a very strong assumption making difficult the identification of the whole spectrum of effects of public capital on output.

The cost and profit functions approaches are developed within a multivariate context framework with the estimation of the dual cost and profit functions and derived input demand systems. These approaches provide, therefore, a clear answer to the first problem above mentioned regarding the simultaneity of private variables. For firm i, the optimization problem may be expressed as a cost minimization (or a profit maximization), given the inputs prices and the output level. This condition may be stated as:

$$\begin{aligned} &\underset{K_i,L_i,M_i}{Min} \quad C_i = w_i L_i + r_i K_i + z_i M_i \\ &s.a. \qquad Y_i = F\left(L_i, K_i, M_i, A^*, G\right) \end{aligned} \tag{2.2}$$

where i is an index for firm i; C represents the production costs; w, r and z represent prices of labor, private capital and intermediate inputs, respectively; Li, Ki and Mi represent quantities of labor, private capital and intermediate inputs, respectively.

The total effect of public capital on output is measured by the magnitude of the production cost reduction due to an increase of the level of public capital, considering the public capital's effects on the demand for private sector inputs. The signs of these indirect effects provide information about the nature of the relationships between inputs. The effect of public capital, expressed in terms of cost reduction corresponds to the cost side concept equivalent to the marginal product in the production function framework, and it is seen as a shadow price, or a proxy of public capital's true market price.

Within this context, Lynde and Richmond (1991) estimate translog cost functions, while Lynde and Richmond (1993) estimate translog profit functions. All of them support Aschauer's results on the important role of public capital infrastructure on the productivity of private sector.

Nevertheless, the cost and profit functions approaches do not eliminate completely the problem of possible endogeneity of variables. Although private inputs are no longer exogenous to the level of output, and the indirect effects of public capital on output are

taken into account, public investment continues to be considered an exogenous variable, not being affected by private sector variables. That is, the public capital's endogeneity remains unsolved and the relationship between public investment and output continues to be unidirectional. Also, the cost and profit functions approaches remain static in nature, not accounting for the whole effects of lagged shocks in variables.

The recognition of the importance of considering dynamic elements and the potential reverse causation from output to public capital led to the adoption of the Vector Autoregressive Model (VAR) approach, as an alternative line of research. This methodology was pursued by Pereira and Flores (1999) and Pereira (2000, 2001a, 2001b). In this context, a VAR model is estimated, in which a limited number of variables is distinguished, and where each one is explained by their own and other remaining variables past values. The model, of order p to be estimated, VAR(p), may be represented, in very general terms, by the following equation:

$$x_t = a_0 + a_1 t + \beta_1 x_{t-1} + \beta_2 x_{t-2} + ... + \beta_p x_{t-p} + ECT_t + e_t , \qquad (2.3)$$

where xt-i are vectors of the endogenous variables under consideration; i are matrices of parameters, with i = 1, ..., p; a0 and a1 are vectors of deterministic components; ECTt is the error correction term; et is a vector of residuals; and p is the order of the model.

The adoption of the VAR approach makes more difficult the comparison of results with those obtained within the context of other approaches. Besides the reasons already mentioned like differences in data and in the focus of the analysis, now similar terms like elasticity and marginal product are not comparable with the way such terms are used in the context of production and cost functions approaches. Within the VAR approach, these concepts include all the dynamic feedbacks among the variables. That is, they measure both the direct effects of public investment on output and the indirect effects of public investment on output, through changes in the evolution of private inputs. All the above mentioned studies, despite the adoption of different measures of variables, find statistical significant direct and indirect effects of public input on private sector output.

Studies with a sectoral focus are not abundant. The reason is probably due to the difficulties inherent in getting the necessary data. This explains also the fact why most studies concentrate on analyzing specific sectors, in particular on manufacturing. The studies range from those using the production function approach to those which estimate cost functions. Costa et al. (1987), Fernald (1993) and Pinnoi (1992) estimate a production function, while Holleyman (1996) and Nadiri and Mamuneas (1994, 1996) adopt the cost function estimation.

The general conclusion is that the estimated elasticities tend to be smaller than the ones estimated by Aschauer, and that public capital seems to affect industries differently. Also, industries react differently to different components of public infrastructure. The evidence provides support to the conclusion that, in general, manufacturing industries

seem to beneficiate from public investment, in particular from investments in highways, public buildings and water and sewer systems. On the other side, the agriculture sector, traditionally a declining sector, does not seem to take many dividends. On the indirect effects of public capital on output, the results are mixed and once more strictly connected to each industry characteristics.

Once more, most of the literature does not address the total final effects of public capital on output, since public capital remains an exogenous variable not being affected by shocks in the private variables. Also, these studies remain static in nature. In fact, the functions specifications do not allow for lagged effects on variables. However, Pereira and Andraz (2003a) is probably the first study to estimate the total effects of public investment on private sector performance. The empirical results are based on VAR/ECM models for the US economy and for twelve industries covering the whole spectrum of economic activity in the US. Empirical results at the aggregate level indicate that public investment affects positively private inputs as well as private output. These aggregate results, however, hide a wide variety of industry-level effects. Indeed, empirical results suggest that public investment tends to shift the sectoral composition of employment toward construction and transportation and the composition of private investment toward manufacturing, public utilities, and communications. Furthermore, public investment tends to shift the composition of private output toward construction and durable manufacturing and to a lesser extent toward transportation and wholesale trade.

Aschauer's work has also inspired research on the impact of public capital formation with a regional, state and metropolitan focus. Using data sets to estimate nation-wide production functions, different papers provide evidence that supports Aschauer's conclusion. Among them are the studies of Eberts (1986, 1990b), Duffy-Deno and Eberts (1986), and Costa et al. (1987).

The evidence reported by studies using regional, state and local U.S. data does not completely eliminate the divergence of estimates on the impact of public capital on production. Nevertheless, the estimated effects are lower and more acceptable than the effects reported by studies using aggregate national level data. The main conclusion of this literature seems to be, paraphrasing Garcia-Milà et al. (1996), that no evidence of a positive linkage between public capital and private output has been found within the production function framework.

One possible explanation for the inconclusive nature of this literature on the regional effects of public capital is that it ignores spillover effects (see, for example, Boarnet (1998)). Indeed, it could be argued that spillover effects should be an integral part of the analysis of the regional impact of public capital formation. The positive effects of public capital formation in a region can be induced by public infrastructures installed in the region itself. However, the better accessibility of a region can be generated by a greater public capital formation installed in other regions. This leads us to the concept of spillover effects of public capital formation, i.e., the fact that a region may benefit from public infrastructures installed elsewhere. Pereira and Andraz (2003b) deal directly with the possible existence of regional effects of public investment and the possible existence

of regional spillovers in the US. The empirical results suggest that only a small fraction of the aggregate effects of public investment can be captured by the direct effects in each state from public investment installed in the state itself. Indeed, these direct effects account for only 20% of the aggregate effects of public investment identified by the state-specific models. In turn, the spillover effects captured by the different states from public investment undertaken elsewhere correspond to 80% of the total aggregate effects of public investment. This establishes the empirical relevance of regional spillovers of public investment and suggests that many states benefit substantially from public investment undertaken outside their boundaries. In another paper, Pereira and Andraz (2004) expand this investigation on the regional incidence of the aggregate effects of public investment in the US taking into consideration the possible existence of regional spillovers. Empirical results allow one to establish several stylized facts. First, public investment affects private sector variables positively at the aggregate level as well as in most states. Second, overall, the spillover effects of public investment are at least 80% of the total effects for all private sector variables. Third, the spillovers have a clear geographical pattern in that they tend to be more important in western states and the corridor between the Great Lakes and the Gulf Coast. Fourth, public capital formation has contributed to concentration of private sector activity in the largest states.

Other reason for the divergence of results among studies has to do with the use of different methodologies. Most studies use the production function approach, which do not consider the indirect effects of public capital on output, through the impacts on labor and private capital. Further evidence is provided by studies of Morrison and Schwartz (1992, 1996) using the cost function approach. The authors conclude that public capital in motorways and in water and sewer systems provide important cost savings to manufacturing production, even if the state and region specific effects are excluded from analysis.

3. Other International Empirical Evidence

The problematic of the effects of public capital stock on a country's economic development became soon a worldwide concern, giving rise to several studies using data from other countries.

Most studies focus on one single country using different approaches ranging from the static single equation approach to the dynamic multi-equations approaches. Among these countries are the European countries, like Germany, Portugal, Spain, Sweden and the United Kingdom, where the problematic of the infrastructure endowment and its connection to regional economic development has assumed particular importance in the context of the European Union.

3.1 Empirical evidence for Germany

In Germany, the unification process that began with the fall-down of the Wall of Berlin, led to a special motivation for the analysis of the economic benefits of public infrastructure investment. Information about its impacts on private sector productivity has been considered absolutely necessary in order to allocate efficiently the public investment expenditures in the process of reconstructing, since about 70% of the infrastructure equipment of the ex-East Germany was, at that time, completely obsolete or scrapped.

Several papers use exclusively the cost function approach to detect the productivity effects of public capital in German economy. Among them are studies by Seitz and Licht (1995) and Seitz (1995).

Recognizing the importance of the spatial dimension of public investment, Seitz and Licht (1995) exploited regional differences in public capital provision to identify its impact on manufacturing industry in eleven states of the ex-West Germany. On average, there are important production cost savings in almost all regions due to public investment, especially in those that represent the largest areas. Using local data, for 85 cities, Seitz (1995) finds also important cost reductions. All these studies are consensual in that public and private capital are complements, that is, public infrastructure crowds-in private capital, and that public infrastructure is labor saving, that is public capital and labor are substitutes. This substitution relationship between public capital and labor is due to the fact that private inputs are found to be substitutes.

3.2. Empirical evidence for Portugal

The relative backwardness of the Portuguese economy vis a vis the European Union partners justified the establishment of structural funds programs after 1989, towards the development of a modern transportation infrastructure network, intended to improve the accessibility to interior regions and the insular islands, as well as to external markets, reducing therefore the impact from the country's peripheral geographic position relative to central European countries. Therefore, over the last decade, the strategy of development in Portugal has been largely based on the development of transportation infrastructures.

Interestingly enough, despite the central role of public infrastructure development and the intuitive knowledge of the relative scarcity of public infrastructures in Portugal, no information was available on the actual impact of this development strategy due to the absence of the most basic data on public investment itself.

However, the problem of the absence of a data set has now been largely solved. Indeed, the construction of a detailed database of public investment in transportation infrastructures was just recently concluded (see Pereira and Andraz (2001)). This database includes data on public investment in national roads, municipal roads, highways, ports,

airports, and railways, by districts and by regions (NUTS II) and covers the period from 1974 to 1998. The construction of this database opened the door to a long investigation process about the effects of public investment on the Portuguese economic performance. Pereira and Andraz (2005) present the evidence of such effects at national level and identify the most productive infrastructures. The evidence at sectoral level is presented by Pereira and Andraz (2003c), while the effects at regional level are presented by Pereira and Andraz (2003d). Those empirical studies reveal an important role of public investment in transportation infrastructures. The authors found that, in the long-term, aggregate public investment crowds in private investment as well as employment. More importantly, it has a positive effect on output. Indeed, one euro invested in public investment increases output in the long-term by 9.5 euros. This figure suggests that public investment pays for itself 3.3 times in the form of tax revenues over the life span of the public capital asset. Furthermore, the marginal product figure corresponds to a rate of return of 15.9%. This rate of return is clearly higher than the rate of return expected on private investment activities.

The analysis at sectoral level makes clear that the high positive aggregate effects of public investment on private employment mask a wide disparity of results at the industry level. In absolute terms, the industries that benefit the most from public investment are Construction, Trade, Transportation, Finance, Real Estate, and Services. In turn, relative to their size, the industries that benefit the most are Mining, Non-Metal Products, Metal Products, Construction, Restaurants, Transportation, and Finance, and, therefore, public investment tends to shift the industry mix toward these industries.

To identify the regional effects of public investment, the authors estimate region-specific VAR models relating private sector variables in a region to public investment located in the region itself. In doing so the authors find that while public investment in the region has positive effects for most regions, the sum across regions of these marginal products is well below the marginal product estimated for the whole country at the aggregate level. This suggests the possible existence of spillover effects from public investment in other regions.

To identify the actual relevance of the spillover effects of public investment, the authors estimate region-specific models relating private sector variables in the region to both regional public investment and public investment outside the region. In the regional models, both public investment in the region and public investment elsewhere are considered. Empirical results suggest that spillover effects are very important and account for at least 70% of the overall positive effects of public investment. These spillover effects have a clear geographical pattern in that they tend to be more important in the central regions, of Centro, Lisboa e Vale do Tejo and Alentejo and less so in the peripheral regions of Norte and Algarve. Furthermore, the empirical results suggest that although public investment has been a powerful instrument to promote long-term output growth, employment and private investment in Portugal, it does so in a way that is rather unbalanced across regions. The authors conclude that public investment has markedly contributed to the concentration of economic activity in the Lisboa e Vale do Tejo area, and therefore has contributed markedly to the macrocephalia of the country. Also, public

investment did not seem to have a significant impact to stem the tide of demographic desertification in Alentejo region.

3.3. Empirical evidence for Spain

The Spanish economy is analyzed by several studies, which oscillate on methodology between the production and the VAR approaches. Studies using the production function are, among others, Bajo and Sosvilla (1993), Garcia-Fontes and de la Figuera (1994), using aggregate data at national level. Mas et al. (1993, 1996) focus on regions. The studies using the VAR approach, also vary on the level of data aggregation. Flores et al. (1996) use data at the aggregate national level, Pereira and Roca (1998, 2001) report sectoral evidence, and Pereira and Roca (1999) focus on regions.

The studies of Mas et al. (1993, 1996) adopt Aschauer's (1989a) methodology based on partial equilibrium models, and find positive and statistically significant effects of public capital on private sector output, providing, therefore, supporting evidence of Aschauer's conclusion for Spain. The estimated output elasticities are 0.24 and 0.62, respectively. A much lower estimate, of 0.19, is reported by Bajo and Sosvilla (1993), which use the capital variables measured in terms of flows and considers all categories of public investment and not only the core public capital [as Argimón et al. (1993)] or the productive capital including transportation, hydraulic infrastructures and urban structures [as Mas et al. (1993)]. It is worthy to note that the result reported by Argimón et al. (1993) accords with the U.S. literature [Aschauer (1989a) and Munnell (1990)] on the large effects of core infrastructure, within which transports are included, on output. Once more, the estimates are substantially reduced, when the variables are corrected for non-stationarity.

The studies using the VAR approach may be considered an expansion of previous studies, in the sense that all public capital's effects on output, and not only the direct ones, are considered, by accounting for the possibility of variables endogeneity. Also, the possibility of considering lagged effects, represent a large step, relative the other studies, in providing the accurate estimates of the effects. All studies report positive effects of public capital on private output.

Regarding the indirect effects of public capital on output, all the mentioned studies are consensual about the evidence that public capital and private inputs are complements, that is, public infrastructure crowds-in private capital, and stimulate employment.

3.4. Empirical evidence for Sweden

The evidence for Sweden is provided by Berndt and Hansson (1992) and Andersson et al. (1990). Berndt and Hansson (1992), estimate a cost function for the

private and the manufacturing sectors and Andersson et al. (1990) estimate a regional production function. While the former uses core infrastructure as a measure of public investment, the last uses proxies for transportation and education investments. The general conclusion is that increases in public infrastructure capital reduce costs in private and manufacturing sectors and that total production is statistically influenced by road, airport and R&D capacity.

3.5. Empirical evidence for the United Kingdom

Lynde and Richmond (1993a) approach the problem of estimating the impact of public capital on production for the United Kingdom, by using the dual relationship between the production technology and the cost function. There is evidence of a significant role of public capital on the manufacturing sector production. The authors found that, in the period up to 1979, its contribution was of approximately the same order of magnitude as that of changes in the private capital-labor ratio, accounting on average for about 17% of productivity growth. However, during the 1980s, the contribution of public capital to productivity growth was negligible, even negative on average, and the total factor productivity accounted for more than 80% to productivity growth.

4. Summary and Concluding Remarks

The discussion of the effects of public investment on productivity has been developed through the estimating of either static uni-equation or dynamic multi-equations frameworks. The main aspects regarding the methodologies were described, as well as their main limitations and advantages. The cost function approach turned out to be the solution to some drawbacks inherent to production approach, in particular by the use of more information, like inputs prices, and by the possibility to consider the potential endogencity of inputs accommodating, thereby, feedback adjustments of private sector inputs and output in response to shocks in public capital stock. However, most studies using these approaches do not address the treatment of the statistical properties of time series data, with dramatic consequences on OLS estimators' properties.

The studies using the vector autoregressive model approach, in which public investment is analyzed within the framework of an economic system, not only explore statistical properties of data, but also consider in detail the question of the endogeneity of both private and public variables. In other words, the distinguish feature between this and the remaining approaches lays on the difference between total effect and partial effect of public capital on growth. Although it is possible to limit the focus of one's analysis and

not account for the full systemic effects of infrastructure investment, it is important to note the shortcomings of such exercise. Other important issue of VAR approach is its dynamic nature, by considering the influence of lagged effects. In turn, both production and cost functions approaches are static, considering only the effects of contemporaneous shocks.

The empirical results review calls attention to several aspects. First, there is a general evidence that suggests that nonmilitary public investment contributes significantly to output growth, production costs reduction and profit increases, not only in the U.S. but also in many other countries. Second, the magnitude of effects varies considerably among studies because of differences in econometric methodology, variable definitions, studies focus and the level of data aggregation. Third, the earlier studies, at national level, estimate output elasticities with respect to public infrastructure capital that range from about 0.30 to 0.40. It is believed that those estimates are too high, and are motivated by several methodological problems. There appears to be a convergence of opinions toward a much lower estimate at aggregate level. Fourth, as the geographic focus narrows, the estimated elasticities with respect to public capital become smaller. This result suggests the existence of spillover effects. Fifth, the inclusion of variables capturing region specific characteristics on productivity overturned results that had been previously obtained without their inclusion. Finally, sixth, public infrastructure investment contributes to productivity as a direct input to production function and by its influence on private factors of production. This evidence raises the importance of the endogeneity of inputs and points also to the direction of causality among inputs (public and private) and between output and public capital.

In addition, all studies have been challenged on conceptual and econometric grounds, from which we should take some considerations as guidelines to our research. Studies about the impact of public infrastructure investment should be based on flexible functional forms in order to accommodate the complex relationship between public capital and private sector inputs and output. Moreover, public infrastructure investment and private sector output are potentially inter-related and the simultaneous relation between them should be fully considered. Before the estimation of effects, tests should be undertaken in order to avoid spurious relations and to guarantee the "optimal" estimators properties. On a different vein, it is important to undertake a microeconomic analysis, by exploring the effects of public investment in different regions, since the aggregate results may hide, as we have seen, significant differences. The sectoral analysis is also important, as almost all the studies at sectoral level have explored the effects of infrastructure capital in the manufacturing sector (or in a specific subset of this sector). The analyze should consider all sectors of the economy in order to identify which sectors benefit more and which benefit less from an increase of infrastructure capital stock.

All these considerations point towards the importance of estimating structural dynamic models, in particular VAR models, using higher levels of data disaggregation regionally and sectorally.

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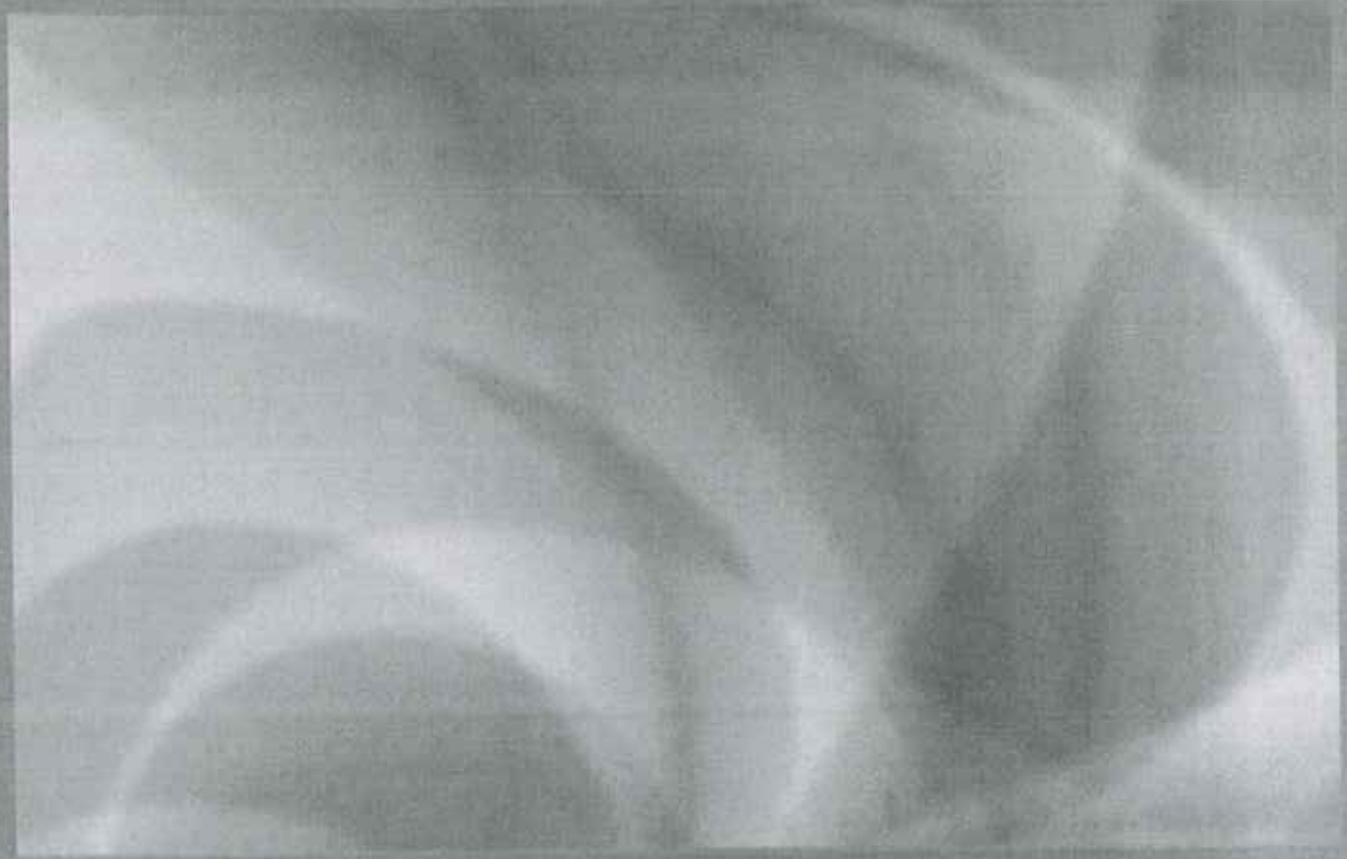
ESTUDOS II



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