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Review of literature on the productivity of public capital

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ABSTRACT

This paper summarizes previous results on the productivity of public capital. In recent literature, Aschauer's (1989) estimate for the productivity of public capital is often considered too high and the size of the effect is still open to debate. However, the positive effect of public capital on the productivity of the private sector is quite widely accepted.

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1 Introduction

Despite the lively discussion around the public expenditure, public investments had obtained little attention from economists before Aschauer's article (1989). Aschauer investigated the productivity of public capital in the United States and obtained strong evidence for the high productivity of the public capital.[1] Since then, there has not been a lack of productivity studies focusing on the public investments.

The purpose of this paper is to review shortly the results from the recent productivity studies concerning the effects of public capital on the productivity of private sector.

General motivation for productivity studies focusing on the public capital has been decreasing trend in public investments (as a share of GDP), which can partly be a consequence of prevailing pressures to cut public expenditure.

The size of the public sector increased in many countries rapidly until 1980, and thereafter it has stayed at a high level.[2] Large public sectors together with a deceleration of economic growth have lead to a pressure to cut public expenditure. Overall, obtaining a smaller public sector has become one of the political targets in many countries, especially in the Nordic countries.

From the political point of view, it is some times easier to cut public investments than public consumption expenditures. For example, in the US and the UK the share of public investment in GDP has declined under the level of 1913.[3] If public investments have an additional effect on the productivity of the private sector, this decreasing trend appears concerning.

Economic growth has become an increasingly interesting issue among economists, maybe due to the decreasing trend in growth rates. In some developing countries, a great deal of hope is placed in large public investment projects as a source of accelerating economic growth in the future. Naturally, the direction of causality is not trivial. Lower public investments can lead to lower economic growth and vice versa. All in all, knowledge about the effects of public investments on overall economic growth would have important policy implications.

[1] According to Aschauer's results the elasticity of the output of the private sector with respect to the public capital stock is at least 0,36.

[2] See Table I.1. (p.6–7) in Tanzi & Schuknecht (2000)

[3] See Table II.13. (p.48) in Tanzi & Schuknecht (2000)

The effects of public capital on private production may realize directly or indirectly. Directly, public capital may offer some intermediate services to private sector and thus lower the costs and improve the competitiveness of private firms. Public and private capital can also be complements in production, which means that public capital has also indirect effects on private production. In this way, public capital may improve the productivity of private capital and lead to increases in private production.

It is also interesting that there is no commonly accepted estimate of the size of the productivity effect of public capital although the subject has been studied for almost 20 years. A positive effect of public capital on the productivity of the private sector is quite widely accepted, but the size of the effect is still open to debate.

The definition of public capital has received a great deal of attention in literature. Usually, public capital is defined based on ownership and the stock is constructed using the perpetual inventory method. However, the definition of public capital is not so self-evident as it may seem.

It would be tempting to use public capital and infrastructure capital as synonyms, but these concepts should not be confused. Public capital includes part of the infrastructure, but there are also a great many other items included. In addition, part of the infrastructure capital is included in the private sector's accounts in the National Accounts. More discussion about the terminology and its problems can be found in Mehrotra and Välilä (2006, 446) or Romp and de Haan (2007, 13–15).

In many countries, including Finland, there is no measure available for the whole infrastructure capital stock.[4] In addition, a variable which describes the service flow that capital stock produces would be preferable instead of a stock variable (see OECD 2001). Again, the lack of proper data restricts the use of such capital service flow variable in many cases.

Focusing on the public capital means that a part of the infrastructure capital is not included in the analysis. For example, in modern Finland only roads and railroads[5] are included in the public capital stock and other parts of infrastructure (airports, energy and telecommunication networks, water supply and sewer systems, for instance) are included in the accounts of the private sector.[6]

[4] In Finland, Uimonen (2007, 2008) has, however, recently constructed stocks for road and railroad capital.

[5] However, these comprised about 40 % of the total net fixed public capital stock in 2005

[6] I have not found any publication or research, where these movements between public and private sector would have been summarized. For example, airports moved to private sector's accounts in 1989 and over half of the public buildings switched from public to private in 1999.

However, the use of infrastructure capital stock (if it would be available) would lead to problems with private production and employment. For example, the production of energy and telecommunication network is counted in the accounts of the private sector. Therefore, an increase in network capital (i.e. infrastructure investments) will, by definition, lead to an increase in the private production. This is not the case with the public capital.

2 Review of recent literature

2.1 Starting point

Aschauer's article *Is Public Expenditure Productive?*, published in the *Journal of Monetary Economics* in the year 1989, was an effective starting point for an intensive discussion. Aschauer's results were so striking that the potential importance of public investments was no longer ignored. Aschauer was the first to argue clearly that the decline in the productivity in the United States in the 70's may have been caused by the decline of public investments, which started at the end of the 60's.

A theoretical background for including public investments in the production function can be found in the Arrow's and Kurz's book *Public Investment, the Rate of Return, and Optimal Fiscal Policy* published in 1970. They added public capital for the first time as an input to the production function. Initial estimations can be found for Japan in Mera's (1973) article[7], for the United States at the aggregate level in Ratner's (1983) article[8] and for the United States at the state level in Costa, Ellson and Martin's (1987) cross-sectional study. Mera's results are a bit mixed, but Ratner and Costa *et al.* conclude that public capital has a positive impact on the productivity of the private sector in the United States. Despite these earlier studies, it was Aschauer's results that truly started the discussion which has continued ever since.

Aschauer's (1989) theoretical model is simply an expanded production function of the Cobb-Douglas form where private sector's production is regressed against private employment, non-residential private capital stock and public capital stock. Aschauer's point estimates for the elasticities of private production with respect of private employment, private capital and public capital are 0.35, 0.26 and 0.39,

[7] First order elasticity estimate for public capital in the manufacturing sector from translog production function is 0,189.

[8] According to Ratner, at the aggregate level the estimate for the elasticity of private production with respect to public capital is 0,058, which is much lower than Aschauer's corresponding estimate. However, Tatom (1991) re-estimated Ratner's equation from the original period, but with updated data and got elasticity estimate of 0,277.

respectively. The elasticity estimate of private production with respect to public capital varies between 0,36 and 0,56, depending on the specification of the regression function.

2.1.1 The most common approach: Production function

A) Country-level studies

Aschauer's results drew the attention of economists and politicians immediately to public investments and their role in explaining productivity growth. Gramlich (1994) and Strum, Kuper and de Haan (1996) are good reviews about developments right after Aschauer's article. For example, Strum *et al.* (1996) have made a conservative estimate of positive effect.[9] This section focuses on more recent studies.

Nourzad (1998) used Johansen's cointegration method and his results support the hypothesis of the positive effect of public core infrastructure on productivity growth in the long run. Point estimates, the elasticity of GDP with respect of private employment, private capital and public core infrastructure are 0.12, 0.62 and 0.34, respectively for the US in the period 1948–1987.

Ligthart (2002) examined the link between output and public capital in Portugal 1965–95 utilizing Cobb-Douglas production function and VAR model. Ligthart's results support positive productivity effect of public capital. However, Ligthart uses GDP instead of private production as a dependent variable, which is problematic, because an increase in public capital leads, by definition, to an increase in GDP.[10] Point estimates based on Johansen's cointegration method for the elasticities of GDP with respect of private employment, private capital and public capital are 0.188, 0.441 and 0.370, respectively, when constant returns to scale restriction is imposed. As Ligthart points out the coefficient of employment is quite low and the coefficient of public capital quite high.

Kamps (2006) has estimated country-specific regressions for OECD-countries. Kamps' results support a positive productivity effect of public capital, but elasticity estimates of private production with respect of public capital are quite high for some countries in the light of the economic theory (for example 0.8 for the United States). Parameter estimates for private capital and labour are not presented in the Kamps'

[9] "..,public capital probably enhances economic growth, a conclusion that most economists intuitively would ascribe to" (Strum et al. 1996, 21).

[10] Also capacity utilization rate has been included in basic estimation as a multiplicative term in the production function, which is critisised, for example, in Duggal, Saltzman and Klein (1999).

paper. Kamps states only that there are some problems especially with the coefficient of labour input, which makes the interpretation of the results difficult.

Although Evans and Karras (1994) did not find support for a positive productivity effect of public capital in panel of seven countries, more recently there have been more promising results from panel data studies in a sense that they are more statistically reliable. They support the positive effect of public capital on the productivity of private sector (e.g. Hjerppe, Hämäläinen, Kiander and Virén 2007; Kamps 2006; Dessus & Herrera 2000).

B) Regional studies

The direction of research on the productivity of public capital has changed toward regional panel analyses.[11] The tightest restriction in these analyses has been, and still is, the availability of suitable capital stock data. Therefore, only a few studies have been made outside the US.

In the regional setup, public capital is often seen as an instrument of regional policy. Central government can support poorer areas by financing large infrastructure projects, which hopefully will also have long term impacts on the local economic activity. One purpose of the research on the regional productivity studies is to find out, if public capital can be used effectively in the regional policy.

The history of regional productivity analyses focusing especially on the productivity of public capital and applying the production function approach could be thought to begin from Mera's (1973) research with the regions of Japan. In the 90s, most of the regional studies used the data concerning the states of the US (e.g. Munnell (1990), Garcia-Mila & McGuire (1992), Evans & Karras (1994), Holtz-Eakin (1994) and Garcia-Mila, McGuire & Porter (1996)), with mixed results.[12]

More recently, regional capital stock data has also been increasingly available for European countries, which has lead to more regional studies using such data. Stephan (2003) has studied a panel of 11 West German *'Bundesländer'* and found that public capital is productive for manufacturing sector. Cadot, Röller and Stephan (2006) have studied 21 French regions in 1985-1992 using simultaneous equation model. They found that the statistically significant estimate for elasticity of private production with respect to infrastructure is 0,08.

[11] Problems such as high multicollinearity, lack of co-integration and an economically unreasonable size of elasticity estimates have been frequent in country-specific aggregate time series analyses. Problems arise in cross-country panels, for example, from different definitions of data and various economic environments among the countries included. In the regional framework, these problems disappear or are less severe.

[12] In the 21st century data concerning the states of the US has been used mainly in cost function studies (e.g. Cohen & Morrison Paul (2004).

Moreno and López-Bazo (2007) have applied production function approach to 50 Spanish regions in 1965-1997. They found that local public capital is more important than transportation infrastructure. This result holds, even, if spill-over effects are taken into account. Interestingly, Moreno and López-Bazo also argue that the public capital is more productive in regions where the ratio of public capital stock to private capital stock is low. This result gives some guidance for the effectiveness of public capital as a tool for regional policy. The Spanish case has been studied also by Salinas-Jimenez (2004), with a conclusion of a positive effect only if spatial (or spill-over) effects were taken into account. An Italian case has been studied for instance by Destefanis and Sena (2005), who ended up with the conclusion that public capital has a positive effect at least in some regions.

Usually, results from regional studies have come to show lower estimates for the impact of public capital than studies using aggregate level data. A natural explanation to this is that the aggregate analysis takes externalities into account. Especially with transportation infrastructure, these externalities can be remarkable. Therefore, spill-over effects of public capital have also attached a lot of attention (see Pereira & Roca-Sagalés (2003))

C) Meta analysis

The issue about the size of the effect is far from settled. Recently, Bom and Ligthart (2008) have taken a totally new approach to summarize vast literature and have made a meta analysis based on 76 studies which all have taken the production function approach. The resulting weighted average output elasticity of public capital is 0,08 when the publication bias is corrected.[13] This estimate is highly significant and more reasonable in size than the elasticities reported in many individual studies (for example in Kamps (2006)). In the Finnish case, this average elasticity would suggest a marginal productivity of public capital to be about 14 per cent in 2005.[14] This could be compared with the marginal productivity of private capital, which is usually assumed to be the real interest rate.

Needless to say that the elasticity estimates are estimated from historical data and nothing guarantees that such returns could be attained in the future. It is easy to imagine, for instance, that the rate of return for the construction of the basic highway network is higher than the rate of return from expanding the existing network.

[13] Arithmetic average of elasticity estimates in the sample of 76 studies is 0,193 and median 0,159.

[14] The formula for calculating the marginal productivity of public capital is $\frac{\partial Y}{\partial K2} = \gamma \cdot \frac{Y}{K2}$, where Y is private production (or GDP), $K2$ is public capital stock and γ is the elasticity of private production with respect to public capital. In 2005, $\frac{Y}{K2}$ was 1,77 in Finland.

2.1.2 Other approaches

In addition to the division between country and regional level studies, previous research can be divided based on the approach or level of aggregation of the data. Some studies have used data over all sectors while others have focused only to some specific sector such as manufacturing. There are also differences in the definition and scope of the public capital variable.

The main alternative approaches to the production function approach have been cost or profit functions and Vector autoregressive models (VAR). Although, the production function approach is still the most commonly used framework, focus has been moving to the VAR models, which are more data-oriented and are not based on the economic theory in a similar way as the production functions are. These alternative approaches are reviewed more deeply in Strum *et al.*. (1996) and Romp *et al.* (2007).

The relationship between infrastructure and growth has also been studied by the help of nonlinear models. Duggal *et al.* (1999), for instance, have used infrastructure as a technological constraint assuming that the technological growth depends nonlinearly on the infrastructure and time trend. Their results support Aschauer's original findings. Aschauer (2001) has also used a nonlinear model to examine state specific data from the US. He concludes that the public capital has a statistically significant positive effect on economic growth. Moreover, Aschauer states that the optimal size for the public capital stock is 50–70 per cent of the private sector's capital stock.

One branch of literature takes human capital also into account. For example, Romer (1990) and Mankiw, Romer and Weil (1992) have used the augmented Solow model.[15] The results have usually pointed out that human capital has an important role in the private sector's productivity growth and that the effect of human capital on productivity is positive.

2.1.3 Results relating to Finland

Country-specific time series analysis has been the most commonly used method in empirical analysis. However, Finnish data has been used only in a few studies. The same applies also to other Nordic countries, where public sectors are bigger than in general. Therefore, it would be interesting to know, if results in Nordic countries are in line with results from other countries.

[15] See Benhabib and Spiegel (1994), Aschauer (2000), Bassanini, Scarpetta and Hemmings (2001) for other studies, where human capital is included.

The latest research, to my knowledge, focusing on the Finnish case and using the production function approach was published in 2000 (Björkroth & Kjellman). Probably, the lack of reliable data on infrastructure capital has restricted this type of research in Finland.

Results from researches using Finnish data have been mixed. Ford and Poret (1991) have, for example, estimated a country-specific time series regression for Finland for the period of 1967–1988. They use four different specifications in differences and conclude that only one of the specifications leads to a statistically significant positive estimate for the public capital. Björkroth and Kjellman (2000) do not arrive with a statistically significant effect of public capital on the productivity of the private sector. In estimation, they follow Tatom's (1991) model specification and use Finnish data from 1970–1997. Also Pereira (2001) includes Finland in his sample of 12 OECD-countries. His results indicate that infrastructure has a positive effect on the productivity of the private sector. However, the size of the effect is in Finland smaller than, for example, in Sweden, Germany or the US. Pereira's empirical findings are based on 29 annual observations starting from the 60's.

Based on the period of 1960–2001 Kamps' (2006) estimate for the elasticity of private production with respect to public capital with differenced data for Finland is 0,313.[16]

In addition, Luoto (2006) has investigated the relationship between infrastructure capital and long-run growth in Finland using a Bayesian estimation methods. Luoto's general conclusion is that infrastructure capital has had a positive effect in the long-run economic growth. Recently, Uimonen and Tuovinen (2008) have utilized cost function and Finnish data, concluding that infrastructure decreases private sector's costs.

[16] Previously, in his book (2004) Kamps gets even larger coefficient for Finland (0.717). Generally, he notes that the coefficient on public capital is quite large in some countries and coefficient on private capital (not reported) is even negative for some countries. Therefore Kamps concludes the chapter "..,making it difficult to interpret the estimated coefficients as parameters of a Cobb-Douglas production function". (Kamps (2004, 45))

3 Discussion

Aschauer started an important discussion about the role of public capital. Right after Aschauer's article various authors (e.g. Tatom (1991) and Hulten & Schwab (1991)) presented statistically insignificant results for the productivity of public capital and denied the Aschauer hypothesis.[17] On the other hand, at the beginning of the 90's there were several studies which came to conclusions of high elasticity estimates.[18] Among the first studies, the problems with econometric methods or with model specification were common. Although there are still unsolved problems, most authors conclude in the studies done within the last ten years that public capital has a positive effect on the private sector's productivity.

For example, in the sample of 76 studies used in Bom and Ligthart (2008) meta-analysis, only 8 studies have ended up with negative elasticity estimate (only two with statistical significance) for public capital. Among the studies published in the 21st century only 1 out of 23 ended up with negative elasticity. Recently, Romp *et al.* (2007) have made an extensive literature review and ended up with similar results.

Considering the width of the range of different elasticity estimates, it seems that used data, level of aggregation, variables and methods have quite extensive effects on results. There have been problems, for example, with the availability of comparable capital stock series across countries as Kamps (2006) points out. Discussion for the reasons of heterogeneity in results can be found in Bom and Ligthart (2008).

It seems that the positive effect of public capital on the productivity of the private sector is nowadays quite unanimously accepted. Despite vast literature, the size of the effect is still open to question.[19]

The results of aggregate studies could be seen as a general argument for increasing public investments. However, the productivity of individual projects should be judged based on project specific cost-benefit analyses and not on overall result from aggregate studies.

[17] For example, Tatom (1991) have argued that high elasticity estimates are produced by spurious regression. He used first differences to make variables stationary, which lead to insignificant estimate for public capital. Munnell (1992) has criticised differencing and argues that it would destroy long-run relationships.

[18] E.g. Strum and de Haan (1995) have re-estimated Aschauer's equations and obtained even higher elasticity estimate for public capital. Hence, Aschauer's results are not based on flawed data or computational error. Despite this, Strum and de Haan (1995) conclude that well-founded conclusions cannot be made, due to several econometric problems.

[19] Already Aaron (1990, 61) have stated that "The issue is not the sign of the coefficient of that variable – on that everyone agrees. The issue is the size of the coefficient..."

In the future, it could be useful to divide the capital stock according to its purpose of use. In this way, the productivity of different capital items could be investigated more properly. If there are items that have substantial positive externality and they are counted in the accounts of private sector, there is still scope for public policies to improve the incentives to increase investments in such capital stock items. In addition, more emphasis should be given to human capital. Publicly provided human capital may have a large role in explaining the continuous growth in the private sector's productivity. Until now this has been ignored because the effects of the infrastructure have been overemphasized.

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Aboa Centre for Economics (ACE) was founded in 1998 by the departments of economics at the Turku School of Economics, Åbo Akademi University and University of Turku. The aim of the Centre is to coordinate research and education related to economics in the three universities.

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Aboa Centre for Economics (ACE) on Turun kolmen yliopiston vuonna 1998 perustama yhteistyöelin. Sen osapuolet ovat Turun kauppakorkeakoulun kansantaloustieteen oppiaine, Åbo Akademin nationalekonomi-oppiaine ja Turun yliopiston taloustieteen laitos. ACEn toiminta-ajatuksena on koordinoida kansantaloustieteen tutkimusta ja opetusta Turun kolmessa yliopistossa.

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