IS PUBLIC CAPITAL PRODUCTIVE? EVIDENCE FROM A META-ANALYSIS

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ABSTRACT:

An important debate exists with regards to the role that public investment must play for economic recovery and economic growth. The underlying idea behind this has much to do with the value of output elasticity of public capital. For this reason this paper presents a Meta-analysis of this elasticity. To do it, almost 2,000 elasticities previously estimated from 145 papers are considered. In addition, for each elasticity, some thirty associated features relative to the methodology used for each case or relative to the characteristics of data samples, are also taken into account. The results obtained reveal an average short-term elasticity of 0.13 (0.16 in the long-term). Evidence is also found of the importance of the methodology adopted for the results obtained as well as the publication bias. Finally, we find a minor reduction in the value of the elasticity as public capital endowments increase.

KEYWORDS: Public capital, Infrastructures, Meta-analysis, Meta-regression analysis, Publication bias.

JEL: H54, 040, R11

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1. Introduction

The importance during The Great Recession attached to fiscal consolidation has meant the significant contraction of the amounts accorded to public investment in advanced economies. This in fact provokes an important and increasing debate on the role that public investment must play for world economic recovery. In one side, some support larger public investment effort arguing that this type of public expenditure reinforces stronger long term growth as well as boosting aggregate demand in the short term (Group of Twenty, 2014 and Barbiero and Darvas, 2014). Furthermore, the weight of the stock of net public expenditure in GDP has declined in the majority of economies during the last decade. The lack of maintenance has reduced the quality and thus effectiveness of public capital in general, and of infrastructures and core capital, particularly. In line with these mentioned long term effects, the present investment in infrastructures may become self-financing due to the future increases in production (Abiad et al, 2014).

Even those supporting these ideas are cautious, as total long term macroeconomic impact —multiplier effect— of public investment depends on the degree of economic slack and monetary accommodation, the efficiency of public investment, the way in which public expenditure increases are financed, and the public-debt-to-GDP ratio and corresponding distorting effects.

Precisely, detractors of the increase in public investment argue that these expenditures may deteriorate notoriously and permanently public finances[1], highlighting distorting effects of the excess in public investment being financed with taxes on future economic growth (Fisher and Turnovsky, 1998). In fact, based on the contributions of Barro (1990), there exists an optimal level of public productive expenditure —and hence infrastructure expending—. If expenditures exceed this optimal level, the additional distortionary taxation needed to be financed may provoke a reduction in growth rates. Additionally, it is often argued that the macroeconomic multiplier associated to public investment is small. This can be explained in terms of its little effectiveness associated to a low or null output elasticity of infrastructures. Other factors as the poor selection of investment projects, the existence of a certain waste of investment resources, or even the fall in the profitability of public investments resulting from decreasing returns to scale or the exhaustion of

[1] The case of Japan in the 1990s is often pointed out. The increase in public investment contributed notoriously to the increase in its public-debt-to-GDP ratio (Syed, Kang and Tokuoka, 2009).

network effects, especially in those developed economies with acceptable public capital levels and full infrastructure networks, may help in understanding poor returns from public investments (Abiad et al, 2014 and Calderón and Servén, 2014).

The argument related to the efficiency of public investment seems to gain relevance in current debates. This efficiency depends on the sensibility of production (short and long term) to productive investment, as well as the management processes of public decision making in terms of projects selection and their implementation and monitoring. All these elements shape the output elasticity of public investment.

Evidence of the fact that public capital generates positive externalities in the private sector was first perceived back in the fifties of the last century[2]. It was not, however, till the end of the last century that this idea became really important, as it attempted to link the fall in productivity in North America to the fall in public investment. Thereafter, a sizeable amount of publications, considered precursors in this sense, (for example Aschauer, 1989a) emphasized the important role of public capital in economic growth.

The influence of the wave papers previously mentioned, led to a frenzy of investment that, for many countries, meant a radical change in the infrastructure network. Nonetheless, the indiscriminate increase in the stock of infrastructure and the new literature results point to the fact that infrastructures may have less of an effect on productivity (even zero or negative effects), leading to some confusion on this issue.

Attempting to clarify this issue, Pfähler et al. (1996) look at 40 papers done on the United States, but arrive at no clear conclusion, since 40% of them showed positive and statistically significant results, while 44% of them showed no effect. A more recent study, done by Straub (2008), which analyzed 69 papers, shows that 61% of the studies obtained positive and significant elasticities for public capital while 36% of them showed statistically insignificant results. Other authors, applying the meta-analysis or meta-regression technique, attempted to provide a synthesis of these results (Button, 1998; Ligharth and Martin, 2011; Bom and Ligharth, 2014 and Melo et al.,

[2] Certain papers (Meade, 1952; Hirschman, 1958; Hansen, 1965, among others) pointed to the need for a minimum of public infrastructure to attract productive factors, especially capital and skilled labour, that can support the economic development of certain territories.

2012), and came up with similar conclusions with regard to the positive impact – which is clearly prevalent – albeit the magnitude varies across different findings[3].

The diversity of results is associated with the high level of methodological heterogeneity of these types of studies, as well as with the factors linked to the data sample (De la Fuente, 2010). Against such a backdrop, the aim of this paper is to offer a synthesis of previous empirical evidence, to assess the contribution of public capital investment to economic growth.

To that end, in the second section, we shall take a very close look at the production function approach, focusing on the output elasticity of capital, given that the meta-analysis requires that the parameter under study be the same in all the papers considered. In this revision, we shall place special emphasis on the different criticisms and limitations that gradually came to the fore in the approaches adopted, as well as those that gradually replaced them. Third section outlines the meta-analysis methodology and the meta-regression analysis that will be used later on to present a synthesis of the results of a representative sample of articles. Section four looks at how the meta-samples of articles and elasticities of public capital are obtained and discusses their main features. To do this, almost two thousand elasticities obtained from one hundred and forty-five papers are selected. Section five presents the results obtained, for both the meta-analysis and the meta-regression analysis. We shall then end, in the final section, with our conclusions and policy implications.

2. Overview of methodological approaches, with special emphasis on the production function.

The studies that have attempted to establish the effect of public capital on private productivity have used different methodological approaches: the estimation of production functions (where the appreciable body of seminal papers is placed), those which, using the dual approach, estimate cost or benefit functions (Demetriades and Mamuneas, 2000; Bonaglia et al., 2000, Cohen and Morrison, 2004, among others), VAR models (Batina, 1998; Flores de Frutos et

[3] Button (1998) analyses 26 studies and obtains an average elasticity of 0.343. Ligharth and Martin (2011) take 282 results from 49 papers and find an elasticity of between 0.169-0.184. Bom and Ligharth (2014) with a total of 578 estimators drawn from 68 papers, obtain an elasticity of between 0.082-0.103. Finally, Melo et al. (2012) present 563 observations from 33 different publications that exclusively analyze the effect of transport infrastructures, obtaining values in the range 0.0277-0.4068.

al., 1998; Pereira, 2000, 2001; Ligthart, 2002; among others) and models based on different theories of growth (Easterly and Rebelo, 1993; Sánchez-Robles, 1998; Esfahani and Ramírez, 2003; among others).

Of all these, the one most used is, without doubt, the production function –using Cobb-Douglas type-, which encompasses more than half of the publications (Straub, 2008) and which, therefore, will be the focus chosen for the analysis that follows.

Although some previous papers exist[4], the ones considered as seminal are those published towards the end of the eighties, and based on aggregate time series for the United States. Aschauer (1989a) and Munnell (1990) obtained elasticities around 0.4. Such high values led to the elaboration of a wide range of studies that returned a wide array of elasticity values for public capital that oscillated between 0.2 and 0.6. Such high elasticities led to reasonable doubts being raised about these results, pointing to many problems of an econometric and methodological nature, which led to extensive literature on the subject – some a thousand five hundred articles – that carefully outlined the importance of certain methodological decisions as well as the nature of information within the results found. These papers showed much more moderate, even non-significant elasticities. We shall now present these criticisms and alternatives, non-chronologically.

2.1. Specification of the production function

There has been a predominance of papers that use the restrictive Cobb-Douglas type production function[5]. There is still no agreement on the restrictions imposed ex ante with regards to returns to scale: no restrictions (Munnell, 1993; Baltagi and Pinnoi, 1995, among others); constant returns only imposed on private factors (capital and labor); and those forcing constant returns over all productive factors (Aaron, 1990; Tatom, 1991, among others).

Another important factor is if public capital can be considered a productive factor not paid by companies – or paid for indirectly through taxes – (Arrow and Kurz, 1970), but which still have some of the features inherent to a private asset, given the possibility of congestion and partial

[4] The first paper to estimate a production function with public capital (in this case social capital) was a study by Mera (1973), which obtained an elasticity of 0.2 for Japanese regions. This was followed by Ratner (1983), Costa et al. (1987) and Ram and Ramsey (1989), who analysed North America and came up with positive elasticities, although they also showed a wide range of estimated effects.

[5] Some other more flexible types of production functions have been previously used, i.e. the translogaritmic formulation (Pinnoi, 1994; Charlot and Schmitt, 2000; Canning and Bennathan, 2000, among others). However, the results found for output elasticities of capital are not substantially different.

exclusion or if public capital is part of the technological restriction that determines productive efficiency (Duggall et al., 1999). In the first case this factor must be incorporated in the production function as an additional factor. In the latter, it should therefore not be included in the production function, although it would determine productive efficiency (as Barro and Sala-i-Martin, 1995, point out).

Finally, the additional variables included in the specifications of the production function differ across different papers. The economic cycle has been considered introducing variables such as the use of productive capacity, the rate of unemployment or annual indicators. Tatom (1991) points to the need to introduce energy prices because any increase (or decrease) in them leads to an increase (or fall) in the rate of obsoleteness[6]. Another body of papers introduces variables that capture the effect of economies of agglomeration on efficiency (Keleijan and Robinson, 1997). Finally, some authors (García-Milá and Mcguire, 1992) also control for the human capital that can determine certain changes in the levels of productivity.

2.2. Measurement of the variables

Another feature of this literature is the use of different forms of measuring the variables. With regard to public capital, there is a crucial debate about the definition used. For the purposes of this paper, and with a view to providing a synthesis, there are as many as three different definitions of public capital. Total public capital includes all the elements of capital that are the property of the different Public Administrations. The definition of productive capital, which would consider capital goods aimed at health, education, housing and community services, energy installations, communication and transport infrastructure[7]. Finally, the definition including just transport infrastructures or focusing on one of the four major elements that constitute them: roads (highways), railways, air and maritime infrastructures[8].

A second crucial factor regards the way in which public capital is quantified. Normally, monetary measurements are used, but they are criticized because the prices of capital goods vary

[6] Baily (1981) purports that an increase in energy prices will provide an incentive to replace machinery that uses it intensively.
[7] The exclusion of elements of health, education and housing, which correspond to the so-called social infrastructures, leads to a restricted definition of productive or economic capital which in literature is known as "core infrastructures".
[8] In fact, the greater use of value added is based on the fact that is more easily available, as well as the problems of identification of the elasticities resulting from the joint inclusion of intermediary consumption and labour.

importantly from country to country, as does the efficiency in the execution of the project (Pritchett, 1996). For that reason, some studies (Canning, 1998; and Estache and Goicoechea, 2005) opt for measuring in physical terms (e.g. length of the road or highway network, number of hospital beds, etc.), or use synthetic indices that bring together several categories of infrastructures (Cutanda and Paricio, 1994; Delgado and Alvarez, 2000; Mitra et al., 2002; and Sahoo et al., 2010).

Another key factor refers to the output variable used: production or, mainly, value added. Sims (1969) and Arrow (1972) point out, the value added function is a theoretical concept that is valid if the underlying gross production function has a nested form (i.e., it can be easily separated between the value added function and intermediary consumption) and efficiency only affects value added.

2.3. The nature and disaggregation of statistical information

The seminal papers used aggregate time series (Ashauer, 1989a; Munnell, 1990; among others). Other papers incorporating cross-section variability amongst countries (Ford and Poret, 1991; Nourzad and Vrieze, 1995, among others) and amongst regions (Munnell and Cook, 1990; Hulten and Schwab, 1991, among others) became available. After that, based on the overestimation of the parameters that were used in the latter studies, as well as the availability of new data bases, data panels began to be used (Bonaglia et al., 2000; Charlot and Schmitt, 2000, among others). These new databases allowed the use of econometric techniques that can control for unobserved individual effects.

The consideration of information with high geographic disaggregation (regions or states, provinces or counties, municipalities, etc.) generates a debate as to what is the crucial public capital that must be considered: Public capital that is administered by territorial administrations (Hulten and Schwab, 1991; Holtz-Eakin and Lovely, 1996, among others), or the capital of all levels of the administration in each geographical area (Eberts, 1990; Boarnet, 1998, among others).

In some studies, it is notable that greater geographical disaggregation have effects in the results obtained due to the impossibility to take into account the so-called network effect and the measurement problem linked to the border effect. It is for this reason that the capital of neighboring territories is often incorporated (Boarnet, 1998; Berechman et al., 2006; Delgado and

Alvarez, 2007; among others), or to a lesser degree, the accessibility that the territory possesses (Petersen, 2011a, 2011b).

Another crucial factor here is linked to the use of sectorial information. It is usually pointed out that the manufacturing branches will be those most favored by public capital, even if the results haven't always corroborated this hypothesis (Shanks and Barnes, 2008; Fernald, 1999; among others).

2.4. Econometric methodology

Although in this field of economic analysis a great variety of econometric techniques has been used, we shall only refer here to the problems that have caused the greatest concern. So, a first consideration is that the analyses that incorporate a great number of countries, states, regions or municipalities show great heterogeneity in their behavior, determined by idiosyncratic factors that can produce inconsistency in the estimations if they are correlated with the error term. To address this problem, a within model is used (of fixed effects, first differences, deviations from the time mean, etc.).

However, the main source of concern in this context is endogeneity between production and some productive factors like public capital (which in fact derives from a problem of causality). Put differently, public investment would be considered a superior asset, so governments would tend to invest more in periods of rapid growth (De la Fuente, 2010). Consequently, there will be an upward bias in the estimations of public capital returns (Eisner, 1991; Munnell, 1992 and Gramlich, 1994)[9]. The literature suggests different methodologies to address this problem, through the use of any of the variants implemented within Instrumental Variables methodologies –2SLS, 3SLS, GMM, etc. – (Holtz-Eakin, 1994; Baltagi and Pinnoi, 1995; Finn, 1993; Ai and Casssou, 1995; among others).

Another economic problem arises due to the presence of spurious correlation (Rubin, 1991) due to the presence of time trends in the variables (see, for example, Sturm and De Haan, 1995). To solve this problem, estimators in first differences are introduced (Aaron, 1990; Hulten

[9] Some authors have used the Granger test to examine the relation of causality between public capital and output. Duffy-Deno and Eberts (1991) suggest that causality is established in both directions, Holtz-Eakin (1994) finds a certain ambiguity in the direction of causality and Tatom (1993) finds that causality can be greater from infrastructures towards production than in reverse.

and Schwab, 1991; Tatom, 1991, among others). However, Munnell (1992) criticizes this solution since it modifies the nature of the relationship between variables, given that it eliminates the long term component of the possible correlation between variables. For these reason some papers argue that if the estimators in levels are carried out with non-stationary but cointegrated variables, the estimators would be consistent. The literature offers different econometric procedures to test the null hypothesis of no cointegration that has been used in this field of research (Bajo and Sosvilla, 1993; Argimón et al., 1994; Crescenzi and Rodríguez-Pose, 2008; Bronzini and Piselli, 2009; among others).

3. Meta-analysis methodology

Meta-analysis is a statistical technique used to synthesize the individual results of many previous studies, with the aim of obtaining more accurate and statistically robust general conclusions, on a parameter of interest. Precisely as a result of this, in recent years, the use of this methodology has been extended to the socio-economic field (Stanley, 2005, 2008; Brons et al., 2006, 2008; Bom and Ligthart, 2014; Feld and Heckemeyer, 2011, among others)[10].

Meta-analysis attempts to find the "consensus" value of a parameter of interest (η_0) from the estimation of the expression,

$$\hat{\eta}_{is} = \eta_0 + v_{is} \qquad (1)$$

where $\hat{\eta}_{is}$ denotes value i for the parameter of interest obtained from study s, and v_{is} is the error term with the usual assumptions.

The most basic method is the fixed effects model, which assumes the existence of one single real value within the population, which implies that $v_i \sim N(0, \sigma_i^2)$. On the contrary, the random effects method assumes that the studies are a random population sample and, therefore, randomly distributed around the population mean. That is to say, the different papers are going to show a different value as a result of their methodological heterogeneity, with differences between

[10] It was Pearson (1934) who proposed this technique, even though the first meta-analysis was carried out by David (1934).

the results of different studies and intra-studies, which means that $v_i \sim N\left(0, \sigma_i^2 + \tau^2\right)$[11]. To choose between both estimators, the Q homogeneity test (Shadish and Haddock, 1994) is applied[12]. If the null hypothesis is rejected, one accepts the existence of important methodological differences that modify the value of the parameter of interest. Rewriting equation (1) as follows,

$$\hat{\eta}_{is} = \tilde{\eta}_0 + \sum_{k=1}^{K} \alpha_k Z_{ik} + \tilde{v}_{is} \qquad (2)$$

where Z are the independent k variables (meta-regressors) that capture the relevant methodological differences or the characteristics of the data samples of the different empirical studies and explain the systematic variation of the results among studies. Expression (2) can be estimated using fixed or random effects —also called mixed effects—. Solution to the Q homogeneity test provides the suitable estimator to use.

This methodology considers two sources of publication biases, one originated in the size of the samples used in each paper of the meta-sample, and the other derived from the exclusion of results that do not match the dominant paradigm.

The problems related to the size of the samples are initially controlled through the WLS estimation. However, estimators obtained with small samples usually show more erratic values that may not be necessarily corrected with the mentioned weighting procedure. This problem can be addressed following Card and Krueger (1995), Ashenfelter et al. (1999), Görg and Strobl (2001), introducing the standard error of the parameter as an additional independent variable in the regression.

The greater predisposition on the part of reviews, evaluators and institutions to accept results that match the dominant paradigm is controlled with the inclusion in the meta-sample of results published not only in articles that go through stricter filters, but also in books or grey literature (working papers, reports, papers presented at congresses, etc.), including an indicator variable to differentiate between the two types of publications. Similarly, the authors themselves

[11] Fixed and random effects models are estimated by means of the Weighted Least Squares (WLS) estimator. In the fixed effect model the weights are the inverse of the variance of each estimator of the meta-sample ($w_i = 1/\sigma_i^2$). In the random effects the weights are obtained as the inverse of the sum of the variances between-studies and intra-studies ($w_i = 1/(\sigma_i^2 + \tau^2)$)

[12] The Q statistic follows a χ^2 distribution, and the H_0 is the homogeneity hypothesis ($\tau^2 = 0$).

might be more interested in finding the most conventional results in order to publish their articles. In this way, the self-selection of the authors can be contrasted by building a dummy variable that points to the preference explicitly shown by authors between results included in their paper (Bom and Ligthart, 2014).

4. Meta-sample

To carry out the meta-analysis, it is necessary to gather an important number of values of estimated elasticities obtained from previous studies (meta-sample). The meta-sample has been built at two levels: papers consulted, and the output elasticities of public capital estimated within them.

4.1. Meta-sample of articles

In order to carry out a proper meta-analysis, the studies selected have to be representative of the population of studies done. To achieve this, a biblio-metric study was first carried out, aimed at finding the fundamental studies or "core articles" of the literature and at quantifying the size of the population of studies. To do so, we selected the references on the topic included in the most recently published literature reviews, Pfähler et al. (1996), Sturm et al. (1998), Button (1998), Gillen (2001), Romp and De Haan (2007), Straub (2008), Boscá et al. (2011), Ligthart and Martin (2011), Pereira and Andraz (2011), Melo et al. (2012) and Bom and Ligthart (2014). Some 280 different references were gathered -including 30 papers, published solely as working papers, and more than five years old-.

Next we obtain and analyze all cited articles in those available papers. The result of this was the accumulation of a total of some 5,639 quotes, where a half of those correspond to 750 papers which deal specifically with the interrelation between some kind of public capital and the productive activity (production, productivity, costs, benefits, etc.). Eleven of these cited articles[13] account for more than 50% of the quotes. This reduced group of papers is therefore considered the tight and most influential nucleus of research on this question, all of them having been published between 1989 and 1996. We then consulted the WoK (Web of Knowledge) and the EBSCO

[13] All of these articles received more than 25 quotes. These articles are indicated by an asterisk in Table 1.

platforms[14] to obtain the articles that cite these 11 papers. This allowed us to estimate the population of papers that deal with this issue, calculated to be in the region of 1,500. So, using the so-called Bradford Law (Bradford, 1946) of the dispersion of literature, it can be concluded that with a sample equivalent to 10% (150 articles), we will obtain between 50% and 67% of the information content of this literature[15].

From the 280 initial papers, the meta-sample was reduced to 145, either because the studies were not available or did not meet any of the methodological requirements in order to be included in the final meta-sample. For instance, whenever a Cobb-Douglas type production function —or equivalent— were not estimated, or even when included, the article was not offering the elasticity of output with respect to public capital and its standard deviation.

Of these papers, 110 are published in academic reviews. On the other hand, the period encompassed, with respect to the year of publication, goes from 1983 to 2011. Furthermore, the vast majority of papers focus solely on the study of one single country (119 articles) while some 18 countries are represented, with the USA, with 44, being the economy with the greatest presence.

4.2. Meta-sample of elasticities

Following the suggestions of Bijmolt and Pieters (2001), we built the meta-sample of elasticities considering all the values provided by each study. This also allows for a better control and testing of publication biases and of the influence of methodological decisions[16]. The sample is made up of some 1,928 estimated values for the output elasticity of public capital, which implies an average of 13 values per article (see Table 1). Of these elasticities, 58% refer to positive and statistically significant values, close to 37% are non-significant and only 5% are statistically negative.

[14] This tool has allowed for a joint search in the Academic Search Premier, Business Source Complete, Econlit and Eric data bases of the following words: Production and Public capital, Production and Infrastructures, Productivity & Public capital, Productivity & Infrastructures, Effects and Infrastructures.

[15] The Bradford law is a particularization of the Zipf law (Zipf, 1972). In concrete terms, this law indicates that the information content included in consecutive groups of reviews and articles follows the 1, 1/k, $1/k^2$, $1/k^3$ progression. The empirical contrasts of that law allocate k values in the (2-3) interval (Urbizagastegui, 1996 and Potter, 1998). In Garfield (1980), there is a detailed discussion of both regularities. In order to obtain the information content in relative terms (%) to the first decile –that including most influential papers- the value of x in $\sum_{i=1}^{10} \frac{x}{k^{i-1}} = 100$ must be derived.

[16] On the one hand, had we opted for calculating the mean of all the results of each paper (Stanley, 1998), we would lose the option of being able to test, at least, the self-selection bias of the authors; as well, only meta-regressors that capture between-study differences and non-intra-studies (such as the use of different econometric techniques) would be included. On the other hand, had we chosen to take one single value per work (Van der Sluis et al., 2005), as well as the previous limitations, it would not always have been possible to do so, due to the fact that in many articles the authors do not clearly decide for one of their results. Furthermore, in both cases, a considerable amount of observations would be lost: instead of 1,928, it would be 145.

Figure 1 shows the distribution of the meta-sample of elasticities. It also shows an important accumulation of values around the average. The presence of some outliers, especially in the positive region, can also be observed, which leads to clear asymmetry to the right, with a sample median of 0.115, clearly below the overall mean (0.189).

(Table 1, around here)

(Figure 1, around here)

4.3. Meta-regressors

In order to analyze the influence of methodological decisions and the nature of information on the values of the output elasticity of public capital, we take as many as 29 different features associated to each elasticity value. An outline of these features is presented in an orderly fashion in Table 2. In the first column of this Table we present the number of elasticities in the meta-sample in each of considered categories.

(Table 2, around here)

For the specification of the production function, we have gathered four different aspects. The first refers to the theoretical focus used where there is a prevalence of results obtained from direct estimations of production functions (about 85% of the sample). There are also other values that correspond to papers that estimate elasticities from models of growth (10%), quasi-production functions[17] (3%) or production frontier (2%). Secondly, we also gather the assumptions done on the returns to scale issue, where it is discernible that it has been normal not to impose, a priori (71%), or imposing constant returns on all production factors (15%) or only the private ones (14%). A third aspect distinguishes between results that directly introduce public capital in the production function (51%) either by calculating or estimating a productivity indicator and then analyzing the impact on it of public capital endowments (49%).

Finally, we also consider the additional variables incorporated in the production function. The most common variables were obviously selected, i.e. the economic cycle (27%), any human capital indicator (17%), any element that captures the effect of energy prices on the obsolescence of physical capital (4%), and finally, production density indicators (5%). Moreover, we take into

[17] In this context, functions which are generally of productivity with semi-logarithmic specification are called quasi-production functions.

account the inclusion in the estimated equation of public capital as an additional factor of production (20%)[18]. The way in which estimations control for the time dimension, i.e. technical progress, was also taken into account, distinguishing between consideration either of a time trend (22%), or time fixed effects (23%).

With regard to the definition of the public capital used, 44% include the total of this magnitude, while only 23% remains with some measure of productive public capital and 33% choose the one specific to transport infrastructures. Another factor refers to the specific measure of public capital: stock variables (93%) or flows (7%)[19]. A distinction is also made between the specific ways of measuring: it could be through monetary evaluation (83%) or non-monetary evaluation (17%). Greater homogeneity is found in relation to the output variable selected, given that 90% of the studies use value added, as against only 10% that do so with production.

In relation to the nature of the data, there is a predominance of panels (71%). An important number of papers use time series (24%), and a minority uses cross-sectional data (5%). With regard to the geographical scope of the sample, most are elasticities referred to one single country (75%), even though an important number of elasticities refer to a group of countries (17%), and, more exceptionally, those that focus on the specific analysis of administrative units beneath country level – zones or specific regions – (8%).

Information was also taken from the administrative level that manages capital: only state – central or federal – (4%), or only corresponding to Territorial Administrations (4%), the remaining incorporate aggregated public capital in the territory (92%). In the same way, we also considered whether public capital belonging to other administrative levels is included (4%), as well as that of neighboring territories (13%). Another important factor refers to sectorial coverage: for the economy as a whole (69%) or referring to specific sectors: industry (22%), or the rest of sectors (95%).

A fourth group of differential features of the studies focuses on econometric procedures. Here, it is common to control for the existence of individual effects (61%) and less common to do corrections to obtain efficient estimators – heterocedasticity and serial correlation – (37%), to deal

[18] For instance, if the considered public capital is productive capital, but within the production function, social public capital was also introduced.
[19] This is the option used in growth models as well as in estimations of the production function in first differences.

with the problem of endogeneity through some procedure of instrumental variables (25%), to calculate long-term elasticities – usually through dynamic models – (11%), and, to control for the possible existence of spurious correlation (21%).

Finally, within the fifth group of features, there is a predominance of elasticities taken from articles in journals (69%), although there also is a noted presence in the sample of other forms of dissemination (31%). Furthermore, most of the values correspond to studies published in this century (62%), although in the 90s there was a notable concentration of such papers (35%) and only a small minority of the same in the 80s (3%). With respect to each value obtained, we consider if the author gives greater credibility to them than the others included in the work (69% are credible for the authors). In this sense, it must be pointed out that although there always is a credible value in each study, it is also common to present various estimations, without showing preferences for any of them. Only in 25 articles were just one value presented as the preferred value.

5. Results

The meta-regression analysis is carried out by incorporating as meta-regressors dummy variables built from the characteristics of the different results. In this sense, in every group of dummy variables we have eliminated one of them, to avoid perfect multi-colinearity. Once the dummy variables are constructed, the mean is subtracted, so that the inclusion of the different groups of dummies does not modify the value of the constant, which is the estimated average elasticity. However, the interpretation of the coefficients associated to the different methodological options is still carried out in relation to the omitted one (in Table 2 the omitted dummy is indicated by an asterisk). The variable identifying the year of publication is introduced in logarithm. Furthermore, we have included the interaction of dummies for countries and five-year periods when we have five or more observation belonging to the corresponding groups.

The results of the meta-regression analysis by mixed effects, the preferred procedure departing from the Q statistic, are also summed up in Table 2[20]. Second column offers the meta-

[20] In the basic meta-analysis, expression (1), the Q test value rejects the null hypothesis that τ^2 equals zero, and therefore, the results obtained by the random effects model are preferred to those obtained by fixed effects. This supports the need for a meta-regression analysis. The τ^2 between-studies variance was estimated through maximum restricted likelihood, an approach recommended by Thompson and Sharp (1999) as the most adequate.

regression with the complete sample. Last column carries out a meta-regression solely for the values that the authors have considered credible. In general, the results obtained in the two regressions practically match; with very slight discrepancies.

The (constant) mean values obtained for the output elasticity of public capital elasticity are statistically significant and positive in both cases, with values between 0.120 and 0.132. These values are very much below (about a third) the value obtained by Aschauer, and above those taken as definitive in some recent meta-analyses (Bom and Ligthart, 2014). In the first column we included a dummy variable that captures self-selection carried out by the author himself from amongst his results. Furthermore, in both columns we indicate if the results are published in journals. In both cases, these dummies are statistically significant, confirming the presence of both types of biases, towards higher values.

The larger coefficient obtained for the quadratic standard error when the elasticity is positive in relation to when it is negative, can be interpreted as the existence of publication bias originated by those erratic results provided by small samples, being corrected.

With regard to meta-regressors, there is evidence of the importance of the theoretical focus adopted. The use of a growth model or a frontier approach would imply a fall in the estimated elasticities with respect to the production function. On the contrary, the value increases notably (trebling) in cases where the quasi-production function is used. Additionally, results suggest that when constant returns to scale on all factors are imposed, the elasticity of public capital tends to increase, the opposite occurs when this restriction is forced on private factors. However, the values obtained show that the elasticities are statistically equal or slightly higher if public capital is obtained through the estimation of a productivity function.

On the other hand, a certain positive influence is perceived on the elasticity of public capital when the economic cycle is introduced in the estimated function. The inclusion of variables that control for the density of economic activity reduces the elasticity value, as expected.

It is discernible that productive capital shows a higher effect on productivity than public capital as a whole. Surprisingly, we find the contrary effect with the use of transport infrastructures.

A negative effect results if the public capital variable is measured through a flow. The way in which capital is measured and the used output variable don't show statistically significant differences.

The use of time series offers, as was to be expected, mean elasticities that are generally much higher than those which used panel or cross sectional data. In the same way, when the sample refers to a geographical area smaller than the country, the elasticities obtained increase. In this same sense, a very important negative effect is detected when territorial public capital is used against the total. The conjunction of these results implies that the effect of the public capital of all the Public Administrations in a territory, when the units of analysis are in a range smaller than the State, is greater than the simple consideration of the one pertaining to these territorial administrations, which underlines the importance of the network effects. That is why it is found that the inclusion of capital of another administrative level in the same equation brings down the elasticity of the one being analyzed. The net result of all the previous effects indicates that greater territorial disaggregation brings elasticities down.

With regard to the econometric procedure, the studies considering individual effects obtain higher values for the mean elasticity of public capital that offset, but does not compensate, the effect obtained for panels - necessary to carry out this control-. The contrary occurs with the analyses that introduce mechanisms for the improvement of efficiency in the results and, also, control for the possible existence of spurious correlations. As expected, long term elasticities are statistically higher than short term ones (0.16 vs 0.13).

Finally, with respect to the year of publication, it has been observed that there is a very slight downward tendency only when the values preferred by the authors are considered, which might be due to three possible explanations: improvement in econometric techniques conveniently not controlled in the meta-regression specification, a more accurate measuring of the different variables with an improvement in the quantification procedures especially relative to public capital, and, finally, to the fact that the general increase in public capital endowments has lessened the impact, which would be indicative of a very weak presence of decreasing returns in this factor. However, it is striking that this negative effect of the passage of time on elasticity is only detected in

the case of the results chosen by the authors themselves, which would perhaps be indicative of another self-selection bias towards lower values as a result of a change in the paradigm.

However, this very slight downward tendency in the output elasticity of public capital requires careful analysis as it has important and evident implications on the effectiveness of infrastructure investment policies. In those economies with high capital endowments, additional public capital investments could be losing effectiveness. Infrastructure investment expenditure may have overcome Barro's golden rule and thus the optimal ratio. In fact, the original elasticities of the meta-sample are negatively correlated with the period in which they are observed (Figure 2.A)[21]. However, when per capita GDP of the country is used as a proxy of its public capital (Figure 2.B), the tendency reverses, probably due to the influence of those papers published in late 1980s and the beginning of the 1990s using US data and offering very high elasticities.

The estimation of these functions using the meta-regression elasticities and introducing interaction dummies for five-year periods and country, gives different results due to the depuration of elasticities from the effects provoked by methodological decisions and/or the diversity of the employed data. The downward tendency with the time dimension is still observed (Figure 2.C), although resulting slope is much smaller. However, the correlation between per capita GDP and the elasticities is negative (Figure 2.D), evidencing the fall in the effectiveness of additional public capital investments.

Figure 2.E depicts the mean of original elasticities together with country specific estimated ones. Extreme values are corrected when controlling for methodological aspects. However, there are still relevant and significant differences amongst countries, either due to existing public capital endowments when investments are carried out, or because the selection of investment projects is more adequate and more efficient in the use of public resources in some economies than in others, where corruption may be more settle down.

6. Conclusions

[21] Both the original elasticities and estimated ones depicted in Figure 2 refer to countries and five-year periods appropriately indicated by corresponding dummy variables. The last Figure shows mean values by country for each considered five-year period. The computation of the elasticities for each country and five-year period is carried out by adding up the estimated intercept resulting from the whole meta-sample (Table 2) and the obtained coefficient for the corresponding dummy.

Nowadays, there exists an important debate with regards to the role that public investment must play in the process of economic recovery and long term growth. The basics of this debate have to do with the actual effectiveness of public investment, and more precisely, those investments in infrastructures.

This paper carries out a meta-regression analysis with the aim of providing a synthesis of previous evidence on the value of output elasticity of public capital or public infrastructures, obtained in a Cobb-Douglas type production function or an equivalent specification. The need for this meta-analysis is justified by the high level of disparity in the results found in literature. This great variability is, for some authors, the result of methodological differences adopted in studies. We therefore also offered a succinct overview of these controversies.

To obtain the meta-sample, we carried out a biblio-metric analysis with the aim of estimating the population of articles on the question, selecting a representative sample and calculating the information content. Almost two thousand values were obtained, corresponding to 145 articles, which account for 50-67% of the information content of the body of work. In this sense, the present meta-analysis on this question, as far as the authors know, is broader and stricter than those carried out to date, more than tripling the information content.

The results of the meta-analysis, especially the acceptance of the random effects model, suggests a need for carrying out a meta-regression analysis in order to assess the extent to which the different methodological decisions and the nature of the information used influence the results obtained. Taking as many as 29 different features associated with each of the values for output elasticity of capital, the meta-regressors were constructed. The results of the meta-regression analysis again confirmed the undeniable, positive effect of public infrastructures on productivity: mean elasticity is found to be at 0.13, about a third of the figure obtained for seminal articles of the late 1980s. Furthermore, evidence was also found of the importance of methodological decisions and the nature of information to the results. In concrete terms, it was found that the theoretical focus adopted, the inclusion of certain variables in the production function, the definition and way of measuring public capital, the structure and range of the sample, the geographical and sectorial

disaggregation and coverage considered and the econometric procedures, all have an influence on the results obtained.

There is, as well, a degree of certainty regarding the importance of the different concepts of publication bias. Particularly worrying is what is derived from the self-selection of authors and of reviewers for the acceptance of papers that publish and veer towards conventional results. This behavior could possibly be limiting the possibility of further of knowledge, due to a certain degree of scientific conservatism.

We find at least four relevant results with regards to the effectiveness of public investments. First, there exists a systematic, statistically significant and positive effect of public capital on productivity. Secondly, this effect is as expected larger in the long run than it is in the short term. Obtained elasticities are slightly higher than those usually employed to compute multipliers, suggesting that public investments will be self-financed in the long term due to generated returns. Nonetheless, it must be noticed that there exists some conditioning elements as the degree of economic slack and monetary accommodation, the efficiency of public investment, and the way in which public expenditure expansions are financed, paying special attention to the public-debt-to-GDP ratio and associated distorting effects.

In third place, the effects are similar amongst different economies, but with a clear influence of the institutional context and the different capacities of countries to properly select and execute investment projects. Without doubts, this provides evidence of the importance of adequate selection and monitoring processes when carrying out new public investments.

Finally, we find a very slight reduction in the value of the elasticities as public capital endowments increase —approximated by the level of per capita GDP—, nevertheless, the values are always positive. This again, confirms that the selection of projects should be more selective in order to benefit more from network effects, and thus avoid the investment in unproductive projects. A proper maintenance of existing infrastructures seems also crucial, as early deterioration of these infrastructures may well be behind the observed fall in effectiveness.

BIBLIOGRAPHY

* Aaron, H.J. (1990): "Discussion", en A.H. Munnell, (ed.), Is There a Shortfall in Public Capital Investment?, Federal Reserve Bank of Boston, Boston.

* Abdih, Y. and Joutz F. L. (2008): "The Impact of Public Capital, Human Capital, and Knowledge on Aggregate Output", IMF Working Papers 08/218, International Monetary Fund.

Abiad, A.; Almansour, A.; Furceri, D.; Mulas, C. and Topalova, P. (2014): "Is it time for an infrastructure push? The macroeconomic effects of public investment", World economic Outlook, October, 75-114.

* Ai, C and Cassou, S. P. (1995): "A Normative Analysis of Public Capital", Applied Economics, 27(12), 1201-09.

* Alonso-Carrera, J. and Freire-Serén M. J. (2002): "Infraestructuras Públicas y Desarrollo Económico de Galicia", en A. de la Fuente, M.J. Freire y J. Alonso, Infraestructuras y desarrollo regional, Doc. de Economía 15, Fundación CaixaGalicia.

* Alvarez-Pinilla, A., Orea-Sánchez, L. and Fernandez Alvarez. J (2003): "La productividad de las infraestructuras en España", Papeles de Economia Española, 95, 125-136.

* Andrews, K. and Swanson, J. (1995): "Does Public Infrastructure Affect Regional Performance?", Growth and Change, 26. 204–216.

* Argimón, I.; J.M. González-Paramo and J.M. Roldán (1994): "Productividad e infraestructuras en la economía española", Moneda y Crédito, 198, 207-241.

Arrow, K.J. and Kurz, M., (1970): Public investment, the rate of return and optimal fiscal policy, Johns Hopkins University Press, Baltimore.

Arrow, K.J. (1972); The Measurement of Real Value Added, Institute for Mathematical Studies in the Social Sciences.

* Arslanalp, S.; Barnharst, F.; Gupta, S. and Sze, E. (2010): "Public capital and growth", Working Paper No. 175, International Monetary Fund, Julio.

* Aschauer, D.A. (1989a): "Is public expenditure productive?", Journal of Monetary Economics, 23(2), 177-200.

* Aschauer, D.A. (1989b): "Public investment and productivity growth in the Group of Seven", Economic Perspectives, Federal Reserve Bank of Chicago, Septiembre, 17-25.

* Aschauer, D. A. (1990): "Highway capacity and economic growth", Economic Perspectives, Federal Reserve Bank of Chicago, Septiembre, 14-24.

* Aschauer, D.A. (1998): "The Role of Public Infrastructure Capital in Mexican Economic Growth", Economia Mexicana. Nueva época, VII(1), 47-78.

Ashenfelter, O.; Harmon, C. and Oosterbeek, H. (1999): "A review of estimates of the schooling/earnings relationship, with tests for publication bias", Labour Economics, 6(4), 453-470.

Baily, M.N. (1981): "Productivity and services of capital and labour", Brooking Pappers on Economic Activity, 1, 1-50.

Asterisks indicate the articles used in the meta-analysis.

Bajo-Rubio, O. and Sosvilla, S. (1993): "Does public capital affect private sector performance? An analysis of the Spanish case, 1964-1988", Economic Modelling, 10(3), 179-185.

* Bajo-Rubio, O.; Díaz-Roldán, C. and Montávez-Garcés, M.D., (2002): "Optimal Endowments of Public Investment: An Empirical Analysis for the Spanish Regions", Economic Working Papers at Centro de Estudios Andaluces E2002/14, Centro de Estudios Andaluces.

* Baltagi, B. H. and Pinnoi, N., (1995): "Public Capital Stock and State Productivity Growth: Further Evidence from an Error Components Model", Empirical Economics, 20(2), 351-59.

Barbiero, F. and Darvas, Z., (2014): "In sickness and in health: Protecting and supporting public investment in Europe", Bruegel Policy Contribution, 2014/02.

Barro, R.J. (1990): "Government Spending in a Simple Model of Endogenous Growth", Journal of Political Economy, 98(5), 103-26.

Barro, R.J. and Sala-i-Martín, X. (1995): Economic Growth, The MIT Press.

* Batina, R.G. (1998): "On the Long Run Effects of Public Capital and Disaggregated Public Capital on Aggregate Output", International Tax and Public Finance, 5(3), 263-281.

* Berechman, J., Ozmen, D. and Ozbay, K. (2006): "Empirical analysis of transportation investment and economic development at state, county and municipality levels", Transportation, 33(6), 537-551.

* Berndt, E. R. and Hansson, B., (1992): "Measuring the Contribution of Public Infrastructure Capital in Sweden", Scandinavian Journal of Economics, 94(0), S151-68,

Bijmolt, T.H.A. and Pieters R.G.M. (2001): "Meta-Analysis in Marketing when Studies Contain Multiple Measurements", Marketing Letters, 12, 157-169.

* Björkroth, T. and Kjellman, A., (2000): "Public capital and private sector productivity - a Finnish perspective", Finnish Economic Papers, 13(1), 28-44.

* Boarnet, M. G. (1998): "Spillovers and the Locational Effects of Public Infrastructure", Journal of Regional Science, 38, 381-400.

Bom, P.R. and Ligthart, J.E. (2014): "What Have We Learned From Three Decades of Research on the Productivity of Public Capital?", Journal of Economic Surveys, 28(5), 889-916.

* Bonaglia, F., La-Ferrara, E. and Marcellino, M. (2000): "Public Capital and Economic Performance: Evidence from Italy", Giornale degli Economisti e Annali di Economia, 59(2), 221-244.

* Boopen, S. (2006), "Transport Infrastructure and Economic Growth: Evidence from Africa Using Dynamic Panel Estimates", Empirical Economics Letters, 5, 1, 37-52.

Boscá, J., Escriba, J., and Murgui, M. (2011): "La efectividad de la inversión en infraestructuras públicas: Una panorámica para la economía española y sus regiones", Investigaciones Regionales, 20, 195-217.

Bradford, S.C. (1946): Documentation, Crosby Lockwood, London.

* Bronzini, R. and Piselli, P. (2009): "Determinants of long-run regional productivity with geographical spillovers: The role of R&D, human capital and public infrastructure", Regional Science and Urban Economics, 39(2), 187-199.

Asterisks indicate the articles used in the meta-analysis.

Brons, M.R.E. (2006): "Meta-Analytical Studies in Transport Economics: Methodology and Applications", Dissertation, Vrije Universiteit Amsterdam.

Brons, M., Nijkamp, P., Pels, E. and Rietveld, P. (2008): "A meta-analysis of the price elasticity of gasoline demand, a SUR approach". Energy Economics, 30, 2105-2122.

Button, K. (1998): "Infrastructure investment, endogenous growth and economic convergence", The Annals of Regional Science, 32(1), 145-162.

* Cadot, O., Röller, L. and Stephan, A., (1999): "A Political Economy Model of Infrastructure Allocation: An Empirical Assessment", CEPR Discussion Papers 2336.

* Cadot, O., Roller, L. and Stephan, A., (2006): "Contribution to productivity or pork barrel? The two faces of infrastructure investment", Journal of Public Economics, 90(6-7), 1133-1153.

* Calderón, C. and Servén, L., (2002): "The Output Cost of Latin America's Infrastructure Gap", Working Papers Central Bank of Chile 186, Central Bank of Chile.

* Calderón, C. and Servén, L., (2005), "The Effects of Infrastructure Development on Growth and Income Distribution" DEGIT Conference Papers c010_056, DEGIT, Dynamics, Economic Growth, and International Trade.

Calderón, C. and Servén, L. (2014): "Infrastructure, Growth, and Inequality. An Overview", Policy Research Working Paper 7034, World Bank.

* Canning, D., (1998): "A database of world infrastructure stocks, 1950-95", Policy Research Working Paper Series 1929, The World Bank.

* Canning, D., (1999): "Infrastructure's contribution to aggregate output", Policy Research Working Paper Series 2246, The World Bank.

* Canning, D. and Bennathan, E., (2000): "The social rate of return on infrastructure investments", Policy Research Working Paper Series 2390, The World Bank.

* Cantos-Sánchez, P.; Gumbau-Albert, M. and Maudos, J. (2005): "Transport infrastructures and regional growth: Evidence of the spanish case", MPRS. Paper No. 15261.

Card, D. and Krueger A.B. (1995): "Time-Series Minimum Wage Studies: A Meta-Analysis", American Economic Review, 85, 238-243.

* Charlot, S. and Schmitt, B., (2000): "Public Infrastructure and Economic Growth in France's Regions," ERSA conference papers 142, European Regional Science Association.

* Cohen, J.P. (2010): "The Broader Effects of Transportation Infrastructure: Spatial Econometrics and Productivity Approaches", Transportation Research: Part E: Logistics and Transportation Review, 46(3), 317-326.

Cohen, J.P. and Morrison Paul, C.J. (2004): "Public Infrastructure Investment, Interstate Spatial Spillovers, and Manufacturing Costs", The Review of Economics and Statistics, 86(2), 551-560.

* Creel, J. and Poilon, G., (2008): "Is public capital productive in Europe?" International Review of Applied Economics, 22(6), 673-691.

Asterisks indicate the articles used in the meta-analysis.

* Crescenzi, R. and Rodriguez-Pose, A., (2008): "Infrastructure endowment and investment as determinants of regional growth in the European Union" EIB Papers 8/2008, European Investment Bank, Economic and Financial Studies.

* Crihfield, J.B. and Panggabean, Martin P.H., (1995): "Is public infrastructure productive? A metropolitan perspective using new capital stock estimates" Regional Science and Urban Economics, 25(5), 607-630.

* Crowder, W. J. and Himarios, D., (1997): "Balanced Growth and Public Capital: An Empirical Analysis," Applied Economics, 29(8), 1045-53.

* Cutanda, A. and Paricio, J. (1994): "Infrastructure and regional economic growth: the Spanish case", Regional Studies, 28(1), 69-77.

* Costa, J.d.S., Ellson, R.W. and Martin, R. C. (1987): "Public capital, regional output, and development: Some empirical evidence", Journal of Regional Science, 27, 419-437.

* Dabán, T. and Lamo, A. (1999): "Convergence and public investment allocation Spain 1980-1993". Dirección General de Análisis y Programación Presupuestaria, Ministerio de Economía y Hacienda, Working paper, Nº D-99001.

* Dalamagas, B., (1995): "A Reconsideration of the Public Sector's Contribution to Growth", Empirical Economics, 20(3), 385-414.

David, F.N. (1934): "On the $P\lambda_n$ test for randomness: Remarks, further illustration, and table of $P\lambda_n$ for given valves of $-\log_{10}(\lambda_n)$", Biometrica 26, 1-11.

* De la Fuente, A. (2002): "The effect of Structural Fund spending on the Spanish regions: an assessment of the 1994-99 Objective 1 CSF," UFAE and IAE Working Papers 538.02, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC).

De la Fuente, A. (2010): "Infrastructures and productivity: an updated survey" UFAE and IAE Working Papers 831.10, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC).

* De la Fuente, A., and Domenech (2006): "Capital humano, crecimiento y desigualdad en las regiones españolas", Moneda y crédito, 222.

* De la Fuente, A., and Vives, X., (1995): "Infrastructure and Education as Instruments of Regional Policy: Evidence from Spain", Economic Policy, 20, 11-40.

* Delgado, M.J and Álvarez, I. (2000): "Las infraestructuras productivas en España: Estimación del stock en unidades físicas y análisis de su impacto en la producción privada regional", Revista Asturiana de Economía, 19, 155-80.

* Delgado, M.J and Álvarez, I. (2004a): "Infraestructuras y eficiencia técnica: Un análisis de técnicas frontera", Revista de Economía Aplicada, 12(35), 65-82.

* Delgado, M.J. and Álvarez, I. (2004b), "Infraestructuras de Transportes: Medición y Análisis de los Efectos Desbordamiento para los Sectores Productivos Españoles", Documentos del Instituto Complutense de Análisis Económico 0407, Universidad Complutense de Madrid, Facultad de Ciencias Económicas y Empresariales.

* Delgado, M.J and Alvarez, I. (2007): "Network infrastructure spillover in private productive sectors: evidence from Spanish high capacity roads" Applied Economics, 39(12), 1583-1597.

Asterisks indicate the articles used in the meta-analysis.

* Delorme, C.Jr., Thompson, H.Jr. and Warren, R.Jr., (1999): "Public Infrastructure and Private Productivity: A Stochastic-Frontier Approach" Journal of Macroeconomics, 21(3), 563-576.

Demetriades, P.O. and Mamuneas, T.P., (2000): "Intertemporal Output and Employment Effects of Public Infrastructure Capital: Evidence from 12 OECD Economics". Economic Journal, 110(465), 687-712.

* Dessus, S. y Herrera, R., (2000): "Public Capital and Growth Revisited: A Panel Data Assessment" Economic Development and Cultural Change, 48(2), 407-18.

* Dodonov, B., Von Hirschhausen, C., Opitz, P. and Sugolov, P., (2002): "Efficient Infrastructure Supply for Economic Development in Transition Countries: the Case of Ukraine", Post-Communist Economies, 14(2), 149-167.

* Duffy-Deno K.T. and Eberts, R.W. (1991): " Public infrastructure and regional economic development: A simultaneous equations approach", Journal of Urban Economics, 30(3), 329-343.

Duggal, V.G., Saltzman, C. and Klein, L.R., (1999): "Infrastructure and productivity: a nonlinear approach", Journal of Econometrics, 92(1), 47-74.

Easterly, W. and Rebelo, S. (1993): "Fiscal Policy and Economic Growth: An Empirical Investigation", Journal of Monetary Economics, 32, 417-458.

* Eberts, R.W. (1990): "Cross-sectional analysis of public infrastructure and regional productivity growth" Working Paper 9004, Federal Reserve Bank of Cleveland.

* Eisner, R. (1991): "Infrastructure and regional economic performance: comment," New England Economic Review, Septiembre, 47-58.

* Eisner, R. (1994): "Real government saving and the future", Journal of Economic Behavior and Organization, 23, 111-126

* Eerenburg, S.J., (1998): "Productivity, Private and Public Capital, and Real Wage in the US", Applied Economics Letters, 5(8), 491-95.

* Escribá, F. J. and Murgui, M. J. (2007): "El Capital Tecnológico como Factor de Producción en las Regiones Españolas, 1980-2000", Investigaciones Regionales, 10, 33-52.

Esfahani, H.S. and Ramírez, M.T., (2003): "Institutions, infrastructure, and economic growth", Journal of Development Economics, 70(2), 443-477.

Estache, A. and Goicoechea, A., (2005): "A "research" database on infrastructure economic performance", Policy Research Working Paper Series 3643, The World Bank.

* Evans, P. and Karras, G. (1994a): "Is government capital productive? evidence from a panel of seven countries", Journal of Macroeconomics, 16(2), 271-279.

* Evans, P. and Karras, G. (1994b): "Are Government Activities Productive? Evidence from a Panel of U.S. States", The Review of Economics and Statistics, 76(1), 1-11.

* Fedderke, J.W. and Bogetic, Z. (2006): "Infrastructure and growth in South Africa: direct and indirect productivity impacts of 19 infrastructure measures", Policy Research Working Paper Series 3989, The World Bank.

Feld L.P. and Heckemeyer J.H., (2011): "Fdi And Taxation: A Meta-Study", Journal of Economic Surveys, 25(2), 233-272.

Asterisks indicate the articles used in the meta-analysis.

Fernald, J. (1999): "Roads to Prosperity? Assessing the Link between Public Capital and Productivity", American Economic Review, 89(3), 619-638.

* Fernandez, M. and Montuenga-Gomez, V. (2003): "The Effects of Public Capital on the Growth in Spanish Productivity", Contemporary Economic Policy, 21(3), 383-393

* Fernández, M. and Polo, C. (2001): "Capital público y productividad privada en España: una panorámica", Revista Galega de Economía, 1.

* Fernández, M. and Polo, C. (2002): "Productividad del capital público en presencia de capital tecnológico y humano", Revista de Economía Aplicada, 29, 151-161.

* Fingleton, B. and Gómez-Antonio, M. (2011): "Regional productivity variation and the impact of public capital stock: an analysis with spatial interaction, with reference to Spain" Working Papers 1102, University of Strathclyde Business School, Department of Economics.

* Finn, M. (1993): "Is all government capital productive?", Economic Quarterly, fall, 53-80.

Fisher, W.H. and Turnovsky, S.J. (1998): "Public Investment, Congestion, and Private Capital Accumulation", The Economic Journal, 108, 339-413.

* Flores de Frutos, R., Gracia-Diez, M. and Perez-Amaral, T., (1998): "Public Capital Stock and Economic Growth: An Analysis of the Spanish Economy", Applied Economics, 30(8), 985-94.

* Ford, R. and P. Poret (1991), "Infrastructure and Private-Sector Productivity", OECD Economics Department Working Papers, No. 91.

* Garcia-Mila, T., McGuire, T.J. and Porter, R.H., (1996): "The Effect of Public Capital in State-Level Production Functions Reconsidered", The Review of Economics and Statistics, 78(1), 177-80.

* Garcia-Mila, T. and McGuire, T.J., (1992): "The contribution of publicly provided inputs to states' economies", Regional Science and Urban Economics, 22(2), 229-241.

* García-Fontes, W. and Serra, D. (1994): "Capital Público, Infraestructuras y Crecimiento", en VV.AA. (eds): Crecimiento y convergencia regional en España y Europa, vol. 2. Instituto de Análisis Económico. Barcelona, 451-78.

Garfield, E. (1980): "Bradford's law and related statistical patters", Current contents, 19, 5-12.

Gillen, D. (2001): "Public Capital, Productivity, and the Linkages to the Economy: Transportation Infrastructure", Building the future: Issues in public infrastructure in Canada, Policy Study 34, 36-72.

* Gonzalez-Paramo J.M., (1995): "Infraestructuras, productividad y bienestar" Investigaciones Economicas, 19(1), 155-168.

Görg, H. and Strobl, E., (2001): "Multinational Companies and Productivity Spillovers: A Meta-analysis", Economic Journal, 111(475), 723-39.

* Gorostiaga, A., (1999): "¿Cómo afecta el capital público y el capital humano al crecimiento?", Investigaciones Economicas, 23(1), 95-114.

Gramlich, E. M., (1994): "Infrastructure Investment: A Review Essay", Journal of Economic Literature, 32(3), 1176-96.

Asterisks indicate the articles used in the meta-analysis.

Group of Twenty (2014): "Communiqué Meeting of Finance Ministers and Central Bank Governors", Sydney, 22-23 February 204.

* Hämäläinen, P. and Malinen, T. (2011): "The relationship between regional value-added and public capital in Finland: what do the new panel econometric techniques tell us?" Empirical Economics, 40(1), 237-252.

Hansen, M. (1965): "Unbalanced Growth and Regional Development", Western Economic Journal, 4, 3-14.

* Harmatuck, D. (1996): "The influence of transportation infrastructure on economic development", Logistics and Transportation Review, 32(1), 76-92.

Hirschman, Albert O. (1958): The Strategy of Economic Development, Yale University Press, New Haven.

* Haughwout, A.F., (2000): "State Infrastructure, the Distribution of Jobs, and Productivity", mimeo Federal Reserve Bank of New York.

* Holtz-Eakin, D., (1994): "Public-Sector Capital and the Productivity Puzzle", The Review of Economics and Statistics, 76(1), 12-21.

* Holtz-Eakin, D. and Lovely, M.E., (1996): "Scale economies, returns to variety, and the productivity of public infrastructure", Regional Science and Urban Economics, 26(2), 105-123.

* Holtz-Eakin, D. and Schwartz, A.E., (1995a): "Infrastructure in a structural model of economic growth", Regional Science and Urban Economics, 25(2), 131-151.

* Holtz-Eakin, D. and Schwartz, A.E., (1995b): "Spatial productivity spillovers from public infrastructure: Evidence from state highways", International Tax and Public Finance, 2(3), 459-468.

* Hulten, C.R.; Bennathan, E. and Srinivasan, S. (2006): "Infrastructure, Externalities, and Economic Development: A Study of the Indian Manufacturing Industry", World Bank Economic Review, 20(2), 291-308.

* Hulten, C.R. and Schwab, R. (1991): "Public capital formation and the growth of regional manufacturing industries", National Tax Journal, 64(4), 121-134.

* Hurlin, C. (2006): "Network effects of the productivity of infrastructure in developing countries", Policy Research Working Paper Series 3808, The World Bank.

* Isaksson, A. (2009): "Public capital, Infrastructure and Industrial Development", Research and statistics Branch, working paper.

* Kamps, C. (2006): "New Estimates of Government Net Capital Stocks for 22 OECD Countries, 1960-2001", IMF Staff Papers, 53(1), 6.

* Kataoka, M. (2005): "Effect of Public Investment on the Regional Economies in Postwar Japan". Review of Urban and Regional Development Studies, 17, 115-139.

* Kawaguchi, D.; Ohtake, F. and Tamada, K., (2005): "The productivity of public capital: evidence from the 1994 electoral reform of Japan", Discussion Paper 627, The Institute of Social Economic Research.

Asterisks indicate the articles used in the meta-analysis.

* Kawaguchi, D.; Ohtake, F. and Tamada, K., (2009): "The productivity of public capital: Evidence from Japan's 1994 electoral reform", Journal of the Japanese and International Economies, 23(3), 332-343.

* Kelejian, H. and Robinson, D. (1997): "Infrastructure productivity estimation and its underlying econometric specifications: a sensitivity analysis", Papers in Regional Science, 76, 115-131.

* Kemmerling, A. and Stephan, A., (2002): "The Contribution of Local Public Infrastructure to Private Productivity and Its Political Economy: Evidence from a Panel of Large German Cities", Public Choice, 113(3-4), 403-24.

* Khanam, B. R. (1996): "Highway Infrastructure Capital and Productivity Growth: Evidence from the Canadian Goods-Producing Sector", Logistics and Transportation Review, 32, 251-268.

* La Ferrara, E. and Marcellino, M., (2004): "TFP, Costs, and Public Infrastructure: An Equivocal Relationship", en Artis, A., Banerjee, A. y Marcellino, M. (eds): The Central and Eastern European Countries and the European Union. Cambridge University Press, Cambridge.

Lall, S.; Shalizi, Z. and Deichmann, U. (2004): "Agglomeration economies and productivity in Indian industry", Journal of Development Economics, 73, 643-673.

* Lanzas, J. R. and Martinez, D. (2003): "El capital público y privado como determinantes del crecimiento industrial en las regiones españolas", Cuadernos de CC.EE y EE, 44-45, 99-111.

* Le, M.V. and Suruga, T. (2005): "Foreign direct investment, public expenditure and economic growth: the empirical evidence for the period 1970-2001", Applied Economics Letters, 12(1), 45-49.

* Ligthart, J.E. (2002): "Public Capital and Output Growth in Portugal: An Empirical Analysis", European Review of Economics and finance, 1, 3-30.

Ligthart, J.E. and Martin Suarez, R. (2011), "The Productivity of Public Capital: A Meta-analysis", Infrastructure Productivity Evaluation pp. 5-32 Springer Briefs in Economics. New York and Heidelberg.

* Marrocu, E. and Paci, P. (2010): "The effects of public capital on the productivity of the Italian regions", Applied Economics, 42(8), 989-1002.

* Mas, M.; Maudos, J.; Pérez, F and Uriel, E. (1993a): "Capital Público Y Productividad De La Economía Espanola" Working Papers. Serie EC 1993-08, Instituto Valenciano de Investigaciones Económicas, S.A. (Ivie).

* Mas, M.; Maudos, J.; Pérez, F and Uriel, E. (1993b): "Competitividad, productividad industrial y dotaciones de capital público", Papeles de Economía Española, 56, 144-159.

* Mas, M.; Maudos, J.; Pérez, F and Uriel, E. (1994): "Capital Público y Productividad en las Regiones Españolas", Moneda y Crédito, 198, 163-192.

* Mas, M.; Maudos, J.; Pérez, F and Uriel, E. (1996): "Infrastructures and Productivity in the Spanish Regions", Regional Studies, 30(7), 641-649.

* Mas, M.; Maudos, J.; Pérez, F and Uriel, E. (1998): "Public capital, productive efficiency and convergence in the spanish regions (1964-93)", Review of income and wealth, 44(3), 383-396.

* Mas, M. and Maudos, J. (2011): "Infraestructuras y crecimiento regional en España diez años después", mimeo.

Asterisks indicate the articles used in the meta-analysis.

Meade, J.E., (1952): "External Economies and Diseconomies in a Competitive Situation", The Economic Journal, 62(245), 54-67.

Melo, P.C.; Graham, D.J. and Brage-Ardao, R. (2012): "The productivity of transport infrastructure investment: A meta-analysis of empirical evidence", Economic and Social Research Council, mimeo.

Mera, K. (1973): "Regional production functions and social overhead capital: an analysis of the Japanese case", Regional and Urban Economics, 3(2), 157-186.

* Mitra, A.; Varoudakis, A. and Veganzones-Varoudakis, M.A., (2002): "Productivity and Technical Efficiency in Indian States' Manufacturing: The Role of Infrastructure," Economic Development and Cultural Change, 50(2), 395-426.

* Mizutani, F. and Tanaka, T. (2010): "Productivity effects and determinants of public infrastructure investment", The Annals of Regional Science, 44(3), 493-521.

* Montolio, D. and Solé-Ollé, A. (2009): "Road investment and regional productivity growth: the effects of vehicle intensity and congestion", Papers in Regional Science, 88(1), 99-118.

* Moreno, R.; Artis, M.; Lopez, E. and Surinach, J., (1997): "Evidence on the complex link between infrastructure and regional growth", Working Papers in Economics 19, Universitat de Barcelona. Espai de Recerca en Economia.

* Moreno, R. and López-Bazo, E. (2007): "Returns to local and transport infrastructure under regional spillovers", International Regional Science Review, 30, 47-71.

* Munnell, A.H. (1990): "Why has productivity growth declined? Productivity and public investment", New England Economic Review, 3-22.

Munnell, A.H. (1992): "Infrastructure Investment and Economic Growth", Journal of Economic Perspectives, 6(4), 189-98.

* Munnell, A.H. (1993): "An assessment of trends and economic impacts of infrastructure investment", en Infrastructure Policies for the 1990s, OECD, Paris, Capitulo 2.

* Munnell, A.H. and Cook, L.M. (1990): "How does public infrastructure affect regional economic performance?", New England Economic Review, 11-33.

* Nombela, G., (2005): "Infraestructuras del transporte y productividad". Presupuesto y Gasto Público, 39, 191-215.

* Nourzad, F. (1998): "Infrastructure Capital and Private Sector Productivity: A Dynamic Analysis", Quarterly Journal of Business and Economics, 37, 13-25.

* Nourzad, F., (2000): "The Productivity Effect of Government Capital in Developing and Industrialized Countries", Applied Economics, 32(9), 1181-87.

* Nourzad, F. and Vrieze, M. (1995): "Public capital formation and economic growth: some international evidence", The Journal of Productivity Analysis, 6(4), 283-295.

* Otto, G. and Voss, G. (1994): "Public capital and private sector productivity", The Economic Record, 70(209), 121-132.

Asterisks indicate the articles used in the meta-analysis.

* Otto, G. and Voss, G. (1996): “Public capital and private production in Australia”, Southern Economic Journal, 62(3), 723-738.

* Otto, G. and Voss, G., (1998): "Is public capital provision efficient?", Journal of Monetary Economics, 42(1), 47-66.

* Owyong, D.T. and Thangavelu, S.M., (2001): "An Empirical Study on Public Capital Spillovers from the USA to Canada", Applied Economics, 33(11), 1493-99.

* Ozbay, K.; Ozmen-Ertekin, D. and Berechman, J., (2007): "Contribution of transportation investments to county output", Transport Policy, 14(4), 317-329.

Pearson, K. (1934): "On a new method of determining goodness of fit", Biometrica, 26, 425-442.

* Pedraja, F.; Ramajo, J. and Salinas, J. (1999): "Eficiencia productiva del sector industrial español: un análisis espacial y sectorial", Papeles de Economia Española, 80, 51-67.

* Pedraja-Chaparro, F.; Salinas-Jimenez, M.; and Salinas-Jimenez, J. (2002): "Efectos del capital público y del capital humano sobre la productividad de las regiones españolas", Papeles de Economia Espanola, 93, 135-147.

Pereira A.M. and Andraz, J.M. (2011): "On the economic effects of public infrastructure investment: A survey of the international evidence," Working Papers 108, Department of Economics, College of William and Mary.

Pereira A.M. (2000): "Is All Public Capital Created Equal?", Review of Economics and Statistics, 82, 513-518.

Pereira A.M. (2001): "On the Effects of Public Investment on Private Investment: What Crows In What?”, Public Finance Review, 29, 3-25.

Petersen, T. (2011a): "Accessibility and productivity: A cost function microdata panel approach", mimeo.

Petersen, T. (2011b): "Estimating the link between accessibility and productivity with propensity score matching", mimeo.

Pfähler, W., Hofmann, U., and Bonte, W. (1996): "Does Extra Public Infrastructure Capital Matter? An Appraisal of Empirical Literature", Finanzarchiv, 53(1), 68-112.

* Picci, L. (1999): "Productivity and Infrastructure in the Italian Regions", Giornale degli Economisti e Annali di Economia, 58(3-4), 329-353.

Pinnoi, N. (1994): “Public infrastructure and private production: measuring relative contributions”, Journal of Economic Behavior and Organization, 23(2), 127-148.

Potter, W.G. (1988): "Of making many books there is no end: Bibliometrics and libraries", Journal of Academic Librarianship, 14, 238-240.

Pritchett, L., (1996): "Mind your P's and Q's: the cost of public investment is not the value of public capital", Policy Research Working Paper Series 1660, The World Bank.

* Ram, R. and Ramsey, D. (1989): “Government capital and private output in the United States – additional evidence”, Economic Letters, 30, 223-226.

Asterisks indicate the articles used in the meta-analysis.

* Ramirez, M.D. (2010): "Are Foreign and Public Capital Productive in the Mexican Case? A Panel Unit Root and Panel Cointegration Analysis", Eastern Economic Journal, 36(1), 70-87.

* Ratner, J. (1983): "Government capital and the production function for US private output", Economic Letters, 13, 213-17.

* Rodríguez-Vález, J.; Álvarez-Pinilla, A.; Fernández-Vázquez, E. and Arias-Sampedro, C. (2009): "La contribución de las infraestructuras a la producción: estimación por máxima entropía", Revista de Economia Aplicada, 17(2), 76-96.

* Rodríguez-Vález, J. and Arias-Sampedro, C., (2004): "Desbordamiento espacial de la productividad de las infraestructuras: una aplicación con fronteras estocásticas", Estudios de Economía Aplicada, 22, 1-16.

Romp, W. and de Haan, J. (2007): "Public Capital and Economic Growth: A Critical Survey", Perspektiven Der Wirtschaftspolitik, 8, 6-52.

* Rovolis, A. y Spence, N. (2002): "Promoting regional economic growth in Greece by investing in public infrastructure", Environment and Planning C: Government and Policy, 20(3), 393-419.

Rubin, L.S. (1991): "Productivity and the public capital stock: another look" Working Paper Series / Economic Activity Section 118, Board of Governors of the Federal Reserve System (U.S.).

* Sahoo, P.; Dash, R.K. and Nataraj, G., (2010): "Infrastructure development and economic growth in China" IDE Discussion Papers 261, Institute of Developing Economies, Japan External Trade Organization(JETRO).

* Sahoo, P. and Kumar, R. (2009): "Infrastructure development and economic growth in India", Journal of the Asia Pacific Economy, 14(4), 351-365.

* Salinas-Jimenez, M.M., (2004): "Public infrastructure and private productivity in the Spanish regions", Journal of Policy Modeling, 26(1), 47-64.

* Sánchez-Robles, B. (1998): "Infrastructure Investment And Growth: Some Empirical Evidence", Contemporary Economic Policy, 16(1), 98-108.

Shadish, W. R., and C. K. Haddock (1994): "Fixed Effects Models", en Cooper, H. y Hedges, L.V. (eds): The Handbook of Research Synthesis, Russel Sage Foundation, New York.

Shanks, S. and Barnes, P., (2008): "Econometric Modelling of Infrastructure and Australia's Productivity", International Research Memorandum, Cat No. 08-01, Productivity Commission, Canberra, January, unpublished.

* Shioji, E., (2001): "Public Capital and Economic Growth: A Convergence Approach", Journal of Economic Growth, 6(3), 205-27.

Sims, C.A. (1969): "Theoretical Basis for a Double Deflated Index of Real Value Added", The Review of Economics and Statistics, 51(4), 470-471.

* Sloboda, B. and Yao, V. (2008): "Interstate spillovers of private capital and public spending", The Annals of Regional Science, 42(3), 505-518.

Stanley, T.D. (1998): "New Wine in Old Bottles: A Meta-Analysis of Ricardian Equivalence", Southern Economic Journal, 64, 713-727.

Stanley, T.D. (2005): "Beyond publication bias", Journal of Economic Surveys, 19, 309–345.

Asterisks indicate the articles used in the meta-analysis.

Stanley, T.D. (2008): "Meta-regression methods for detecting and estimating empirical effects in the presence of publication selection", Oxford Bulletin of Economics and Statistics, 70, 103–127.

* Stephan, A. (2001): "Regional Infrastructure Policy and its Impact on Productivity: A Comparison of Germany and France", CIG Working Papers FS IV 01-02, Wissenschaftszentrum Berlin (WZB), Research Unit: Competition and Innovation (CIG).

* Stephan, A. (2003): "Assessing the contribution of public capital to private production: evidence from the German manufacturing sector", International Review of Applied Economics, 17(4), 399-417.

* Straub, S.; Vellutini, C. and Warlters, M., (2008): "Infrastructure and economic growth in East Asia", Policy Research Working Paper Series 4589, The World Bank.

Straub, S. (2008): "Infrastructure and Growth in Developing Countries: Recent Advances and Research Challenges", ESE Discussion Papers 179, Edinburgh School of Economics, University of Edinburgh.

* Sturm, J.E. and de Haan, J., (1995): "Is public expenditure really productive?: New evidence for the USA and The Netherlands", Economic Modelling, 12(1), 60-72.

* Sturm, J, Kuper, G, and de Haan, J (1998): Modelling Government Investment and Economic Growth on a Macro Level: A Review, Market behaviour and macroeconomic modeling, New York, 359-406.

Syed, M.; Kang, K. and Tokuoka, K. (2009). "Lost decade in translation: What Japan's Crisis could Portend about Recovery from the Great Recession", IMF Working Paper 09/282.

* Tatom, J. (1991): "Public capital and private-sector performance", Review of the Federal Reserve Bank of St. Louis, 78(3), 3-15.

Tatom, J. (1993): "Is an infrastructure crisis lowering the nation's productivity?", Review of the Federal Reserve Bank of St. Louis, Noviembre, 3-21.

Thompson, S.G. and Sharp, S.J. (1999): "Explaining heterogeneity in meta-analysis: a comparison of methods", Statistics in Medicine, 18, 2693-2708.

Urbizagastegui, R. (1996): "Una revisión crítica de la ley de Bradford", Investigación Bibliotecnológica, 10(20), 16-26.

Van Der Sluis, J., Van Praag M. and Vijverberg W. (2005): "Entrepreneurship Selection and Performance: A Meta-Analysis of the Impact of Education in Less Developed Countries", World Bank Economic Review, 19, 225-261.

* Vidyattama, Y. (2010): "A Search for Indonesia's Regional Growth Determinants", ASEAN Economic Bulletin, 27(3), 281-294.

* Vijverberg, Wim P. M.; Vijverberg, Chu-Ping C. and Gamble, J.L. (1997): "Public Capital And Private Productivity", The Review of Economics and Statistics, 79(2), 267-278.

* Yamano, N. and Ohkawara, T. (2000): "The Regional Allocation of Public Investment: Efficiency or Equity?", Journal of Regional Science, 40(2), 205-229.

* Yamarik, S. (2000): "The Effect of Public Infrastructure on Private Production During 1977-96" mimeo, University of Akron, Akron, Ohio.

Asterisks indicate the articles used in the meta-analysis.

* Yeaple, S.R. and Golub, S.S. (2007): "International Productivity Differences, Infrastructure, and Comparative Advantage", Review of International Economics, 15(2), 223-242.

* Zhang, X. (2008): "Transport infrastructure, spatial spillover and economic growth: Evidence from China", Psychometrika, 3(4), 585-597.

* Zhang, X. and Fan, S., (2001): "How productive is infrastructure?: new approach and evidence from rural India", EPTD discussion papers 84, International Food Policy Research Institute (IFPRI).

Zipf. G.K. (1972): Human behavior and the principle of least effort, Hafner, New York.

Asterisks indicate the articles used in the meta-analysis.

TABLE 1. OVERVIEW OF STUDIES INCLUDED IN THE META-ANALYSIS AND STATISTICS ASSOCIATED TO CAPITAL ELASTICITIES OBTAINED

Num.	Author	Country	Obs.	Mean	Standard deviation
1	Ratner (1983)	USA	2	0.057	0.001
2	Da Costa et al. (1987)	USA	3	0.204	0.067
3	Aschauer (1989a)*	USA	30	0.398	0.102
4	Aschauer (1989b)*	G-7	11	0.495	0.136
5	Ram and Ramsey (1989)	USA	6	0.160	0.092
6	Aaron (1990)	USA	5	0.248	0.136
7	Aschauer (1990)	USA	36	0.285	0.056
8	Eberts (1990)	USA	16	0.166	0.409
9	Munnell (1990)*	USA	6	0.330	0.066
10	Munnell and Cook (1990)*	USA	9	0.126	0.095
11	Berndt and Hansson (1992)	Sweden	2	1.144	0.646
12	Duffy-Deno and Eberts (1991)	USA	2	0.087	0.009
13	Eisner (1991)*	USA	27	0.061	0.170
14	Ford and Poret (1991)	10 OECD Countries	47	0.400	0.261
15	Hulten and Schwab (1991)*	USA	6	-0.144	0.190
16	Tatom (1991)*	USA	4	0.094	0.149
17	Garcia Milà and McGuire (1992)*	USA	2	0.045	0.001
18	Finn (1993)	USA	1	0.158	
19	Mas et al. (1993a)	Spain	4	0.205	0.138
20	Mas et al. (1993b)	Spain	8	-0.019	0.284
21	Munnell (1993)	USA	26	0.096	0.101
22	Argimón et al. (1994)	Spain	27	0.411	0.261
23	Cutanda and Paricio (1994)	Spain	7	0.399	0.058
24	Eisner (1994)	USA	1	0.270	
25	Evans and Karras (1994a)	7 OECD Countries	20	-0.068	0.187
26	Evans and Karras (1994b)*	USA	18	-0.062	0.087
27	Garcia-Fontes and Serra (1994)	Spain	28	0.135	0.129
28	Holtz-Eakin (1994)*	USA	15	-0.024	0.104
29	Mas et al. (1994)	Spain	12	0.245	0.045
30	Otto and Voss (1994)	Australia	19	0.428	0.598
31	Ai and Cassou (1995)	USA	6	0.189	0.031
32	Andrews and Swanson (1995)	USA	4	0.072	0.057
33	Baltagi and Pinnoi (1995)	USA	18	0.071	0.101
34	Crihfield and Panggabean (1995)	USA	15	-0.026	0.025
35	Dalamagas (1995)	Greece	5	-0.158	0.703
36	De la Fuente and Vives (1995)	Spain	1	0.212	
37	Gonzalez-Paramo (1995)	Spain	4	0.480	0.185
38	Holtz-Eakin and Schwartz (1995a)	USA	6	0.039	0.061
39	Holtz-Eakin and Schwartz (1995b)	USA	14	0.009	0.028
40	Nourzad and Vrieze (1995)	7 OECD Countries	18	0.053	0.008
41	Sturm and De Haan (1995)	USA and Holland	18	0.738	0.258
42	Garcia Milà et al. (1996)*	USA	8	0.058	0.145
43	Harmatuck (1996)	USA	1	0.027	
44	Holtz-Eakin and Lovely (1996)	USA	2	-0.138	0.008
45	Khanam (1996)	Canada	6	0.118	0.032
46	Mas et al. (1996)	Spain	18	0.103	0.030
47	Otto and Voss (1996)	Australia	2	0.232	0.091
48	Crowder and Himarios (1997)	USA	12	0.248	0.101
49	Kelejian and Robinson (1997)	USA	26	-0.066	0.090
50	Moreno et al. (1997)	Spain	25	0.070	0.056
51	Vijverberg et al. (1997)	USA	8	0.262	0.256
52	Aschauer (1998)	46 developing countries	8	0.237	0.083
53	Batina (1998)	USA	1	-0.110	
54	Boarnet (1998)	USA	6	0.225	0.082
55	Canning (1998)	152 Countries	1	-0.012	
56	Erenburg (1998)	USA	5	0.342	0.120
57	Flores de Frutos et al. (1998)	Spain	1	0.210	
58	Mas et al. (1998)	Spain	1	0.101	
59	Nourzad (1998)	USA	1	0.340	
60	Otto and Voss (1998)	Australia	4	0.060	0.003
61	Sanchez-Robles (1998)	57 Countries	10	0.005	0.005
62	Sturm et al. (1998)	Holland	9	0.969	0.353
63	Cadot et al. (1999)	France	4	0.100	0.002
64	Canning (1999)	57 Countries	3	0.032	0.123
65	Dabán and Lamo (1999)	Spain	5	0.111	0.012
66	Delorme et al. (1999)	USA	3	0.222	0.051
67	Gorostiaga (1999)	Spain	2	0.025	0.006
68	Pedraja et al. (1999)	Spain	9	0.241	0.134
69	Picci (1999)	Italy	36	0.433	0.296
70	Björkroth and Kjellman (2000)	Finland	3	0.090	0.239
71	Bonaglia et al. (2000)	Italy	35	0.075	0.478
72	Canning and Bennathan (2000)	67 Countries	4	0.067	0.055
73	Charlot and Schmitt (1999)	France	8	0.216	0.116
74	Delgado and Álvarez (2000)	Spain	8	0.255	0.084
75	Dessus and Herrera (2000)	28 developing countries	2	0.120	0.014
76	Haughwout (2000)	USA	6	0.074	0.108
77	Nourzad (2000)	24 Countries	8	0.473	0.052
78	Yamano and Ohkawara (2000)	Japan	2	0.091	0.081
79	Yamarik (2000)	USA	24	0.045	0.041
80	Fernández and Polo (2001)	Spain	68	0.290	0.165
81	Owyong and Thangavelu (2001)	Canada	13	0.706	0.262
82	Shioji (2001)	USA and Japan	12	0.243	0.204
83	Stephan (2001)	Germany and France	4	0.102	0.022
84	Zhang and Fan (2001)	India	5	0.051	0.023
85	Alonso-Carrera and Freire-Séren (2002)	Spain	1	0.126	
86	Bajo-Rubio et al. (2002)	Spain	5	0.046	0.006
87	Calderón and Servén (2002)	101 developing countries	11	0.059	0.087
88	De la Fuente (2002)	Spain	1	0.106	
89	Dodonov et al. (2002)	13 Eastern European countries	3	0.519	0.076
90	Fernández and Polo (2002)	Spain	9	0.150	0.171
91	Kemmerling and Stephan (2002)	Germany	3	0.169	0.001
92	Ligthart (2002)	Portugal	16	0.242	0.103
93	Mitra et al. (2002)	India	16	0.285	0.183
94	Pedraja-Chaparro et al. (2002)	Spain	12	0.028	0.135
95	Rovolis and Spence (2002)	Greece	62	0.214	0.343
96	Alvarez-Pinilla et al. (2003)	Spain	17	0.139	0.070
97	Fernandez and Montuenga (2003)	Spain	34	0.311	0.292
98	Lanzas and Martinez (2003)	Spain	4	0.168	0.103
99	Stephan (2003)	Germany	6	0.628	0.176
100	Delgado and Álvarez (2004a)	Spain	13	0.120	0.205
101	Delgado and Álvarez (2004b)	Spain	55	0.025	0.068
102	La Ferrara and Marcellino (2004)	Italy	31	0.144	0.286
103	Rodríguez-Valez and Arias (2004)	Spain	2	0.145	0.021
104	Salinas-Jimenez (2004)	Spain	10	0.175	0.291
105	Calderón and Servén (2005)	121 Countries	20	0.011	0.007
106	Cantos-Sánchez et al. (2005)	Spain	100	0.024	0.073
107	Kataoka (2005)	Japan	4	0.139	0.174
108	Kawaguchi et al. (2005)	Japan	16	0.237	0.217
109	Le and Surunga (2005)	105 Countries	6	0.060	0.015
110	Nombela (2005)	Spain	27	0.221	0.217
111	Berechman et al. (2006)	USA	9	0.027	0.025
112	Boopen (2006)	38 Sub-Saharan and Islands	12	0.088	0.089
113	Cadot et al. (2006)	France	3	0.083	0.003
114	De la Fuente and Domenech (2006)	Spain	4	0.059	0.003
115	Fedderke and Bogetic (2006)	South Africa	74	0.306	0.905
116	Hulten et al. (2006)	India	4	0.045	0.010
117	Hurlin (2006)	24 Countries	4	0.101	0.061
118	Kamps (2006)	22 OECD countries	60	0.399	0.523
119	Delgado and Álvarez (2007)	Spain	18	0.004	0.006
120	Escribá and Murgui (2007)	Spain	6	0.098	0.019
121	Moreno and Lopez-Bazo (2007)	Spain	9	0.034	0.016
122	Ozbay et al. (2007)	USA	7	0.088	0.072
123	Yeaple and Golub(2007)	18 Countries	10	0.627	0.189
124	Abdih and Joutz (2008)	USA	1	0.390	
125	Creel and Poilon (2008)	6 European countries	11	0.131	0.132
126	Crescenzi and Rodriguez-Pose (2008)	Europe 15	34	0.130	0.144
127	Sloboda and Yao (2008)	USA	8	-0.008	0.007
128	Straub et al. (2008)	East Asia	15	-0.105	0.653
129	Zhang (2008)	China	8	0.106	0.000
130	Bronzini and Piselli (2009)	Italy	17	0.094	0.109
131	Isaksson (2009)	57 Countries	53	0.466	0.295
132	Kawaguchi et al. (2009)	Japan	6	-0.178	0.196
133	Montolio and Solé-Ollé (2009)	Spain	18	0.136	0.069
134	Rodríguez-Valez et al. (2009)	Spain	8	0.142	0.130
135	Sahoo and Kumar (2009)	India	4	0.267	0.085
136	Arslanalp et al. (2010)	44 Countries	57	0.050	0.077
137	Cohen (2010)	USA	2	0.084	0.032
138	Marrocu and Paci (2010)	Italy	6	0.105	0.093
139	Mizutani and Tanaka (2010)	Japan	4	0.080	0.007
140	Ramirez (2010)	Mexico	15	0.165	0.107
141	Sahoo et al. (2010)	China	6	0.332	0.050
142	Vidyattama (2010)	Indonesia	7	0.115	0.046
143	Fingleton and Gómez-Antonio (2011)	Spain	1	0.139	
144	Hämäläinen and Malinen (2011)	Finland	11	0.112	0.164
145	Mas and Maudos (2011)	Spain	4	0.098	0.051
TOTAL			**1928**	**0.189**	**0.330**

Source: Own elaboration

TABLE 2: ELASTICITY VALUES OF THE META-SAMPLE ACCORDING TO CHARACTERISTICS AND METHODOLOGICAL OPTIONS FOLLOWED IN THE PAPERS OF THE META-SAMPLE

	Obs.	Mean	Standard deviation	Mean Self-selection
A. Specification of Production Functior				
A.a. Theoretical approach				
* Production Function	1639	0.19	0.34	0.20
Growth	186	0.12	0.23	0.14
Quasi production function	69	0.43	0.31	0.37
Function frontier	34	0.06	0.14	0.08
A.b. Economies of scale				
* No constant returns	1363	0.17	0.28	0.16
Constant returns in all factors	300	0.28	0.27	0.30
Constant returns in private factors	265	0.20	0.54	0.26
A.c. Inclusion of public capital in the production function				
* In the production function	988	0.15	0.27	0.16
Through a productivity function	940	0.23	0.38	0.23
A.d. Variables incorporated in the production function				
Cycle	518	0.25	0.31	0.25
Human capital	319	0.19	0.51	0.20
Density of activity	104	0.10	0.18	0.15
Energy	68	0.13	0.27	0.16
Another type of public capital	377	0.09	0.24	0.10
Trend	433	0.23	0.32	0.19
Temporary effects	450	0.06	0.12	0.06
B. Measuring the variables				
B.a. The definition of public capital				
* Total	853	0.23	0.32	0.23
Productive	435	0.24	0.25	0.25
Transport	640	0.11	0.37	0.13
B.b. Form of measure public capital				
* Stock	1791	0.20	0.33	0.20
Flow	137	0.10	0.24	0.16
* Monetary	1607	0.19	0.29	0.19
Nonmonetary	321	0.19	0.49	0.24
B.c. Variable output				
* Value added	1737	0.19	0.34	0.19
Production	191	0.22	0.27	0.23

	Obs.	Mean	Standard deviation	Mean Self-selection
C. Nature and disaggregation of statistical informatio				
C.a. Data structure				
* Panel	1372	0.14	0.31	0.15
Time series	471	0.36	0.34	0.35
Cross section	85	0.12	0.32	0.16
C.b. Sample geographical breadth				
* Individual Country	1447	0.19	0.34	0.20
Group countries	319	0.17	0.29	0.18
Less than country	162	0.21	0.36	0.21
C.c. Responsible administrative level of capital				
* Total Public Capital	1778	0.19	0.34	0.20
Public Capital of central public administrations	71	0.24	0.28	0.34
Public Capital of territorial public administrations	79	0.04	0.18	0.06
Another territorial public capital	78	0.03	0.19	0.05
Public capital neighbors	246	0.09	0.23	0.10
C.d. Sector coverage				
* All sectors	1337	0.19	0.27	0.20
Industry	421	0.24	0.49	0.24
Rest of sectors	170	0.06	0.18	0.05
D. Econometric methodology				
D.a. Individual effects				
* No individual effects	748	0.20	0.27	0.20
With individual effects	1180	0.18	0.36	0.19
D.b. Econometric treatments				
Efficiency	705	0.22	0.32	0.23
Instrumental variables	487	0.15	0.41	0.15
Long term	216	0.21	0.55	0.29
Spurious correlation	405	0.27	0.31	0.28
E. Publication				
E.a. Publication type				
* Journal	1324	0.22	0.36	0.25
No journal	604	0.13	0.25	0.09
E.b. Credibility				
Credible	1336	0.20	0.33	0.20
* Not credible	592	0.17	0.34	0.17
E.c. Year of publication				
* Decade 80	52	0.37	0.16	0.37
* Decade 90	674	0.19	0.29	0.20
* Decade 00	1202	0.18	0.35	0.18
TOTAL	**1928**	**0.189**	**0.330**	**0.196**

Source: Own elaboration

TABLE 2: RESULTS OF THE META-REGRESSION ANALYSIS FOR OUTPUT ELASTICITY OF PUBLIC CAPITAL (MIXED EFFECTS)

	Observations(1)	ALL		CREDIBLES	
Constant		0.132***	(0.000)	0.120***	(0.000)
Self-selection	1336	0.026***	(0.000)		
Publication in Journal	1324	0,037***	(0.000)	0,022***	(0.038)
se2		-2.820***	(0.000)	-2.033***	(0.000)
se2+		6.137***	(0.000)	7.348***	(0.000)
A. Specification of Production Function					
A.a. Theoretical approach					
* Production Function	1639				
Growth	186	-0.049***	(0.000)	-0.023	(0.110)
Quasi production function	69	0.235***	(0.000)	0.217***	(0.001)
Function frontier	34	-0.085***	(0.000)	-0.071***	(0.001)
A.b. Economies of scale					
* No constant returns	1363				
Constant returns on all factors	300	0.015	(0.122)	0.026**	(0.027)
Constant returns on private factors	265	-0.026**	(0.028)	-0.017	(0.244)
A.c. Inclusion of public capital in the production function					
* In the production function	988				
Through a productivity function	940	0.018**	(0.014)	0.009	(0.233)
A.d. Variables incorporated in the production function					
Cycle	518	0.004	(0.712)	0.035**	(0.014)
Human capital	319	0.002	(0.833)	-0.001	(0.932)
Density of activity	104	-0.026	(0.140)	-0.070***	(0.001)
Energy	68	0.016	(0.246)	-0.008	(0.682)
Another type of public capital	377	0.003	(0.679)	0.002	(0.821)
Trend	433	0.031***	(0.002)	0.030***	(0.008)
Temporary effects	450	-0.006	(0.495)	0.012	(0.321)
B. Measuring the variables					
B.a. The definition of public capital					
* Total	853				
Productive	435	0.014	(0.196)	0.022*	(0.082)
Transport	640	-0.018*	(0.066)	-0.017	(0.141)
B.b. Form of measure public capital					
* Stock	1791				
Flow	137	-0.026**	(0.022)	-0.017	(0.276)
* Monetary	1607				
Nonmonetary	321	0.011	(0.220)	0.011	(0.282)
B.c. Variable output					
* Value added	1737				
Production	191	-0.020	(0.240)	0.016	(0.389)

	Observations(1)	ALL		CREDIBLES	
C. Nature and disaggregation of statistical information					
C.a. Data structure					
* Panel	1372				
Time series	471	0.142***	(0.000)	0.092***	(0.000)
Cross section	85	-0.043**	(0.021)	-0.085***	(0.000)
C.b. Sample geographical breadth					
* Individual Country	1447				
Group countries	319	0.076***	(0.001)	0.052*	(0.077)
Less than country	162	0.068***	(0.000)	0.057***	(0.000)
C.c. Responsible administrative level of capital					
* Total Public Capital	1778				
Public Capital of central public administr	71	0.046**	(0.020)	0.065***	(0.004)
Public Capital of territorial public admini	79	-0.098***	(0.000)	-0.099***	(0.000)
Another territorial public capital	78	-0.059***	(0.001)	-0.084***	(0.000)
Public capital neighbors	246	0.004	(0.593)	-0.004	(0.559)
C.d. Sector coverage					
* All sectors	1337				
Industry	421	0.003	(0.763)	-0.001	(0.955)
Rest of sectors	170	-0.009	(0.302)	-0.009	(0.286)
D. Econometric methodology					
D.a. Individual effects					
* No individual effects	748				
With individual effects	1180	0.029***	(0.000)	0.047***	(0.000)
D.b. Econometric treatments					
Efficiency	705	-0.028***	(0.000)	-0.033***	(0.003)
Instrumental variables	487	0.003	(0.655)	-0.010	(0.263)
Spurious correlation	216	-0.022*	(0.076)	0.002	(0.879)
Long term	405	0.029***	(0.008)	0.039***	(0.002)
E. Publication				0.325	
Year of publication		0.001	(0.380)	-0.003**	(0.038)
Q-test		35486.003***		19909.035***	
Total Observations		1928		1336	

In parenthesis are presented p-values for the H0: B=0. ***,** and * denote significance at 1, 5 and 10% respectively. In all estimations we introduced a set of dummy variables for each country in every five years periods when there are at least 5 obsevations referring to it.
(1) Refers to the number of observations of the sample -elasticities in the metasample- that fulfill every criterion (i.e. the number of ones in the dummy)

FIGURE 1: DISTRIBUTION OF THE VALUES OF OUTPUT ELASTICITY OF PUBLIC CAPITAL IN THE META-SAMPLE

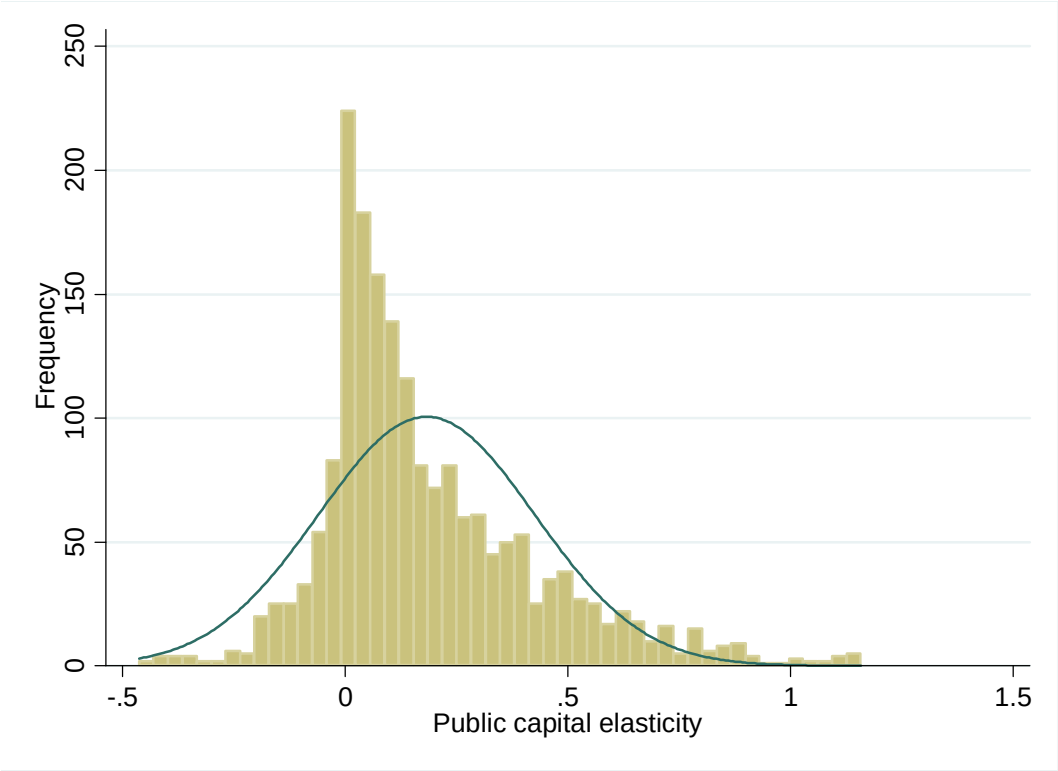
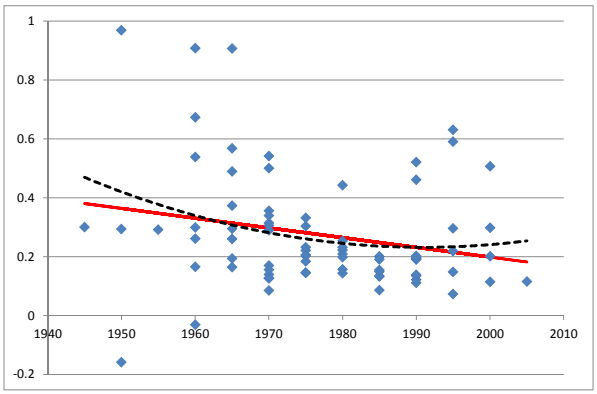
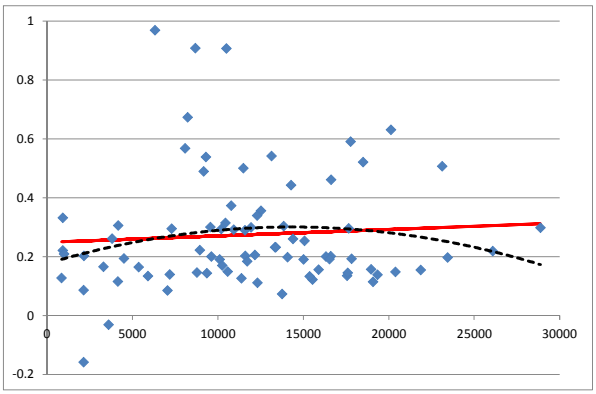


FIGURE 2. RELATIONSHIP BETWEEN ORIGINAL AND ESTIMATED ELASTICITIES AND TIME, PER-CAPITA GDP AND COUNTRIES

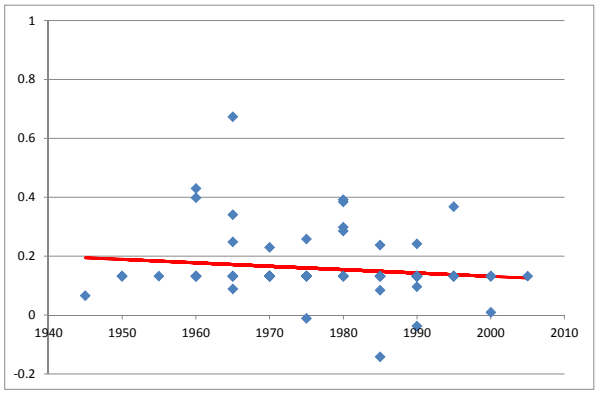
A. Original elasticities (meta-sample) and five-years periods



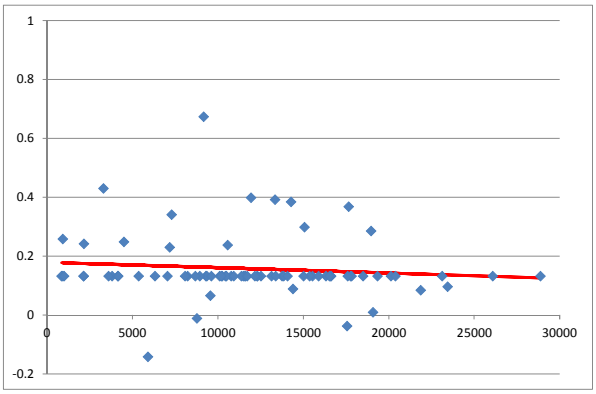
B. Original elasticities (meta-sample) and Per-capita GDP



C. Estimated elasticities (from meta-regression) and five-years periods



D. Estimated elasticities (from meta-regression) and Per-capita GDP



E. Average original and estimated elasticities by country