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David Roibás y Jose Baños

Departamento de Economía

Universidad de Oviedo

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José Baños

Oviedo Efficiency Group
Department of Economics, University of Oviedo,

David Roibás[1]

Oviedo Efficiency Group
Department of Economics, University of Oviedo

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[1]Corresponding author: David Roibás, Department of Economics, University of Oviedo, Avda. del Cristo s/n, 33006, Spain. Phone: (+34) 985103789, Fax: (+34) 985104871, Email: droibas@uniovi.es.

INTRODUCTION

The impact of investment in transport infrastructure on economic growth has become a topic of some considerable controversy in recent decades. From a position where such investment was often seen as an example of an unproductive public sector investment, the 1980s introduced a number of studies which, by various methods, claimed that there was substantial growth impact. Obviously, the macroeconomic consequences of infrastructure arise from the construction itself. This makes such investment attractive during periods of slack economic growth or recession. However, the key role of the infrastructure is not just in its construction, but also in the impact of its use on the general economy. The overall impact on the economy of a reduction in the cost of transport is easy to understand. Just like with any good, if the cost of production is reduced, prices may fall and the quantity bought will increase. Besides, a reduction in cost can change the pattern of consumption. In this sense, the role of the transport infrastructure can also explain the location of production factor, and in particular, the choice of location for firms. Firms establish themselves in places which enable them to minimize the total cost of transport, taking into account the supply of inputs, including labor.

In principle, the effects of infrastructure on economic growth are different among different modes of transport. Investment in railways appears to have more limited effects, whereas the effects on major highways can be more extensive, not only because such highways have a larger number of access points, but also because road transport is the dominant mode of transport and impacts on a much wider range of activities.

Nevertheless, estimating the total impact of infrastructure has generated important debate. Since the appearance of seminal articles by Ratner (1983) and Aschauer (1989), the productivity of public capital has been the subject of study in many papers. In the first of the most recent studies that address this issue Ratner (1983) estimates an aggregate production function for the US economy that includes public capital as an input, and finds that the coefficient of public capital is positive and significant although fairly small (0.056). Using a very similar specification with a longer time series for the same country, Aschauer (1989) estimates a much larger coefficient for this variable, with output elasticities of public capital ranging from the order of 0.4 to 0.5, which was larger than the elasticity of private capital. This author also disaggregates the public capital stock and finds that the types of infrastructure with the largest impact on productivity are those having to do with transport and the supply of energy and water.

Criticisms of this approach, especially from an econometric point of view, have led to a large number of subsequent studies. In particular, since these papers used aggregate national time-series data, some authors argued that the empirical results could be due to spurious correlation caused by common trends in the variables. Among the other main criticisms leveled against these studies were the lack of relevant variables (such as human capital) or the problem of reverse causality, that is, the direction of causality may run from economic activity towards public investment. When researchers started using state-level data the estimated elasticities were much lower. In fact, the empirical evidence shows that geographical disaggregation of data usually results in lower productivity of public capital. This finding has been attributed to spillover effects of public capital from one region into neighboring regions. These spatial spillovers are due to the network effect of public capital. Thus, since most elements of public capital have network characteristics (i.e., roads, telecommunications, railways, etc.) it is expected that the stock of public capital in one region will affect production in other regions.

In general terms, later studies tend to suggest that there is a positive elasticity of public infrastructure, but that the value is nearer to 0.1 (see, for example, Lau and Sin, 1997 or Quinet and Vickerman, 2004). However, some research by Evans and Karras (1994), Holtz-Eakin (1994) and Holtz-Eaking and Schwartz (1995) contradict the hypothesis that investment in public infrastructures always favored high rates of economic growth.

Nonetheless, several surveys of this vast amount of literature already exist, including Gramlich (1994), Draper and Herce (1994), and De la Fuente (1996, 2000).

In Spain, due to the availability of high quality data sets, especially for series for capital, a large amount of empirical literature on this topic has appeared. Several studies have obtained somewhat disparate results (see Mas et al., 1994; De la Fuente and Vives, 1995; Argimón et al. 1994; Bajo and Sosvilla, 1993; González-Páramo, 1995). They generally obtain significant elasticity between the aggregate level of production and public capital stock, though the magnitude of this elasticity is very different. Some studies have tested this hypothesis using regional data (García-Fontes and Serra, 1994; Mas et al. 1996; Álvarez et al 2003 and 2006; Arias and Rodríguez-Vález, 2004). More recently, using the dual approach and thus estimating a cost function, Boscá et al. (1999), Boscá et al. (2002), Avilés et al. (2001), and Moreno et al. (2002) have also analyzed the importance of infrastructures in the Spanish regions.

Nevertheless, few studies have specified the individual effect of transport infrastructures. Looney and Frederiksen (1981) specified road investment and found a significant impact, similarly to that of Fritsch and Prud'Hommer (1997). Cantos et al. (2005) show the importance of transport infrastructures in explaining the productivity gains of the private sector in the Spanish regions. They found an elasticity of regional GDP to the total of transport infrastructures which could reach a value of 0.061, when the network effect of infrastructures is considered.

In this paper, it is assumed that the impact of transport infrastructures may not be immediate. Transport infrastructures allow for faster communications which improve competitive advantages of connected places. Firms can, thus, look for new locations that become more competitive once the transport infrastructures are built. However, the reallocation of economic activity cannot be immediate. On the other hand, the investment in transport infrastructures allows the local firms to reconvert from its initial activities to other more profitable activities before the investment is done (see Martin and Rogers, 1995 or Holtz-Eakin and Lovely, 1996) . As an example we can consider the transformation of many farms to rural tourism activities in which the same labor and capital infrastructures are used in a more profitable activity. Therefore, the new investment infrastructures create some opportunities to generate economic growth by a more profitable use of the previously existing input endowment. However, several years will be generally necessary in order to finish these reallocation and transformation processes allowed by new infrastructures. Thus, even if other input endowment is maintained constant, the influence of infrastructures in increasing productivity is expected to be realized during several periods of time while firms are changing their activities and looking for better places.

Similarly, Pakes and Schankerman (1984) or Soete y Patel (1985) assumed that the effects of R&D investments on economic growth are not immediate, but that there is a delay of some periods between making the expenditure on R&D and noting its effects.

In order to capture this dynamic adjustment an econometric model including lags on transport infrastructures is used. The inclusion of lags in the equation to be estimated allows the impact generated by a new infrastructure during the following periods of time to be assessed. In particular, an Almon polynomial is used in this study to estimate the dynamic impact of infrastructure on Spanish provinces during the period 1986-2006.

The rest of the paper is organized as follows. The second section presents the model to be estimated. The third section analyzes the data used in the empirical analysis. Results are presented in fourth section and, finally, the fifth section concludes.

2.- THE MODEL

As in most of studies addressing the effect of infrastructures on economic growth, we considered that the technology underlying the production function is of the Cobb-Douglas type. Thus, it is supposed that the value added (y) depends on labor (x_1), private capital (x_2), non-transport public infrastructures (x_3) and transport public infrastructures (x_4). With this approach it is easy to obtain the output elasticity of public capital in infrastructures as well as its sign and significance. Although the use of the Cobb-Douglas production function is open to criticism, we still use it because the main aim of this paper is to calculate the dynamic adjustment of the impact of transport infrastructures on regional growth.

In this sense, it is assumed that the full impact of infrastructures on provincial productivity needs ten years to be completed. Thus, the equation to be estimated becomes:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{3} \beta_j \ln x_{jit} + \sum_{k=0}^{10} \beta_{4,t-k} \ln x_{4i,t-k} + e_{it} \tag{1}$$

where *i* stands for individual *t* for time period *j* for input and *k* for lags. e_{it} is the error term. According to Almon (1965) parameters $\beta_{4,t-k}$ are assumed to follow a polynomial relationship. In particular, a third order polynomial is considered. Thus, $\beta_{4,t-k}$ responds to the following structure:

$$\beta_{4,t-k} = \alpha_0 + \alpha_1 k + \alpha_2 k^2 + \alpha_3 k^3 \tag{2}$$

Substituting (2) in (1) and after some manipulation, equation (1) becomes:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{3} \beta_j \ln x_{jit} + \alpha_0 z_{0it} + \alpha_1 z_{1it} + \alpha_2 z_{2it} + \alpha_3 z_{3it} + e_{it} \tag{3}$$

where:

$$\begin{aligned} z_{0it} &= x_{4it} + x_{4it-1} + x_{4it-2} + x_{4it-3} + \ \dots + x_{4it-10} \\ z_{1it} &= x_{4it-1} + 2\ x_{4it-2} + 3\ x_{4it-3} + \ \dots + 10\ x_{4it-10} \\ z_{2it} &= x_{4it-1} + 2^2 x_{4it-2} + 3^2 x_{4it-3} + \ \dots + 10^2 x_{4it-10} \\ z_{3it} &= x_{4it-1} + 2^3 x_{4it-2} + 3^3 x_{4it-3} + \ \dots + 10^3 x_{4it-10} \end{aligned} \tag{4}$$

3.- DATA

The data consists of 21 annual observations for the 50 provinces of Spain over the 1986 – 2006 period. Gross Added Value is used in thousands of Euro from 2000 from the Statistics National Institute (INE) as the measure of output. Four inputs are taken into consideration: public transport infrastructures, public capital in non-transport infrastructures, private capital and labour. The source of private and public capital, measured in thousands of Euro from 2000, is Mas et al. (2005) and Instituto Valenciano de Investigaciones Económicas (IVIE).

Public capital stock in transport infrastructures is the result of adding the following components: roads and highways, ports, airports and railways. The other public capital taken into account includes water infrastructures and urban structures. The so-called non-residential private capital is used as private capital stock, since it is assumed that the residential capital does not provide productive services. Finally, labor, measured as number of workers, comes from the Labor Force Survey (INE).

Table 1 resumes the statistics corresponding to the variables used in the empirical analysis.

Table 1. Variables used in the empirical analyisis

Variable	Units	Mean	Std. Dev.	Min	Max
Value added	Million €	10166	15619	947	123000
Labor	1000 Workers	285.703	378.563	29.524	2977.088
Private capital	Million €	17703	26724	1702	227002
Non-transport infr.	Million €	1353	1291	132	10235
Transport infr.	Million €	2996	3084	438	30763

4.- RESULTS

Equation (3) was estimated using the fixed effect estimator with the econometric software Stata. In order to compare the models production function without lags on transport infrastructures was also estimated. Table 2 resumes the estimation of Cobb-Douglas provincial production function without including lags on transport infrastructures.

Table 2. Production function without lags on transport infrastructures

Variable	Parameter	Estimation	Standard error	t-statistic
x_1	β_1	0.368	0.028	13.25
x_2	β_2	0.182	0.026	7.14
x_3	β_3	0.140	0.021	6.56
x_4	β_4	0.144	0.016	9.09

Scale elasticity is 0.83, which is a value in the range of García-Fontes y Serra (1994) that calculate a scale elasticity of 1.01, Delgado y Álvarez (2000) that found a value equal to 0.89 or Cantos et al (2005) who estimate a value of 0.70.

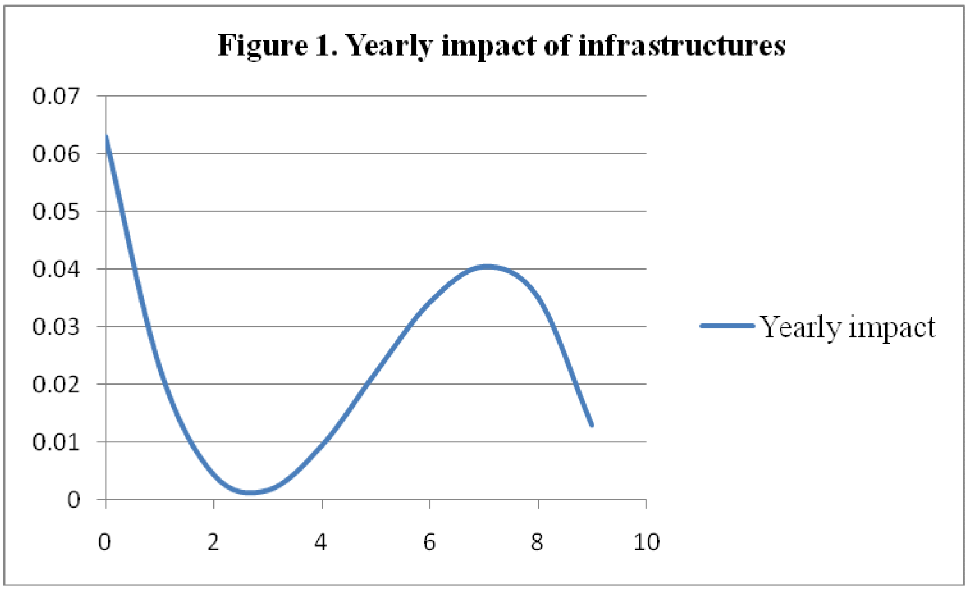
Table 3 shows the results when lags on transport infrastructures are included in the model.

Table 3. Production function including lags on transport infrastructures

Variable	Parameter	Estimation	Standard error	t-statistic
x_1	β_1	0.357	0.027	13.39
x_2	β_2	0.116	0.025	4.63
x_3	β_3	0.136	0.020	6.87
z_0	α_0	0.063	0.020	3.22
z_1	α_1	-0.053	0.023	-2.31
z_2	α_2	0.013	0.006	2.42
z_3	α_3	-0.001	0.000	-2.51

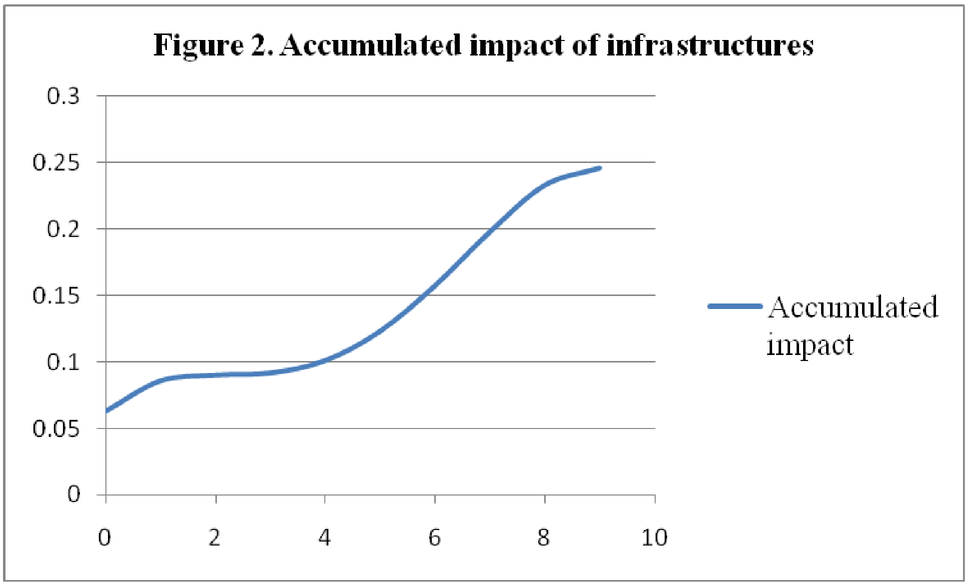
Table 3 shows that all the parameters related with lags on transport infrastructures are highly significant which is consistent with the hypothesis that the full impact of transport infrastructures on provincial productivity is not immediate. The short term parameter (α_0) shows that the immediate impact of infrastructures on production is less than a half of the elasticity estimated in the model without lags. According to the results, once an infrastructure is incorporated to the stock of public capital it takes nine years until its full contribution to production is realized. Thus, its long run elasticity grows to 0.25, which is soundly larger than the contribution estimated by the model without lags.

Figure 1 shows the yearly impact of infrastructures in provincial production. During the first three periods before the infrastructure is built, its impact on productivity is positive but it is also decreasing. From the fourth to the seventh period the impact of transport infrastructures is growing and in the last periods it is decreasing.



This adjustment profile suggests that there is an initial impact of transport infrastructures related with economic activity planned during the construction of the infrastructures, which may include the construction of some other infrastructures related with the constructed ones. Three periods before the infrastructures are finished some new economic activity is generated by these infrastructures. This new activity could be related to the economic activity reallocation allowed by the new infrastructures. New infrastructures allow for better places for firm activity, but this effect could be not immediate. Geographical reallocation of economic activity requires some time for studying the new possibilities and to physically reallocate firms' activity.

Figure 2 show the accumulated impact of transport infrastructures during the periods before the infrastructures are finished. According to the profile analyzed in Figure 1, the output elasticity of transport infrastructures grows from an immediate impact of 0.06 to, almost, 0.25 nine years before the moment when the adjustment period is finished.



This adjustment profile shows an important contribution of infrastructures to provincial productivity, but a long period of time is necessary to allow for the full impact of infrastructures to be completed.

Even though it is the first time that the Almon polynomial distributed lag - the method employed in this paper- is utilized to evaluate the impact of transport infrastructures on provincial productivity, the results are similar to those obtained in studies applying other dynamic approaches to the Spanish economy. Therefore, the conclusions reached in this work about the path of the accumulated response of output with respect to shock in public capital are in line with those derived from cointegration techniques or VAR estimates, at both Spanish aggregate and regional levels by Bajo and Sosvilla (1993) and Marvao and Roca-Sagalés (2003), respectively.

5.- CONCLUSIONS

Transport infrastructures reduce time in connecting locations. This reduction of time allows the competitiveness of some locations to be improved making them, thus, more attractive for economic activity. However, the geographic reallocation process of economic activity is not immediate. Firms need some time to plan and execute reallocation processes and, thus, the impact of transport infrastructures on productivity needs several periods of time to be completed.

To assess the evolution of the impact of transport infrastructures in economic activity a third degree Almon polynomial is used. According to our results, nine years are necessary to complete the impact of transport infrastructures on provincial productivity. The output elasticity of transport infrastructures grows from an initial impact of 0.06 to a long run elasticity of 0.25. These results show that a long period of time could be necessary to evaluate the full contribution of investment in transport infrastructures.

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