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TRANSPORT INFRASTRUCTURES AND REGIONAL GROWTH: EVIDENCE OF THE SPANISH CASE*

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Abstract

This paper analyses the impact of transport infrastructures on the economic growth of both regions and sectors, distinguishing among modes of transport. It also attempts to capture the spillover effects or network effects associated with transport infrastructures. Two different methodologies are used: the first adopts an accounting approach on the basis of a regression on total factor productivity (*TFP*) indices, the second uses econometric estimates of the production function. Our study obtains very similar elasticities with both methodologies for the private sector of the economy, both for the aggregate capital stock of transport infrastructures and for the various types of infrastructure. Important network effects of these infrastructures on the private sector have also been observed. However, the disaggregated results for sectors of production are not conclusive.

Key words: Transport infrastructures, productivity, regions, sectors.
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1. Introduction

One of the subjects most discussed by economic literature is the impact of infrastructures on economic growth. Most studies have evaluated this phenomenon in the aggregate, attempting to quantify the contribution of infrastructures to economic development. The pioneering studies by Aschauer (1989a, 1989b) concluded that infrastructure endowments were a factor of enormous importance in explaining the evolution of economic growth in the USA.

Later studies (Deno, 1991, Deno and Eberts, 1991, García-Mila and McGuire, 1992, Munnel, 1990) have reinforced, though with reservations, the results obtained in Aschauer's studies. The scope of these studies was limited to the analysis of a single country or state, where on the basis of time series or cross-section data the level of output was regressed against indicators representing the stock of private capital, the level of employment, and of public capital (including basic transport infrastructures).

For the Spanish economy, 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 (Mas et al. 1999; García-Fontes and Serra, 1994**)**. More recently, estimating a cost function (duality approach), Boscá et al. (1999), Boscá et al. (2002), Avilés et al. (2001), and Moreno et al. (2002) have also analised the importance of infrastructures in the Spanish regions.

In the recent literature at international level, some studies have obtained results that contradict the hitherto widely accepted hypothesis that investment in public infrastructures always favoured high rates of economic growth. Evans and Karras (1994), Holtz-Eakin (1994), Holtz- Eaking and Schwartz (1995) and Holtz-Eaking and Lovely (1996) find hardly any evidence of the so-called spillover effects of public infrastructures. The main criticism of these studies is that by not taking into account the potential endogeneity of public capital they may lead to erroneous results. After all, the most productive regions could easily be those that spend most on investment in new infrastructures.

The number of studies that analyse at disaggregated level the effect of the most important public infrastructures, separating the capital endowments of the various modes of transport, is certainly small. Among them, the studies by Rephann and Isserman (1994) and Amitabh and Thompson (2000) have shown that investment in infrastructures, and more specifically those relating to new motorways, favoured the growth of the most urbanised regions, as well as the territories that they crossed. On the other hand, investment in new motorways in areas or regions of a rural character did not necessarily favour their development, as it could bring the more developed urban areas closer, thus reinforcing their development to the detriment of the rural areas. Finally, these two studies also show how the new motorway infrastructures can favour the development of certain sectors or industries at the expense of the decline of others. Altogether, these studies propose the importance of a disaggregated analysis at both regional and sector level, and show the problems of studies that use aggregate data.

In this context, our study aims to advance the analysis of the impact of transport infrastructures on economic growth in four directions: regional, sector, by type of infrastructure, and analysis of spillover effects. In particular, the objective of this study is to determine the impact on the economic growth of both sectors and regions of the various transport infrastructures differentiating by mode of transport. This analysis enables us to differentiate the relative importance of the investments in infrastructures of each mode of transport, distinguishing which is most important in terms of growth, and also distinguishing the differences in the impact on the different economic sectors.

These objectives are approached for both the aggregate of the private sector of the economy and for the major business sectors: agriculture, industry, construction and business sector services. The period of study covers the years 1965 to 1995, and thus has available a wide panel of data.

As a means of testing the validity of our results, we will estimate the output elasticity of transport infrastructures by means of two different methodologies. The first will use an accounting approach, which on the basis of a regression on the indices of total factor productivity (TFP), calculates the output elasticity of the infrastructures. The second methodology uses econometric estimations of the production function. The first approach has hardly been used, and this is one of the contributions of our paper. We want to check whether the results obtained are similar to those obtained with the second of the approaches.

Finally, given the problem of inverse causation associated with the relationship of simultaneity between production and infrastructures (Holtz-Eakin, 1994), the analysis uses an estimator of instrumental variables given that in the presence of endogeneity the ordinary least square estimator produces biased and inconsistent estimates. In addition, the evidence of other studies (Holtz-Eakin, 1993) has shown that the estimation of production functions that do not consider the existence of individual effects that capture the influence of unobservable characteristics specific to each region or state generate biased estimates of the impact of public capital, so in our study we will use panel techniques.

With these objectives, the structure of the study is as follows. Section 2 gives a descriptive analysis of the evolution of transport infrastructures in Spain in the period analysed. Section 3 sets out the two methodological approaches used to quantify the effect of transport infrastructures on the productivity of the Spanish regions, the results obtained being offered in section 4. Section 5 attempts to measure the spillover effects associated with transport infrastructures. Finally section 6 contains the main conclusions of the study.

2. **Transport infrastructures in Spain**

The information available, detailed in the appendix, allows four types of transport infrastructures - roads[1], ports, airports and railways - to be analysed separately. Although the source of information used (FBBV) also allows other forms of public capital (water infrastructures, urban structures, health and education) to be

[1] Although the motorways are privately owned, they have been included with the stock of roads

analysed, they have been excluded as the objective of this study is centred exclusively on transport infrastructures.

Figure 1 permits observation of the evolution of transport infrastructures in Spain from 1955 to 1996 in relation to productive (i.e. non-residential) private capital and Gross Added Value (GAV). For this purpose the value of the variables in the initial year is taken as 100. The figure shows the important process of capitalisation of the Spanish economy during the years analysed, with a growth rate of public capital in infrastructures and of productive private capital higher than that of GAV. Thus in the three decades analysed, while the real GAV of the Spanish economy was multiplied by 2.7, productive private capital was multiplied by 3.8, reaching 4.5 in the case of transport infrastructures. Evolution over time is markedly affected by the economic cycle, with a growth in the sub-periods 1965-75 and 1989-95 greater than that corresponding to the period of crisis 1975-85.

In the specific case that concerns us, figure 2 shows the evolution of the different types of transport infrastructure. The first outstanding trait is the greater relative increase in roads which multiplied by 6.2 in real terms from 1965 to 1996, twice the growth of the other three types of transport infrastructure. Thus in the case of port infrastructures, airports and railways, growth has been more modest, airports having grown least in the period analysed and with negative rates in some years.

Figure 3 shows the evolution of the percentage structure of public capital in transport infrastructures. The highest percentage corresponds to roads, on average 60% of the total in the period. As a consequence of its higher growth rate, its share of the total increased from 51% in 1965 to 69% in 1996. Finally, airports have the lowest share of total transport infrastructures, only 2% in 1996.

Table 1 shows the regional differences in the endowment of transport infrastructures, using the ratio infrastructures/GAV. We observe that the ratio has grown during the period analysed, passing from a value of 0.12 in 1965 to 0.19 in 1995. All the regions, except the Balearics, increased their stock of capital expressed as a percentage of GAV, the regions of the north of Spain (Basque Country, Cantabria and

Asturias) having the highest rtes of growth in this ratio. It can be seen that, in general, the richest regions (Balearics, Madrid, Catalonia) present a ratio below the national average, the poorest regions above it. If we further observe the standard deviation data in the last row of the table, the inequalities in the infrastructures/GAV ratio have become greater over the three decades analysed.

To conclude this description, it is of interest to analyse the evolution of the ratio of transport infrastructures to productive private capital. Table 2 shows how this ratio grew in the period considered (from 0.14 in 1965 to 0.17 in 1995) as a consequence of a more intense process of investment in infrastructures than in private capital. This is not true in the case of all the regions, specifically in Aragón, Balearics, Canaries, Castilla La-Mancha, Castilla-León and Extremadura. Once again, it is the regions of the north of Spain (Cantabria, Basque Country and Asturias) that experience the most intense process of capitalisation in transport infrastructures relative to private capital. Finally, also in this ratio, inequalities have change with time, as shown by the evolution of the standard deviation. In particular, there is a reduction in the inequalities in the period 1965-75, a significant increase until 1985, and a reduction after 1995, in such a way that in this last year the inequalities are slightly lower to those existing in 1965.

3. Methodology

In this section we present two different methodological approaches to the impact of transport infrastructures on the productivity of the Spanish regions. In this way we will be able to see whether there are discrepancies between these approaches when the results are presented. Specifically, we present a first approach in which the public capital destined for infrastructures is considered as an ordinary factor of production, and a second approach in which, after the value of total factor productivity is determined, it is explained by the endowment of transport infrastructures[2].

3.1. The production function approach

[2] There would be a third approximation consisting of the aplication of the duality approach by the estimation of cost functions, where infrastructures are considered as an exogenous productive input. In this way we can quote the works of Morrison and Schwart (1996) for the US, as well as those already cited in section 1 for the Spanish regions. The application is not the focus of our work.

Under the first approach, public capital destined for transport infrastructures is considered an ordinary input in the production function. As is usual in these studies, we will assume that the technology underlying the production function is of the Cobb-Douglas type. The main aim of this approach will be to obtain the output elasticity of public capital in infrastructures as well as its sign and significance.

The production function for the Spanish regions extended with public capital in transport infrastructures is as follows:

$$Y_{it} = A_{it}\, L_{it}^{\alpha}\, K_{it}^{\beta}\, T_{it}^{\gamma} \qquad (1)$$

where:

Y_{it} = private production of region *i* in year *t*.
$A_{it} = A_{i0}\, e^{\mu t}$
A_{i0} = initial level of efficiency for each region *i* in year *t*.
μ = rate of disembodied technical progress.
L_{it} = employment of region *i* in year *t*.
K_{it} = private capital of region *i* in year *t*.
T_{it} = public capital in transport infrastructures of region *i* in year *t*.

And taking logarithms:

$$Ln\, Y_{it} = Ln\, A_{i0} + \mu\, t + \alpha\, Ln\, L_{it} + \beta\, Ln\, K_{it} + \gamma Ln\, T_{it} + e_{it} \qquad (2)$$

Public capital in transport infrastructures can in turn be subdivided into different components: roads, ports, airports and railways, and the elasticity corresponding to each of them can be estimated.

3.2. The total factor productivity approach

To calculate the value of TFP, following Solow (1957), we take into consideration the Cobb-Douglas production function with private inputs. However, we propose a more generic standard specification in which the role of public capital in infrastructures is also considered:

$$Y_{it} = A_{it} \ f(L_{it} \ \ K_{it} \ \ T_{it}) \tag{3}$$

Deriving with respect to time we obtain:

$$\dot{Y}_{it} = \dot{A}_{it} + \varepsilon_L \dot{L}_{it} + \varepsilon_K \dot{K}_{it} + \varepsilon_T \dot{T}_{it} \tag{4}$$

where ε is the elasticity of output with respect to labour (*L*), private capital (*K*) and public capital in transport infrastructures (*T*). This latter capital can in turn be subdivided into its different components (roads, ports, airports and railways) so that the elasticity of each of them could be estimated. Carrying out simple operations, the above expression can be re-written as follows:

$$\dot{A}_{it} = \dot{Y}_{it} - \ s_{L,it} \dot{L}_{it} - s_{K,it} \dot{K}_{it} + (1-\rho) \ \dot{K}_{it} - \varepsilon_T \dot{T}_{it} \tag{5}$$

where $\rho = \varepsilon_L + \varepsilon_K$ and the term (1-ρ) indicate the type of returns to scale in private inputs present in the production function, or in other words, the discrepancy from constant returns to scale. Furthermore, following Hulten and Schwab (1993), it is assumed that the income earned by labour and private capital is equivalent to their respective marginal productivities (s_L and s_K).

From this equation we can obtain the growth rate of TFP as follows:

$$\dot{TFP}_{it} = \dot{A}_{it} + (\rho - 1) \ \dot{K}_{it} + \varepsilon_T \dot{T}_{it} \tag{6}$$

where $\rho = \varepsilon_L + \varepsilon_K$.

Integrating in time in (6) we obtain the following expression:

$$LnTFP_{it} = LnA_{it} + (\rho - 1)LnK_{it} + \varepsilon_T\ LnT_{it} \qquad (7)$$

Nevertheless, it can be assumed that $LnA_{it}= lnA_{i0}+\lambda t$, i.e. that the efficiency level of each region is determined by the initial level of efficiency plus the growth rate of exogenous technical progress common to all regions. Thus the final expression to be estimated is:

$$Ln\,TFP_{it} = Ln\ A_{i0} + \lambda t\ + (\rho - 1)\ Ln\ K_{it} + \varepsilon_T\ LnT_{it} \qquad (8)$$

The *TFP* series were generated in terms relative to the efficiency of a base region for a base year. In this way, the values obtained for *TFP* show its importance in a region in comparison with the efficiency results obtained for the other regions. Taking as base the value of this productivity for the whole of Spain (*j*) in the year 1965 (*b*), it is possible to express the productivity differential between two region and for each period of time by the logarithmic difference in the output of each after discounting the weighted logarithmic difference of the inputs, taking as weightings the averages of the shares of the two regions. This is the definition proposed by Christensen, Cummings and Jorgenson (1981):

$$\begin{aligned} Ln\,TFP_{it} - LnTFP_{jb} &= (LnY_{it} - LnY_{jb}) - (1/2(\alpha_{it} + \alpha_{jb})(LnL_{it} - LnL_{jb})) \\ &\quad - (1/2((1-\alpha_{it}) + (1-\alpha_{jb}))(LnK_{it} - LnK_{jb})) \end{aligned} \qquad (9)$$

where α and $(1-\alpha)$ are the shares in income of labour and capital respectively. Also, α_i is defined by the ratio "compensation of employees in region i / total income of the same region", excluding in both terms the non-business services sector. Consequently, the objective of this definition of TFP is to compare it not only over time, but also between regions. Note that, for construction, the TFP of each region must be considered in relative terms with respect to the whole of Spain in 1965, because $TFP_{jb}=TFP_{Spain,\ 1965}=1$.

Having calculated the values of the regional *TFPs*, the effect of capital in transport infrastructures can be analysed on the basis of the following equation:

$$Ln\,TFP_{it} - LnTFP_{jb} = Ln\,A_{i0} + \lambda t + (\rho - 1)\;Ln\,K_{it} + \varepsilon_T LnT_{it} \qquad (10)$$

where $TFP_{jb} = 1$.

Likewise, the relative importance of the different types of transport infrastructures can be analysed by estimating the following equation.

$$\begin{aligned} Ln\,TFP_{it} - LnTFP_{jb} = Ln\,A_{i0} + \lambda t + (\rho - 1)\;Ln\,K_{it} + \varepsilon_{1T}\;LnR_{it} \\ + \varepsilon_{2T} LnP + \varepsilon_{3T} LnA + \varepsilon_{4T} LnRA \end{aligned} \qquad (11)$$

where R is the stock of capital in roads, P in ports, A in airports and RA in railways.

4. Results

Table 3 contains the results of the estimation of the Cobb-Douglas production function of the Spanish regions for both the private sector of the economy and for the sub-sectors of agriculture, industry, construction and business services sector. The estimation covers the period 1965-1995, and was done using fixed effects (within-groups estimator) and time effects, given the panel data nature of the sample available. Also, in order to solve the problems of bias and inconsistency deriving from the endogeneity of the capital in infrastructures, we used the estimator of instrumental variables, instrumenting the capital in infrastructures using the first lag in the variables.

Table 3 presents the aggregate results for the total capital stock of transport infrastructures, and disaggregated for the four types of infrastructure analysed: roads, ports, airports and railways. For the aggregate of the private sector of the economy, the estimation of the Cobb-Douglas production function shows elasticity values for private capital and labour of 0.343 and 0.318, respectively, with decreasing returns to scale in private inputs. In the case of transport infrastructures, the results show a significant positive effect with an elasticity of 0.042[3]. If the total infrastructure capital is

[3]The results are in concordance (although more reduced) with those of other papers that analyse the private sector in the Spanish regions: in Mas et al. (1995) the elasticity associated to the productive public capital (infrastructures) is 0.08; Boscá et al. (2002) obtain an output elasticity for public infrastructures of

disaggregated by functions, positive and significant effects are obtained in the case of roads and airports, the effect of ports and railways not being significant. Quantitatively, the magnitude of the importance of capital stock in roads stands out, with an elasticity of 0.088 as against only 0.0076 for airports. The fact that the capital stock in roads represents around 60% of the total of transport infrastructures would explain the positive effect (and its magnitude) of transport infrastructures on production.

Consequently, the importance of the capital stock in roads obtained at aggregate level for the private sector is a consequence of the positive results obtained for all sectors except construction, and of the major importance of these sectors in the total of the private sector[4]

The results by major sectors of activity show very different results with regard to the importance and magnitude of transport infrastructures. Thus, of the four sectors considered, transport infrastructures are only shown to be statistically significant in agriculture, with an elasticity of 0.072. However, this paradoxical outcome could be explained by the big increase of the productivity experimented for the Spanish agriculture for this period as result of the disappearance of many sectorial jobs.

As mentioned before, the studies by Rephann and Isserman (1994) and Chandra and Thompson (2000) also propose the importance of a disaggregated analysis. More precisely, they have shown that infrastructures relating to new motorways favoured the growth of the most urbanised regions but did not favoured the development of rural areas because it could bring the more developed urban areas closer, thus reinforcing their development to the detriment of the rural areas. Also, these two studies show how the new motorway infrastructures can favour the development of certain sectors or industries at the expense of the decline of others.

By types of transport infrastructure, the results are also very heterogeneous, the stock in roads (quantitatively the most important) being significant in all the sectors of

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0.09 (0.035 in the long run). De la Fuente (1996) shows that the importance of public capital is practically negligible when the production function is estimated in first differences or introducing fixed effects (however, it is very important to take into account that De la Fuente also introduces additionally the human capital in the estimation).

[4] On average for the period analysed, 30% of private GAV is generated by industry and 41% by services.

production except construction, with a much higher elasticity in agriculture (0.124) than in industry (0.067) and in services (0.013). Also outstanding is the importance of airports in agriculture and in industry, and of railways in agriculture, construction and services. In the case of ports, paradoxically, a significant negative effect is obtained in construction and in services. Apart from the agriculture sector, the results obtained are in line with those obtained by Chandra and Thompson (2000) where they show that road infrastructures only increase earnings in sectors that produce nationally traded goods such as manufacturing industry (and agriculture), whereas for industries producing regionally traded goods such as retail and services the earnings may decrease. Therefore, the authors conclude that the net effect on regional economic activity is ambiguous. In a similar way, the results in the construction sector are limited, because although the authors find that the effect on this sector is positive, this effect disappears very soon over time.

The use of the *TFP* approach to the analysis of the impact of transport infrastructures provides the results that appear in table 4. The results for the aggregate of the private sector are very similar to those obtained in the estimation of the production function: a positive and significant effect of the capital stock in transport infrastructures with an elasticity close to 0.04, and the non-rejection of the hypothesis of decreasing returns to scale in private inputs. For the different types of transport infrastructures, the results are also relatively similar to those of the production function approach, highlighting the magnitude of the positive impact of roads (0.070).

At sector level, though in general the signs of the elasticities obtained using the production function are maintained, some discrepancies occur regarding the magnitude and significance of transport infrastructures, and the model therefore has less explanatory capacity. Outstanding once again is the importance of the stock of roads for industry, and of railways in construction and services, as well as that of ports on agriculture.

The discrepancies that appear between the *TFP* approach and the production function approach may be due to the weightings used in the construction of *TFP*. Thus the information source used (FBBV) disaggregates the total income into labour income, mixed income and capital income, and it is not possible to separate the mixed incomes. For this reason, the share of labour incomes in the total was estimated by dividing this income by the total income, and imputing mixed income to capital. Consequently the *TFP* estimated under-values the contribution of the labour factor and over-values that of capital.

This second approach, scarcely used by literature, shows that, at least in the case of the Spanish regions, the general results are the same regarding the first. Therefore, the differences among sectors are due to the peculiarities of the sectors themselves and not to the methodology employed.

5. Transport infrastructures and network effect

The extensive literature on the importance of infrastructures in productivity gains has shown the importance of spillover effects insofar as the network-type characteristic of transport infrastructures generates positive external effects beyond the regions in which they are located. In this sense, the studies carried out on a sub-national scale (states, regions or metropolitan areas) obtain lower elasticities for the infrastructures than those obtained at national level. This result shows that the infrastructures of a region have effects not only on that region, but also on other regions connected through a network of transport infrastructures, especially on the neighbouring regions[5]

With the aim of analysing and quantifying the possible spillover effects associated with transport infrastructures, we repeated the estimations but extending the capital stock in transport infrastructures to include that of the geographically adjacent regions, as it is to be expected that the network effects (especially in the case of roads and railways) and therefore the positive external effects, will be of greater intensity in relation to the nearest regions[6].

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5 See Hulten and Schwab (1991)

6 The argument is similar to that used in Holtz-Eaking and Schwartz (1995). The difference is that we consider only the effect of the capital of the adjoining regions (a single *ring*) because in the majority of

Table 5 shows the results of the estimation of the Cobb-Douglas production function considering the possible network effect associated with transport infrastructures. For the total of the private sector, transport infrastructures have a positive impact on productivity, with an elasticity (0.062) higher than that obtained before (0.042) considering only the capital stock of each region. This result may be reflecting spillover effects associated with network-type infrastructures, as such transport infrastructures generate external effects that are beneficial not only for the regions in which they are installed, but also for others connected to them. This result is similar to that obtained by Mas et al. (1996), Kelejian and Robinson (1997) and Moreno et al (1997). However, these last two papers find that the estimated coefficients may vary if the correlation between the error terms is taken into account.

Disaggregating transport infrastructure capital by functions and considering the network effect reveals once again the importance of the stock in roads, with an elasticity (0.13) higher than that obtained previously in Table 3 (0.09). Such spillover effects are also seen to be important in the case of ports[7], though airports cease to be significant once the capital stock of adjoining regions is included . The latter result may be due to the fact that the network effects associated with airports are usually produced among more distant regions, as they can generate positive external effects in regions much further from the adjoining ones. It must also be taken into account that the empirical approach used to capture the spillover effects presents limitations in the case of the island regions (Canaries and Balearics), as although they have no regions adjoining them, they can generate and receive positive external effects to/from other regions that our model will not capture.

The estimation of the network effect at sector level presents diverse results, so it is difficult to establish valid conclusions, as in some cases we obtain elasticities of lower magnitude. It is notable that the elasticity associated with ports increases in the four sectors compared to the estimation without the network effect, which would

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Spanish regions, if we add the capital stock of a second *ring* we obtain the capital stock of the whole of Spain.

[7] Given the length of Spain's coastline and that the capital stock is widely scattered among its numerous ports, a substantial network effect could be expected on the adjoining regions, but not on the regions of a theoretical *second ring*.

indicate that this is a infrastructure whose benefits are transmitted intensively not only to the region where it is located, but also to the adjoining ones.

Finally, the use of the *TFP* approach for the private sector with the extended capital stock (table 6) shows similar results to those obtained in the Cobb-Douglas estimation (table 5). The positive effect obtained for transport infrastructures (0.061) is practically identical to that obtained in the Cobb-Douglas approach, and of greater magnitude than that obtained using each region's own capital stock (0.038). This confirms the existence of spillover effects or network effects associated with transport infrastructures.

In the disaggregation by types of infrastructures the importance of the stock of roads stands out once more, with an elasticity of 0.13, much higher than that obtained above and identical to that obtained with the Cobb-Douglas approach. There is also an increased elasticity in the case of ports, reinforcing the importance of the network effect, though the elasticity is lower than that obtained with the production function approach. For the railways and particularly for airports the network effect seems to be less important, confirming the results obtained also after estimating the production function.

However, the results by sectors of production are not conclusive, as although infrastructure elasticities of greater magnitude are usually obtained, there are some exceptions to this general behaviour. Even so, these results (together with those obtained in the other estimations already described for the production function approach) show that the results lose reliability when we disaggregate the analysis to sector level.

5. Conclusions

In recent years several studies have been published on the importance of the capital stock in transport infrastructures, with substantial disparity among the results obtained. In the Spanish case, although the results are unanimous regarding the importance of public infrastructures, the ouput elasticity associated to the infrastructures presents a relevant degree of variation, due to the many approaches and statistical sources used, the analysed sectors and periods, the econometric techniques, etc. In this context, the aim of this study has been to throw some more light on this subject, deepening and widening the research hitherto made in four directions: regional, sectorial, by type of infrastructure, and analysis of the spillover or network effects associated with transport infrastructures.

On the basis of the results obtained by regions in the period 1965-95 and for the two methodologies used, it has been estimated that a growth of 10% in transport infrastructures produces an increase in the value of the production generated by the private sector of around 0.38-0.42%. When we disaggregate the infrastructures by type of transport, the roads sector seems to have a clear predominance and significance. This result indicates that it is road infrastructures that explain with some extent the economic growth of the Spanish regions. In this respect, we have to take into account that the growth of road infrastructures in Spain during the last twenty years has been spectacular, reducing one of the most substantial historical deficits. The development of road infrastructures in Spain has therefore been a key element in Spain's economic growth, as against the development of other transport infrastructures, also important, but with less of a deficit in their endowment of infrastructures.

The results by sectors are much less conclusive than those obtained at aggregate level. The loss of significance of many of the elasticities estimated, and even the appearance of some negative signs, make it difficult to draw valid conclusions. However, with the exception of the agriculture sector, the results are similar to those obtained in other papers that show that transport infrastructures only increase earnings in sectors that produce nationally traded goods such as manufacturing industry (and agriculture) whereas for industries producing regionally traded goods such as retail and services the earnings may decrease.

When the network effect of infrastructures is estimated with the inclusion of the infrastructures of adjoining regions, the aggregate estimation for both methodologies obtains an elasticity for the total of transport infrastructures of 0.061, higher than that obtained considering only the capital stock of each region. This is evidence of the existence of a very substantial network effect, which confirms the importance of investment in transport infrastructures, not only in the region in which it is made, but also in other regions. When we disaggregate by modes of transport, the two methodologies detect important network effects for roads and ports. These do not seem to hold for the railways, nor, especially, for airports, though this may be explained by the mode of incorporating this aspect into such a peculiar sector as that of airports.

The main conclusion of our study is that the results obtained from the two approaches used are compatible with each other, and show the importance of transport infrastructures in explaining the productivity gains of the private sector in the Spanish regions. We have also verified important network effects of these infrastructures on the private sector. However, when we disaggregate our analysis to sector level, the results are not conclusive; it will consequently be necessary to examine this aspect more closely in future research.

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Appendix: Statistical Sources

The principal sources of information used are those detailed below:

a) Production (GAV) and employment: The *Fundación BBV* (FBBV) offers information for these two variables at provincial scale from 1955 to 1998, though the information is biennial. The information also appears disaggregated at sector level, though the study uses information disaggregated into 5 sectors of activity: agriculture, industry, construction, business services sector, and non-business services sector. The sum of the first four provides the production and employment of the private sector of the economy.

b) Stock of private capital: the information comes from the estimations made by the IVIE and published by the FBBV. The information covers the period 1964-96 and various sectors of activity. Nevertheless, since we are modelling the private sector, we use the so-called non-residential private capital, the information being disaggregated for agriculture, industry, construction and business services sector.

c) Transport infrastructures: the information comes from the estimations made by the IVIE and published by the FBBV. The information distinguishes the following types of infrastructures: roads and motorways, ports, airports and railways. The period differs with the type of infrastructure, information being available at least from 1955 to 1995.

As a consequence of the different periods of the sources analysed, the period analysed in the study is from 1965 to 1995, because though data on private capital exist from 1964, production and employment information is not available for that year.

Table 1. Transport infrastructures / GDP

	1965	1975	1985	1995
Andalucia	0.14	0.15	0.16	0.26
Aragon	0.19	0.20	0.22	0.21
Asturias	0.14	0.19	0.26	0.34
Balearics	0.14	0.11	0.09	0.09
Canaries	0.12	0.15	0.14	0.15
Cantabria	0.14	0.14	0.18	0.34
C-La Mancha	0.22	0.18	0.21	0.35
C-Leon	0.22	0.23	0.25	0.28
Catalonia	0.07	0.13	0.14	0.15
Extremadura	0.20	0.17	0.18	0.26
Galicia	0.15	0.13	0.18	0.24
La Rioja	0.13	0.13	0.45	0.29
Madrid	0.05	0.08	0.09	0.10
Murcia	0.11	0.08	0.09	0.16
Navarra	0.20	0.22	0.30	0.29
Basque Country	0.08	0.14	0.20	0.23
C. Valenciana	0.09	0.12	0.13	0.17
SPAIN	0.12	0.14	0.16	0.19
Std. Dev.	0.05	0.04	0.09	0.08

Source: FBBV

Table 2. Transport infrastructures / Productive (non-residential) private capital

	1965	1975	1985	1995
Andalucia	0.18	0.16	0.15	0.24
Aragon	0.20	0.19	0.18	0.16
Asturias	0.13	0.16	0.19	0.24
Balearics	0.17	0.09	0.08	0.08
Canaries	0.15	0.16	0.15	0.14
Cantabria	0.10	0.09	0.12	0.25
C-La Mancha	0.28	0.18	0.14	0.25
C-Leon	0.24	0.21	0.18	0.21
Catalonia	0.09	0.16	0.13	0.13
Extremadura	0.25	0.15	0.10	0.18
Galicia	0.16	0.13	0.16	0.20
La Rioja	0.18	0.14	0.44	0.27
Madrid	0.09	0.13	0.13	0.12
Murcia	0.12	0.08	0.09	0.15
Navarra	0.22	0.22	0.28	0.24
Basque Country	0.07	0.12	0.14	0.17
C. Valenciana	0.14	0.15	0.13	0.16
SPAIN	0.14	0.15	0.15	0.17
Std. Dev.	0.06	0.04	0.08	0.05

Source: FBBV

Table 3: Production function estimation by IV (1965-95)

	Private sector		Agriculture		Industry		Construction		Business services	
Labour	0.318 (9.09)	0.398 (10.44)	0.466 (7.25)	0.488 (7.50)	0.974 (17.77)	0.904 (15.69)	0.909 (28.45)	0.930 (29.02)	0.950 (45.42)	0.944 (45.09)
Private capital	0.343 (11.44)	0.307 (10.45)	0.211 (5.89)	0.184 (5.15)	0.250 (9.83)	0.227 (8.58)	0.051 (1.65)	-0.0077 (-0.23)	0.128 (6.10)	0.119 (5.82)
Transport Infras.	0.042 (2.57)		0.072 (1.82)		0.023 (0.94)		-0.025 (-1.34)		0.0021 (0.28)	
Roads		0.088 (7.25)		0.124 (3.93)		0.067 (3.51)		-0.0001 (-0.00)		0.013 (2.40)
Ports		-0.017 (-1.00)		0.065 (1.52)		-0.045 (-1.71)		-0.072 (-3.37)		-0.032 (-4.08)
Airports		0.0076 (2.73)		0.018 (2.90)		0.0073 (1.96)		0.0017 (0.58)		-0.0015 (-1.26)
Railways		0.0030 (0.82)		0.206 (2.30)		-0.0027 (-0.50)		0.0089 (2.19)		0.0059 (3.30)
R^2	0.99	0.99	0.98	0.99	0.99		0.99	0.99	0.99	0.99

In parentheses, t-ratio
Within-group estimator
Time effects have been introduced

Table 4: TFP estimation by IV (1965-95)

	Private sector		Agriculture		Industry		Construction		Business Services	
Private capital	-0.421 (-11.57)	-0.376 (-16.21)	-0.496 (-9.29)	-0.384 (-9.17)	-0.305 (-7.56)	-0.269 (-7.09)	-0.625 (-8.60)	-0.210 (-7.08)	-2.161 (-3.96)	-0.434 (-8.92)
Transport Infras.	0.038 (2.72)		0.020 (0.39)		0.068 (1.85)		0.012 (0.44)		-0.041 (-2.22)	
Roads		0.070 (6.67)		0.053 (1.39)		0.132 (4.99)		-0.028 (-1.80)		-0.0023 (-0.16)
Ports		-0.0095 (-0.63)		0.192 (3.69)		-0.091 (-2.44)		-0.0041 (-0.18)		-0.031 (-1.63)
Airports		0.0028 (1.27)		0.025 (3.28)		0.0091 (1.61)		0.0061 (2.04)		-0.0082 (-2.90)
Railways		0.0060 (1.87)		0.042 (3.93)		0.0028 (0.36)		0.011 (2.59)		0.019 (4.59)
R^2	0.96	0.97	0.90	0.910	0.78	0.83	0.76	0.87	0.93	0.94

Notes: See table 3

Table 5: Production function estimation by IV and network effect (1965-95)

	Private sector		Agriculture		Industry		Construction		Business Services	
Labour	0.331 (9.10)	0.394 (10.11)	0.438 (6.61)	0.438 (6.88)	0.988 (18.52)	1.00 (18.71)	0.914 (28.76)	0.898 (27.12)	0.956 (42.98)	0.917 (42.45)
Private capital	0.335 (11.00)	0.333 (11.22)	0.216 (6.12)	0.207 (5.41)	0.242 (10.01)	0.246 (10.26)	0.039 (1.32)	0.054 (1.75)	0.125 (5.90)	0.109 (5.42)
Transport Infras.	0.062 (1.70)		0.143 (1.65)		0.010 (0.21)		-0.032 (-0.85)		0.013 (0.76)	
Roads		0.130 (3.30)		0.050 (0.54)		0.092 (1.65)		-0.151 (-3.54)		0.023 (1.36)
Ports		0.141 (4.32)		0.184 (2.54)		0.031 (0.76)		0.078 (2.35)		0.0012 (0.09)
Airports		-0.013 (-0.91)		0.064 (1.72)		-0.0011 (-0.05)		0.021 (1.30)		-0.019 (-2.99)
Railways		0.0081 (0.20)		0.020 (2.35)		-0.0076 (-1.44)		0.0085 (2.11)		0.0075 (3.96)
R^2	0.99	0.99	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Notes: See table 3

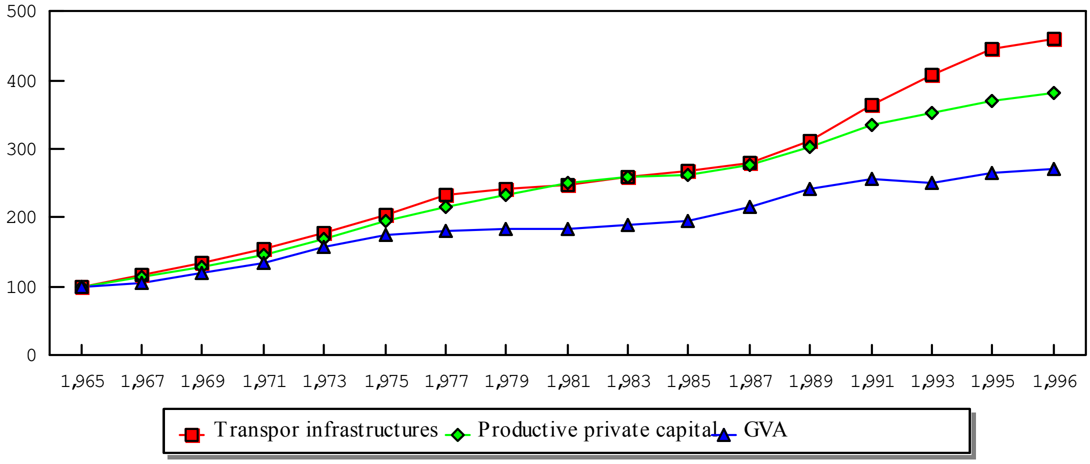
Table 6: TFP estimation by IV and network effects (1965-95)

	Private sector		Agriculture		Industry		Construction		Business Services	
Private capital	-0.371 (-15.41)	-0.365 (-14.88)	-0.377 (-8.65)	-0.378 (-8.20)	-0.229 (-6.70)	-0.219 (-6.33)	-0.220 (-8.44)	-0.208 (-8.13)	-0.211 (-4.19)	-0.444 (-9.65)
Transport Infras.	0.061 (1.98)		0.190 (1.79)		0.113 (1.52)		-0.054 (-1.37)		-0.187 (-4.98)	
Roads		0.131 (3.86)		-0.107 (-0.92)		0.211 (2.48)		-0.184 (-4.27)		0.0032 (0.80)
Ports		0.073 (2.96)		0.146 (1.62)		0.016 (0.26)		0.098 (3.00)		-0.131 (-4.39)
Airports		-0.020 (-1.55)		0.103 (2.25)		-0.016 (-0.51)		0.019 (1.19)		-0.038 (-2.51)
Railways		0.0056 (1.71)		0.052 (4.74)		-0.0010 (-0.12)		0.013 (3.28)		0.026 (6.29)
R^2	0.96	0.97	0.90	0.91	0.78	0.79	0.86	0.87	0.94	0.95

Notes: see table 3

Figure 1. Economic growth and capitalisation in Spain

1965=100 (constant pesetas)



Source:FBBV

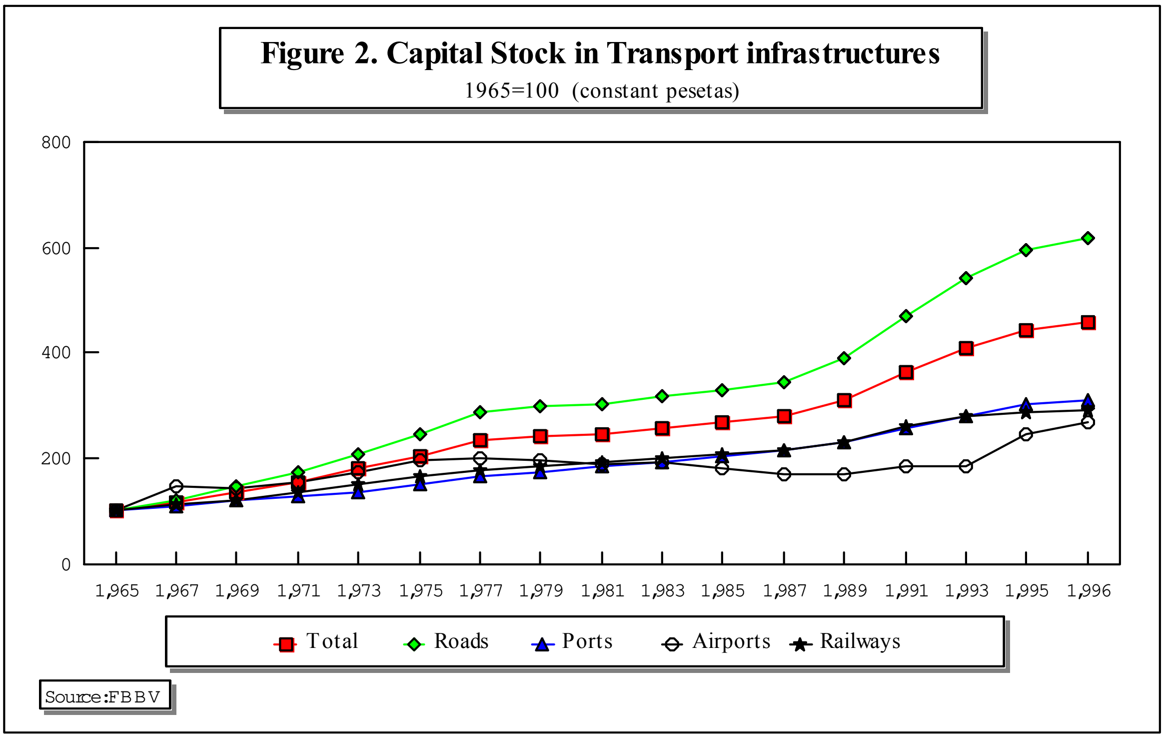
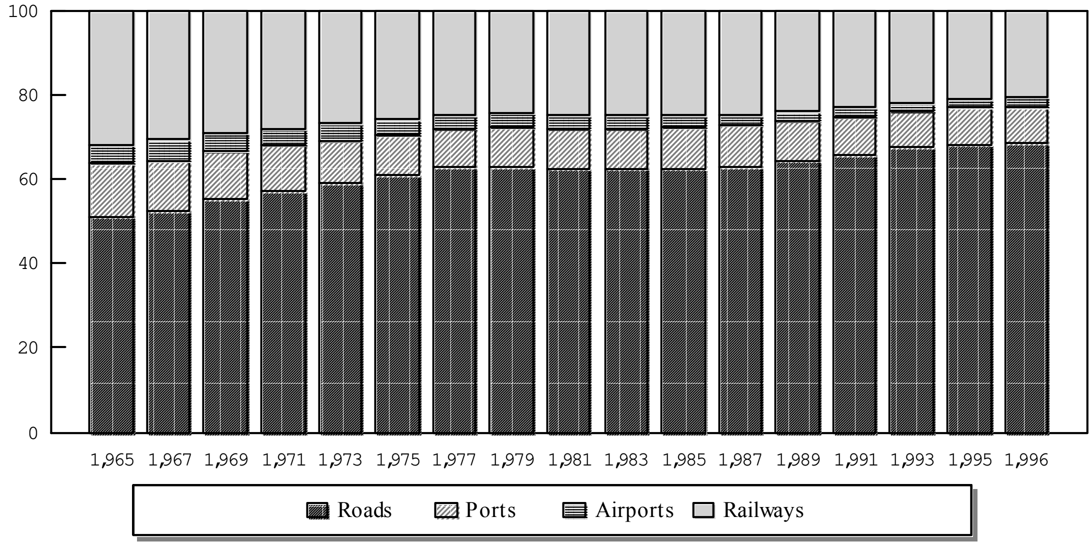


Figure 2. Capital Stock in Transport infrastructures
1965=100 (constant pesetas)
800
600
400
200
0
1,965
1,967
1,969
1,971
1,973
1,975
1,977
1,979
1,981
1,983
1,985
1,987
1,989
1,991
1,993
1,995
1,996
Total
Roads
Ports
Airports
Railways
Source:FBBV

Figure 3. Percentage distribution in transport infrastructures

(percentages)



Source:FBBV