THE EFFECT OF PUBLIC INFRASTRUCTURE ON PRIVATE ACTIVITY: EVIDENCE FROM THE SPANISH REGIONS.

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MARIA JESUS DELGADO and INMACULADA ALVAREZ (2000) Productive Infrastructure and Economic Growth: Evidence from the Spanish Regions. This paper considers the measurement of infrastructure capital in the Spanish economy and investigates the technical relation among the inputs, which offers information about the way infrastructure enters in the production process. Using a translog production function we present panel estimates for the 17 Spanish regions for the period 1980-1995. The results indicate that productive infrastructure encourages private investment and can therefore be considered to be essential for economic growth.

Keywords: Translogarithmic Production Function, Inputs Technical Relations, Regional growth, Productive Infrastructure

INTRODUCTION

Recent studies about the sources of growth have focused their interest on the study of inputs that are external to the firms. Among others: the public capital stock (Aschauer, 1989a,b, Munnell, 1990 and García Milá and McGuire,1992) and the human capital (Mankiw, Romer and Weil, 1992) have being analysed, following the principle that an increase of these inputs will improve levels of production. Besides this direct effect, these inputs may increase aggregate production through external economies. The neo-classical models of economic growth emphasize the former effect, while recent theories of endogenous growth focused on the second.

The aim of this paper is to offer evidence from the Spanish regions about the complex relation between infrastructure capital and economic growth. Transport, communication and energy infrastructures have been considered as important elements for private production[1]. For that reason, we have included these endowments as the components of the productive infrastructure stock studied in this paper. The empirical exercise is carried out for the period 1980-1995 and seeks to provide a better understanding of the linkages between productive infrastructure and the production process. This relationship is central to a number of issues of current interest, but the difficulty of quantifying the effects of public capital has been argued by many authors (Tatom, 1991, Berndt and Hansson, 1992). In this work, we introduce a flexible production function that does not constrain the technical relations among the inputs and therefore avoids the main problems of the Cobb-Douglas production function, frequently employed in this analysis. We should pay more attention to the indirect role of infrastructure as this type of function allows us to examine the complementary or substitutability relationship between factors.

One of the problems of infrastructure studies lies primarily in the lack of comprehensive estimates of productive infrastructure stock that are appropriate for performing time-series and cross-sectional analysis. To fill this gap, we have elaborated a series of this stock for the 17 Spanish regions from 1980-1995 using physics units as a measure for the productive infrastructure (km of roads, km of railway, nº of telephone lines, and so on) according to the methodology proposed by Biehl, 1986, and employing Multivariate Techniques to obtain an aggregate indicator of the regional endowments.

This paper is organised as follows: in the next section we introduce a survey of the main results in this area. The definition and measurement of the regional productive infrastructure indicator used in our analysis are presented in section three. The following section briefly outlines the model of flexible production function incorporating the stock of productive infrastructure. In section five, the infrastructure stock is entered as an input into a translog production function. Estimates of elasticities provide information about the effect of infrastructure capital on private production and about the technical relationship between inputs in the Spanish economy. Finally, some concluding remarks and suggestions for further research are given in section six.

[1] The productive infrastructures have been demostrated to have a positive impact on regional productivity in the Spanish regions (Mas et. al, 1997, Moreno et al. 1998 and Delgado, 1998).

THE TECHNICAL RELATIONSHIP BETWEEN PRODUCTIVE INFRASTRUCTURE AND THE PRIVATE INPUTS

Current studies on productive infrastructure capital show that this stock raises private sector output both directly and indirectly. The direct effect arises because infrastructure capital provides intermediate services to private sector firms, that is the marginal product of infrastructure capital services in the private sector is positive. The indirect effect arises from the assumption that productive infrastructure and private capital are "complements" in production, that is, the partial derivative of the marginal product of private capital services with respect to the flow of infrastructure capital services is positive[2]. Thus, a rise in infrastructure capital raises the marginal productivity of private capital services so that, given the rental price of such services, a larger flow of private capital services and a larger stock of private assets producing them are demanded. The rise in the marginal product of capital increases private capital formation, raising private sector output further.

The indirect effect of a rise in infrastructure capital on private output, however, is not necessarily positive. In fact, this effect can be negative if infrastructure and private capital are substitutes. Economic theory does not dictate when private and infrastructure stocks are complements or substitutes. This analysis is characterised by two opposing forces. On the one hand, infrastructure capital enhances the productivity of private capital, raising its rate of return and encouraging more investment. On the other hand, from the investor's perspective, infrastructure capital acts as a substitute for private capital and "crowds out" private investment. The estimated equations confirmed both forces but suggested that, on balance, infrastructure capital investment stimulates private investment.

The contribution of infrastructure capital to regional economic development has been examined in numerous studies[3], trying to address these issues applying two different approaches. One line of studies estimate production functions including productive infrastructure stock as an input, which offers the most direct aggregate

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[2] There is however, a growing literature that suggests that government spending is a substitute for private sector spending. Attention to this view owes much to Kormendi (1983) and Tatom (1991).

[3] See Gramlich (1994) for a review of the main studies about the impact of infrastructure investment.

evidence on the positive effect of infrastructure on capital formation. The aggregate production function indicates the maximum output that can be produced with labour and capital taking as given technology and other factors influencing production. In the analysis it is assumed that the private sector production function can be represented by a Cobb-Douglas production function. These researches find that infrastructure capital makes a positive and statistically significant contribution to private production, supporting the concept of public capital stock as an unpaid factor of production. Eberts (1986,90), Holtz-Eakin (1994), Garcia-Milá and McGuire (1992) and Munnell (1992) to mention just a few, arrive to this conclusion. Less attention has been given to the technological relationship between public infrastructure and other inputs. In this case a more flexible functional form is needed to emphasise the technical relationship instead of the direct effect of infrastructure. Eberts (1986) finds that public capital and private capital are complements, while public and private capital and labour are substitutes. These results are also supported by Deno (1986,88), using investment data instead of capital stock. He estimates labour and private investment demand equations derived from a Cobb-Douglas production function.

It would also be possible to check on the results by converting production functions to cost functions as was originally suggested by Friedlaender (1990). This line of research based on the "duality approach" examines the impact of infrastructure capital on the private economy by estimating a cost function introducing public capital as a fixed unpaid production factor and recovering its productivity effect by applying duality theory. Following this approach, Dalenberg (1987), Seitz (1992) and Seitz and Licht (1995) also find that public capital is a complement to private capital but a substitute to the private labour input using a translogarithmic cost function.

In the case of Spain, several studies have recently been published analysing the influence of the stock of infrastructure to economic growth following the two approaches mentioned above. Using production functions (Mas et al, 1994 and Dabán et al, 1997) and cost functions (Gil et al.,1998). The technical relations have been studied using a translogarithmic cost function by Moreno, 1998 and a translogarithmic production function by Alvarez et. al, 1999 and find, again, a complementarity relationship between public and private capital and a sustituibility relation between public capital and labour for the Spanish regions.

DEFINITION AND MEASURE OF PRODUCTIVE INFRASTRUCTURE STOCK FOR THE SPANISH REGIONS

This paper focuses on the productive works components of the infrastructure stock. This category includes: roads, railways, airports, ports, energy networks and telecommunications. Installations and facilities that are basic to the growth and performance of an economy. Several definitions and classifications are used throughout the literature. The term productive infrastructure used in this work is broader than public works investment and includes communication and other endowments with private participation which have in common with the rest of public investment that provides the basic foundation for economic activity and generates positive spillovers. Besides, they are, in certain aspects, under government control and thus can be effective public policy instruments in promoting economic development.

One reason for the lack of empirical work on the effect of infrastructure capital in Spain is the need of consistent and accurate measures of this stock that are suitable for empirical analysis. Two basic approaches have been suggested for measuring the infrastructure stock. One method is to measure infrastructure capital in monetary terms by adding up past investment using the perpetual inventory method. There are two main studies in this area for the Spanish economy, they have been published by BBV and the Ministry of Economy[4] but include only public investments. An alternative approach is to use physical measures by taking inventory of the quantity and quality of the pertinent structures and facilities and covering a broader definition of this stock. This is the idea of this research, as the government is not subject to competitive markets, and public infrastructure endowments are not allocated through a price mechanism. Anyway, we are conscious that each approach has its advantages and

[4] These studies offer monetary estimates of the public stock. The work published by BBV collect the public stock from 1964-1994 to regional and provincial level (Fundación BBV,1998). The Ministery of Economy offers a data base called BD.MORES that contains information about public capital from 1980-1995 (Dabán et al, 1998).

disadvantages, but using physical measures of public infrastructure we avoid problems related to the use of prices in the monetary approach.

The data used in this research has been obtained following the work for the European regions by Biehl (1986) and using multivariate techniques to aggregate the data. Biehl (1986) argues that information on the physical characteristics of the assets that reflect capacity and quality should be collected. In the case of highways, for example, it is argued that from physical characteristics of these roads it is possible to estimate the traffic flow capacity.

The indicator of productive infrastructures employed have been calculated aggregating through the Principal Components Analysis[5] the equipment more relevant, which contains roads, airports, ports, railways, communications, electricity and pipelines. From the variables S_1, S_2, ..., S_N, that compile the information about relativized equipment, we obtain principal components:

$$Y_1 = t_{11}Z_1 + t_{21}Z_2 + ... + t_{n1}Z_n$$
$$Y_2 = t_{12}Z_1 + t_{22}Z_2 + ... + t_{n2}Z_n$$
$$.$$
$$Y_n = t_{1n}Z_1 + t_{2n}Z_2 + ... + t_{nn}Z_n$$

Being: Y_i the i-th factor, Z_j the typified variable S_j and t_{ij} the weightings.

We obtain the principal components diagonalizating the correlation matrix R

$$R = TDT` \; ( TT`= T`T = I)$$

In which:

- D is the diagonal matrix $D=diag(\bullet_1 , \bullet_2, ... , \bullet_n)$ that contains the correlation matrix R characteristic roots.
- T is the orthogonal matrix of components coefficients.

[5] Further detailed about the measurement of the productive infrastructure capital used in this work can be found in Alvarez et al,1999.

The principal components factorial structure is calculated identifying the correlation matrix A with the factorial model if we consider the components as factors. Then the factorial model matrix is $A=TD^{1/2}$ and the factors are determinate by the following expression:

$$Y_1 = a_{11}Z_1 + a_{21}Z_2 + ... + a_{n1}Z_n$$
$$Y_2 = a_{12}Z_1 + a_{22}Z_2 + ... + a_{n2}Z_n$$
.
$$Y_n = a_{1n}Z_1 + a_{2n}Z_n + ... + a_{nn}Z_n$$

Where:

- $a_{ij} = t_{ij}VAR(Y_i)$ represents the correlation between the variable S_j and the components Y_i.

In order to calculate the endowments in infrastructure index we have sum over all factors. Each of them weighted by the percentage of total variance that explain. So:

$$I = \sum_{i=1}^{n} \frac{VAR(Y_i)}{n} Y_i$$

Where:
- Y_i is the factor and
- $\frac{VAR(Y_i)}{n}$ is the percentage of total variance that Y_i explains.

Defining the factors Y_i in terms of the observable variables $S_1, ..., S_n$, we obtain the following expression:

$$I = \sum_{i=1}^{n} \frac{VAR(Y_i)}{n} \sum_{j=1}^{n} t_{ij} Z_j$$

Next we consider the factorial structure of the principal components. In that way, we can define the matrix T of weights, as a function of the matrix B, calculated applying a varimax rotation on the correlation matrix A, as:

$$tij = \frac{b_{ij}}{VAR(Y_i)}$$

Then we obtain the indicator as follows:

$$I = \sum_{i=1}^{n} \frac{1}{n} b_{ij} \sum_{j=1}^{n} Z_j = \frac{1}{n}(b_{11} + b_{21} + ... + b_{n1})Z_1 + \frac{1}{n}(b_{12} + b_{22} + ... + b_{n2})Z_2 + ... +$$

$$+ \frac{1}{n}(b_{1n} + b_{2n} + ... + b_{nn})Z_n$$

As it has been mentioned Z_j is the matriz of typified variables, and collects information about the endowments studied:

Z_1: Km high capacity roads	Z_2: Rest of roads Km	Z_3:Km double line elect. railway
Z_4: Km simple line electrified railway	Z_5: Nº Telephone lines	Z_6: Km Pipelines (for oil)
Z_7: Km Pipelines (for gas)	Z_8: Km 400 Kv Electr. Net	Z_9: Km 220 Kv Electricity network
Z_{10}: Km 110-132 Kv network	Z_{11}: Km <110 Kv network	Z_{12}: Area Runway.
Z_{13}: Ports> 4m		

The annual indicator of productive infrastructure obtained for each region (1980-1995) and some summary statistics are shown in table 1 of the Appendix. The estimated series reveal a wide variation across the Spanish regions in terms of the infrastructure endowments. The disparities found were examined using the coefficient of variation and the standard deviation among others dispersion measures. We shall begin by pointing out the relevant characteristics regarding the distribution and changes the regional productive infrastructure.

- First, the results show that País Vasco and Madrid are the regions with the highest productive infrastructure indicator, followed by Cataluña and Cantabria. Aragón, Castilla-León, Castilla-la Mancha and Extremadura are the regions with the lowest productive infrastructure indicator in the years studied. It is also shown that the distance between the worst and the best equipped region stay constant over time.

- We find a constant increase in the infrastructure indicator for all the regions and that the differences among them are maintained throughout time. Baleares, Canarias, Cantabria, Cataluña, Madrid, Valencia and País Vasco obtained infrastructure levels above the mean during the whole period, while the infrastructure levels of the rest of regions are under it. Therefore, there is a high concentration of productive infrastructure in the Northeast of Spain, Madrid and the islands, which shows that the best equipped regions are also those with the highest income levels and high population density.

- The coefficient of variation indicates, for the full period, a stable degree of dispersion, which is an important fact to be considered in further researches on convergence. The lack of productive infrastructure endowments in less developed regions may be an obstacle to increase private production.

THEORETICAL FRAMEWORK

To explore the effect of productive public infrastructure on economic growth and the technical relationships between the public stock and other inputs, a production function is specified and estimated using data from the 17 Spanish regions between 1980-1995. Consider a production function aggregated to regional level in which:

$$Q = f(A,K,L,I) \qquad (1)$$

Where: A is technical change, Q is the private output, K is private capital stock, L is labour and I is productive infrastructure capital.

A variant of the translog specification of a CES production function is chosen to estimate the production relationship. Thus, equation (1) is specified as:

$$\log Q = a_0 + a_1 \log K + a_2 \log L + a_3 \log I + a_{12}(\log K)(\log L) + a_{13}(\log K)(\log I) + \\ + a_{23}(\log L)(\log I) + a_{11}(\log K)^2 + a_{22}(\log L)^2 + a_{33}(\log I)^2 \qquad (2)$$

The Cobb-Douglas production function constrains the elasticity of substitution to be equal to one. Although the constant elasticity of substitution (CES) production function constrains the value of substitutability between factor of production to be constant. Its value is determined by the technology and may change with technical progress, but is not necessarily equal to one. The CES production function is given by:

Q = ☎ [⌧K^-👎 + (1-⌧)L^-👎]^-🖫/👎

The parameter ☎ is a scale parameter which can be used to denote efficiency. The degree to which technology is capital intensive is indicated by ⌧. Finally, the substitution parameter is 👎 and 🖫 gives the degree of homogeneity.

The marginal rate of substitution is given by:

R = F_L/F_K = [(1-⌧)/⌧](K/L)^(1+👎)

Taking logarithms in this relation we have

logR = log((1-⌧)/⌧) + (1+👎)log(K/L)

and so the elasticity of substitution is equal to:

☞ = dlog(K/L)/dlogR = 1/(1+👎)

It can be shown that the CES production function reduces to the Cobb-Douglas as ☞✡ 1 and 👎✡ 0. The empirical evidence suggests that ☞🕒1 so the CES production function is preferred to the Cobb-Douglas. A major problem with the CES production function is that we cannot transform it into a linear-in-parameters form by operations such as taking logarithms. Linear approximations have been used but result from adding standard economic assumption to the CES specification. In consequence, we use the approximation proposed by Kmenta (1967):

This method is based on writing the CES function as

logQ = log☎ - 🖫/👎f(👎)

where: f(👎) = log[⌧K$^{-👎}$ + (1-⌧)L$^{-👎}$]

and taking a Taylor series expansion of f(👎) around the value 👎=0 (which corresponds to the value ☞=1).

The general expansion is

f(👎) – f(0) = 👎f'(0) + ½ 👎^{2}f''(0)

and the first and second derivatives evaluated at 👎=0 are:

f'(0) = -[⌧logK + (1-⌧)logL☸

f''(0) = ⌧(1-⌧)[logK – logL]^2

So the general expansion can be written as follows:

f(👎) – f(0) = -👎[⌧logK + (1-⌧)logL] + ½ 👎^{2}{ ⌧(1-⌧)(logK-logL)^2 } =

= -👎⌧logK - 👎(1-⌧)logL + ½ 👎^{2}{ ⌧(1-⌧)(logK – logL)^2 }

Then we have the approximation:

logQ = log☎-🖫/👎f(👎) = log☎ - 🖫/👎[-👎⌧logK - 👎(1-⌧)logL + ½ 👎^{2}{⌧(1-⌧)(logK – logL)^2}]

logQ = log☎ + 🖫⌧logK + 🖫(1-⌧)logL – ½ 👎🖫{⌧(1-⌧)(log(K/L))^2}

The last term is added to the Cobb-Douglas log-linear regression and indicates the departure from a unitary elasticity of substitution. Expanding the squared term then we have the "transcendental logarithmic" production function of Christensen et al. (1973)

$$\log Q = a_0 + a_1\log K + a_2\log L + a_{11}(\log K)^2 + a_{12}(\log K)(\log L) + a_{22}(\log L)^2 \qquad (3)$$

In adopting equation (3), it is assumed that technical change is similar across regions and if the productive public infrastructure is included as additional input we obtained (2). This functional form permits the consideration of a great range of substitution possibilities and is a first order approximation to any production technology without being necessary to impose a priori restrictions on returns to scale.

$$\log Q = a_0 + a_1\log K + a_2\log L + a_3\log I + a_{12}(\log K)(\log L) + a_{13}(\log K)(\log I) + \\ + a_{23}(\log L)(\log I) + a_{11}(\log K)^2 + a_{22}(\log L)^2 + a_{33}(\log I)^2 \qquad (2)$$

In this specification, cross terms represent relations of complementarily and sustituibility between factors when they are positive or negative, respectively. While the quadratic coefficients characterise returns to scale.

Finally, in order to analyse the elasticities of the private inputs and productive infrastructure it is necessary to differentiate the production with regard to that factors, obtaining the following expressions:

$$\varepsilon_{YL} = \partial \ln Y/\partial \ln L = a_2 + a_{12}(\log K) + a_{23}(\log I) + 2*a_{22}(\log L) \qquad (4)$$

$$\varepsilon_{YK} = \partial \ln Y/\partial \ln K = a_1 + a_{12}(\log L) + a_{13}(\log I) + 2*a_{11}(\log K) \qquad (5)$$

$$\varepsilon_{YI} = \partial \ln Y/\partial \ln I = a_3 + a_{13}(\log K) + a_{23}(\log L) + 2*a_{33}(\log I) \qquad (6)$$

DATA AND ESTIMATION RESULTS

In order to examine the technical relations among the inputs outlined above, we used the translog production function specified (2) and estimated using annual data from the 17 Spanish regions between 1980-1995. Data for the private inputs were obtained from two main sources. First, private output (Q) and labour (L) are obtained from the Contabilidad Regional de España offered by Cordero and Gayoso (1996) and produced by the Instituto Nacional de Estadística (INE, Spanish Statistical Office). Second, series of the private capital stock (K) were taken from BBV (1998). We use the productive infrastructure indicator elaborated in this study (I). All the variables were used at constant 1990 prices. The data used and some descriptive statistics employed in the analysis can be found in the Appendix.

The average annual growth rate during the eighties and mid nineties of the main magnitudes for the Spanish economy are displayed in table 5. The growth rates of the productive infrastructure stock is not equally distributed throughout the period. During the first part of the eighties, the growth rate was low, it increased during the second half to reduce again in the first half of the nineties. The same evolution and intensity is shown by the private production and private capital stock. Whereas labour showed a dramatic decrease during the early eighties and nineties, probably due to the fact that Spanish firms were able to adjust it to the economic cycle easier than the private capital stock.

On the basis of the estimation of the general equation (2) we are interested in analysing the technical relationship between inputs in the Spanish economy. These results offer evidence about the impact of productive infrastructure on economic growth. In Table-A we present the different estimates of the model. In column (a) we show the OLS estimates of the translog function, the results are not significant as we do not control for the fixed effects. We implemented the F-homogeneity test in order to determine when it was necessary to consider unobservable effects. The test offers the following results $F(16,246) = 98.601$, which evidence it is a panel data set. The Hausman test is computed to confirm the appropriate specification (the results obtained are: $\chi^2(9) = 67.493$, which point to the fixed effect model). Column (b) presents the estimates of the fixed effects model in levels, we find again that most of the coefficients are not significant, but the results offer a clear conclusion: productive infrastructure capital and private capital are complements and productive infrastructure and labour are substitutive.

TABLE-A. TRANSLOGARITHMIC PRODUCTION FUNCTION ESTIMATES

	OLS (a)	LEVELS (b)	FIRST DIF. VI (c)
CONSTANT	-2.743 (-0.3015)		
L	-4.0654 (-1.0329)	-0.881 (-0.449)	-9.50094 (-2.634)
K	2.952 (0.627)	1.173 (0.625)	11.413 (2.842)
I	1.03803 (0.568)	-0.599 (-1.536)	-3.2075 (-1.721)
K-L	1.4028 (1.232)	0.217 (0.441)	2.9055 (2.863)
I-K	-0.165 (-0.282)	0.4088 (2.976)	1.0913 (2.316)
I-L	0.164 (0.319)	-0.593 (-3.541)	-1.336 (-3.3077)
$(L)^2$	-0.838 (-1.526)	0.114 (0.516)	-1.183 (-2.411)
$(K)^2$	-0.477 (-0.737)	-0.145 (-0.563)	-1.617 (-2.896)
$(I)^2$	-0.0771 (-0.358)	-0.111 (-1.152)	-0.0393 (-0.231)
Wald test	7760.0974 DF = 9	4307.969 DF = 9	298.0267 DF = 9
Autocorrelation test (First and second order)	3.374 3.345	3.302 2.923	-1.152 -0.998

Note: Sample 1980-1995; dependent variables: L(Q), fixed effects model,in parenthesis robust t-statistics to heterocedasticiy. DF: degrees of freedom. Sources: Cordero y Gayoso: Q and labour, BBV: private capital.

Table B shows the results obtained from the estimation of the regional fixed effects. It can be interpreted that the fixed effects reflect the particular set of circumstances which influence the productivity results of each region and are not captured by the factors specified in the production function (from weather conditions to the productive structure, use of technology, etc.). Its also tested the normality of the disturbance, the Jarque-Bera test offers the following result $\chi^2(9) = 5.068$, so the hypothesis of normality is not rejected.

TABLE B - FIXED EFFECTS

Region	Fixed effects	Region	Fixed effects	Region	Fixed effects	Region	Fixed effects
1	0.491	6	-0.336	11	0.177	16	0.547
2	0.167	7	0.215	12	0.808	17	0.381
3	-0.046	8	0.111	13	0.195		
4	0.076	9	0.669	14	-0.068		
5	0.335	10	-0.101	15	-0.334		

NOTE REGIONAL CODE: Andalucia (1), Aragon (2), Asturias (3), Baleares (4), Canarias (5), Cantabria (6), C.Leon (7), C.Mancha (8), Cataluña (9), Extremadura (10), Galicia (11), Madrid (12), Murcia (13), Navarra (14), Rioja (15), Valencia (16), Pais Vasco (17).

The existence of endogeneity in some of the explicative variables can generate simultaneity bias in the estimated coefficients. For this reason we apply the Hausman test of exogeneity[6] . The test is carried out in two steps. In the first step, we regress the

[6] Hausman J.A.(1978). "Specifiction test in econometrics", Econometrica, Vol.46, Nº6, pp 1251-1271.

variable which is tested on the rest. In the second, the previous regression disturbances are incorporated as an additional variable in the original regression. If the disturbances are significant we reject the hypothesis of exogeneity, being necessary the use of instruments. The results of this test are shown in the next table:

HAUSMAN TEST	RESULTS
LABOUR	3.24727
PRIVATE CAPITAL	6.93684
INFRASTRUCTURE	1.14603

Labour and private capital are endogenous. So, in column (c) we show the estimation selected: we estimated a first difference specification to control for non-stationary of the variables and we instrumented labour and private capital using their lagged value (following the works of García-Milá et.al,1992, Holtz-Eakin,1992, Holtz-Eakin, Newey and Rosen,1988 with panel data). We can observe that private and infrastructure capital are complements whereas a substitute relation emerges for labour and productive infrastructure. Besides decreasing returns to scale are found for the private inputs. These conclusions are in accordance with results reported throughout the literature. The indirect effect of the productive infrastructure implies a rise in the productivity of private capital, which increases private sector output. From these results, we can conclude that an increase of these endowments in less developed regions can be a way to intensify the attractiveness for the location of private activities.

We focus our study in the indirect effect of the private inputs and productive infrastructure stock, but from our results it is also possible to analyse the direct effect by estimating the elasticities through the expressions (4)-(6).

	Elasticity
♏$_{YL}$	0.2511872
♏$_{YK}$	0.6298313
♏$_{YI}$	-0.028087

The analyses carried out shows a reduction in the direct elasticity associated with productive infrastructure capital, the effect of these productive infrastructures on the private economy has decreased over time as more observation are added to the estimation[7]. Therefore, the observation of powerful effects of productive infrastructure on private production during a period does not imply that these will persist with the same intensity in others. On the other hand, the results for labour and private capital show an important and positive direct effect. The high elasticity of private capital is justified by the indirect effect of infrastructure on it. The private capital increases its elasticity by the complementary relation with productive infrastructure.

[7] In Alvarez et at (1999) the period studied is 1985-1995 and the results show a higher elasticity for productive infrastrure and same conclusions about complementarity and sustituibility among the inputs.

CONCLUDING REMARKS

In the study of the link between the productive infrastructure capital and economic growth it is central to determine if private and public capital are substitutes or complements, which offers information about the way infrastructure enters in the production process. With this aim, this work tries to study the indirect effect of the productive infrastructure stock on economic growth.

This paper presents evidence from the Spanish economy, offering a serie of productive infrastructure stock, which allows us to study the differences among the Spanish regions. Using a translog production function we present panel data estimates for the period 1980-1995 and for 17 Spanish regions, exploring the indirect effect of this capital. The results indicate that productive infrastructure capital formation encourages private investment, as private and infrastructure capital have been estimated to be complements. While productive infrastructure capital and private labour are substitutes. It has been shown empirically that there is a technologically induced labour saving effect through higher infrastructure investment.

With regard to regional development policy, investing in productive infrastructures can be considered to be an instrument to improve the competitiveness of the regions. By providing more and better quality infrastructure it its possible to enhance the productivity of private investment and this can be a way to promote convergence among the regions as these better endowments raise private sector output, productivity and private capital formation. Our results support the idea that infrastructure stocks should be increased in less developed regions to ensure that limited infrastructure does not impede the development of new private activity.

Further research should devote more attention to the implications of this relationship to economic growth. Such an extension, could open new avenues to study the impact of certain kind of infrastructure categories like highways or electrified railways which can offer information about the way these investments must be potential. Also the role of this endowments for convergence is another issue to be tackled in our future researches.

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APPENDIX

TABLE 1. PRODUCTIVE INFRASTRUCTURE INDICATOR

REGION	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Andalucia	25	26	26	26	26	25	26	27	28	30	34	33	38	39	39	44
Aragon	19	21	21	21	21	21	22	24	25	26	28	27	28	30	30	31
Asturias	41	42	41	41	43	41	38	41	44	44	47	45	46	55	55	58
Baleares	39	43	43	43	44	42	41	44	45	48	50	50	54	53	54	58
Canarias	42	48	47	47	48	45	44	48	51	50	58	53	55	56	57	66
Cantabria	38	42	42	42	42	40	40	42	51	56	60	59	61	63	67	76
C.Leon	25	27	27	27	27	26	25	27	28	28	31	31	31	32	32	34
C.Mancha	18	19	19	19	19	18	17	18	20	21	24	23	25	25	26	29
Cataluña	63	69	68	69	69	67	68	71	73	76	85	84	87	92	91	98
Extremadura	11	12	12	12	12	12	12	14	16	16	17	17	18	19	19	21
Galicia	27	29	29	29	29	28	29	30	31	32	34	33	38	39	42	44
Madrid	95	105	106	107	108	110	113	127	126	123	144	140	149	158	161	175
Murcia	20	21	21	21	21	21	20	21	22	23	27	25	29	37	38	44
Navarra	23	35	35	35	35	35	33	34	34	34	40	36	38	44	44	48
Rioja	43	55	55	55	56	54	50	54	55	53	61	54	54	55	55	61
Valencia	42	50	50	50	50	48	47	50	50	51	59	54	56	61	65	74
Pais Vasco	93	106	105	105	106	112	102	109	109	101	119	111	108	115	117	133
SPAIN	30	33	32	32	33	32	31	33	35	36	40	39	41	43	43	47
MEAN VALUE	39	44	44	44	44	44	43	46	48	48	54	51	54	57	58	64
ST.DEVIATION	24	27	27	27	28	29	28	31	30	29	34	33	33	35	36	40
VARIATION COEF.	0.62	0.62	0.62	0.62	0.62	0.66	0.66	0.67	0.64	0.60	0.63	0.64	0.62	0.61	0.61	0.62
MINIMUN	11	12	12	12	12	12	12	14	16	16	17	17	18	19	19	21
MAXIMUN	95	106	106	107	108	112	113	127	126	123	144	140	149	158	161	175

TABLE 2. PRIVATE CAPITAL STOCK

REG.	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Andal.	4138844	4217144	4305790	4371228	4379648	4398876	4492178	4656130	4941677	5297702	5619403	5907851	6182228	6266158	6341270	6609467
Aragon	1211596	1239854	1343717	1345418	1355493	1370834	1383408	1425573	1494092	1583381	1664886	1742799	1831336	1891228	1936415	1979106
Asturias	1150060	1144328	1135354	1126736	1116861	1118252	1154227	1214651	1267357	1310479	1343908	1389501	1408169	1397559	1390676	1501260
BaleaR.	826038	840403	855729	862035	860141	862680	874674	901414	956251	1023233	1077232	1132734	1169915	1178219	1226008	1292275
Canar.	921492	945792	968583	982050	989732	1006524	1042538	1097643	1191512	1302550	1381343	1457111	1525192	1560314	1635394	1732902
Cantab.	701868	708057	701229	692511	683321	678905	678633	681328	702254	734011	752336	767897	787641	787140	787704	819741
C.Leon	2264019	2321913	2393429	2444636	2456674	2470751	2492403	2546926	2653679	2799302	2932544	3023891	3165325	3216686	3264099	3379254
C.Man.	1346052	1379393	1422293	1458527	1487373	1506431	1531141	1569554	1643668	1750319	1856922	1944220	2013805	2071914	2083213	2131192
Catal.	6061670	6139259	6165020	6218845	6231419	6258433	6364770	6660187	7118942	7648188	8171997	8714012	9323685	9554531	9724295	10162599
Extrem	672645	692719	705649	714237	712594	705201	707729	718868	755995	796182	834425	869008	900595	921594	939167	1014753
Galicia	2053383	2111468	2146098	2172522	2216337	2246780	2285808	2344652	2447315	2584072	2724064	2864631	2983367	3036403	3084007	3204198
Madrid	3866464	3942322	4014211	4068140	4107665	4162782	4278034	4492795	4794120	5242320	5621597	6074605	6409463	6549026	6799979	6944036
Murcia	617545	641602	661039	677943	685897	693748	715580	752396	804324	871064	936035	991623	1048119	1068976	1101444	1127916
Navarra	601002	613533	620687	626089	628586	633412	643526	669607	703074	751069	800582	843426	891285	929911	971170	957612
Rioja	285404	291265	295866	298251	306746	310414	316556	329926	353441	376419	389407	395079	415422	419987	424558	436453
Valencia	2899418	2986574	3050617	3132232	3170613	3207245	3290026	3439113	3701265	4028680	4283776	4530037	4754845	4862956	5018907	5219786
Pais V.	2923303	2873087	2817829	2784393	2754512	2773791	2810190	2868925	2962487	3116062	3230333	3349918	3436177	3417128	3417127	3602491
SPAIN	32540803	33088713	33603140	33975793	34143612	34405059	35061421	36369688	38491453	41215033	43620790	45998343	48246569	49129730	50145433	52115042
MEAN V.	1914164	1946394	1976655	1998576	2008447	2023827	2062436	2139393	2264203	2424413	2565928	2705784	2838033	2889984	2949731	3065590
ST.DEVI.	1595550	1617119	1629942	1649484	1655435	1666645	1700518	1777446	1898071	2050039	2191824	2341461	2490312	2545211	2600115	2701816
VARI.C.	0.83	0.83	0.82	0.83	0.82	0.82	0.82	0.83	0.84	0.85	0.85	0.87	0.88	0.88	0.88	0.88
MINIMUN	285404	291265	295866	298251	306746	310414	316556	329926	353441	376419	389407	395079	415422	419987	424558	436453
MAXIMUN	6061670	6139259	6165020	6218845	6231419	6258433	6364770	6660187	7118942	7648188	8171997	8714012	9323685	9554531	9724295	10162599

TABLE 3. LABOUR (thousands)																
REGION	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Andalucia	1360	1293	1280	1267	1184	1210	1233	1302	1367	1409	1460	1461	1418	1357	1359	1386
Aragon	342	329	328	328	312	303	310	327	334	342	353	361	350	336	330	331
Asturias	322	307	289	287	274	276	268	275	269	269	277	280	280	268	255	251
Baleares	192	190	194	197	198	191	191	191	211	216	224	223	215	207	211	215
Canarias	319	310	313	317	306	294	305	320	335	340	351	346	342	340	351	369
Cantabria	162	158	147	146	140	139	134	135	134	141	142	139	137	135	132	132
C.Leon	730	722	710	705	655	646	638	671	681	683	690	685	664	634	622	622
C.Mancha	416	407	409	406	383	387	390	397	406	406	420	419	419	399	387	389
Cataluña	1754	1695	1622	1623	1586	1561	1577	1668	1742	1822	1901	1921	1897	1829	1837	1888
Extremadura	243	235	228	223	212	207	206	229	230	233	239	231	226	218	213	211
Galicia	953	929	932	934	925	907	862	874	902	902	898	884	840	807	794	775
Madrid	1064	1036	1075	1081	1051	1049	1102	1136	1158	1212	1279	1302	1287	1251	1236	1274
Murcia	235	226	225	222	223	217	220	238	254	265	274	270	266	256	260	260
Navarra	156	152	150	150	148	153	154	156	157	166	169	173	166	160	160	165
Rioja	81	76	80	76	74	76	79	80	82	86	84	85	82	79	79	81
Valencia	982	973	948	965	552	942	955	1020	1046	1080	1122	1127	1101	1043	1051	1091
Pais Vasco	628	608	615	601	987	567	567	565	573	591	608	624	606	588	578	581
SPAIN	9936	9641	9537	9513	9199	9104	9203	9597	9902	10182	10511	10550	10312	9925	9871	10062
MEAN VALUE	584	567	562	560	542	537	541	564	581	598	617	620	606	583	580	589
ST.DEVIATION	484	468	458	459	446	442	449	473	492	512	534	539	529	508	509	524
VARIATION COEFICIENT	0.83	0.83	0.82	0.82	0.82	0.82	0.83	0.84	0.85	0.86	0.86	0.87	0.87	0.87	0.88	0.89
MINIMUN	81	76	80	76	74	76	79	80	82	86	84	85	82	79	79	81
MAXIMUN	1754	1695	1622	1623	1586	1561	1577	1668	1742	1822	1901	1921	1897	1829	1837	1888

TABLE 4. PRIVATE OUTPUT (millions)																
REGION	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Andalucia	38371	37759	37961	38518	38317	40825	41351	44059	46440	47773	50729	51457	50101	49104	50214	52012
Aragon	9448	9310	9345	9992	10134	10129	10405	11004	11997	12555	12777	12993	12804	12662	13068	13686
Asturias	8298	8523	8517	8053	7812	8053	8023	8015	8320	8768	8886	9009	8994	8845	9002	9418
Baleares	7062	7169	7453	7700	8076	7814	7792	8110	8413	8543	8936	9247	9227	9279	9621	10052
Canarias	9235	9340	9950	10320	10808	11151	12044	12831	13882	13826	13713	13798	14010	14041	14674	15194
Cantabria	4225	4311	4286	4328	4362	4359	4256	4444	4879	5212	5231	5256	5346	5264	5394	5572
C.Leon	18460	17785	17700	18078	17847	17891	18216	19252	19958	19952	20078	20097	19803	20838	20594	21015
C.Mancha	10525	10384	10231	10269	10090	10615	10313	11237	12204	12693	13109	13017	12834	12374	12350	12695
Cataluña	58063	56290	56501	57271	57728	58079	60557	64347	68647	73534	75854	76376	76777	75320	79184	81753
Extremadura	4920	4896	4840	4480	4833	4843	4873	5179	5653	5599	5923	5982	5941	5922	6151	6287
Galicia	18780	18834	18236	18022	17727	17799	17943	18419	19491	19892	20167	20146	20025	19961	20403	20926
Madrid	41670	42104	43044	43213	44060	44795	48506	51676	53301	56537	59153	59853	59432	58973	60581	62352
Murcia	6733	6855	6607	7093	6973	6939	7682	8036	8317	8650	9173	9185	9135	8963	9105	9337
Navarra	5009	5129	5020	5126	5203	5232	5348	5910	5985	6576	6601	6854	6842	6643	6687	7009
Rioja	2784	3086	2992	2998	3003	3296	3198	3078	3180	3309	3473	3577	3725	3690	3977	4173
Valencia	29984	30822	30351	31442	32765	32664	32792	34290	35550	37158	38808	39288	39397	39023	40253	41771
Pais Vasco	22022	22643	22830	22190	21486	22092	22421	22952	23712	25098	25459	25657	25338	25067	25489	27017
SPAIN	295470	295246	295513	298465	301286	307272	315309	332864	350018	365212	378069	383239	381907	378386	387366	402028
MEAN VALUE	17388	17367	17404	17594	17719	18034	18572	19579	20584	21510	22239	22458	22337	22116	22750	23545
ST. DEVIATION	15895	15621	15740	15933	16100	16401	17180	18278	19216	20420	21311	21511	21420	21076	21932	22638
VARIATION COEF.	0.91	0.90	0.90	0.91	0.91	0.91	0.93	0.93	0.93	0.95	0.96	0.96	0.96	0.95	0.96	0.96
MINIMUM	2784	3086	2992	2998	3003	3296	3198	3078	3180	3309	3473	3577	3725	3690	3977	4173
MAXIMUM	58063	56290	56501	57271	57728	58079	60557	64347	68647	73534	75854	76376	76777	75320	79184	81753

TABLE 5. Evolution of the variables (%)

	PRIVATE PRODUCTION	LABOUR	PRIVATE CAPITAL	INFRASTRUCTURE
AAGR 1980-1995	2.07	0.08	3.18	3.03
AAGR 1980-1985	0.78	-1.73	1.14	1.29
AAGR 1985-1990	4.23	2.91	4.86	4.56
AAGR 1990-1995	1.23	-0.86	3.62	3.27

NOTE: AAGR is the average annual growth rate.