

Infrastructures and Productivity in the Spanish Regions

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MAS M., MAUDOS J., PÉREZ F. and URIEL E. (1996) Infrastructures and productivity in the Spanish regions, *Reg. Studies* 30, 641–649. The aim of this paper is to analyse the role of public capital, the types of infrastructures in which it is invested and their territorial distribution in the gains in productivity of the private sector in the Spanish regions in the period 1964–91 using panel data techniques to control for unobserved state-specific characteristics. The results obtained show how the infrastructures most directly linked to the productive process present a significant and positive effect on productivity. They also show the importance of the network effect of the infrastructures of a productive nature as well as a decrease in the elasticity associated with such infrastructures as development progresses.

Productivity Infrastructures Economic development

MAS M., MAUDOS J., PÉREZ F. et URIEL E. (1996) Les infrastructures et la productivité aux régions espagnoles, *Reg. Studies* 30, 641–649. Cet article cherche à analyser le rôle du capital public, les infrastructures dans lesquelles le capital se voit investir, et leur distribution géographique quant aux gains de productivité du secteur privé aux régions espagnoles sur la période de 1964 à 1991. On utilise des techniques de données réunies afin de tenir compte des caractéristiques inobservées spécifiques à l'Etat. Les résultats obtenus démontrent dans quelle mesure les infrastructures qui se rapportent le plus étroitement à la méthode de production ont un effet sensible et positif sur la productivité. Ils démontrent aussi l'importance de l'effet réseau des infrastructures du type productif ainsi qu'une baisse de l'élasticité associée à de telles infrastructures au fur et à mesure que le développement progresse.

Productivité Infrastructures
Développement économique

MAS M., MAUDOS J., PÉREZ F. und URIEL E. (1996) Infrastruktur und Produktivität in den Regionen Spaniens, *Reg. Studies* 30, 641–649. Dieser Aufsatz hat es sich zum Ziel gesetzt, die Rolle von öffentlichen Kapitalmitteln und Arten der Infrastrukturen, in denen sie investiert werden, zu analysieren, sowie deren gebietsweise Verteilung beim Anstieg der Produktivität des Privatsektors der Regionen Spaniens im Zeitraum 1964–1991, wobei 'Panel' Datentechnik zur Überprüfung unbeobachteter, dem Staate eigener charakteristischer Merkmale benutzt wird. Die sie erzielten Ergebnisse zeigen, wie die am engsten mit dem Produktionsprozeß verknüpften Infrastrukturen eine bedeutende und positive Wirkung auf die Produktionsleistung ausüben. Darüber hinaus zeigen sie sowohl die Bedeutung des Netzeffektes der produktionsorientierten Infrastrukturen auf als auch ein Nachlassen der Anpassungsfähigkeit, die bei fortschreitender Entwicklung mit solchen Infrastrukturen in Verbindung gebracht werden.

Produktivität Infrastrukturen
Wirtschaftliche Entwicklung

INTRODUCTION

The aim of this paper is to analyse the importance of the stock of public capital, the types of infrastructures in which it is invested and their territorial distribution in the gains in productivity of the private sector in the Spanish regions.

Earlier studies (MAS, MAUDOS, PÉREZ and URIEL, 1993, 1994a) analysed the effects of public capital on the gross value added (GVA) and the productivity of the Spanish regions. The first referred to

the industrial sector (excluding construction and energy products), while the second considered as a whole the private sector of the economy. In both studies the period analysed was 1980–89 and the source of information was *Contabilidad Regional de España* (Spanish Regional Accounts) published by the National Statistical Institute (INE).

The study here presented expands the earlier analyses, considering a longer period, 1964–91, for which it uses the information on GVA and regional employment provided by the *Banco de Bilbao Vizcaya*

(BBV) in its *Riqueza Nacional de España y su Distribución Provincial* (National Wealth of Spain and its Distribution by Provinces). The series of private and public capital used were estimated by the Instituto Valenciano de Investigaciones Económicas and have been published by Banco de Bilbao-Vizcaya Foundation (MAS, PÉREZ and URIEL, 1995). The longer period studied will enable the importance of public capital in the gains in productivity to be analysed from a long-run perspective.¹

The next section considers the relationship between infrastructures, growth and productivity in the light of the contributions of recent specialized literature. The third section analyses the capacity of public capital to account for the gains in productivity of the Spanish regions. The fourth section is devoted to analysing the 'network effect' associated with certain types of infrastructures, and to analysing how the importance of public capital is different depending on the phase of economic development. A final section presents the main conclusions of the study.

THE ROLE OF INFRASTRUCTURES IN GAINS IN PRODUCTIVITY

Although some authors (see MEADE, 1952) had already suggested that certain types of public capital could be considered as relevant inputs in the production process, it was ASCHAUER, 1989, who explicitly included public capital in the production function. In particular, on the basis of a Cobb–Douglas production function with private inputs and public capital, Aschauer's study revealed the importance of the stock of public capital in explaining the evolution of productivity.

The original study by Aschauer, with obvious implications for political economy, generated a flood of studies whose most substantial contributions have already been described in other papers (see MUNNELL, 1992; MAS, MAUDOS, PÉREZ and URIEL, 1993; and DRAPER and HERCE, 1994). However, it is appropriate to specify some of the conclusions of the debate occurring in the United States, in order to clearly focus the analysis carried out in the following sections.

1. The estimations made by ASCHAUER, 1989, at the national level led to the following conclusions:
 - public capital had a positive and significant effect on private output and total factor productivity, the estimated elasticity being 0.39
 - the composition of this public capital was shown to be relevant, the basic infrastructures (fundamentally those of transport, energy and water and sewer facilities) showing the closest relationship to productivity; on the other hand, other types of public capital, such as that devoted to health, education or to services of a general nature (police, justice, administration, etc.) were less relevant from this same point of view.
2. The level of geographical disaggregation adopted in the estimation had a decisive influence on the magnitude of the elasticities estimated, which decreased progressively as the geographical focus narrowed. Thus, in the testing at US state level carried out by MUNNELL, 1990a, 1990b; EISNER, 1991; and GARCÍA-MILÁ and McGUIRE, 1992, the elasticity of public capital was half that corresponding to the federal level. A similar reduction occurred when the metropolitan area was considered. DUFFY-DENO and EBERTS, 1989, and EBERTS, 1989, estimated elasticities of output with respect to infrastructures of less than 10%, far from the 40% initially estimated by Aschauer for the USA as a whole.

The reduction in the elasticities estimated for public capital as the level of geographical disaggregation increases is accounted for by the presence of 'spillover effects' generated by the network feature of a large part of the infrastructures considered (transport, energy, and water and sewer facilities). This typology implies that the effects on the productivity of a region depend not only on the stock of public capital located there, but also on the network as a whole throughout the territory, and especially on the endowments of the neighbouring regions (HULTEN and SCHWAB, 1991).

However, HOLTZ-EAKIN and SCHWARTZ, 1995, argue that, although the estimated elasticity is larger in aggregate studies, 'no research has targeted specifically the spillover hypothesis'. With this purpose, and using a specific type of public capital – state highways – the results obtained by Holtz-Eakin and Schwartz do not support this hypothesis.
3. Further, as HULTEN and SCHWAB, 1992, pointed out, the network feature of most of the infrastructures should lead to different expectations of their impact depending on the level of development and the amount of public capital already accumulated. According to these authors, the effects of increases in public capital will be greater in the first stages of development, when the stock of public capital is still relatively low, than in mature societies. Therefore, estimations of time series, such as those carried out by Aschauer, would tend to overestimate the current impact of the growth in public capital.
4. HOLTZ-EAKIN, 1994, shows how the estimation procedure affects the relevance of the effect of public capital on private sector productivity. This author argues that only estimates of production function that do not include unobserved state-specific characteristics (individual effects) find substantial productivity impacts of the public capital. However, in the words of Holtz-Eakin, 'it would be wrong to conclude from his analysis that stock of public capital provides no benefits... Instead, future research in this area should be devoted to making more precise the microeconomic linkage

between the provision of infrastructures and the nature of the production process'.

From the review of the main questions posed by the analysis and the empirical evidence with reference to the economy of the US, the lack of unanimity in the quantification of the importance of public capital can be appreciated (see GRAMLICH, 1994, for a recent review). Also apparent is the depth with which the different dimensions of the problem have been treated in the case of the US.

In the case of Spain, several studies have recently been published analysing the influence of the stock of capital in infrastructures on productivity: at a national level (BAJO *et al.*, 1993; ARGIMÓN *et al.*, 1994; and GONZALEZ-PÁRAMO, 1995); at the regional level (MAS, MAUDOS, PÉREZ and URIEL, 1993, 1994a, 1994c); and at provincial level (MAS, MAUDOS, PÉREZ and URIEL, 1995). Although these studies differ in the series used, the types of public capital considered and in the period analysed, the result common to all of them is also the illustration of the importance of public capital in explaining the evolution of productivity, the elasticity of public capital being greater in nationwide studies than in those of regional scope.

PUBLIC CAPITAL AND PRODUCTIVITY IN THE SPANISH REGIONS

The central point of this study is to analyse whether the public capital endowments of each region of Spain favour the increase in productivity of the private sector operating in that territory, and also whether the composition of public capital is important in this respect. Furthermore, it is also important to determine whether the endowments of each region are the only ones which count for its productivity, or whether those of neighbouring regions are also significant.

Recently the Instituto Valenciano de Investigaciones Económicas (IVIE) has carried out the estimation of series of private and public capital at autonomous community (regional) level (see Fig. 1). The estimation of the stock of public capital was initially published by the IVIE in 1993 and some of its results can be seen in MAS, PÉREZ and URIEL, 1993. The complete series corresponding to the period 1964–91 will shortly be published by the Banco Bilbao–Vizcaya Foundation (MAS, PÉREZ and URIEL, 1995). The procedure followed in the estimation is the one habitually used in all countries which estimate their stocks of capital – the permanent inventory method. This method obtains the stock of capital on the basis of the accumulation of the investment made, taking into account certain patterns of depreciation and withdrawal. The definition of public capital refers to the public administration as a whole, consisting of the State, the social security institutions and the territorial administrations (autono-

mous communities – regions – and local councils).² The level of disaggregation of the estimation is as follows: (1) roads and motorways; (2) ports and maritime signalling; (3) water and sewage facilities; (4) urban structures; (5) health; and (6) education.

Through the estimation of a production function we can investigate whether there are statistical regularities in the relationships between each region's public capital stock and the gains in productivity of any of the private factors of production. In this way, we can identify the role of the infrastructures in the diffusion of what we measure as technical progress, or in other words limit the importance of exogenous technical progress.

Let us assume, as in most of the studies mentioned above, that the technology underlying the aggregate production function is Cobb – Douglas, where the output of region *i* in the year *t* depends on the amount of labour and capital (public and private) used:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} G_{it}^{\gamma} \quad (1)$$

where:

$$A_{it} = A_{i0} e^{gt} \quad (2)$$

in which:

Y_{it} = private output (gross value added at factor cost (GVAcf)) (excluding the energy sector) of region *i* in the year *t* at constant prices (pesetas of 1990)

L_{it} = employment in the private sector (excluding the energy sector) of region *i* in the year *t*

K_{it} = stock of private productive capital (excluding the energy sector) of region *i* in the year *t* at constant prices (pesetas of 1990)

G_{it} = stock of public capital at constant prices (pesetas of 1990) of region *i* in the year *t*

g = growth rate of exogenous technological progress.

Expressing equation (1) in logarithmic terms, and calling $a_i = \ln A_{i0}$:

$$\ln Y_{it} = a_i + gt + \alpha \ln L_{it} + \beta \ln K_{it} + \gamma \ln G_{it} \quad (3)$$

On the basis of the estimation of the general equation (3) we are interested in: (1) estimating the effects of public and private capital on labour productivity at regional level, without imposing restrictions on the type of returns in the production function; (2) analysing the importance of the composition (productive/social) of the stock of public capital; and (3) discussing whether the influence of public capital depends only on the infrastructures installed in a particular region or also on the endowments of the adjoining regions.

In order to test the type of returns to scale, both in private inputs and total inputs, involved in the production process, we can reparametrize equation (3) so that:

$$\ln (Y_{it}/L_{it}) = a_i + gt + (\alpha + \beta + \gamma - 1) \ln L_{it} + \beta \ln (K_{it}/L_{it}) + \gamma \ln (G_{it}/L_{it}) \quad (4)$$

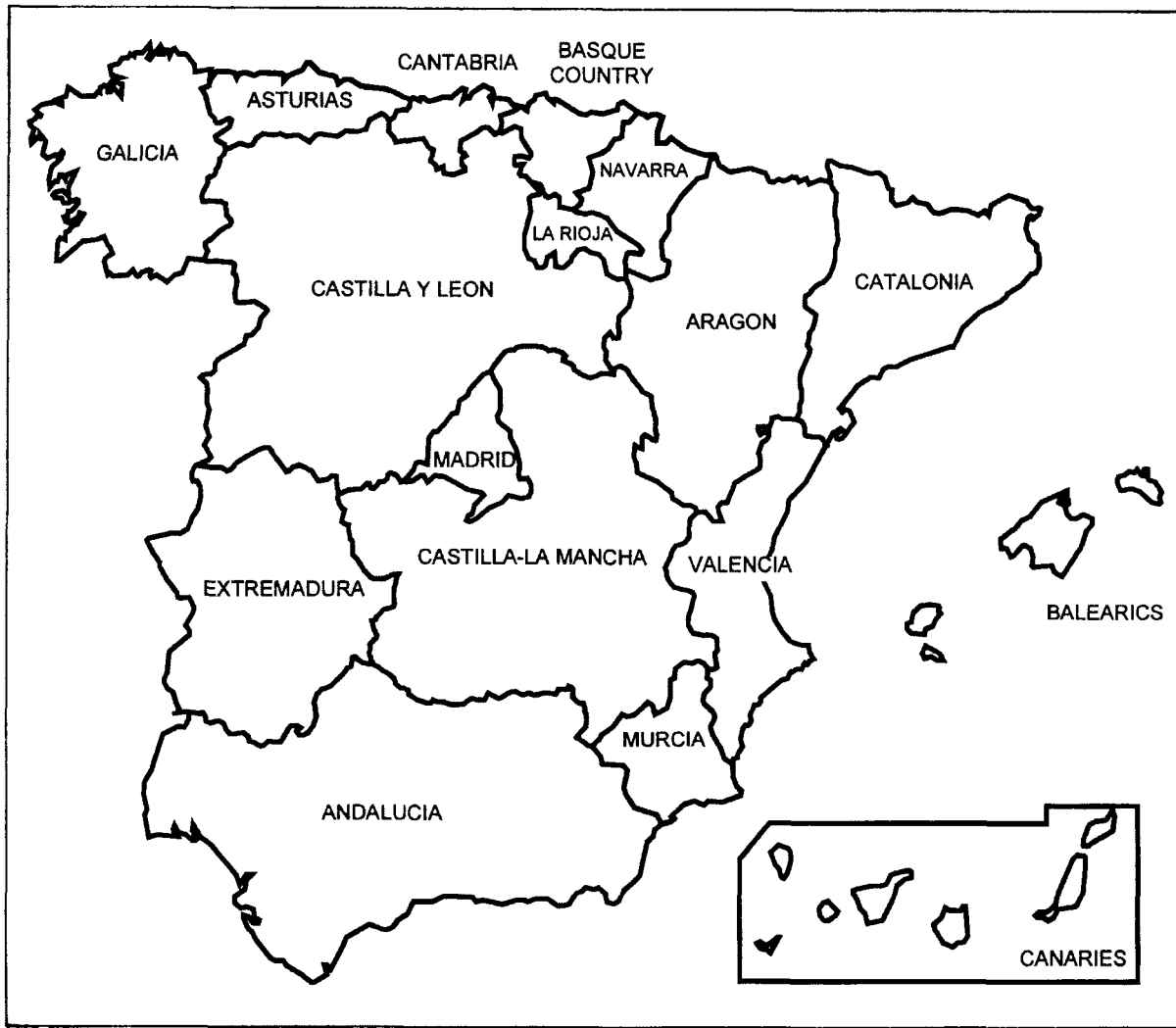


Fig. 1. The Spanish autonomous communities

In equation (4), the lack of significance of the coefficient accompanying employment ($\alpha + \beta + \gamma - 1$) will be an indicator of the presence of constant returns to scale in all inputs (private and public). Equally it is possible to reparametrize equation (3) in such a way that we can test the type of returns associated with the private inputs:

$$\ln(Y_{it}/L_{it}) = a_i + \gamma t + (\alpha + \beta - 1) \ln L_{it} + \beta \ln(K_{it}/L_{it}) + \gamma \ln(G_{it}) \quad (5)$$

where the lack of significance of the coefficient accompanying the labour input ($\alpha + \beta - 1$) will indicate the existence of constant returns to scale in private inputs.

To analyse the role of public capital in the case of Spanish regions³ the above expressions have been used, constructing an economic model with panel data referring to the period 1964–91. Following HOLTZEAKIN, 1994, we assume that country specific characteristics are time-invariant.

Table 1 shows the results obtained from the estimation of the production function, using the fixed effects

model. It can be interpreted that the fixed effects (a_i) reflect the particular set of circumstances which influence the productive 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.

In the first column the estimation of the unrestricted equation (equation (4)) appears, i.e. not imposing the existence of constant returns to scale, whether in all inputs or in private inputs. The lack of significance, at usual significance levels, of the parameter accompanying the labour input (0.0586, with a t -statistic of 1.6314) allows us not to reject the existence of constant returns in all inputs ($\alpha + \beta + \gamma = 1.0586$). Consequently, the second column of Table 1 shows the results of the estimation with this restriction imposed. The results obtained show that public capital positively affects the productivity of the private sector, with an elasticity of 0.0711 (and a t -statistic of 2.3501).

In order to test the types of returns to scale associated with private inputs, the third column of Table 1 shows

Table 1. Total Public capital and productivity

Variables	(1)	(2)	(3)	(4)
Trend	0.0173 (8.8400)	0.0178 (9.1931)	0.0173 (8.8400)	0.0174 (9.4354)
Ln(L) <i>it</i>	0.0586 (1.6314)		-0.0111 (-0.2337)	
Ln(K/L) <i>it</i>	0.4191 (14.5249)	0.3982 (15.3472)	0.4191 (14.5249)	0.4227 (17.3592)
Ln(G/L) <i>it</i>	0.0697 (2.3147)	0.0711 (2.3501)		
Ln(G) <i>it</i>			0.0697 (2.3147)	0.0651 (2.8648)
R ²	0.8443	0.9841	0.8443	0.9843
Sum of squared residuals	0.4864	0.4924	0.4864	0.4866
Standard error of regression	0.0473	0.0475	0.0473	0.0472

Note: Sample: 1964-91; dependent variable: Ln(GVA/L)*it*; fixed effects model; *t*-statistic in parenthesis.
Sources: GVA and employment (L): BBV; private capital (K) and public capital (G): BBV-IVIE, 1995.

the results of the estimation of equation (5). The elasticity of the parameter accompanying the labour input (-0.0111 with a *t*-statistic of -0.2337) allows us not to reject the existence of constant returns in private inputs ($\alpha + \beta = 0.9889$). Imposing this restriction (column (4)), the elasticities associated with labour (α) and with private capital (β) are 0.5773 and 0.4227 respectively.

However, as described above, the effect of public capital on productivity is different depending on its composition. Thus, with the aim of testing this differential effect, equation (3) was estimated, distinguishing between productive public capital and social public capital.

$$\ln Y_{it} = a_i + gt + \alpha \ln L_{it} + \beta \ln K_{it} + \gamma_1 \ln GP_{it} + \gamma_2 \ln GS_{it} \quad (6)$$

where:

GP_{it} = the productive public capital stock of the region *i* in the year *t*, which includes roads, water infrastructures, ports and urban structures (in constant pesetas of 1990)

GS_{it} = the social public capital stock of the region *i* in the year *t*, which includes health and education (in constant pesetas of 1990)

Thus, productive public capital is more directly linked to the productive process and is composed of the basic infrastructures. On the other hand, social public capital may be less relevant in the explanation of the productivity gains, being a question to test.

Once again, it is possible to reparametrize equation (6) in order to test the type of returns to scale both in all inputs (equation (7)) and in private inputs (equation (8)):

$$\ln (Y_{it}/L_{it}) = a_i + gt + (\alpha + \beta + \gamma_1 + \gamma_2 - 1) \ln L_{it} + \beta \ln (K_{it}/L_{it}) + \gamma_1 \ln (GP_{it}/L_{it}) + \gamma_2 \ln (GS_{it}/L_{it}) \quad (7)$$

Table 2. Productivity vs. social public capital

Variables	(1)	(2)	(3)
Trend	0.0174 (8.9756)	0.0174 (8.9756)	0.0173 (9.4062)
Ln(L) <i>it</i>	0.0735 (2.0281)	0.0151 (0.3062)	
Ln(K/L) <i>it</i>	0.4508 (12.9423)	0.4508 (12.9423)	0.4443 (16.1502)
Ln(GP/L) <i>it</i>	0.0831 (3.0474)		
Ln(GS/L) <i>it</i>	-0.0247 (-1.0424)		
Ln(GP) <i>it</i>		0.0831 (3.0474)	0.0863 (3.4292)
Ln(GS) <i>it</i>		-0.0247 (-1.0424)	-0.0212 (-1.0236)
R ²	0.9846	0.9846	0.9846
Sum of squared residuals	0.4775	0.4775	0.4778
Standard error of regression	0.0470	0.0470	0.0469

Notes: See Table 1. GP = productive public capital; GS = social public capital.

$$\ln (Y_{it}/L_{it}) = a_i + gt + (\alpha + \beta - 1) \ln L_{it} + \beta \ln (K_{it}/L_{it}) + \gamma_1 \ln (GP_{it}) + \gamma_2 \ln (GS_{it}) \quad (8)$$

Table 2 shows the results of the estimation of equations (7) and (8). In this case, the existence of increasing returns to scale in all inputs ($\alpha + \beta + \gamma_1 + \gamma_2 = 1.0735$) is not rejected (column 1), whereas the hypothesis of constant returns to scale in private inputs (1.0151) cannot be rejected statistically (column (2)). Results imposing this last restriction are reported in column (3).

With respect to public capital, the results obtained in earlier studies are confirmed: the infrastructures considered to be productive have a positive effect, more significant than the infrastructures of a social character. In particular, the elasticity of labour productivity with respect to public capital of a productive

character (GP) is around 8%, this elasticity being negative, although not significant, in the case of public capital of a social character (GS).⁴

The value of the elasticity of productive public capital is similar to that obtained in similar studies for other countries (DUFFY-DENO and EBERTS, 1989; EBERTS, 1989; MUNNELL, 1990b; EISNER, 1991) when the economic areas considered are not too extensive, such as other states or the metropolitan areas of the US. Also, the elasticity of public capital in infrastructures is less than that of private capital, in agreement with the above-mentioned studies.

However, the elasticity of productive public capital is smaller than that obtained in MAS, MAUDOS, PÉREZ and URIEL, 1994a, also at regional level. There are three possible causes: (1) the sector under analysis is the total private sector (including energy sector) (*ibid.*); (2) the estimation of private capital stock is different;⁵ and (3) the period analysed is longer in the present paper.

INFRASTRUCTURES, NETWORK EFFECT AND ECONOMIC DEVELOPMENT

In order to test the spillover effect or network effect indicated above, and concentrating on the role of productive public capital, Table 3 shows the results of a new estimation of the production function, adding the stock of productive public capital of geographically adjacent regions (GPa) to the productive public capital of each region.⁶ The value of this elasticity is 0.1411 (column 2), clearly higher than that obtained when only the productive public capital of each region is considered, 0.0771 (column 1). Therefore, in the light of the results obtained, we can conclude that the growth in elasticity associated with public capital, when the public capital of each region and that of the neighbouring regions is taken into account, is a favourable indicator for the acceptance of the hypothesis of the spillover effect.⁷

On the other hand, the positive and statistically significant value of the parameter accompanying the labour input in the estimation of the production function when adjacent productive public capital (GPa) is included (0.1069 with a t -statistic of 2.8289) allows us to accept the existence of increasing returns to scale in all inputs as a consequence of the increase in the value of the elasticity associated with public capital (0.1411). The elasticities associated with labour (α) and with private capital (β) are 0.5599 and 0.4059 respectively, values very similar to those obtained when only the productive public capital of each individual region is considered.

The lower part of Table 3 shows the fixed effects specific to each region (a_i) in increasing order. In column 1, outstandingly low values are associated with the regions of Galicia, Extremadura, Castilla-Léon,

Table 3. Network effect of public capital

Variables	(1)	(2)
Trend	0.0168 (9.0625)	0.0152 (7.5283)
$\ln(L)_{it}$	0.0674 (1.8845)	0.1069 (2.8289)
$\ln(K/L)_{it}$	0.4285 (15.5709)	0.4059 (14.1304)
$\ln(GP/L)_{it}$	0.0771 (2.8916)	
$\ln(GPa/L)_{it}$		0.1411 (3.4802)
R^2	0.9845	0.9848
Sum of squared residuals	0.4799	0.4721
Standard error	0.0470	0.0466

Fixed Effects			
Galicia	-1.0298	Extremadura	-1.7492
Extremadura	-1.0006	C-Mancha	-1.6506
C-León	-0.8974	Galicia	-1.6375
C-Mancha	-0.8899	C-León	-1.5844
Andalucía	-0.8483	Cantabria	-1.5315
Asturias	-0.7882	La Rioja	-1.4904
Cantabria	-0.7678	Aragón	-1.4728
Aragón	-0.7615	Asturias	-1.4714
Murcia	-0.6593	Murcia	-1.4493
B. Country	-0.6404	Andalucía	-1.4219
Canaries	-0.6373	Navarra	-1.3001
C. Valenciana	-0.6286	C. Valenciana	-1.2883
Navarra	-0.6231	B. Country	-1.2568
La Rioja	-0.6142	Catalonia	-1.1307
Catalonia	-0.5639	Canaries	-1.0614
Balearics	-0.5467	Madrid	-1.0164
Madrid	-0.3989	Balearics	-0.9081

Notes: See Tables 1 and 2. GPa = productive public capital including that of adjacent regions.

Castilla-La Mancha and Andalucía, and outstandingly high ones with Madrid, the Balearics and Catalonia.⁸

A result which deserves special attention is the fixed effects specific to each region obtained when the role of the public capital of neighbouring regions is taken into account (column 2), in comparison with the values obtained by considering only the public capital of each individual region (column 1). In the model which expressly considers the stock in adjacent regions, the fixed effect should be less, since part of the external effects associated with the public capital of the surrounding territory will be reflected in the estimated parameter corresponding to this 'expanded' public capital. This result is obtained by comparing the magnitude of the fixed effects in columns 1 and 2, which are always less in the second case. Also notable is the variation in the order of the estimated fixed effects corresponding to the island territories of the Balearics and the Canaries. In both these cases, since the criterion used for defining adjacent public capital is geographical, the value of capital in these regions continues to be only their own, enabling them to rise to the top places in the ranking.

Table 4. Economic development and public capital

Variables	1964-73	1964-75	1964-77	1964-79	1964-81
Trend	-0.0004 (-0.0631)	0.0111 (1.5465)	0.0077 (1.3067)	0.0024 (0.5365)	0.0043 (1.1976)
Ln(L) <i>it</i>	0.3235 (3.3295)	0.2169 (2.1927)	0.2530 (3.0040)	0.2901 (4.1330)	0.2696 (5.0227)
Ln(K/L) <i>it</i>	0.6552 (6.7575)	0.4621 (4.8401)	0.5052 (6.1408)	0.5847 (8.7386)	0.5638 (10.5760)
Ln(GP/L) <i>it</i>	0.1404 (2.6354)	0.1469 (3.0002)	0.1362 (3.0245)	0.1324 (3.3071)	0.1309 (3.6024)
R ²	0.9679	0.9657	0.9713	0.9760	0.9802
Sum of squared residuals	0.0818	0.1403	0.1679	0.1911	0.2121
Standard error	0.0357	0.0416	0.0413	0.0407	0.0400
	1964-83	1964-85	1964-87	1964-89	1964-91
Trend	0.0145 (4.5871)	0.0181 (7.1231)	0.0194 (9.3435)	0.0194 (10.6105)	0.0168 (9.0625)
Ln(L) <i>it</i>	0.1348 (2.8444)	0.1054 (2.5021)	0.1243 (3.1967)	0.1159 (3.2294)	0.0674 (1.8845)
Ln(K/L) <i>it</i>	0.4228 (9.2665)	0.3827 (10.5695)	0.3882 (12.9123)	0.3978 (14.5684)	0.4285 (15.5709)
Ln(GP/L) <i>it</i>	0.1270 (3.6445)	0.1176 (3.7097)	0.0959 (3.3081)	0.0845 (3.1281)	0.0771 (2.8916)
R ²	0.9806	0.9828	0.9843	0.9857	0.9845
Sum of squared residuals	0.2819	0.3163	0.3497	0.3814	0.4799
Standard error	0.0435	0.0436	0.0437	0.0436	0.047

Notes: See Tables 1 and 2.

As HULTEN and SCHWAB, 1992, pointed out, the network feature of a large part of public infrastructures should lead one to expect a different effect on productivity depending on the level of development and the size of the stock of capital already accumulated. It is to be expected that in the initial stages of development, in which the stock of capital is relatively small, the effects of increases in this stock will be greater than at the stage of more advanced development with larger amounts of public capital.

With the aim of testing the relationship between the phase of development and the importance of public capital, Table 4 shows the results of the recursive estimation of the most general production function,⁹ taking 1964-73 as the initial period and subsequently expanding the sample until the whole of the period under study, 1964-91, is covered.

In all the sub-periods considered¹⁰ the existence of increasing returns in all inputs, as well as the statistically significant positive effect of public capital of a productive nature, are accepted. Fig. 2 reflects the evolution of elasticity associated with the latter. It can be appreciated that, starting with an elasticity of 0.1404 for the sub-period 1964-73, this decreases progressively as more recent observations are added to the estimation, until an elasticity value of 0.0771 is reached for the whole period. Consequently, the profile of elasticity that the figure presents supports Hulten and Schwab's hypothesis of the relationship between public capital and economic development.

CONCLUSIONS

The aim of this paper has been to provide empirical evidence of the importance of certain forms of public capital in the gains in productivity within the regions of Spain in the period 1964-91 using panel data techniques to control for unobserved regional-specific characteristics.

From this long-run perspective, the conclusions obtained may be summed up as follows:

1. The regional stock of public capital is shown to be relevant in accounting for the gains in productivity of the private sector of the economy, and the infrastructures directly linked to the productive process (roads, water and sewer facilities, urban structures and ports) present a significant positive effect which cannot be established in the case of social infrastructures (education and health). Nevertheless, it must be pointed out that the role of infrastructures of a social character, and particularly education, need to be analysed in greater detail and in a dynamic context, because their effect is produced through their contribution to the improvement of human capital.
2. The elasticity of labour productivity to the stock of productive public capital is greater in the estimations where the stock of public capital considered includes that belonging to each individual region and that of the neighbouring ones. This result may reflect the externalities associated with the network feature

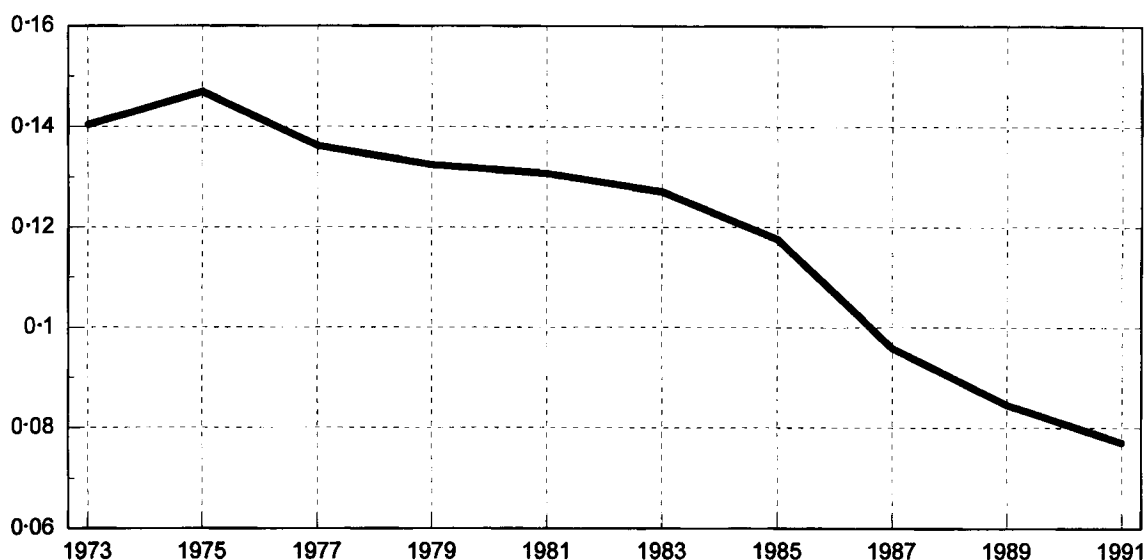


Fig. 2. Recursive estimation of the productive public capital elasticity

of infrastructures of all the regions (spillover effect), since in many infrastructures the state of the network as a whole counts as much as that of each of the parts. Consequently, from the point of view of efficiency, the importance of considering the territorial distribution of infrastructures with a less local horizon than is sometimes used must be underlined.

- Given the network feature associated with certain forms of public capital, the effect of these infrastructures on the productivity of the Spanish regions has decreased over time. The analysis carried out shows a reduction in the elasticity associated with productive public capital as more recent observations are added to the estimation. Therefore, the observation of powerful effects of public capital on productivity in the past does not imply that these will persist with the same intensity in the future.

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NOTES

- BBV provides two-yearly information for the odd years since 1955, except for the years 1960, 1962 and 1964. However, the series of private and public capital are available from 1964 to 1991 so the analysed period is 1964–91.
- The definition of public capital adopted in this paper, following GRAMLICH, 1994, corresponds to the version

that focuses on ownership and includes just the tangible capital stock owned by the public sector.

- See in MAS, MAUDOS, PÉREZ and URIEL, 1994b, 1995, the importance of public capital in the convergence among Spanish regions and provinces.
- This result is consistent with the one obtained in other studies; see ASCHAUER, 1989; MUNNELL, 1992; and MAS, MAUDOS, PÉREZ and URIEL, 1994a, for a review.
- In MAS, MAUDOS, PÉREZ and URIEL, 1994a, the stock of private capital used comes from CALABUIG *et al.*, 1994.
- HOLTZ-EAKIN and SCHWARTZ, 1995, instead of adding the public capital of the neighbouring regions to the capital of each region, introduce these two components separately. However, in the Spanish case we cannot introduce the two components separately since in two regions the stock of public capital of the neighbouring regions is zero (the Balearic and Canary Islands) and we estimate the production function in logarithmics. We only consider the effect of geographically adjacent regions (not several ‘rings’) since, in the majority of the regions, if we add the stock of public capital of the second ‘ring’ we obtain the stock of public capital of Spain (the number of regions in Spain is only 17).
- In MAS, MAUDOS, PÉREZ and URIEL, 1994a, which uses the *Regional Accounts* of the INE as its source of information on production and employment and CALABUIG *et al.*, 1994, on private capital, the same results are obtained. In particular, an elasticity of 0.31 is obtained in association with neighbouring productive public capital as against a value of 0.20 when only the productive public capital of each individual region is considered.
- A similar ranking is obtained in MAS, MAUDOS, PÉREZ and URIEL 1994c, when the effect of public capital on total factor productivity is analysed.
- We do not include social public capital in the estimation as it is not statistically significant.
- BBV provides information about GVA and employment every two years.

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