THE EFFECT OF PUBLIC INFRAESTRUCTURES ON THE PRIVATE PRODUCTIVE SECTOR OF SPANISH REGIONS

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Abstract

In this paper we analyze the effect of infrastructures on the cost and productivity performance of the private productive sector of Spanish regions over the 1980-1993 period. We use a dual approach based on cost functions which allows us to recover the usual parameters estimated with production functions. In addition, we obtain rates of return and cost elasticities of production factors at the regional level. Our framework considers explicitly that some factors are quasi-fixed and their volume can differ from their optimal endowment levels. Our results indicate that the public sector has contributed significantly to enhance productivity and reduce costs in the private sector of almost every Spanish region. Nevertheless, there is still scope for the government to continue its investment efforts, given that there remains an appreciable gap between observed and optimal public capital, and we find that, in the long-run, public capital promotes private investment.

1. Introduction.

Prompted by the research carried out by Aschauer (1988, 1989a and b), many economists have analyzed the relationship between public investment in infrastructures and output, productivity and profitability in the private sector. The results obtained for the American private sector drew economists' attention to this kind of literature because of the quantitative importance of infrastructures. According to Aschauer estimates of a Cobb-Douglas production function, a 1% increase in infrastructure expenditure meant an increase of 0.24 to 0.39% in the output of the private sector. Munnell (1990) confirmed the magnitude of these figures by making use of a similar sample, although the impact of infrastructures on productivity was reduced almost to 1/3 when using panel data techniques for the American states. Subsequent studies such as those of Garcia-Mila, McGuire and Porter (1996) and Holtz-Eakin (1994) have questioned the effect of infrastructures on productivity, pointing out some problems of an econometric nature[1], and arriving at results which were totally different to those of Aschauer.

Nevertheless, studies of the Spanish economy reveal more optimistic results. In short, not only the analyses of the impact of infrastructures carried out with annual data by means of the estimation of production functions[2], but also those papers that used panel data for the Spanish regions[3] have always obtained a positive impact of infrastructures for the whole Spanish economy. However, these studies for the Spanish economy reveal important differences in the magnitude of the estimated elasticity of public capital to output (see the survey by Draper and Herce (1994)), which ranges between 0.11 and 0.70 depending on the sample, period or technique used. At first glance, these more optimistic results about the effect of infrastructures in the Spanish case are not surprising. The impact of public investment on economic performance depends on the stage of development of the country. Nevertheless, there is a great consensus among Spanish economists and policy makers that this stage of development has not yet been reached in Spain. The endemic scarcity of productive infrastructures has motivated in the last decades successive governmental policy packages aimed at

[1] Problems of endogeneity, non-stationarity, omission of variables, measurement error, etc.

[2] See Bajo and Sosvilla (1993), Argimón et al. (1994), Mas et al. (1993) and Serra and Garcia-Fontes (1994).

[3] See Mas et al. (1993), Serra and García-Fontes (1994) and Dabán and Murgui (1997).

reducing the gap between endowments and desired levels of public capital. Thus, it would be surprising if no effects, especially direct effects, where found. These considerations also raise serious doubts that, in the Spanish case, capacity underutilization plays an important role when analyzing the effects of infrastructures.

Despite the copious research, some of which supports and some of which refutes the early conclusions reached by Aschauer (see the surveys by Gramlich (1994) or de la Fuente (1996)), the conclusion that public capital is not at all productive seems unlikely to us. Thus it may be argued that in a debate of this nature it is worthwhile trying an alternative approach for the Spanish case, one which does not focus on the estimation of production functions. The idea is to allow for a more flexible relationship between public and private capital than the one implied in the Cobb-Douglas technology[4]. In addition, we take advantage of the analytical framework provided by duality theory by means of processing relevant information about input and output prices, and allowing the use of technological and behavioral restrictions.

In this paper we make use of a dual approach based on cost functions (see Diewert (1986)), one which has already been used for the analysis of the Swedish economy (see Berndt and Hansson (1992)), the German economy (see Conrad and Seitz (1992) and Seitz (1994)), the English economy (see Lynde and Richmond (1993a)), the American economy (see Morrison and Schwartz (1992 and 1996), Lynde and Richmond (1993b) and Nadiri and Mamuneas (1994)) and the Spanish economy (see Moreno, López-Bazo and Artís (1998), and Boscá, Dabán and Escribá (1999)). Our approach in this paper provides an alternative and complementary framework to analyzing the determinants of productive performance to other recent contributions in the literature. For example, Yamano and Ohkawara (2000) discuss the trade-off between efficiency and equity by estimating aggregate production functions and calculating the marginal productivity of public capital in Japanese regions. Also, Boisso, Grosskopf and Hayes (2000) examine different factors that contribute to explaining productivity differentials across US states by employing Malmquist productivity indexes. One of the most salient

[4] The Cobb-Douglas form has been used more than any other in the literature based on production functions, although it imposes rigid restrictions regarding inputs substitutability as Berndt and Hansson (1992) or Morrison and Schwartz (1992) have pointed out.

results of this contribution is that contrary to other results in the literature, these authors find evidence of neighborhood spillover effects of public capital (highways)[5].

The results in our paper have some advantages over other studies of the Spanish case. These are worth mentioning. First of all, the estimates of this paper give a general picture of the evolution of the Spanish private sector, which is coherent with our beliefs about the behavior of Spanish regions. The approach used allows us to obtain cost-benefit measures and elasticities of the various productive inputs at the regional level, as well as the complementary and substitutable relationship among them. The test statistics indicate clearly that labor and intermediate inputs are pure variable inputs, while private capital is a quasi-fixed factor, the volume of which differs from its static equilibrium level. Throughout we find reasonable magnitudes of returns to scale and output elasticities. The average values for the Spanish economy are around 0.97 for long run returns to scale and 0.23 and 0.09 for the output elasticities of private and public capital, respectively.

Second, our research is more extensive than other works in the literature in the sense that we present short and long-run effects of public and private capital and both cost and output measures of public and also private capital. The typical paper in this literature gives only a partial view, confining itself only to a certain aspect of the problem. For instance, presenting only cost-measures of infrastructures but not the implicit output elasticities, or presenting only short-run measures but not the long-run effects.

The impact of public infrastructures on output and production costs of the private productive sector of the Spanish regions is analyzed using annual data for the 1980-93 period, which have been taken from the BD.MORES database elaborated at the Spanish Ministry of Economy and Finance[6]. The specific functional form for the variable cost function we have chosen is a Generalized Leontief (see Morrison (1988)) which incorporates quasi-fixed and external factors, non-constant returns to scale, and

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[5] The existence of spatial spillover effects is an important issue when analyzing the effects of infrastructures across regions. Nevertheless, we are not going to address explicitly this problem, given that attempts in the literature to uncover these effects have not yielded conclusive results (see, for example Hulten and Schwab, 1991 or Holtz-Eakin and Schwartz, 1995).

[6] See Dabán et al. (1998) for a description of the series included and the methodology employed to construct this database, available on the following e-mail address: adiaz-ballesteros@igae.meh.es

allows for any degree of complementarity or substitutability between fixed and flexible inputs. Additionally, this approach addresses capacity utilization issues that might result from sluggish adjustment by quasi-fixed or external factors.

Our results confirm the relevance of using such a flexible theoretical framework. We find that for the aggregate of the Spanish private sector both public and private capital display positive rates of return, indicating that there is overutilization of economic capacity, confirming our prior beliefs about the Spanish economy. The results also indicate that the public sector has contributed significantly to enhancing productivity and reducing costs in the private productive sector of almost every Spanish region. Nevertheless, there is still scope for the government to continue its investment efforts, given that there remains an appreciable gap between observed and optimal public capital, and we find that, in the long-run, public capital promotes private investment.

The article is structured as follows. Section 2 presents the theoretical model and its empirical specification. Section 3 presents a brief description of the data and relevant information regarding the evolution of the private sector in the Spanish regions. Section 4 presents our main results evaluating the impact of infrastructures both in the short and long-terms. The final section deals with the most important conclusions.

2. Theoretical framework.

Assume that intermediate inputs (M) and labor (L) are variable inputs, and that private capital (K_P) is a quasi-fixed factor in the short-run. Firms, which cannot decide on their volume, are supplied with free services of public capital (K_G). So, the production function may be written as follows:

$$Y = A(t)\, f(L, M, K_P, K_G) \tag{1}$$

where Y represents output, $A(t)$ the variable efficiency level and f an homogeneous function of degree λ in L, M, K_P and K_G. Under competitive conditions, w and v being the price of labor and intermediate inputs respectively, the short-run variable cost function G(•) can be written as follows[7]:

$$G = G(\omega, v, Y, K_P, K_G, t) \tag{2}$$

Total cost (C) will be the result of adding the fixed cost of private capital ($P_{K_P} \cdot K_P$) to the variable costs, i.e.

$$C = G(\omega, v, Y, K_P, K_G, t) + P_{K_P} K_P \tag{3}$$

where P_{K_P} is the user cost of private capital. The firm does not incur any cost for the use of the fixed amount of infrastructures supplied by the public sector, so that these play the role of a positive externality for the individual firm. Notice that this cost function can be obtained from the minimization of private production costs, $\omega\, L + v\, M$, subject to the production function (1). Applying Shephard's Lemma we can obtain the optimal input demand equations for the variable inputs as

$$X^* = \frac{\partial C(\cdot)}{\partial P_X} \qquad \text{where } X = L, M \tag{4}$$

[7] The variable cost function is assumed to be homogeneous of degree one, continuous, monotonically non-decreasing and concave in prices.

Further, differentiating the cost function (2) with respect to public capital, we obtain the shadow value of public capital (Z_{K_G}), which can be expressed using Shephard's Lemma again, as

$$Z_{K_G} = -\frac{\partial G}{\partial K_G} = -\,\omega\,\frac{\partial L^*}{\partial K_G} - v\,\frac{\partial M^*}{\partial K_G} = LK_G + MK_G \qquad (5)$$

which decomposes the cost changes associated with an increase in K_G into adjustment effects on private labor and intermediate inputs. LK_G denotes the response of the optimal demand for labor, and MK_G the response of the optimal demand for intermediate inputs, to an increase in infrastructures. As a consequence, for example, a positive (negative) LK_G means that infrastructures and labor are substitutes (complements), given that an increase in public capital reduces (increases) labor costs.

In order to assess the impact of the provision of public capital on cost and productivity performance of firms it is convenient to translate the shadow price of public capital into an elasticity or shadow share measure such as

$$S^*_{K_G} = -\frac{\partial C}{\partial K_G}\frac{K_G}{C} = -\frac{\partial G}{\partial K_G}\frac{K_G}{C} = \frac{Z_{K_G}\cdot K_G}{C} = -\varepsilon_{C,K_G} \qquad (6)$$

where $S^*_{K_G}$ is the shadow share of public capital in total cost and ε_{C,K_G} is the cost elasticity of public capital. Notice that we can also translate our LK_G and MK_G measures into the corresponding elasticities (ε_{L,K_G} and ε_{M,K_G}).

A similar reasoning, although with some modifications, can be applied to private capital. Given that we consider private capital to be a quasi-fixed factor, its shadow price may be defined analogous to the public capital shadow price as the reduction in variable costs due to an additional increase of the stock of private capital ($Z_{K_P} = -\frac{\partial G}{\partial K_P}$). Z_{K_P} thus represents the marginal benefit of investing in private capital. If the shadow price is positive, it means that an increase in private capital is cost saving for the firm, either because all variable inputs are substitutes with respect to private capital or because the substitutive effects upon private capital and some variable inputs outweigh the existing complementary effects. As before, we can translate the shadow value into a shadow share as follows:

$$S_{K_P}^{*} = \frac{Z_{K_P} \cdot K_P}{C} \tag{7}$$

However, in the case of private capital, given that it is a choice variable for the firm, an increase in private capital produces a direct cost (the user cost of capital) which has to be compared with the cost-saving benefit measured by the shadow price of private capital. The cost elasticity of private capital is then

$$\varepsilon_{C,K_P} = \frac{\partial C}{\partial K_P} \cdot \frac{K_P}{C} = \left(P_{K_P} - Z_{K_P}\right) \cdot \frac{K_P}{C} \tag{8}$$

If the shadow price is positive and higher than the user cost (i.e. the marginal benefit of investment is higher than the marginal cost), the cost elasticity will be negative, reflecting that the observed stock of capital is below its optimal level. In other words, the optimal demand for private capital in the long-run will be that which fulfills $P_{K_P} = Z_{K_P}$, because when Z_{K_P} is higher than P_{K_P}, firms will require higher levels of private capital given that the cost-saving benefits of an additional unit of capital outweigh the cost of investment.

Thus, we can assess the impact of the provision of public capital on the cost and productive performance of firms in two situations. The first is when the private capital stock diverges from the optimal one, i.e. in the short-run equilibrium. The second is when we require that firms have already adjusted their capital levels to the long-run equilibrium, i.e. when we impose the requirement[8] that $P_{K_P} = Z_{K_P}$. Then the optimal capital stock (K_P^*) can be expressed as

$$K_P^{*} = h\,(w, v, P_{K_P}, Y, K_G, t) \tag{9}$$

and replacing it in equation (3), we obtain the long-run cost function[9]:

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[8] Notice that $P_{K_P} = Z_{K_P}$, is the first order condition that results from minimizing equation (3) of short-run total costs with respect to *Kp*.

[9] See Schankerman and Nadiri (1986), and Kulatilaka (1985).

$$C^L\left(w,v,P_{K_P},Y,K_G,t\right)=G^L\left(\omega,v,h\left(w,v,P_{K_P},Y,K_G,t\right),Y,K_G,t\right)+ \\ +P_{K_P}h\left(w,v,P_{K_P},Y,K_G,t\right) \tag{10}$$

From equation (9) we can derive an elasticity measure of the impact of public capital on the optimal private capital stock (ε_{KP*KG}), under the assumption that there are no adjustment costs. In addition, with equation (10) we can reconsider the short-run shadow value of public capital and the corresponding short-run elasticities and convert them into long-run measures.

Finally, although we are assuming that public capital is an external factor that private firms cannot influence, we can derive different measures for the optimal public capital stock under the assumption that the government would minimize firms short-run total costs. Thus, if we assume different values for the user cost of public capital (P_{K_G}) we can compute the optimal public capital stock as[10]

$$K_G^* = g(w,v,P_{K_G},Y,K_P,t) \tag{11}$$

As already mentioned, we have chosen a Generalized Leontief variable cost function to estimate the parameters needed to calculate the shadow values and elasticities shown above. The specification of the Leontief function is the same as in Morrison (1988) which incorporates fixed inputs and does not presuppose the degree of returns to scale. This can be expressed as[11]

$$G = Y\left[\sum_i\sum_j \alpha_{ij}P_i^{1/2}P_j^{1/2} + \sum_i\sum_m \delta_{im}P_i s_m^{1/2} + \sum_i P_i \sum_m\sum_n \gamma_{mn}s_m^{1/2}s_n^{1/2}\right]+ \\ +Y^{1/2}\left[\sum_i\sum_k \delta_{ik}P_i x_k^{1/2} + \sum_i P_i\sum_m\sum_k \gamma_{mk}s_m^{1/2}x_k^{1/2}\right] + \sum_i P_i \sum_k\sum_l \gamma_{lk}x_k^{1/2}x_l^{1/2} \tag{12}$$

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[10] In our framework public capital is an unpaid input for the firm, so that a positive Z_{K_G} implies always that the firm desires more public investment in infrastructures. Nevertheless, the government should take into account the social costs of infrastructures, *i.e.* $P_{K_G} \neq 0$, in order to assess accurately its impact on private sector performance.

[11] Notice that we are employing almost the same notation as in Morrison and Schwarz (1996).

where P_i and P_j denote the prices of variable inputs V_i, x_k and x_l are the quasi-fixed inputs (K_P and K_G); and s_m and s_n denote the remaining arguments (Y and t). Using Shephard's lemma, we get the two input demand equations for the variable inputs[12] which can be written as

$$\begin{aligned} V_i = \frac{\partial G}{\partial P_i} &= Y \sum_i \alpha_{ij} \left({P_j}\big/{P_i} \right)^{1/2} + Y \sum_m \delta_{im} s_m^{1/2} + Y \sum_m \sum_n \gamma_{mn} s_m^{1/2} s_n^{1/2} + \\ &+ Y^{1/2} \left[\sum_k \delta_{ik} x_k^{1/2} + \sum_m \sum_k \gamma_{mk} s_m^{1/2} x_k^{1/2} \right] + \sum_k \sum_l \gamma_{lk} x_k^{1/2} x_l^{1/2} \end{aligned} \qquad (13)$$

Following Morrison and Schwarz (1996) we add to the above system of three equations a fourth one that captures firms profit maximization behavior. This equation is a short-run pricing equation that equates the price of output (P_Y) to the marginal cost (MC). It has to be emphasized that such a condition is not being required but estimated, so that the residual of this equation may capture the extent to which regions have market power.

$$\begin{aligned} P_Y = MC = \frac{\partial G}{\partial Y} &= \sum_i \sum_j \alpha_{ij} P_i^{1/2} P_j^{1/2} + \sum_i \sum_m \delta_{im} P_i s_m^{1/2} + \sum_i P_i \sum_m \sum_n \gamma_{mn} s_m^{1/2} s_n^{1/2} + \\ &+ 1/2\, Y^{-1/2} \left[\sum_i \sum_k \delta_{ik} P_i x_k^{1/2} + \sum_i P_i \sum_m \sum_k \gamma_{mk}\, s_m^{1/2} x_k^{1/2} \right] + \\ &+ 1/2\, Y^{1/2} \sum_i \delta_{iY} P_i + Y^{1/2} \left[\sum_i P_i \sum_m \gamma_{mY}\, s_m^{1/2} \right] + 1/2 \sum_i P_i \sum_k \gamma_{Yk} x_k^{1/2} \end{aligned} \qquad (14)$$

The above system of four equations is estimated to obtain the relevant parameters of the cost function, which we will use to calculate the shadow prices, elasticities and other relevant measures for the analysis of the effect of infrastructures.

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[12] To accommodate heteroscedasticity we will estimate equations (12) and (13) divided by output (Y).

3. The Data.

The basic data for the seventeen Spanish regions are taken from the BD.MORES database[13]. The output measure used in this paper is gross output, which results from adding intermediate inputs to gross value added.

Table 1 presents the evolution of the main economic magnitudes for the private sector in the whole of the Spanish economy. The first column corresponds to gross output, which shows the cyclical pattern of the Spanish economy. Labor and intermediate inputs are clearly pro-cyclical, presenting average negative rates of growth from 1980 to 1985 and positive rates of growth from 1985 onwards.

Table 1. The private sector in Spain.

	Gross Output Y	Private Capital K_P	Public Capital K_G	Labor L	Intermediate Inputs M
1980	22520	21259	3192	10054	10554
1981	21857	21699	3243	9701	9990
1982	21984	22037	3360	9546	10017
1983	22316	22362	3482	9448	10138
1984	22600	22557	3575	9157	10205
1985	22798	22682	3720	9258	10117
1986	23695	23003	3891	9359	10632
1987	25081	23581	4069	9750	11287
1988	26564	24384	4298	10053	12071
1989	28052	25453	4630	10330	12906
1990	29125	26496	5053	10654	13441
1991	29729	27497	5452	10690	13758
1992	29775	28395	5761	10441	13794
1993	29316	28799	5927	10031	13507
Average Annual Growth Rate 1980-93 (%)	2.085	2.370	4.898	0.018	1.979
1980-85 (%)	0.259	1.306	3.116	-1.623	-0.815
1986-93 (%)	3.226	3.035	6.012	1.044	3.725

Note: Figures are in thousands of millions 1980 pesetas, except labor which is in thousands of employees.

Differences in growth rates among the productive factors are important. For the period as a whole public capital displays the highest annual average growth rate (4.9%), followed by private capital (2.4%) and intermediate inputs (2.0%), whereas on average employment remained almost constant. Nevertheless, it is clear that during the 1980-85

[13] See the data appendix for a definition of the series we use in the empirical work.

crisis, the growth rates of output and productive factors (except infrastructures) were very low, being even negative for employment and intermediate inputs. The economic expansion experienced in Spain from 1986 to 1992 is also apparent in the figures, the rates of growth of infrastructures in these years being quite noticeable.

Table 2 presents information about regional disparities using the same economic variables as analyzed before. Asturias is the region with the lowest rate of growth in output, employment and intermediate inputs. Madrid, on the other hand, displays high growth rates of output and all productive factors. Infrastructures have grown in all regions at a higher rate than private capital (with the exceptions of La Rioja and Navarre), showing the important investment effort carried out by Spanish central or local governments.

Table 2. Regional disparities in the private sector.

	$\hat{Y}$	$\hat{K}_P$	$\hat{K}_G$	$\hat{L}$	$\hat{M}$	Y_i/Y
Regions						
Andalusia	2.00	2.28	7.58	0.05	1.77	0.13
Aragon	2.75	1.74	2.52	-0.15	2.99	0.04
Asturias	0.42	1.84	4.63	-1.42	0.26	0.03
Baleares	2.93	2.15	4.60	0.59	2.91	0.02
Canary Islands	2.64	2.76	3.67	0.56	2.51	0.03
Cantabria	1.93	1.23	6.04	-1.33	2.01	0.02
Castile and Leon	1.88	1.63	3.10	-1.06	1.96	0.07
Castile-La Mancha	1.67	2.30	4.51	-0.32	1.40	0.03
Catalonia	2.27	2.64	4.27	0.22	2.07	0.20
Valencia	1.77	2.94	5.64	0.41	1.89	0.09
Extremadura	2.89	1.65	4.94	-0.77	2.92	0.02
Galicia	1.60	2.16	3.95	-1.24	1.62	0.06
Madrid	2.57	3.60	5.91	1.30	2.23	0.13
Murcia	2.00	2.31	8.46	0.68	1.63	0.02
Navarre	2.39	2.82	2.45	0.31	2.62	0.02
Basque Country	1.05	0.97	4.12	-0.39	0.99	0.08
La Rioja	2.26	2.66	0.13	-0.21	2.21	0.01

Note: Average annual growth rates, 1980-1993.

The last column of Table 2 shows the weight of the private sector of each region in Spanish total gross output. As we can see only five regions produce 63% of gross output of the private sector in Spain (Catalonia (20%), Madrid (13%), Andalusia (13%), Valencia (9%) and the Basque Country (8%)).

Finally, Figure 1 shows the relative position of each region in relation to the national average in terms of the ratio of public to private capital and of public capital to output. It is obvious that there are again considerable disparities among the Spanish regions. La Rioja and Navarre are the regions with the highest ratio of public to private capital and, together with Castile-La Mancha, Castile and Leon, the Canary Islands, Asturias, Aragon, the Basque Country and Andalusia, are over the national average. On the other hand, it is worthwhile pointing out the low endowment of public capital in relation to both output and private capital in Madrid, Baleares, Catalonia, Murcia and Valencia.

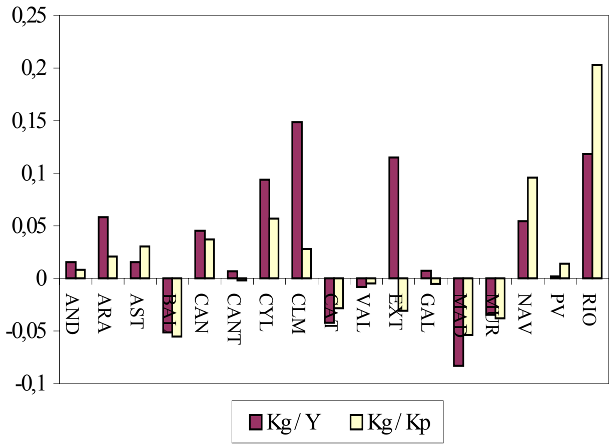

Figure 1. Ratios of public capital to output and private capital.
1980-93, average values.[14]

[14] Key to region names: AND=Andalusia; ARA= Aragon; AST= Asturias; BAL= Baleares; CAN= Canary Islands; CANT= Cantabria; CYL= Castile and León; CLM= Castile-La Mancha; CAT= Catalonia; VAL= Valencia; GAL= Galicia; EXT= Extremadura; MAD= Madrid; MUR= Murcia; NAV= Navarre; PV= Basque Country; RIO= La Rioja.

4. Results for the Spanish private sector.

We have estimated equations (12), (13) and (14) using seemingly unrelated regressions (SUR) techniques. Estimation was carried out using annual data from 1980 to 1993 for the 17 Spanish regions. This procedure allows us to require the theoretical restrictions that derive from Shephard's lemma, while gaining degrees of freedom in the estimation. Furthermore, estimating the model as a system adds structure and increases efficiency of the estimates (standard errors are lower). The usual practice in this kind of literature is to impose the theoretical cross-equation restrictions without presenting formal tests which provide statistical support for them. Usually, this is justified as a way of obtaining reasonable results from an economic point of view. Nevertheless, in Table 3 we present the parameter estimates from our preferred specification along with two different specification tests.

Table 3. Estimated structural coeffiecients.

Parameter	Coefficient	t-ratio	Parameter	Coefficient	t-ratio
α_{11}	-0.359	-5.273	γ_{1tP}	-0.052	-5.372
α_{12}	0.119	5.606	γ_{1YG}	$-0.3\ 10^{3}$	-6.097
α_{22}	1.090	14.70	γ_{1tG}	0.038	1.954
δ_{1Y}	$0.2\ 10^{3}$	7.988	γ_{2YP}	$-0.9\ 10^{4}$	-2.084
δ_{2Y}	$-0.1\ 10^{3}$	-3.381	γ_{2tP}	0.010	0.888
δ_{1t}	0.003	0.270	γ_{2YG}	$0.6\ 10^{3}$	10.53
δ_{2t}	0.021	1.448	γ_{2tG}	-0.091	-3.464
γ_{1yy}	$-0.3\ 10^{7}$	-7.494	γ_{1PG}	0.313	3.911
γ_{1yt}	$0.5\ 10^{5}$	3.338	γ_{1PP}	-0.526	-12.82
γ_{1tt}	$-0.7\ 10^{3}$	-0.415	γ_{1GG}	0.316	1.554
γ_{2YY}	$0.5\ 10^{8}$	1.054	γ_{2PG}	-1.107	-12.87
γ_{2Yt}	$-0.1\ 10^{4}$	-5.744	γ_{2PP}	0.926	22.57
γ_{2tt}	0.003	1.708	γ_{2GG}	1.481	6.372
δ_{1P}	1.130	12.459	$D_1\alpha_{11}$	0.005	1.930
δ_{1G}	-0.769	-6.299	$D_1\alpha_{22}$	-0.006	-2.616
δ_{2P}	-1.203	-11.77	$D_2\alpha_{11}$	-0.010	-2.940
δ_{2G}	0.373	2.555	$D_2\alpha_{22}$	0.040	13.22
γ_{1YP}	$-0.6\ 10^{4}$	-1.727			

R^2 Cost Function	0.941
R^2 Labor Demand	0.743
R^2 Intermediate Inputs Demand	0.613
R^2 Equation Price = Marginal Cost	0.981

Schankerman and Nadiri test χ^2 (10) = 8186.438 (P-Value = 0.00000)

Shephard Lemma test χ^2 (36) = 22.9628 (P-Value = 0.95482)

Test of the Curvature condition for K^*_P: $\gamma_{1PP} + \gamma_{2PP} = 0.40$ χ^2 (1) = 3.7482 (P-Value = 0.05286)

Nº Obs. 238

On the one hand, Shankerman and Nadiri (1986) elaborated a specific econometric test to investigate the divergence of quasi-fixed factors from their static equilibrium levels. The hypothesis to be tested is whether the parameters obtained from the estimate of the short-run specification, coincide with those which are obtained from the estimate of the first order condition $Z_{K_P} = P_{K_P}$. Intuitively, if private capital is at its optimal level the coefficients estimated from the equation representing optimal capital endowment should coincide with the coefficients estimated from the model where private capital is assumed to be a quasi-fixed factor, the volume of which differs from its static equilibrium level. As can be seen in Table 3, the hypothesis that private capital is close to its static equilibrium level is strongly rejected[15]. The result obtained is that the stock of private capital is not found at the optimal level, and therefore must be considered as a quasi-fixed factor when specifying the model.

The above result is reinforced when considering the result obtained from testing the parameter restrictions implied by Shephard's lemma. As can be seen in Table 3, it is possible to accept the null hypothesis that labor and intermediate inputs are at their optimal demand levels[16]. If instead we specify the model assuming that private capital is another flexible input, so that we add a third input demand equation, the parameter restrictions implied by Shephard's lemma are strongly rejected. This implies that Shephard's lemma can only be verified if we assume that private capital behaves as a quasi-fixed factor in the short-term, which is coherent with the results of the Shankerman and Nadiri test. This is potentially an important result given that it is

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[15] This result is similar to the one which Moreno, López Bazo and Artís (1998) obtained for the manufacturing branches in Spanish regions.

[16] The dummy variables included in the equations are very important in getting this result. In fact, if the model is estimated with none of these variables, the test rejects the null hypothesis (($\chi^2(32)$=48.42, P-Value = 0.031). We also tried to estimate a fixed effects model, incorporating regional–specific intercept terms in both input demand equations. Nevertheless, this means incorporating 17x4 additional cross-equation restrictions to the system, that are strongly rejected by statistical tests. In addition, the imposition of those restrictions alters considerably the values obtained for the rest of the coefficients. This casts serious doubts on the plausibility of these results and so we finally decided to pick up regional heterogeneity by introducing only two dummy variables. The first dummy takes the value one in Catalonia, Madrid, Valencia and Murcia and zero in the rest, and the second takes the value one in Castile-La Mancha. Extremadura, Castilla-León, Navarre, Rioja and Cantabria and zero in the rest. These two groups have been chosen because regions in the first group display very low K_G/Y and K_G/K_P ratios compared to the national average. Additionally, those regions in the first group hold considerable weight in the output of the Spanish private sector. The second set of regions follows an opposite pattern.

common practice in the duality literature to impose the restrictions derived from Shephard's Lemma and/or to assume private capital to be a flexible or a quasi-fixed input, despite the fact that the implied restrictions are verified by means of formal econometric tests. In our case, common practice and econometric tests follow the same direction, making us quite confident that our model specification is pointing in the right direction.

Overall, the fit of the four equations is high and the estimated coefficients are statistically significant, although the sign[17] and magnitude of them has little intuitive value from an economic viewpoint given the complexity of the cost function used. The shadow values, elasticities and other measures of cost and productive performance discussed in the theoretical section have been obtained from the estimates presented in Table 3, and are summarized in Tables 4, 5 and 6.

Table 4 presents results for the whole of the Spanish private sector[18], and as we can see the shadow price of private capital (Col. 2) shows an upward trend throughout the period, with the user cost (Col. 1) fluctuating around it. This means that for the economy as a whole, the stock of private capital has not been persistently differing from its long-run equilibrium level[19]. The average Z_{K_P} measure means that a 1-million 1980 pesetas investment in private capital results in a 112.000 pesetas cost saving for one year. From these the average region saves 190.000 pesetas in intermediate inputs (Col.4), while it spends 79.000 additional pesetas in the labor input (Col.3). As a consequence, the negative LK_P means that private capital and labor are complements, while the positive MK_P measure implies a substitutive relationship between intermediate inputs and private capital.

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[17] Nevertheless, the sign of certain coefficients need to be consistent with the so-called curvature conditions (see Diewert and Wales (1987) or Morrison and Schwarz (1994)). In our case, the condition that $\sum\gamma_{kk} > 0$ was not satisfied, so we imposed the requirement that $\sum\gamma_{kk} = 0.40$, which is accepted at conventional significance levels. The reason for imposing that the sum of the two implied coefficients is 0.40, is that this value is among all the positive values which are statistically acceptable the most "conservative" one, in the sense that it generates levels of K_P^* closer to the observed levels of K_P .

[18] If not stated otherwise the average results for the whole Spanish economy are computed as non-weighted regional averages.

[19] Recall that, as Kulatilaka (1985) points out, the counterpart that the shadow price does not coincide with the user cost is that the optimal capital stock does not coincide with the observed one.

With regard to the shadow price of public capital (Col. 5), Z_{K_G} shows a clear decreasing trend. The high values in the first years reveal the scarcity of infrastructures in the Spanish economy at the beginning of the eighties. Nevertheless, the declining pattern of the gross return to public capital indicates that the government has contributed significantly to reducing the existing gap between optimal and observed public capital. Finally, Columns 6 and 7 provide additional information about the distribution of the cost saving benefits of infrastructures investment. Public capital reduces private cost through a reduction of expenditure in intermediate inputs until 1990 and through the reduction of labor cost. Most noticeable is the fact that while private capital and labor are complements, infrastructures and labor seem to be substitutes.

Table 4. Shadow prices in the private sector.

Year	P_{KP}	Z_{KP}	LK_P	MK_P	Z_{KG}	LK_G	MK_G
Regional averages	[1]	[2]	[3]	[4]	[5]	[6]	[7]
1980	0.043	0.062	-0.109	0.171	0.321	0.264	0.057
1981	0.079	0.072	-0.089	0.162	0.370	0.213	0.157
1982	0.099	0.080	-0.078	0.158	0.367	0.184	0.183
1983	0.089	0.090	-0.075	0.166	0.365	0.176	0.190
1984	0.126	0.102	-0.071	0.175	0.358	0.168	0.189
1985	0.110	0.113	-0.068	0.181	0.325	0.150	0.177
1986	0.127	0.112	-0.074	0.183	0.287	0.168	0.132
1987	0.156	0.120	-0.080	0.196	0.261	0.194	0.084
1988	0.132	0.125	-0.083	0.205	0.249	0.216	0.048
1989	0.146	0.133	-0.083	0.212	0.219	0.223	0.015
1990	0.157	0.138	-0.081	0.216	0.183	0.214	-0.012
1991	0.146	0.142	-0.079	0.217	0.153	0.199	-0.026
1992	0.155	0.143	-0.072	0.213	0.143	0.175	-0.014
1993	0.113	0.143	-0.061	0.203	0.137	0.139	0.012
Average	0.120	0.112	-0.079	0.190	0.267	0.192	0.085
Standard deviation[1]		0.0044	0.0045	0.0077	0.0208	0.0225	0.0323

Note: All figures are expressed in 1980 constant pesetas. [1]Standard deviation of the sample mean.

In Table 5 we can find similar information to that in Table 4, but at the regional level. There are important regional disparities, for example, the shadow price of private capital (Col. 2) is on average higher than the user cost (Col. 1) in Andalusia, Castile and Leon, Catalonia, Valencia, Madrid, Navarre, the Basque Country and La Rioja. Thus, as has already been argued, this implies that in these regions observed private capital has

Table 5. Shadow prices and cost elasticities. Average values, 1980-93.

	P_{KP}	Z_{KP}	$\varepsilon_{C,KP}$	$\varepsilon_{L,KP}$	$\varepsilon_{M,KP}$	Z_{KG}	$\varepsilon_{C,KG}$	$\varepsilon_{L,KG}$	$\varepsilon_{M,KG}$
Regions	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Andalusia	0.118	0.159	-0.044	0.139	-0.461	0.041	-0.001	-0.222	0.176
Aragon	0.119	0.093	0.030	0.167	-0.353	0.230	-0.054	0.002	-0.109
Asturias	0.121	0.103	0.017	0.325	-0.413	0.223	-0.040	-0.066	-0.033
Baleares	0.119	0.009	0.128	0.196	-0.197	0.931	-0.125	-0.039	-0.239
Canary Islands	0.117	0.114	0.003	0.255	-0.484	0.184	-0.043	-0.018	-0.076
Cantabria	0.123	0.043	0.085	0.275	-0.296	0.534	-0.091	0.026	-0.200
Castile and Leon	0.118	0.148	-0.036	0.190	-0.494	-0.038	0.010	-0.074	0.078
Castile-La Mancha	0.112	0.086	0.042	-0.068	-0.244	0.161	-0.048	0.153	-0.224
Catalonia	0.127	0.184	-0.052	0.138	-0.448	0.030	-0.004	-0.305	0.231
Valencia	0.123	0.141	-0.019	0.176	-0.429	0.156	-0.025	-0.167	0.079
Extremadura	0.111	0.011	0.192	-0.413	0.338	0.540	-0.137	0.267	-0.574
Galicia	0.115	0.104	0.011	0.152	-0.354	0.283	-0.050	-0.099	-0.021
Madrid	0.130	0.149	-0.015	0.213	-0.436	0.388	-0.036	-0.224	0.125
Murcia	0.115	0.037	0.086	0.196	-0.221	0.819	-0.107	-0.030	-0.187
Navarre	0.124	0.169	-0.041	0.425	-0.562	0.051	-0.012	-0.016	-0.012
Basque Country	0.128	0.145	-0.017	0.244	-0.449	0.144	-0.024	-0.157	0.067
La Rioja	0.118	0.217	-0.084	0.667	-0.667	-0.169	0.058	0.062	0.062
Average	0.120	0.112	0.017	0.193	-0.363	0.267	-0.043	-0.053	-0.050
Spain[1]			-0.011	0.171	-0.411		-0.028	-0.153	0.063
Standard deviation[2]		0.004	0.005	0.014	0.015	0.021	0.004	0.009	0.012

Notes: [1]The elasticities for Spain are obtained as weighted averages, being taken as weights the ratios of the regional value of the variable to the national value. [2]Standard deviation of the sample mean.

been on average below its optimal level. It is noticeable that of these eight regions, seven of them are the ones with the most weight in Spanish total gross output (jointly these regions represent more than 70 per cent of private production).

This is the reason why the non-weighted average of the elasticity of cost to private capital (Col. 3) is positive, while the same elasticity is negative for the whole of Spain (constructed weighting regional relative cost shares). This is an important result as additional private investment efforts in the regions with more weight in Spanish output would have benefited the firms in these regions through the reduction of production costs[20]. In contrast, the nine regions with positive cost elasticities and consequently where observed private capital has been on average above the optimal one, represent less than 30 per cent of total output. In Columns 4 and 5 we can find further information about the impact of private capital on the cost performance of private firms in Spanish regions. In all the regions, except Castile-La Mancha and Extremadura, additional private capital endowments result in labor cost increases (Col. 4). Also with the exception of Extremadura, private capital reduces costs through the substitution of intermediate inputs (Col. 5). Summing up, in almost every Spanish region private capital and labor are complements while intermediate inputs and private capital are substitutes.

With regard to the shadow price of public capital (Col. 6), as expected it is positive in all regions, with the exceptions of Castile and Leon and La Rioja[21], showing the productive effect of infrastructures and the benefit in terms of cost reductions to private firms. Given that we are assuming that infrastructures are supplied freely, private firms do not face a user cost, so that the elasticity of cost to public capital (Col. 7) is negative in the fifteen regions where Z_{K_G} is positive.

The relationship between public capital and labor and intermediate inputs is also shown in the last two columns of Table 5. Public capital and labor are substitutes in

[20] In fact, average annual growth of the investment rate has been 1.4% in the five regions with higher Z_{Kp} values, and –0.04% in the five regions with lower values. Thus, along the sample period, investment in private capital has flown relatively more to the most profitable regions.

[21] The fact that shadow prices of public capital in Castile and Leon and La Rioja are negative falls into incoherence from a theoretical point of view. However, La Rioja displays an unusual pattern because of its very high initial ratios of public to private capital and public capital to output, and because it is the only region where public capital shows almost no growth along the sample period.

most regions (except in Aragon, Cantabría, Castile-La Mancha and Extremadura), contrasting sharply with the complementary relationship between labor and private capital shown previously. Finally, there are important regional disparities in the relationship between infrastructures and intermediate inputs. Both factors are substitutes in ten regions and complements in seven. The important fact is that these seven regions are again the biggest ones, which represent jointly more than 70 per cent of Spanish gross output. This explains that the simple regional average of the elasticity of public capital to intermediate inputs takes a negative value (-0.050), while the Spain measure (the weighted average) is positive (0.063).

In Table 6 we translate our cost performance measures into output elasticities and returns to scale measures. Our results for the whole of the Spanish economy seem quite reasonable, indicating that the estimation of cost functions may be appropriate to analyze the productive effects of quasi-fixed inputs. With regard to output elasticities[22], Table 6 shows that the values for the whole of the Spanish private productive sector are 12.7% for private capital and 2.6% for public infrastructures. Given that our output measure is gross output, these elasticities would be around 23% for private capital and 9% for public capital, if the variable considered were gross value added. As before there are also significant differences across regions which confirm the regional pattern that emerges from the analysis of previous results[23]. Finally, the last two columns of Table 6 show information about short-run returns to variable inputs and long-run returns to scale[24]. For the average region, returns to scale are almost constant ($\lambda^{LR} \approx$ 0.97), although firms are producing not only over the minimum of their average variable costs, but also over the minimum of total costs in the short-term ($\lambda^{SR} \approx$ 0.83). In this case, regional disparities in the degree of short or long-run returns are not as important as in other indicators, indicating quite a reasonable pattern of the Spanish private sector:

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[22] Output elasticities are computed as is common in this literature according to the formulas $\varepsilon_{Y,Kp} \equiv \frac{S^*_{Kp}}{\varepsilon_{C,Y}}$ and $\varepsilon_{Y,Kg} \equiv \frac{S^*_{Kg}}{\varepsilon_{C,Y}}$, where $\varepsilon_{C,Y}$ is the short-run elasticity of total cost to output.

[23] In most Spanish regions the values of the output elasticities are quite reasonable, although there are a few exceptions.

[24] Short-run returns to variable inputs are defined as the ratio of average variable costs to marginal costs, while long-run returns are obtained adding the output elasticities of the four productive inputs.

regions operate under constant returns to scale, but with decreasing returns to variable factors in the short-run.

Table 6. Output elasticities and returns to scale. Average values, 1980-93.

Regions	$\varepsilon_{Y,KP}$ [1]	$\varepsilon_{Y,KG}$ [2]	λ^{SR} [3]	λ^{LR} [4]
Andalusia	0.159	0.001	0.819	0.975
Aragon	0.107	0.053	0.840	0.991
Asturias	0.092	0.039	0.871	0.993
Baleares	0.008	0.108	0.749	0.841
Canary Islands	0.118	0.040	0.814	0.940
Cantabria	0.041	0.084	0.807	0.951
Castile and Leon	0.160	-0.010	0.810	0.997
Castile-La Mancha	0.138	0.049	0.842	1.002
Catalonia	0.162	0.004	0.848	0.988
Valencia	0.135	0.024	0.825	0.969
Extremadura	0.009	0.158	0.913	1.017
Galicia	0.106	0.049	0.858	1.014
Madrid	0.103	0.032	0.795	0.931
Murcia	0.036	0.102	0.835	0.933
Navarre	0.136	0.011	0.808	0.968
Basque Country	0.127	0.022	0.814	0.981
La Rioja	0.165	-0.051	0.806	0.913
Average	0.106	0.042	0.827	0.965
Spain[1]	0.127	0.026	0.828	0.972
Standard deviation[2]	0.0043	0.0036	0.0028	0.0030

Notes: [1]The elasticities for Spain are obtained as weighted averages, being taken as weights the ratios of the regional value of the variable to the national value. [2]Standard deviation of the sample mean.

The analysis in the above paragraphs is of a short-run nature, in the sense that it has not taken into account the existence of an indirect effect of public capital on the desired stock of private capital. In other words, the possible complementary or substitutable relationship between public infrastructures and private capital can be further investigated. As shown in the theoretical section, we are able to determine the stock of optimal private capital by means of equation (9), given the amount of infrastructures. In the first column of Table 7 we present the ratio of optimal to observed private capital. Regional disparities in this indicator are the same as the ones

Table 7. Long-run elasticities.

Regions	K_P^*/K_P [1]	$\varepsilon_{KP*,KG}$ [2]	Z^L_{KG} [3]	ε^L_{CKG} [4]	ε^L_{LKG} [5]	ε^L_{MKG} [6]	ε^L_{YKG} [7]	ε^L_{YKP} [8]
Andalusia	1.239	0.638	0.201	-0.038	-0.170	0.053	0.037	0.154
Aragon	0.882	0.866	0.130	-0.032	-0.031	-0.045	0.030	0.117
Asturias	0.827	1.178	0.118	-0.018	-0.154	0.042	0.016	0.083
Baleares	0.510	0.904	0.353	-0.042	-0.194	0.016	0.039	0.057
Canary Islands	0.985	0.768	0.174	-0.041	-0.024	-0.067	0.038	0.117
Cantabria	0.611	1.187	0.160	-0.024	-0.130	0.004	0.021	0.073
Castile and Leon	1.196	0.856	0.089	-0.025	-0.017	-0.040	0.023	0.156
Castile-La Mancha	0.916	0.787	0.071	-0.024	0.123	-0.185	0.022	0.168
Catalonia	1.280	0.547	0.279	-0.037	-0.260	0.132	0.038	0.149
Valencia	1.087	0.612	0.230	-0.038	-0.156	0.037	0.037	0.128
Extremadura	0.548	1.073	0.040	-0.012	0.093	-0.129	0.009	0.124
Galicia	0.948	0.804	0.238	-0.044	-0.119	0.003	0.041	0.108
Madrid	1.093	0.525	0.481	-0.041	-0.207	0.082	0.041	0.098
Murcia	0.729	0.674	0.460	-0.061	-0.088	-0.058	0.056	0.084
Navarre	1.188	0.755	0.190	-0.047	0.022	-0.113	0.044	0.121
Basque Country	1.086	0.675	0.214	-0.037	-0.137	0.028	0.035	0.122
La Rioja	1.466	0.870	0.091	-0.031	0.137	-0.205	0.029	0.133
Average	0.976	0.807	0.207	-0.035	-0.077	-0.026	0.033	0.117
Spain[1]	1.066			-0.037	-0.143	0.063	0.035	0.127
Standard deviation[2]	0.0200	0.0218	0.011	0.001	0.008	0.008	0.001	0.002

Notes: [1]The elasticities for Spain are obtained as weighted averages, being taken as weights the ratios of the regional value of the variable to the national value. [2]Standard deviation of the sample mean.

presented in previous tables, namely the biggest regions show on average a relative shortage of private capital, while the smallest regions show observed private capital to be above the optimal one. Again, both the simple and the weighted regional averages reflect this fact.

Figures 2 and 3 show the evolution of the shadow price of private capital and its user cost, as well as the stock of optimal capital and the observed one for the whole Spanish private sector. As we can see both figures are mirror images. There are no remarkable discrepancies between optimal and observed capital stock from 1980 to 1988, although from 1988 to the end of the sample period there is persistent over-utilization of production capacity.

As stated before, the optimal stock of private capital depends on the endowment of public capital, so we will study the relationship that exists between them. It is useful to calculate the effect of an increase in infrastructures on the optimal private capital stock. Column 2 of Table 7 shows the average value of the elasticity of optimal private capital to public infrastructures for each region. In all of them and throughout the whole period both factors are complementary (ε_{KP*KG}>0). Thus, infrastructures generate a positive impact on the shadow price of private capital, and as a result they help promote new investment in private capital in the long-run.

Assuming that firms in each region have reached the optimal private capital stock, the next step is to calculate the shadow price of public capital in this situation. As can be seen in Column 3, the long-run shadow price of public capital is positive in all the regions, with especially high values in Madrid, Murcia, Baleares, Catalonia and Valencia. The gross return to infrastructures is consequently high in most regions, reflecting the fact that there is still scope for the Spanish local or central government to continue its investment efforts to alleviate the scarcity of infrastructures in the long-run. The same conclusion can be drawn looking at the cost elasticity to public capital (Col. 4) which is negative in all regions and does not present important disparities across large and small regions.

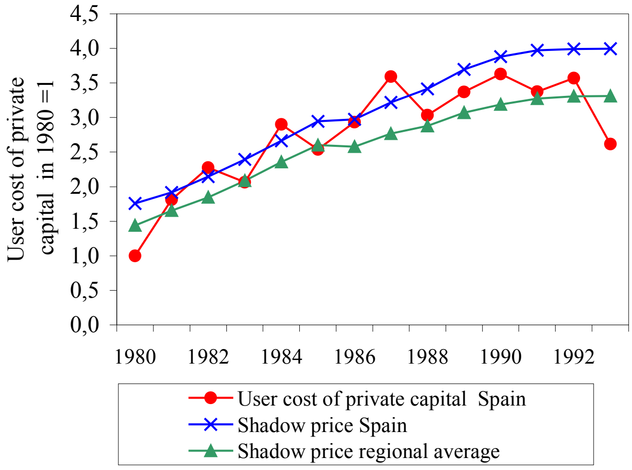

Figure 2. Shadow price and user cost of private capital. Spain 1980-1993.

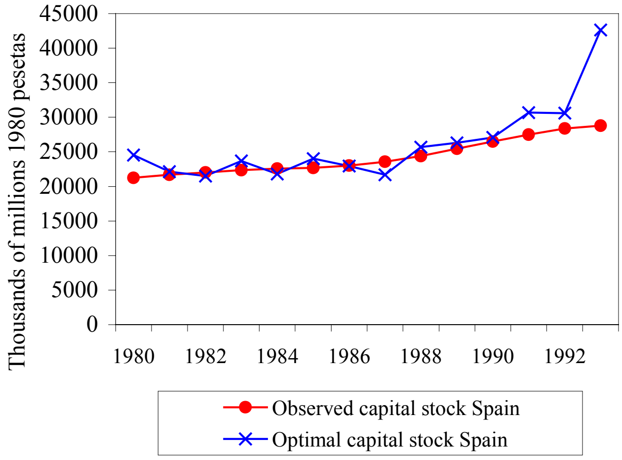

Figure 3. Optimal and observed private capital stock. Spain 1980-1993.

Given the above results, it is also possible to reconsider the complementary and/or substitutable relationship between public infrastructures and variable inputs. Apart from the direct or short-run effect dealt with in the preceding paragraphs, there will be an indirect effect on the demand for variable inputs. This indirect effect may be generated by the influence of public capital on the demand for private capital, which in turn would generate additional demand for the other inputs. As can be seen in Column 5, once we take into account both direct and indirect effects in the long-run labor and infrastructures are substitutes in all the Spanish regions (with four exceptions). The most noticeable result is that in the five biggest regions (Madrid, Catalonia, Valencia, Andalusia and the Basque Country) the long-run elasticity of labor to public capital is lower than in the short-run. The reason is that new infrastructures supplied by the public sector in the long-run will generate additional demand for private capital, which further generates new demand for labor. Finally, in the long-run intermediate inputs and public capital are substitutes in eight regions and complements in the remaining nine, although among the latter regions are the largest ones.

The final piece of information displayed in Table 7 refers to the output elasticities of private and public capital (Cols. 7 and 8). The average output elasticity of private capital in the long-run shows reasonable values around 0.12; being approximately four times higher than the one corresponding to public capital (0.035). As we can see the elasticity of public capital to output is higher in the long-run than in the short-run, and the regional pattern of these elasticities confirms previous findings about the regions where infrastructures have the biggest productive effect. Nevertheless, given that in general we have found a high rate of return to public infrastructures in Spain, it seems reasonable to have an idea of their optimal level and where they should be located.

Throughout this paper we have considered public capital as an unpaid input for firms. However, to be more precise about the productive profitability of public infrastructures we should compare the short-run shadow price of infrastructures with some measure of the social user cost of them. To do this we use three different measures of the social user cost of infrastructures. First, we consider a zero social cost of public capital investment. Second, we use the user cost of public capital available on our database[25], which has no variation across regions, given that the cost of opportunity which the public sector faces when allocating money to infrastructures is the same no matter what region the money goes to. Third, we consider as an upper bound to the

[25] The user cost of public infrastructures available in the BD.MORES database is negative until 1984, while it is positive and grows steadily from 1985 to 1993. In real terms the regional average is 0,0576 if we do not consider the first five years, while it is 0,0187 if we consider the complete time span. We will not take into account the negative figures in our calculations.

social cost of infrastructures the user cost of private capital for the whole Spanish private productive sector.

In Figure 4 we have depicted the time evolution of the stock of observed public capital, as well as the optimal stock obtained by means of equation (11) under the different assumptions regarding the social user cost. The initial endowment of infrastructures in 1980 was clearly insufficient; no matter what user cost is used as reference. Nevertheless, at the end of the sample period both the optimal and the observed capital stocks have neared considerably[26], reflecting the enormous investing effort carried out by the public sector in these years. Hence, investment in public infrastructures has been very important, although it is still insufficient, if we take into account that the regions that have more weight in total Spanish gross output have the higher shadow prices of public capital in the long-run.

With regard to the optimal placing of public infrastructures, the results across regions obtained for the long-run shadow price of public capital (Col. 3 of Table 7) show that the most profitable regions are Madrid, Murcia, Baleares, Catalonia, Galicia, Valencia and the Basque Country. In Figure 5 we have ordered the regions in terms of the differences between the long-run shadow price of public capital and the different user cost measures. In almost every case, it would be convenient that the public sector provides the regions with higher levels of public infrastructures. If we consider the upper bound case (i.e. the user cost of private capital) there are four regions (Castile and Leon, Castile-La Mancha, la Rioja and Extremadura) where the allocation of new infrastructures would not be profitable. Nevertheless, we must bear in mind that this valuation of productive profitability of infrastructures responds only to efficiency criteria, and ignores equity or welfare issues that the public sector should also take into account.

[26] If we look at the optimal public stock obtained using the private user cost as reference, it is inclusively lower than the observed one at the end of the sample period. Nevertheless, the utilization of the user cost of private capital is just an upper bound, given that the rate of depreciation of public capital is lower than that of private capital and the prices of both of them are different.

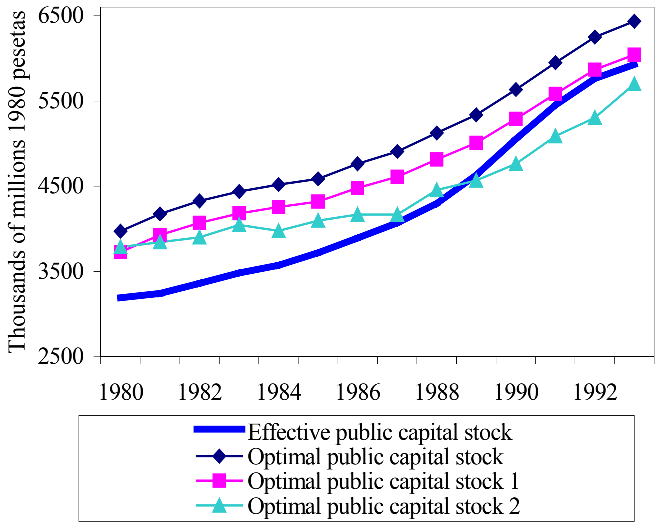

Figure 4. Optimal public capital stock and observed capital[27].
Spain 1980-93

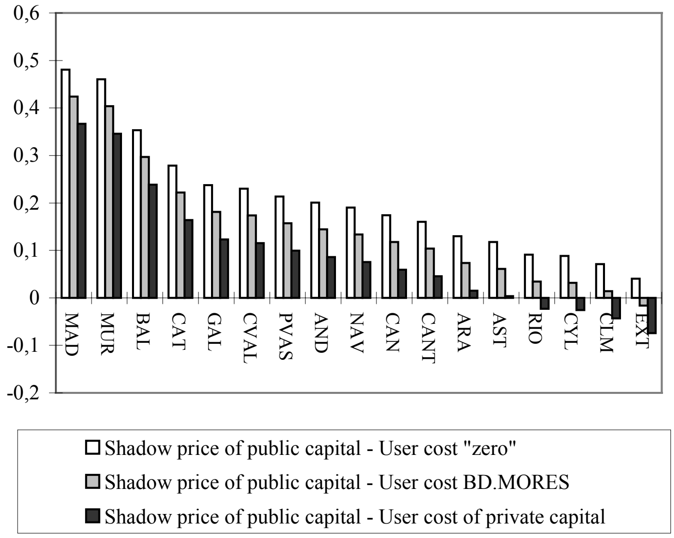

Figure 5. Localization of infrastructures. Average values 1980-1993

[27] Optimal public capital stock, optimal public capital 1 and optimal public capital 2 denote the optimal public capital levels computed under different assumptions about the user cost of public capital. First, we assume a zero user cost of public capital; second, we consider the user cost of public capital in the BD. MORES; and finally we use the user cost of private capital.

5. Conclusions.

In this paper we have dealt with the effect of infrastructures on cost performance and productivity of the private sector in the Spanish regions. Our choice has been a dual approach based on cost functions, unlike the majority of studies on the Spanish regions that estimate production functions. Using such an approach we are able to process more information, as well as recover the conventional parameters obtained from the estimation of production functions. In addition, we also obtain at the regional level cost-benefit measures and elasticities of the various productive inputs, as well as the complementary and substitutable relationship among them. In our framework we allow for the existence of quasi-fixed or external inputs, that may not be at their static equilibrium levels.

The estimation of a Generalized Leontief Cost Function together with the equations that derive from the theoretical restrictions required by Shephard's Lemma, allows us to test whether private factors are at their optimal demand levels. In this sense, the tests statistics indicate clearly that labor and intermediate inputs are pure variable inputs, while private capital is a quasi-fixed factor, the volume of which differs from its static equilibrium level. This is an important result since it is commonplace in the literature to require either that private capital is a variable or a quasi-fixed factor without any formal econometric test that supports one or the other view. If common economic sense may be sometimes enough to require some theoretical restrictions, in our case, both aspects work in the same way.

From the econometric analysis above it is possible to come to some conclusions regarding the effects of public and private capital on the structure of costs and productivity of the private sector in the Spanish regions throughout the 1980-93 period. In relation to the shadow price or gross rate of return of both factors, it is worthwhile mentioning that we have found positive and significant shadow prices of private capital in all the regions. Further, the shadow price of private capital is higher than the user cost in those regions that have more specific weight in Spanish total gross output throughout the period. This means that the cost elasticity of private capital is negative in the aforesaid regions and positive in the remainder, which implies also that the optimal stock of private capital is above the observed one in these regions. In almost every region, investing in new units of private capital seems to contribute positively to job creation and to a saving of intermediate inputs.

The general panorama seems to be different with regard to public infrastructures. The shadow prices of public capital are positive and significant in all the Spanish regions (with the outstanding exceptions of Castile and Leon and La Rioja). Furthermore, unlike the average shadow price of private capital, which shows a slight upward trend, the average public capital shadow price shows a clear downward trend throughout the period. This trend implies that the government has reduced, at least partially, the shortage of infrastructures that the Spanish productive sector had at the beginning of the eighties. Nevertheless, there is still margin for the public sector to make further investment efforts, especially if we take into account that the long-run shadow prices of public capital (*i.e.* once private capital is at its optimal level) are still positive and high in the most productive regions.

With regard to the complementary and substitutable relationships between infrastructures and other inputs, in the short-run the results are more heterogeneous than in the case of private capital. Nevertheless, employment and infrastructures are substitutes, and intermediate inputs and infrastructures are complements in the largest regions. However, if we take into account that the optimal stock of private capital depends on the existing volume of public capital, it is also possible to study the relationship between them. In our case we have found that both factors are unambiguously complementary in all the Spanish regions (the average elasticity of optimal private capital to infrastructures is 0.81). In other words, infrastructures generate a significant positive impact on the shadow price of private capital, favoring its accumulation in the long-run.

If we translate our cost performance measures into output elasticities and returns to scale measures we find reasonable results for the whole of the Spanish economy. With regard to output elasticities, the values for the whole of the Spanish private productive sector are 12.7% for private capital and 2.6% for public infrastructures. Given that our output measure is gross output, these elasticities would be around 23% for private capital and 9% for public capital, if the variable considered were gross value added. There are also significant differences across regions, which confirm the regional pattern which emerges from the analysis of previous results. Finally, for the average region, returns to scale are almost constant, although firms are producing not only over the minimum of their average variable costs, but also over the minimum of total costs in the short-term. In this case, regional disparities in the degree of short or long-run returns are not as important as in other indicators, indicating quite a reasonable pattern in the Spanish private sector: regions operate under constant returns to scale, but with decreasing returns to variable factors in the short-run.

Although our estimated model suggests unambiguously that public capital has exercised a positive impact on productivity and cost performance of private firms in Spain, there remain a number of important issues to be dealt with in the research agenda. First, it would be desirable to address the spatial spillover problem, looking into the effects of investment in one region on productivity in other regions. Second, the characteristics of the infrastructure could be taken into account, given that, for instance, the impact of a highway is not necessarily the same as the impact of an energy supply network.

6. References

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Data Appendix

The basic data for the seventeen Spanish regions are taken from the BD.MORES database. The level of regional disaggregation corresponds to NUTS2 in Eurostat nomenclature of statistical territorial units (see Dabán et al. (1998)). The series taken from this database are:

Gross value added. Includes production of goods and services at factor costs produced in the region by the private productive sectors: agriculture (forestry and fishing), industry (mining, manufacturing, construction and utilities) and private services (commerce, transport, and communications, banking and other private services). Housing rents are excluded.

Gross earnings of private employees.

Number of employees.

Private capital stock. Net stock of capital held by the productive private sector. It does not include the stock of residential buildings, nor the stock of productive infrastructures.

Public capital stock. Net stock of productive infrastructure. It comprises transportation networks, energy supply networks, water supply and sewage systems. These may be offered by government or government agencies, by regulated private or public enterprises, or by public or private organizations.

User costs of private and public capital. The user cost of private capital for a given region is computed as $P_{K_P} = \frac{q}{p}(r - \hat{q} + \delta)$, where q is the private capital investment deflator, p is the output deflator, r is a long run interest rate, δ is the private capital depreciation rate and $\hat{q}$ is the rate of growth of the investment deflator. The user cost of public capital is computed analogously, the interest rate being the average return to public debt.

The series of intermediate inputs and their price indices are taken from Díaz (1998), and are fully compatible with BD.MORES data.