Hacienda Pública Española / Revista de Economía Pública, 178-(3/2006): 9-21

Econometric testing of spatial productivity spillovers from public capital

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Recibido: Febrero, 2004
Aceptado: Junio, 2006

Abstract

In this paper we review two different approaches followed in the empirical literature to test for the existence of public capital spillovers. Additionally, we explore the role played by an additive aggregator of public capital in neighboring regions versus the multiplicative aggregator used previously in the literature. In the empirical application we compare the different methodologies using a panel data set of the 47 mainland Spanish provinces. We do not find evidence of the existence of spillover effects of public infrastructure.

Key words: Public capital, public infrastructure, spatial spillovers.

JEL classification: H54, R11, R53.

1. Introduction

The productivity of public capital has been a subject of increasing interest since the publication of some seminal articles in the 1980s (Ratner, 1983; Aschauer, 1989) [1]. Several surveys of this vast literature exist, including Gramlich (1994), Draper and Herce (1994), and de la Fuente (1996, 2000). In Spain, due to the availability of high quality data sets, a large amount of empirical literature has appeared on this topic. Partial surveys of the Spanish literature can be found in Sanaú (1997), Fernández and Polo (2001) and Álvarez *et al.* (2003).

Early papers found that the productivity of public capital was quite high. Aschauer (1989), for example, estimated an output elasticity of public capital of 0.39, which was larger than the elasticity of private capital. However, these findings were soon criticized on several grounds. In particular, since these papers used aggregate national time-series data, some authors argued that the empirical results could be due to spurious correlation caused by common trends in the variables. Other criticisms leveled against these studies were the omission

of relevant variables (such as human capital) or the problem of reverse causality, i.e., the direction of causality may run from economic activity to public investment.

An interesting result appeared when researchers started using state-level data, namely that the estimates of the output elasticity of public capital were much lower [2]. Apparently, geographical disaggregation of data usually results in lower productivity of public capital. This finding has been attributed to the existence of spillovers of public capital from one region into neighboring regions. These spatial spillovers are explained as the result of the network effects of public capital, that is, since most elements of public capital have network characteristics (e.g., roads, railways, etc.) the stock of public capital in one region is expected to affect production in other regions. However, it has also been argued that there may be negative spillovers from public infrastructure. The argument in this case is that public infrastructure investment in one location can draw resources (and therefore production) away from other locations since «it enhances the comparative advantage of that location relative to other places» (Boarnet, 1998).

The issue of spatial spillovers has also been addressed in other areas of economic research. In the economic growth literature, there is evidence that fast-growing countries cluster together, implying that location matters for growth (see, for example, Moreno and Trehan, 1997). In public economics, some researchers are interested in the degree to which state spending is influenced by the spending of neighboring states (see, for example, Case *et al.,* 1993). In development economics, some papers try to test the Myrdal-Hirschman core-periphery hypothesis of unbalanced growth which implies that the development of some regions may have a positive influence on nearby regions (see, for example, Ying, 2000). Finally, in regional analysis some studies find that regional convergence depends on location (see, for example, Chua, 1993).

In this paper we review some of the different approaches followed in the empirical literature to test for the existence of public capital spillovers. Furthermore, we explore the role played by an additive aggregator of public capital in neighboring regions versus the multiplicative aggregator used previously in the literature. This new specification not only provides another test for the existence of spillover effects but also sheds some light on the properties of alternative tests previously proposed in the literature. In an empirical application we compare the different methods using a panel data set of the 47 mainland Spanish provinces.

The structure of the paper is as follows. In section 2, we review the modeling of spillover effects. In section 3, we describe the data and the empirical models, while in section 4 we present and discuss the estimation results. Section 5 contains some conclusions.

2. Spatial spillover effects of public capital

The early claims by Munnell (1990) and others that the use of state-level data misses part of the spillover benefits of public capital did not result in rigorous statistical testing of this hypothesis. In fact, the papers that first analyzed this issue used an indirect «test»: they estimated the same model at different levels of geographical aggregation. This approach was

used by Holtz-Eakin (1994), who did not find larger elasticities at higher levels of regional aggregation.

The first statistical test of this hypothesis was carried out by Holtz-Eakin and Schwartz (1995). They estimated a Cobb-Douglas production function of the form [3]

$$\ln Y_i = \alpha_0 + \alpha \ln K_i + \beta \ln L_i + \gamma \ln G_i^e \tag{1}$$

where subscript *i* indexes regions, *Y* is aggregate production, *K* is private capital, *L* is labor and G^e is the «effective» stock of public capital

The effective stock of public capital in region *i* (G_i^e) differs from the within-region stock (G_i) due to the contribution of the stock of other regions. The idea behind this concept is that output in one region can be affected (positively or negatively) by public capital investments in nearby regions. Therefore, the relevant stock of capital for explaining variations in the region's aggregate production should include some measure of public capital in other states. Holtz-Eakin and Schwartz (1995) defined G_i^e as:

$$G_i^e = G_i \prod_j^N G_j^{\theta w_{ij}} \tag{2}$$

where *j* indexes nearby regions ($j \neq i$) and w_{ij} is the weight of other regions' public capital stock, which tries to account for spatial heterogeneity. A common choice for the weights (w_{ij}) is to make them equal to one for adjacent provinces and zero for non-bordering provinces (e.g. Kelejian and Robinson, 1997). Other alternatives are to define the weights in terms of the inverse of the distance from other regions (e.g. Álvarez *et al.,* 2003) or to construct the weights so that they reflect the commercial relationships among regions (e.g. Cohen and Morrison Paul, 2004). The parameter θ measures the effect of the public capital of other regions on the effective capital stock. When $\theta = 0$ the effective and actual measures coincide [4].

Substituting (2) into (1) yields the basic model to be used for testing for the existence of spillover effects:

$$\ln Y_i = \alpha_0 + \alpha \ln K_i + \beta \ln L_i + \gamma \ln G_i + \gamma\theta \sum_{j=1}^{N} w_{ij} \ln G_j \tag{3}$$

A positive value for θ can be interpreted as evidence of the existence of the spillover effect [5]. This model can be estimated by replacing γθ in equation (3) by a single parameter δ. Then the model becomes:

$$\ln Y_i = \alpha_0 + \alpha \ln K_i + \beta \ln L_i + \gamma \ln G_i + \delta \sum_{j=1}^{N} w_{ij} \ln G_j \tag{4}$$

Now, a positive and significant estimate of the parameter δ can be interpreted as empirical evidence in favor of a spillover effect. Despite the apparent appeal of this model, to our best knowledge, it has been estimated very few times (e.g. Avilés *et al.,* 2003).

One alternative which has not been explored in the literature is to use a linear aggregator to construct the effective stock of public capital, that is:

$$G_i^e = G_i + \theta \sum_{j=1}^{N} w_{ij} G_j \tag{5}$$

where, N is the number of regions.

Substituting this definition of effective public capital into equation (1) makes the resulting model nonlinear in parameters:

$$\ln Y_i = \alpha_0 + \alpha \ln K_i + \beta \ln L_i + \gamma \ln \left(G_i + \theta \sum_{j=1}^{N} w_{ij} G_j \right) \tag{6}$$

Although the evidence in favor of a spillover effect hinges again on the significance of the parameter θ, the models in (4) and (6) have quite different implications regarding the influence of public capital located in the region relative to public capital in neighboring regions. In both models the effective stock of public capital, G_i^e, can be viewed as an aggregate stock which includes a whole set of implicit assumptions on the substitution between the stock of public capital in a given region and the stock of public capital in neighboring regions.

In the Holtz-Eakin and Schwartz model, the substitution between the observed stock in a given region and in a neighboring region can be measured as:

$$\varepsilon_{ij} = -\left. \frac{d \ln G_i}{d \ln G_j} \right|_{dG^e = 0} = \theta w_{ij} G_j, \quad \forall j \neq i \tag{7}$$

Given a particular value for w_{ij}, this elasticity depends on the parameter θ. Assuming, as is frequently done in empirical work, that $w_{ij} = 1$ for an adjacent region and further assuming that the estimated value of θ is, say, 0.3, the elasticity in (7) implies that it is possible to reduce the stock in one region by 30% if the stock in an adjacent region increases by 100%.

On the other hand, using the linear aggregator in (5) the substitution of public capital in a region by public capital in a neighboring region can be measured as:

$$\varepsilon_{ij} = \theta w_{ij} \frac{G_j}{G_i}, \quad \forall j \neq i \tag{8}$$

In this model, the elasticity ε_{ij} is an increasing function of the ratio G_j/G_i. Therefore, the larger the stock of capital of the neighboring region relative to the stock of public capital in the region analyzed, the larger the stock of the region's public capital that can be reduced while its production is kept constant. Assuming again that $w_{ij} = 1$ and $\theta = 0.3$, the stock in one region can be reduced by 30% when the stock in a neighboring region increases by 100% if $G_i = G_j$, but can only be reduced by 15% if $G_i = 2G_j$.

Some papers have used an alternative «test» developed by Mas *et al.* (1994) which is based on the comparison of two models. The procedure followed is to first estimate a standard production function that includes the stock of public capital in each region as an explanatory variable. Then, they estimate another production function where the public capital in each region has been augmented with a weighted sum of the public capital stock in neighboring regions. If the estimated elasticity of the model with the augmented stock is higher than the elasticity of the former model, this is interpreted as evidence of spillover effects. Since there is no way to statistically test the null hypothesis that the two coefficients are equal, we will refer to this two-step procedure as a «pseudo-test» [6]. See Álvarez *et al.* (2004) for an extensive analysis of this approach.

An interesting feature of the model in (6) is that it can be used to shed some light on the empirical performance of the «pseudo-test» of Mas *et al.* In fact, the first equation estimated in their approach corresponds to the case of $\theta = 0$ in equation (6):

$$\ln Y_i = \alpha_0 + \alpha \ln K_i + \beta \ln L_i + \gamma \ln G_i \tag{9}$$

The second equation estimated in the «pseudo-test» corresponds with the case of $\theta = 1$ in equation (6):

$$\ln Y_i = \alpha_0 + \alpha \ln K_i + \beta \ln L_i + \gamma \ln \left(G_i + \sum_{j=1}^{N} w_{ij} G_j \right) \tag{10}$$

Mas *et al.* (1994) suggest comparing the estimate of γ in the two models. However, it is quite clear that θ can be estimated, and if it is significantly different from zero then this result can be interpreted as evidence of the existence of a spillover effect. Therefore, it is difficult to see the rationale of setting the values of θ equal to zero and one beforehand and comparing the estimates of the parameter γ.

In the next section we perform an empirical comparison of these models. On the one hand we will compare the two models based on two different aggregators of public capital in neighboring regions. On the other, we will compare these two standard models with the method developed by Mas *et al.* (1994) [7].

3. Data and Empirical Model

In this section we discuss the empirical details of the estimation of the three models described in Section 2 (Holtz-Eakin and Schwartz, Additive Effective Capital, and Mas *et al.*). For this purpose we use a balanced panel dataset of the 47 mainland provinces of Spain for the period 1985-1999. The output is Gross Value Added in thousands of 1986 euros (Source: Funcas). The production factors are private capital (*K*) in thousands of 1986 euros (Source: IVIE), number of workers (*L*) (Source: IVIE), and road infrastructure (*G*) measured as the number of kilometers of highways (Source: Ministerio de Fomento).

We use the Cobb-Douglas functional form. In order to control for time-invariant regional heterogeneity we have included individual (i.e., provincial-level) fixed effects in all models. The differences in the weights of productive sectors on final output between provinces are likely to be a source of time-variant heterogeneity. As a proxy for these differences in the composition of final output we use the percentage of employment in the agricultural sector (*Z*). Neutral technical change is modeled as a quadratic function of time. Time effects for 1993 and 1994 are included to control for a period of substantial economic downturn. The stock of infrastructure of neighboring provinces has been constructed using only the stocks of adjacent provinces (i.e., those provinces sharing a border) [8]. Therefore, the models to be estimated are:

a) Holtz-Eakin and Schwartz

$$\begin{aligned}\ln Y_{it} &= \alpha_i + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln G_{it} + \delta G_{it}^{A1} \\ &+ \phi_t + \phi_{t1} t + \phi_{t2} t^2 + \phi_2 \ln Z_{it} + \phi_1 D_{93it} + \phi_2 D_{94it} + \varepsilon_{it}\end{aligned} \tag{11}$$

where subscript *t* indexes time, and $G_{it}^{A1} = \sum_{j \in J_i} \ln G_{jt}$ measures the stock of adjacent provinces and J_i is the set of provinces bordering province *i*. In this model, a positive value of the parameter δ can be interpreted as empirical evidence in favor of spillover effects.

b) Additive index of public capital in neighboring regions

$$\begin{aligned}\ln Y_{it} &= \alpha_i + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln \left(G_{it} + \theta G_{it}^{A2}\right) \\ &+ \phi_t + \phi_{t1} t + \phi_{t2} t^2 + \phi_2 \ln Z_{it} + \phi_1 D_{93it} + \phi_2 D_{94it} + \varepsilon_{it}\end{aligned} \tag{12}$$

where $G_{it}^{A2} = \sum_{j \in J_i} G_{jt}$.

In this model, a positive value of the parameter θ can be seen as empirical evidence of the existence of infrastructure spillovers.

c) Mas *et al.*

This method involves the estimation of two models. The first one is a standard production function with the stock of public capital,

$$\begin{aligned}\ln Y_{it} &= \alpha_i + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln G_{it} \\ &+ \phi_t + \phi_{t1} t + \phi_{t2} t^2 + \phi_2 \ln Z_{it} + \phi_1 D_{93it} + \phi_2 D_{94it} + \varepsilon_{it}\end{aligned} \tag{13a}$$

In the second model the public capital in each region has been augmented with the stock of public capital in neighboring regions measured as G_{it}^{A2}:

$$\begin{aligned}\ln Y_{it} &= \alpha_i + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma^A \ln \left(G_{it} + G_{it}^{A2}\right) \\ &+ \phi_t + \phi_{t1} t + \phi_{t2} t^2 + \phi_2 \ln Z_{it} + \phi_1 D_{93it} + \phi_2 D_{94it} + \varepsilon_{it}\end{aligned} \tag{13b}$$

Mas *et al.* (1994) argue that $\gamma^A > \gamma$ can be interpreted as evidence of the existence of spillover effects.

4. Estimation and Results

The models in (11), (13a) and (13b) were estimated by OLS using the Within estimator, while model (12) was estimated by Non-Linear Least Squares [9]. The estimates are shown in table 1.

Table 1
Estimation of the models

		Holtz-Eakin and Schwartz		Additive Effective Capital		Mas *et al.* Eq. 13a		Mas *et al.* Eq. 13b	
Variable	**Par**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**
*ln*K	$\alpha\prod$	0.188	7.41	0.189	7.75	0.188	7.40	0.194	7.64
*ln*L	$\beta\prod$	0.250	11.92	0.248	12.54	0.253	12.13	0.239	11.72
*ln*G	$\gamma\prod$	0.011	4.75	–	–	0.010	4.66	–	–
G^{A1}	$\delta\prod$	0.0007	0.97	–	–	–	–	–	–
$ln(G+\theta G^{A2})$	$\gamma\prod$	–	–	0.020	3.64	–	–	–	–
G^{A2}	$\theta\prod$	–	–	0.104	1.13	–	–	–	–
$ln(G+G^{A2})$	γ^{A}	–	–	–	–	–	–	0.021	3.78
T	ϕ_t	0.037	17.89	0.035	17.91	0.036	18.32	0.035	16.87
T^2	ϕ_{tt}	–0.001	–11.85	–0.001	–12.06	–0.001	–11.85	–0.001	–11.45
Z	ϕ_z	–0.025	–2.37	–0.020	–2.03	–0.024	–2.26	–0.020	–1.94
D93	ϕ_1	–0.034	–5.86	–0.035	–6.28	–0.034	–5.86	–0.035	–6.04
D94	ϕ_2	–0.032	–5.52	–0.033	–5.90	–0.032	–5.49	–0.034	–5.70

The R^2 is quite high in all models (above 98%). This is an expected result due to both the inclusion of provincial dummy variables and the high correlation between some of the explanatory variables and the output. The value of the Hausman test in the linear models allows us to reject the null hypothesis of no correlation between the individual effects (provinces) and the explanatory variables. The fixed effects model performs better than a random effects model since the allocation of private inputs and public capital across provinces might be affected by unobservable variables that influence output as well. If this were the case we would be facing an endogeneity problem. In principle, this problem could be solved using instrumental variables correlated with the explanatory variables but uncorrelated with random disturbances. Unfortunately, such instrumental variables are difficult to find in this particular empirical exercise. However, if the unobservable variables are constant over time they can be treated as provincial fixed effects and not as part of the random disturbance, thereby avoiding the potentially harmful endogeneity problem. The inclusion, in addition, of an explanatory variable measuring the output share of the agricultural sector in each province may further reduce the problem of endogeneity by controlling for provincial heterogeneity.

The four models yield similar results regarding the output elasticities of labor, private capital and highway infrastructure. The elasticities of labor and private capital are positive and significant in the four models although the values are lower than those reported in previ-

ously published research. The four models also yield almost identical results for the estimated coefficient of the control variables. The technical change was 1.8% on average, being larger at the beginning of the sample period ($\phi_{tt} < 0$). The coefficient for the variable measuring the percentage of the labor force in the agricultural sector is negative and significant, indicating that regions where agriculture is relatively more important tend to produce less aggregate output for given inputs. The dummy variables for *1993* and *1994* have a negative sign, reflecting the economic recession in those years.

The output elasticity of within-province public capital is positive and significant in the three models. The model of Holtz-Eakin and Schwartz provides a direct estimate of this elasticity ($\gamma = 0.011$), which is quite low. In the model with an additive index of public capital in neighboring provinces, the output elasticity of public capital can be calculated as $\frac{\gamma G_{it}}{G_{it} + \theta G_{it}^A}$. The value of this elasticity evaluated at the sample mean of the variables involved is 0.01. This estimate is significantly different from zero [10].

Regarding the existence of spatial spillover effects, no evidence is found in the first two models. In the first model, using the conventional aggregator, a positive estimate of the parameter δ can be seen as evidence of a spillover effect. The estimate of δ is very low (0.0007) and not significantly different from zero. In the second model, using an additive aggregator of public capital, a positive estimate of the parameter θ can be taken as evidence of a spillover effect. The estimate of θ (0.104) is again not significantly different from zero. However, the «pseudo-test» of Mas *et al.* (1994) suggests the existence of a spillover effect. It should be stressed that one of the estimates used in this approach is obtained in a model that includes a restriction not supported by the data ($\theta = 1$). In fact, we can reject the null hypothesis of $\theta = 1$ (with a t-statistic of –9.73) using the estimates of the production model with an additive aggregator of public capital in neighboring regions. This particular result casts further doubts on the use of this test to analyze the existence of public capital spillovers.

Therefore, our results do not show evidence of spatial spillovers of highway infrastructures across Spanish provinces. This is contrary to the evidence found in most papers using Spanish regional data, which have often found either positive or negative spatial spillovers. In particular, the papers that have used the Mas *et al.* approach have always found the existence of positive spillovers (Gil *et al.,* 1997, Ezcurra *et al.* 2005; Lanzas and Martínez, 2003; Cantos *et al.,* 2005). The same result was found in some papers that use different methodologies (Avilés *et al.,* 2003; Pereira and Roca, 2003). One exception is Moreno and López-Bazo (2005), who find negative spillovers of public capital. Finally, Delgado and Álvarez (2005) have found both positive and negative spillovers depending on the sector analyzed. We did not find evidence of spatial spillovers probably because in the present paper we are using a provincial dataset (versus the regional dataset used in previous research), and the higher level of disaggregation allows for a better treatment of unobserved heterogeneity, which may affect the estimation of the spillover's parameters.

In this sense, a comment is in order on the explanations given for the existence of negative spillovers. The decrease in production is generally associated with the migration of pri-

vate factors to the region in which public capital increases (Boarnet, 1998). We find a serious mismatch between the sensible theoretical explanation and the empirical testing of the hypothesis. In fact, a negative coefficient of public capital in a production function is interpreted as evidence of a negative spillover. However, this negative coefficient shows a decrease in production when public capital increases in a neighboring region while keeping constant private factors and public capital in the region analyzed. Therefore, the finding of a negative spillover in a production function cannot be attributed to the migration of private factors across regions.

Finally, we would like to briefly discuss the role of congestion of public capital in the spillover effect [11]. Congestion of public capital in neighboring regions seems to have been largely overlooked in previous research. In fact, the models referred so far in the present paper do not include any measure of the degree of utilization of public capital in neighboring regions. However, it is reasonable to expect that the effect of public capital will depend on its degree of utilization. For example, a road can have a different impact depending on whether it is barely used or heavily congested. On the other hand, the inclusion of private inputs as explanatory variables controls for the degree of utilization of public capital in the region analyzed. In fact, private inputs can be seen as «proxies» for economic activity. However, the models in (9) and (10) do not include any allowance for the degree of utilization of public capital in neighboring regions. We propose to address this issue by dividing public capital in a neighboring region by a variable that measures the utilization of that public capital. Some candidates are the surface area of the region, population and employment.

The correction using the surface area of the region yielded almost the same results as in table 1. The only difference appeared in the fixed effects. This was expected since the surface area is time-invariant. Another issue is that the surface area is not necessarily related to economic activity if there is substantial spatial agglomeration of population and economic activity. In table 2 we show the results of estimating the three models by dividing adjacent public capital by labor in the adjacent region (the results using population, not reported in table 2, were very similar).

The estimates of the parameters other than adjacent public capital do not change much in relation to the estimates in table 1. However, the estimation of the effect of public capital in bordering regions is quite different in the model of Holtz-Eakin and Schwartz, where we now find negative spillovers of public capital. The Additive-Effective Capital model still yields no spillover effect. Finally, the comparison of the coefficients in the two equations of Mas *et al.* shows a very small increase in the coefficient of adjacent public capital. Therefore, the results about the existence of spillover effects are inconclusive when we correct public capital in adjacent regions by some measure of congestion.

Table 2
Estimation correcting adjacent public capital by employment

		Holtz-Eakin and Schwartz		Additive Effective Capital		Mas *et al.* Eq. 13a		Mas *et al.* Eq. 13b	
Variable	**Par**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**
*ln*K	$\alpha\prod$	0.189	7.45	0.187	7.62	0.188	7.40	0.188	7.38
*ln*L	$\beta\prod$	0.244	11.51	0.254	12.68	0.253	12.13	0.254	12.15
*ln*G	$\gamma\prod$	0.012	5.06	–	–	0.010	4.66	–	–
G^{A1}	$\delta\prod$	–0.0015	–2.12	–	–	–	–	–	–
$ln(G+\theta G^{A2})$	$\gamma\prod$	–	–	0.015	3.48	–	–	–	–
G^{A2}	$\theta\prod$	–	–	4.59	0.84	–	–	–	–
$ln(G+G^{A2})$	γ^{A}	–	–	–	–	–	–	0.012	4.71
T	ϕ_t	0.037	18.89	0.036	18.58	0.036	18.32	0.036	18.18
T^2	ϕ_{tt}	–0.001	–12.07	–0.001	–12.23	–0.001	–11.85	–0.001	–11.82
Z	ϕ_z	–0.027	–2.51	–0.022	–2.19	–0.024	–2.26	–0.023	–2.20
D93	ϕ_1	–0.034	–5.86	–0.035	–6.22	–0.034	–5.86	–0.034	–5.92
D94	ϕ_2	–0.032	–5.55	–0.033	–5.84	–0.032	–5.49	–0.033	–5.54

5. Conclusions

In this paper we have reviewed different approaches for testing for the existence of spatial spillovers of public infrastructure. In particular, we analyze the implications of using an additive versus a multiplicative aggregator of public capital in neighboring regions. The main differences arise from the substitution between public capital within the region analyzed and public capital outside this region.

In the empirical part of the paper we find for our sample of Spanish provinces that the method developed by Holtz-Eakin and Schwartz shows that there are no spillover effects of public capital in adjacent regions. The same result is found when using a linear aggregator, which to the best of our knowledge has not been employed in this literature. On the other hand, the approach developed by Mas *et al.* concludes that spatial spillovers exist. However, this result has to be treated with caution since, as we show in the paper, it is obtained under parametric constraints not supported by the data.

Finally, after controlling for possible congestion in the public capital of adjacent regions the evidence about spillover effects is mixed. While no evidence of the spillover is found using the additive model, the Holtz-Eakin and Schwartz model now shows that there are negative spillovers. This suggests that more effort is needed to improve modeling of the spillover phenomenon.

Notes

1. By public capital we mean the stock of infrastructure built by the public sector. As such, public capital is different from public expenditure. Moreover, a distinction is usually made between what is termed «productive»

public capital (e.g., transport infrastructure) and «social» public capital (that related to education and health). The empirical literature cited below mainly uses the first concept, referring to it as «public infrastructure».

2. See García-Milá *et al.* (1996) for a comprehensive review of the problems involved in estimating state-level production functions.
3. In this paper we focus on the analysis of the role of public capital in production using a primal approach. Other papers have analyzed this issue using a dual approach (e.g. Morrison and Schwartz, 1996).
4. Here we write the effective stock of public capital as a function of the *observed* stock of public capital in other regions. Holtz-Eakin and Schwartz (1995) make the effective stock of public capital dependent on the *effective* stock of public capital in other regions, a formulation which complicates the problem.
5. Holtz-Eakin and Schwartz (1995) estimated model (3) using nonlinear least squares (NLLS) since their model is slightly different (see footnote 4).
6. Several papers that have followed this approach are Mas *et al.* (1996), Gil *et al.* (1997), Ezcurra *et al.* (2005), Lanzas and Martínez (2003), Álvarez *et al.* (2003) or Cantos *et al*. (2005).
7. These three options do not exhaust all the possibilities. Some papers check for across-region spillovers using different models or approaches. Moreno *et al.* (1997) use spatial econometric techniques, Pereira and Roca (2003) use a VAR model, while Rodríguez-Vález and Arias (2004) check for spillovers in the framework of a stochastic production frontier.
8. In this case the weights (w_{ij}) are assumed to be equal to one for adjacent provinces and zero for non-bordering provinces.
9. All models were estimated using Limdep V. 8 (Greene, 2002).
10. Using the delta method it can be shown that the t-statistic of this estimate is the same as the t-statistic of the parameter γ.
11. We thank an anonymous referee for raising this issue.

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Resumen

En este trabajo se analizan dos aproximaciones seguidas en la literatura empírica para contrastar la existencia de efectos desbordamiento del capital público. Además, se estudian las consecuencias de usar un agregador aditivo del capital público en regiones vecinas en vez del agregador multiplicativo usado previamente en la literatura. En la aplicación empírica se comparan las diferentes metodologías usando un panel de las 47 provincias peninsulares españolas. Los resultados empíricos no muestran evidencia de la existencia de efectos desbordamiento de las infraestructuras públicas.

Palabras clave: capital público, infraestructuras públicas, desbordamiento espacial.

Clasificación JEL: H54, R11, R53.