Productivity and accessibility of road transport infrastructure in Spain. A spatial econometric approach.

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Abstract

Empirical literature studying the effects of public capital on the performance of private enterprises remains inconclusive after more than 20 years since Aschauer seminal paper. Depending on the methodology adopted, the type of infrastructure and the level of data aggregation, a wide range of impacts have been found. While the results using aggregated models show significant effects, more disaggregated applications have reached low or no significant impacts. Traditionally, differences in these results have been explained because of the existence of regional spillovers and network effects caused by transport and communication infrastructure. According to this idea, the aggregate effect seems to be composed by direct and spillover effects of public capital formation. We firmly believe that consistency of the results in these works might be improved in two ways: testing for the existence of spatial dependence among regions and including an accessibility measure. This article pays special attention to road transport infrastructure impacts on the productivity of the Spanish economy. In particular, a classic production function is estimated testing different spatial econometric models including an accessibility measure for the 47 mainland Spanish provinces.

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1. Introduction

Measuring the economic effects of public infrastructure improvements on the productivity of private capital has been at the center of the academic debate for the last two decades[i]. The idea is that public capital plays a significant role as an input factor in the production process. The first empirical works regarding this issue come from the 1970s (Mera, 1973), but it is since the extraordinary results obtained by Aschauer (1989) when the research community showed a revived interest in matters of public infrastructure provision effects. In these early works the authors found a large and significant effect on the output caused by public capital (Aschauer estimated an output elasticity of approximately 0.4 and results in Munnell (1990) ranged from 0.31 to 0.39). In an age when productivity growth of most OECD-countries had experienced an important slowdown, policy administration and scholars wondered if this could be caused, at least in part, by an insufficient provision of public capital. In this context, Aschauer´s main findings were quite appealing, because an increase in public investment in infrastructure seemed a straightforward solution to the alarming productivity slowdown.

It is certain that enterprises need a minimum level of public infrastructure to produce their outputs and sell them in the markets, but one should not expect that the marginal output effect of extra public infrastructure will remain constant at every level of the latter. In the case of transport infrastructure, building an interstate network might cause an important increase of productivity but building a second might not (Hulten, 2004). Following these ideas, several methodological and conceptual objections appeared in response to early articles on public capital productivity: Issues of spurious relationships (García-Milà, McGuire and Porter, 1996), reverse causation bias (Fernald, (1999) and Chandra and Thomson, (2000)), the use of aggregate data at country and industry levels (Gramlich, 1994) and not taking into account dynamic feedbacks in the relationship between public capital and private-sector performance (Pereira, 2000). Subsequent research failed to find such large positive effects of public capital on private output: (Holtz-Eakin and Schwartz,1995). In fact, differences in estimates of public capital showed a geographical pattern: in these articles, regional data was used to fit the models obtaining low estimates of marginal productivity while the early studies, using national data, obtained large impacts. The criticisms of these works raised doubts about many theoretical and methodological shortcomings but generally neglected the economic impacts across boundaries.

Some researchers suspected the existence of spillover effects (Cohen and Morrison, 2004) understood as leakages: thus, the impacts generated from public capital formation would not be confined within a region. If spillovers are indeed present, part of the effect of public capital would be underestimated when using regional data. Recent developments in Spatial Econometrics methodologies have allowed exploring the potential existence of spatial interdependencies between observations, particularly when using data for geographically contiguous areas. Dealing with the issue of spatial dependence, often known as spatial autocorrelation, is justified by the existence of measurement errors in observations. These errors might follow a spatial pattern as a result from the arbitrary delineation of spatial units and a lack of correspondence between the spatial extent of the phenomenon of interest and the administrative boundaries for which data are collected. The latter is closely related to the wider impacts derived from transportation infrastructures including network and other types of spillovers.

Two alternative modeling approaches have been used in the spatial econometric literature to overcome the shortcomings caused by spatial dependence. The first, named spatial error model, incorporates a spatial autoregressive process among disturbances into a regression in a similar way to a first-order autoregressive model estimated when serial correlation exists. In empirical productivity literature authors like Cohen and Morrison (2004) and Kelejian and Robinson (1997) have used these models although the alternative method has been more popular. The second approach includes spatial dependence in a regression model adding, as additional right-hand regressors, variables corresponding to *neighbors* of a region. Ignoring a spatial lag when it should be in the model may affect the standard errors of elasticities of independent variables and may lead to erroneous inference. In this regard, we estimate a production function model that includes spatial lags of the independent variables, and also the spatial lag of the dependent variable. While some works have included the public capital in other regions to explain the produced output in a certain area, it is not usual to find the spatial lag of the output as an independent variable[ii].

When exploring the existence of spillover effects it should be beard in mind that different categories of public capital may not have the same spatial effects on output, i.e. urban and water facilities projects may enhance economic activities in local areas, whereas communication and transport infrastructure may cause important network effects. Transport infrastructures are one of the public capital components generating the greatest interest. Spillover effects seem especially important in this sort of projects because public endowments in a region may not affect only that region, but also other geographical units connected by a transport network (Boarnet, 1998). In fact, state highways are a natural focus to test these effects since, specially the interstate highway system, are designed with interstate linkages in mind (Holtz-Eakin and Schwartz, 1995). In the case of Spain, road transport infrastructures have been promoted specially, where implementation of the Infrastructure and Transport Strategic Plan raised the quality of the network to European levels in a short period of time. Delgado y Álvarez (2007) motivated their study on Spanish highways underlining the impact of the European funds assigned to finance infrastructure projects in less-developed areas in order to promote growth and cohesion within European Union Territories. Despite recent developments, also the nature of infrastructure spillovers remains inconclusive: positive and negative spillovers have been found. Positive spillovers are explained by the connectivity characteristic of transportation infrastructure: any piece of a network is related and subordinate to the whole system, increasing the interrelationships between areas (Moreno and López-Bazo, 2007). In case congestion exists, additional infrastructures would also enhance economic activity (Cohen and Morrison, 2003). On the other hand, a negative spillover could appear in case factor migration processes arise representing evidence of leeching behavior: infrastructure improvements in neighboring areas enhances the comparative advantage of that location and then the region would attract productive resources, assuming they are mobile (Boarnet, 1998). A recommendation from Cohen (2010) to test the direction of the spillovers, is that it can be important to examine the sign and significance of elasticities conditional to the geographical level (national vs. regional) and the type of infrastructure (transport vs. non-transport capital).

In this context, the objective of this study is to measure the output effect of road transport infrastructures in the case of Spain. In particular we aim to account for marginal productivity effects within a province and also contrast the existence of spillovers outside the local area. Most of the studies carried out in Spain to date has focused on the regional level NUTS 2[iii], but following the recommendations by Rephann and Isserman (1994) we build a more disaggregated database using NUTS 3 level. The spillover effects will be computed using spatial lag given in Anselin (1988) with alternative weighting matrixes and, moreover, road infrastructure endowment indicators are substituted by an accessibility measure in the production function. Stock capital indicators are not a satisfactory measure of the connectivity properties of the network, rather only of the quantitative properties of the infrastructure. Using this framework we try to overcome the usual problems in the literature that might be causing the current ambiguous state of results as pointed out by Mikelbank and Jackson (2000). These authors argue that any tool not considering the adequate geographic scale, the correct accessibility measures and the interactions between them will not capture the true relationship between space economy and public capital.

The structure of this paper is as follows. In section 2, we review the methodological issues of production function approach. In section 3, we describe the data used and the empirical models. In section 4, we present the estimation results. Section 5 contains some conclusions.

2. Theoretical background

In this paper we focus on the impacts of changes in productivity from greater infrastructures investments using a primal approach[iv]. The main aim of this article consists on the estimation of the output elasticity of road infrastructures, and to reach this objective, production function methodology is better than cost and profit function methods (Pfähler et al, 1996). Following a classical production model, value-added output (Y) of the regions is related to the amounts of quasi-factor private capital (K) and labor (L), and transport infrastructures capital (INF).

$$Y = f(L, K)g(INF) \qquad (1)$$

$$g'(INF) > 0$$
$$f_k > 0;\ f_{kk} < 0$$
$$f_l > 0;\ f_{ll} < 0$$

As it is shown in Equation (1), transport infrastructures are considered as an external factor of production whose choice is considered to be out of control of the firms. In addition, public capital is assumed to be complementary to both labor and capital. Also assuming factors of production are mobile and competitive markets, each factor will be paid its marginal revenue product.

Transport infrastructure is likely to produce spillovers in other regions. In order to explain the possible negative spillovers, we follow explanations by Boarnet (1998). Supposing an increase in public capital in region A, there would be a rise in the price of labor and capital in the region, inducing the resources to move from other regions to region A. This migration would yield a new output in region A,

$$Y_A = f(L_A + \Delta L, K_A + \Delta K)g(INF_A + \Delta INF) \tag{2}$$

reducing the output in the rest of the regions. Therefore, total output in one region would depend positively on its infrastructure stock and negatively on others´ because the existence of negative output spillovers. Foundations of the existence of positive spillovers rely on the network characteristics of transport infrastructures in which any piece is subordinate to the entire system (Moreno and López-Bazo, 2007). Congestion may play a crucial role when explaining positive spillovers: an increase in the provision of transport infrastructures where bottlenecks exist might improve the performance of the whole network.

In our model, the existence of spillover of public infrastructure will be tested introducing a spatial lag of the explanatory variables (INF_N) containing information about transport infrastructures as shown in Equation (3):

$$Y = f(L,K)g(INF, INF_N) \tag{3}$$

We expect that if finally spillovers exist, they will be stronger the closer the two regions. In order to test for the consistency of the results models are estimated using three different weighting matrices that will be explained in the next section.

The important role that the infrastructure plays in the economy of a region is determined by the infrastructure services it provides. Transportation projects cause important spatial location services, beyond reducing travel and logistics costs. They can enlarge the market potential of businesses, which can serve broader markets more economically. In addition, improvements in transport system can provide firms with a greater variety of specialized labor skills and input products, helping them to become more productive. Measuring infrastructure as a stock fails to take account of the actual supply of this services that determine its productivity contribution (Oosterhaven and Knaap, 2003). In order to overcome this problem, some authors have proposed the use of accessibility measures instead of the stock of infrastructure (Forslund and Johansson (1995) and Rietveld and Nijkamp, 2000). The concept of accessibility is closely related to the concept of mobility, development, social welfare and environmental impact. Therefore, accessibility can be thought as a proxy of a set of effects related or caused by transport infrastructure (Condeço-Melhorado et al. 2011). Introducing the accessibility measure provides an advantage over the variables infrastructures stock as it can be understood as a measure of the potential spatial interaction and also the intensity of spillovers.

Since the main purpose of this study is to compute the impact of road infrastructures on private sector performance, public infrastructures were divided in two different variables: one for roads public capital and other for the rest of modes of transport. Despite the large dependence of Spanish companies on road transport mode[v], other modes of transport endowments are also included to test for its possible impact. However, better information about road transport infrastructures and vehicles is available, and allows building an accessibility measure that accounts for road services.

Following Fernald (1999), we suppose that road services depend upon the flow of services provided by the aggregate stock of government roads (ROAD) as well as the stock of vehicles (VEH) as it is shown in Equation (4):

$$Roadservices_{it} = f(ROAD_{it}, VEH_{it}) \tag{4}$$

Based on Fernald´s idea as a starting point we have built a measure that relates the accessibility of a certain province with the stock of vehicles in that geographical area and also with the road infrastructures in other regions. As it is shown in equation (5),

$$Accessibility_{it} = VEH_{it} * \sum_{j}^{n} \frac{ROAD_{jt}}{d_{ijt}} \tag{5}$$

the potential *access* of the vehicles in province *i* to the infrastructures network in any other region *j* is weighted by the distance separating province *i* and *j*. Instead of using Euclidian distances between mainland provinces, time-variant distances were computed in a fashion discussed in the next section. Two alternative accessibility measures have been tested: One where the weighted sum includes all the other regions in Spain and another accessibility variable where just the k-4th nearest neighbors are taken into account. We impose a restriction in the access to road network to test for the sensitivity of this measure. We expect the impact to be larger in the unrestricted version of the variable because in this case, access to the whole road system would be granted for transport vehicles.

3. Data and Empirical model

In this section we discuss the data employed in the estimation of the model described in Section 2 and the econometric specification adopted. We use a balanced panel dataset of 47 Spanish provinces covering the period from 1997 to 2006. Data was collected from two main sources: Gross Added Value, measured in thousands of 2000s Euro and labor force, measured in thousands of workers came from the National Statistics Institute (INE). Latest series of capital stock for the Spanish economy were obtained from BBVA Foundation-Ivie (see Mas, Pérez and Uriel, 2007). New methodology applied to Spanish capital stock estimates is based in two OECD manuals (2001a, 2001b) and provides the distinction between net wealth and productive capital stock for each asset type. The productive capital stock or volume of capital services at constant prices is a quantity concept that takes into account the loss of efficiency as the asset ages, and it is the relevant concept for productivity analysis. The dataset contains disaggregated information for seventeen asset types and six types of infrastructure (road, water, railway, airport, port and urban infrastructure. Transport infrastructures have been collapsed into one single variable excluding the stock of roads because it is already included in the accessibility variable.

The measurement of the time-variant distance is carried out by a simple computation involving two variables available in the Permanent Survey of Road Transport of Goods (PSRTG), issued by the Spanish Ministry of Development. It is possible to retrieve the mean travel distance of the goods by dividing the total ton-kilometers by the transported tons in each origin-destination pair of provinces. The distance variable, measured in this way, reports information on the routes chosen by the transport companies. It might be seen as a proxy of the travel times between two provinces without the clear disadvantage caused by the selection of points of origin and destination in a discretionary way.

The empirical model we estimate is based on the log-linear Cobb-Douglas production function. We estimate two specifications relying on the results obtained in different tests explained in Section 4: one specification that includes time effects (Equation 6) and an alternative model with spatial fixed effects (Equation 7):

$$\begin{aligned}\ln Y_{it} &= \alpha + \lambda_t + \rho_1 \ln WY_{it} + \beta_1 \ln L_{it} + \beta_2 \ln HK_{it} + \beta_3 \ln K_{it} \\ &+ \beta_4 \ln Acc_{it} + \beta_5 \ln Trans_{it} + \rho_2 \ln WAcc_{it} + \rho_3 \ln WTrans_{it} + \varepsilon_{it}\end{aligned} \tag{6}$$

$$\begin{aligned}\ln Y_{it} &= \alpha_i + \rho_1 \ln WY_{it} + \beta_1 \ln L_{it} + \beta_2 \ln HK_{it} + \beta_3 \ln K_{it} \\ &+ \beta_4 \ln Acc_{it} + \beta_5 \ln Trans_{it} + \rho_2 \ln WAcc_{it} + \rho_3 \ln WTrans_{it} + \varepsilon_{it}\end{aligned} \tag{7}$$

Where ln denotes logarithm, ε is a well behaved error term, and subscripts i and t denote provinces and time periods, respectively. On the right hand side of the equation the following variables are included: labor (L) and human capital (HK), private capital (K), and the transport infrastructure variables: Accessibility (Acc) and other modes of transport (Trans). In order to control for neutral technical change, time dummies (λ_t) are also included in the first setting.

Moreover, the above equations include the spatial lag of the dependent variable and the spatial lag of some explanatory variables. This is the common approach in the literature to capture and measure the spatial spillovers effects: $WY_{it}=W\cdot Y_{it}$, $WAcc_{it}=W\cdot Acc_{it}$ and $WTrans_{it}= W\cdot Trans_{it}$, where W (N x N) is a spatial weight matrix which defines dependence across N regions. Three different criteria have been used to built W^{vi}. W_n stands for a physical contiguity matrix, in which its elements would be 1, for two bordering provinces and 0 for all others. W_{d150} is another binary weighting matrix in which its elements would be 1, for those provinces within a radius of 150 kilometers from the centroid of the province of reference and 0 for provinces beyond that distance. These matrixes treat physical proximity as the main driver for the presence of spillovers. Boarnet (1998) suggests adopting alternative criteria and as Delgado and Álvarez (2007) highlight, the spillover effect is more likely to be transmitted among those regions whose commercial channels are more intense. In this sense, we have created a symmetric matrix (*Wot*) using information about the bilateral road transport operations between the regions.

4. Results

In this section, we estimate the aggregate production function models proposed in Section 3 for the case of Spanish provinces. One option could be applying pooled OLS but it is too simplistic since the existence of spatial and/or time heterogeneity is omitted. Spatial and/or time specific variables may be introduced as explanatory variables to solve this. Spatial specific effects control for all time-invariant variables while time specific effects capture all spatial invariant variables.

We compute the common tests to analyze the existence of spatial dependence and then choose the most adequate model (spatial lag or spatial error) against a model without any spatial interaction effects. We calculate Lagrange Multiplier (LM) tests for a spatially lagged dependent variable and for spatial error autocorrelation, as well as the robust LM-tests which test for the existence of one type of spatial dependence conditional on the other . In first place (Table 1), the accessibility variable is not included into the explanatory variables when the different models are estimated. Then, the models and specification tests (Table 2) are re-calculated including the accessibility variable obtained using the information of the neighboring structure provided by the spatial weight matrix (k-nearest neighbor). Our hypothesis is that the accessibility in each province is really conditioned by its neighboring provinces.

In the first case, the Langrange Multiplier tests and their robust version point out the existence of spatial autocorrelation.

Table 1
Results of the specification tests without the accessibility variable

Model	Pooled OLS	Spatial fixed effects	Time-period fixed effects	Spatial and time-period fixed effects
LMlag	14.9439 (0.000)	108.9218	58.9710	1.9686 (0.161)
R-LMlag	1.2812 (0.258)	61.3312	30.8094	5.1677 (0.023)
LMerror	263.7635	47.6551	153.7499	0.0772 (0.781)
R-LMerror	250.1008	0.0645 (0.800)	125.5883	3.2763 (0.070)

Furthermore, the comparison of the obtained results allows testing one of the beliefs in the spatial economic and econometric field: the existence of spatial autocorrelation is consequence of a misspecification problem, i.e., an important economic phenomenon is not included into the explanatory variables (Anderson and Grassjo, 2009). In this case, there are differences in the value of the LM statistics when the accessibility variable is included into the model but the spatial autocorrelation does not disappear.

The likelihood ratio test (LR) is performed to test if the spatial fixed effects are jointly insignificant. Similarly, the hypothesis that the time-period fixed effects are jointly insignificant must be rejected. These test results justify the extension of the model with spatial and time-period fixed effects, which is also known as the two-way fixed effects model (Baltagi, 2005).[vii]

Table 2
Results of the specification tests with the accessibility variable

Model	Pooled OLS	Spatial fixed effects	Time-period fixed effects	Spatial and time-period fixed effects
LMlag	4.1774 (0.041)	49.7561 (0.000)	12.1534 (0.030)	2.5475 (0.110)
R-LMlag	1.7519 (0.186)	27.5782 (0.000)	4.7368 (0.000)	9.0061 (0.003)
LMerror	274.4081 (0.000)	22.2230 (0.000)	56.6871 (0.000)	0.0024 (0.961)
R-LMerror	271.9826 (0.000)	0.0450 (0.832)	49.2705 (0.000)	6.4609 (0.011)

Using this model specification, the test results point to a spatial lag specification. However, following Elhorst (2010) we consider a spatial Durbin specification where the spatial lags of the explanatory variables (WX) are also included as regressors. The employed Maximun Likelihood estimation techniques deal with the problem of endogeneity that arises when including a spatial lag of the dependent variable on the right hand side of the equation.

Although the specification tests point to spatial lag or spatial error model, we may be careful in the model selection. In this sense, Lesage and Pace (2009) recommend to consider the spatial Durbin model where the spatial lag model is extended including the spatially lagged independent variables:

$$y_{it} = \delta \sum_{j=1}^{N} w_{ij} y_{it} + \alpha + x_{it}\beta + \sum_{j=1}^{N} w_{ij} x_{ijt}\theta + \mu_i + \lambda_t + \varepsilon_{it} \qquad (8)$$

Where β and θ are K×1 vector of parameters. On this model we test if the spatial Durbin can be simplified to the spatial lag model and the second hypothesis whether it can be simplified to the spatial error model (Burridge, 1981). If both hypotheses H_0: θ=0 and H_0: θ+δβ=0 are rejected, then the spatial Durbin may be the selected model. These hypotheses can be tested using Wald or LR test and the results are summarized in Table 3. In this paper, we are following Elhorst (2010) and the model selection strategy could be considered as a mixed between the bottom-up strategy and the general to specific alternative recently developed.

Table 3: Specification test of the spatial panel data models

	Spatial fixed effects	Time fixed effects	Spatial and time fixed effects
Wald test spatial lag	57.4924	180.1093	20.9106
LR test spatial lag	41.6698	106.4926	21.3739
Wald test spatial error	84.3165	193.4343	19.8300 (0.0013)
LR test spatial error	84.3165	10.9660 (0.0521)	24.2117

Hausman's specification test can be used to test the random effects model against the fixed effects model (see Lee and Yu, 2010b for mathematical details). The result (39.05, 11 df, $p<0.001$) indicate that the random effects model must be rejected. This conclusion is confirmed using the estimation of the parameter "phi" (Baltagi, 2005), which measures the weight attached to the cross-sectional component of the data and which can take values on the interval [0,1].

We find phi=0.014822, with t-value of 6.856, which just as Hausman's specification test indicates that the fixed and random effects models are significantly different from each other. The same conclusion is obtained when only the spatial fixed effects or time fixed effects are included in the model speciation. The Hausman statistic values in both cases are 100.259 and 314.9529).

The results obtained through the estimation process are displayed in Table 4 and Table 5, including time effects and spatial effects respectively. Both Tables contains the estimates of the production function model with the inclusion of the accessibility variable not restricted, and those results yielded by the model with the accessibility variable restricted to the k-4th neighbors. The different specifications of the models are estimated using three alternative spatial weight matrices as it was described above.

Overall, the results are consistent with other production function studies and indicate the existence of transport infrastructure spillovers. As explained below, there are some results shared by all the estimated models. The R^2 is above 98% in all the models showing a high fit between the Output and the independent variables. All the specifications of the model including time effects (Table 4) yield similar results regarding the output elasticities of labor, human capital and private capital. Moreover, these elasticities are quite stable. The elasticities of labor (around 0.56) and private capital (between 0.25 and 0.30) are positive and significant in all the models, and the values are around the share of these two inputs in aggregate output. The variable human capital is also positive and significant showing the higher productivity of those employees with a better qualification compared to those with a lower education.

Estimations of the output elasticity of other modes of transport capital are also positive and significant and show quite stable pattern regardless the empirical specification. The estimated coefficients accompanying accessibility are positive and highly significant although their sizes show greater variation. Results obtained for the accessibility variable when it is not restricted are around 0.22, being twice the elasticity yielded by the model when this variable is restricted to k-4th neighbors . This difference is an expected result. In the first measure, the province has access to the entire road network so the impact is likely to be higher. If the vehicles in the province are supposed to be unable to reach the whole network, and they can just use a part of it, we expect the impact of this infrastructure on the productivity to be lower.

As it has been explained in the previous section, the presence of spillovers is tested through the use of spatial lags employing different weighting matrixes. In the first model, where the whole road network system is usable, we find strong evidence of negative spatial spillovers for the accessibility variable. As it is shown in Columns 1 to 6, the estimated parameter is larger in absolute terms when we use information of the number of transport operations between provinces (-0.099) than in the case of the contiguity matrix (-0.092). The interpretation of this result is not straightforward. Negative sign of the spillover measure is usually interpreted as if a better accessibility causes an attraction of private productive factor from those regions with lower public capital endowment (Boarnet, 1998). In our case, it would be indicating that this effect would be stronger the higher commercial linkages between provinces than in the restricted case of using just provinces sharing a border. Results obtained when the spatial lag is applied to those provinces falling within a radius of 150 kilometers is an intermediate case, because it mostly includes contiguous provinces and some others. Using this matrix to weight the road accessibility we found a lower negative spillover effect in absolute terms. As for the rest of modes of transport spillovers, using this specification of the model we found no clear evidence of its existence. The coefficient accompanying the spatial lag of the dependent variable is significant and moves in the interval 0.84 – 0.123 using the W_{ot} matrix and W_n matrixes respectively. This result indicates that the weighted average of the output of neighbor provinces affect positively the production in the greographic unit under analysis.

Private inputs elasticities are hardly modified when accessibility variable is restricted to k-4th nearest neighbors. On the other hand, we find major changes in variables capturing spillovers. Road accessibility spillovers are now positive meanwhile other modes of transport infrastructure spillovers are significant and negative. It is also worth noting that the spatial lag of the dependent variable is still positive and significant, but in the case of using W_{d150} it becomes statistically insignificant.

In Table 4, we present results of the spatial Durbin model including spatial effects. Private factors estimated coefficients present an important decrease in their magnitudes when introducing spatial effects[viii]. Labor elasticity moves around 0.25 and it is always highly significant. Coefficients of the variables human capital and stock of the rest of transport infrastructure are statiscally no different from zero. Elasticity estimates of private stock of capital are positive but very low.

Changes in the accessibility measure elasticities are also remarkable. Its magnitude ranges from 0.021 to 0.093 while its upper limit in the setting with time dummies was 0.227 and the lower was 0.096. The spatial spillovers of independent variables are also significant when including spatial effects, although our findings show switched signs. In this specification, spillovers from accessibility are positive, whereas negative spillovers from other transport infrastructure are found.

Table 3: Spatial Durbin model with TIME EFFECTS

	Accessibility measure Not Restricted						**Accessibility restricted to K4 neighbors**					
	Wn		**Wd150**		**Wot**		**Wn**		**Wd150**		**Wot**	
	(1)		**(2)**		**(3)**		**(4)**		**(5)**		**(6)**	
Variable	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**
L	0.563***	26.71	0.567***	25.45	0.566***	22.71	0.587***	23.28	0.571***	22.82	0.539***	22.25
HK	0.193***	8.25	0.178***	6.97	0.135***	5.87	0.192***	7.47	0.169***	6.21	0.152***	6.37
K	0.232***	12.95	0.245***	12.91	0.241***	12.58	0.293***	15.11	0.300***	15.25	0.306***	15.77
Acc	0.227***	11.99	0.206***	10.59	0.206***	11.78	0.096***	6.36	0.108***	7.28	0.116***	9.69
Trans	0.0286***	4.47	0.033***	4.95	0.038***	5.69	0.031***	4.39	0.032***	4.39	0.038***	5.64
W*Acc	-0.092***	-4.97	-0.062***	-3.53	-0.099***	-3.16	0.032**	1.99	0.042***	2.77	0.073***	2.62
W*Trans	0.020*	1.73	0.01	0.88	-0.024	-0.82	-0.023*	-1.93	-0.026**	0.889	-0.0142***	5.01
W*Y	0.123***	8.99	0.086***	5.77	0.084***	11.68	0.023*	1.82	-0.003	-0.166	0.069***	9.02
Intercept	3.146	-	3.29	-	3.648	-	4.356	-	4.279	-	3.648	-
Corrected R2	0.991		0.99		0.984		0.991		0.99		0.984	
Log-likelihood	453.103		493.405		457.444		453.103		493.405		455.8	
N. Obs.	470		470		471		470		470		471	

*Time dummies estimated coefficients not shown. * Significant at 10%. ** Significant at 5%. *** Significant at 1%*

Table 4: Spatial Durbin model with SPATIAL EFFECTS

	Accessibility measure Not Restricted						Accessibility restricted to K4 neighbors					
	Wn		Wd150		Wot		Wn		Wd150		Wot	
	(1)		(2)		(3)		(4)		(5)		(6)	
Variable	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**	**Coef.**	**t-ratio**
L	0.249***	9.16	0.257***	9.40	0.253***	9.50	0.277***	10.08	0.289***	10.52	0.266***	10.08
HK	-0.001	-0.01	0.002	0.13	-0.017	-1.29	0.015	1.18	0.018	1.41	-0.012	-0.94
K	0.061**	2.14	0.058 **	2.09	0.044	1.63	0.082***	2.91	0.083**	2.09	0.051	1.91
Acc	0.082***	5.96	0.093***	6.71	0.067***	5.11	0.049***	4.74	0.057***	5.43	0.040***	4.40
Trans	-0.005	-0.89	-0.003	-0.51	-0.009*	-1.65	-0.001	-0.18	0.002	0.34	-0.006	-1.18
W*Acc	0.053***	(3.18)	0.040**	2.48	0.077***	4.11	0.032***	2.69	0.021*	1.79	0.082***	4.59
W*Trans	-0.028**	-2.54	-0.033***	-2.71	-0.020	-1.04	-0.020*	-1.85	-0.028***	-2.26	-0.022	-1.18
W*Y	0.174***	3.27	0.180***	3.54	0.120*	1.78	0.275***	5.83	0.278***	6.15	0.165**	2.52
Corrected R2	0.95		0.949		0.953		0.946		0.944		0.952	
Log-likelihood	1138.65		1134.87		1148.44		1127.31		1123.39		1145.76	
N. Obs.	470		470		470		470		470		470	

*Spatial fixed effects not shown. * Significant at 10%. ** Significant at 5%. *** Significant at 1%*

5. Conclusions

In this paper we try to find a correct specification of an aggregated production function in order to measure the impacts of road infrastructure endowments on the economy of Spain. The main contribution of the work is the creation of an accessibility variable that combines the stock of vehicles in a certain province with information about the surrounding road network weighted by the distance. Using this variable, we try to avoid shortcomings caused by the use of stock variables of transport infrastructure.

The empirical models include spatial lags of the independent variables and also of the dependent variable, which it is not a common approach in the literature. Controlling, alternatively, for spatial effects and time effects, we find strong evidence of the positive impact of better road accessibility on the private economy. On the other hand, results show inconclusive evidence of spatial spillovers of transport infrastructures in line with most papers using Spanish provincial data: Delgado and Alvarez (2007) putting into practice a stochastic frontier approach found positive and negative spillovers depending on the sector of the economy under review and the definition of the weighting matrix. Moreno and López Bazo (2007) using a production function found the existence of negative spatial spillovers of transport infrastructure. In contrast, Álvarez et al. (2006) replicated the models used by Holtz- Eakin and Schwartz (1995) and Mas et al (1994) using data of Spanish provinces and did not find either positive or negative spillovers.

Some of the main future research lines that could be followed after this work are the use of alternative accessibility measures for road and other modes of transport. Furthermore, we are interested in exploring the application of different methodologies, specially the use of dynamic spatial panel models.

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[i] Different surveys on this topic compare the different studies focusing their attention on the methodology adopted and the data used. For a detailed discussion see: Gramlich (1994) and Pereira and Andraz (2010). Due to the high quality of available data in Spain a lot of empirical works have appeared recently. De la Fuente (2010) and Álvarez et al (2003) make an exhaustive revision of international works but also Spanish studies.

[ii] Exceptions of some papers introducing a spatial lag of the dependent variable in the study of productivity of public capital are Kelejian and Robinson (1997) and Cohen (2010).

[iii] There are several works exploding regional data to study this issue in Spain (for exhaustive information see recent survey by De la Fuente (2010)), whereas available papers using data on provinces are just a few: Álvarez et. al (2003), Delgado and Álvarez (2007) and Moreno and López Bazo (2007).

[iv] Other papers have deal with this issue through a dual approach. Cost function models rely on duality theory and allow for a richer analysis through the estimation of optimal input demand equation. Among the shortcomings of this type of model is that information on factor prices is required. Estimating a profit function is an alternative that allows for estimating unconditional demand effects but it is even more extensive than cost function approach in data requirements. Information required by cost and profit function approaches is not available at NUTS-III level in Spain.

[v] According to the National Statistics Institute, road transport mode was chosen in more than 77% of freight movements in Spain in year 2007.

[vi] The three weighting matrixes have been row normalized following a standard practice in the spatial econometric literature. After the transformation, the sum of all elements in each row equals one. Note that the row elements of a spatial weights matrix show the impact on a particular unit by all other units.

[viii] Elhorst (2010) emphasize that empirical works usually find significant differences among the coefficient estimates from models with and without spatial fixed effects. Models that include spatial fixed effects use the time-series variation of the data, whereas models without controlling for spatial fixed effects utilize the cross-sectional component of the data. Models of the first type would tend to give short-term estimates and models without controls for spatial fixed effects would tend to give long-term estimates (Baltagi 2005).