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## External Effects And Cost Of Production

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# **40<sup>th</sup> European Regional Science Association Congress**

## **EXTERNAL EFFECTS AND COST OF PRODUCTION**

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### **Abstract:**

This paper addresses the role of external effects in the process of production. We define two types of external effects: those derived from inputs external to the firm but which affect its production, and those derived from externalities that cross the barriers of a given economy. Using a production function that explicitly considers the presence of both types of external effects, we derive a cost function by application of the duality theory. This cost function includes the external effects and at the same time it takes into consideration the different relationships between inputs. Two types of externalities across economies are then addressed: those arising from interactions across regions and those due to linkages across industries. We propose the application of spatial econometric techniques to test for the presence of such spillovers. For regional externalities, we focus on the physical interaction between regions, while sectoral interdependencies are obtained through the use of input-output relationships. Some specific characteristics of the resulting empirical model (cross-section and time-series dimension of the data and nonlinearity in some of the parameters) are discussed from a spatial viewpoint. We apply this framework to the case of manufacturing industries in the Spanish regional economies from 1980 to 1991.

"The Whole is more than the sum of the parts, in that, not only does the interrelation of parts bring out latent characteristics in each, as in any complex, but the complex as a whole takes on a new character not explainable out of the parts" (Hartshorne, 1939).

## 1. INTRODUCTION

Recent studies (Romer, 1986; Lucas, 1988) have stressed the importance of factors external to the firm in the production process. These factors are supposed to have a direct effect on the level of production or to enhance the productivity of traditional inputs. Broadly speaking, we can identify two types of external effects. Firstly, those inputs within the economy in which a firm is located that are not directly remunerated by the firm, but contribute to the production process (for example, the level of human capital, the stock of public capital or infrastructure, and the amount of social capital). Hereafter, we will refer to this type of external effect as external inputs. Secondly, externalities from different sources that are assumed to cross the *barriers* of the economies that generate them -be they industries or countries/regions. These externalities across economies have recently been considered in open versions of the growth models from a theoretical point of view, whereas several papers have also reported empirical evidence.

Specifically, the empirical literature on economic growth in the last decade has generally considered external inputs as engines for increases in total factor productivity. Aschauer (1989), Munnell (1990), Garcia-Milà and McGuire (1992) among others have analyzed the contribution of the stock of public capital in the performance of an economy, whereas Kyriacou (1991) and Benhabib and Spiegel (1994), *inter alia*, have devoted special attention to the role of human capital as a factor in the growth process. Although some results lend support to the relevance of such factors, a lack of robustness seems to characterize the outcome of the analyses.

When it comes to externalities across economies, several studies (Caballero and Lyons, 1992; Burnside, 1996), starting from the seminal paper by Caballero and Lyons (1990), have sought to test empirically the existence of spillovers across industries within an economy and to estimate their magnitude. It is argued that using national aggregates instead of industry disaggregated data does not enable returns to scale that are external to the industry and that end up internalizing at a national level to be identified. This implies gathering internal returns to scale and external returns together in the same

parameter. One of the practical implications of this is that, unless properly specified, external economies may cause the estimated internal returns to scale to be biased. A similar problem is found when considering the possibility of externalities crossing geographical barriers of economies. A country is simply an administrative delimitation so that when considered in isolation, across-economy linkages are mixed with the country's own returns. Thus, part of the growth experienced by an economy may be due to a contagious effect, i.e. an economy grows because those that neighbor it are growing at a high rate. This idea is not unlike the relationship between growth, international trade and the diffusion of knowledge across economies (Grossman and Helpman, 1991; Coe and Helpman, 1995; Park, 1995). Trade makes products and services that embody foreign knowledge available and provides technologies that would otherwise be unavailable or very costly to acquire. Another line of argument in the literature looks beyond the trade-diffusion channel, seeking other sources for technology flows (Verspagen, 1997; Keller, 1998). Whatever the case, this paper holds with the idea of the importance of externalities, both across industries and across geographical units, while introducing three new ideas.

First, we proxy across-industry spillovers by using a measure that accounts for forward and backward linkages across sectors, instead of a raw measure for thick-market effects as has been usually adopted. Concerning spillovers across aggregated economies, we descend to a regional level given that externalities can be expected to be higher. Besides, we support the belief that geographically close regions may be more related due to pecuniary as well as technological external effects.

Second, for the empirical consideration of externalities we use techniques from spatial econometrics. To date, most empirical analyses have not devoted special attention to an econometric method capable of robustly testing and estimating externalities of this kind. Our empirical exercise directly addresses this issue. Specifically, we assess the adequacy of traditional spatial statistics for detecting externalities and adapt them to the specific features of our empirical model (nonlinearity in some of the parameters and the cross-section and time-series dimension of the data). For regional externalities, we consider spatial dependence based on the interaction between contiguous regions. When it comes to sectoral spillovers, we suggest the transfer of the idea of spatial dependence to a sectoral context, in which the assumption of industrial interdependence is obtained by using input-output relationships.

Finally, most of the studies analyzing external inputs or across-economy linkages

have focused on the utilization of production functions. However, here, using a production function that explicitly considers the presence of externalities, we derive a cost function by application of the duality theory. In this framework, the impact of external effects on costs of production can be potentially broken down to see their effect through each private input and the level of output, while we can separate such effects from input utilization. Thus, a better understanding of the mechanisms behind the effects of such externalities can be derived.

The paper is organized as follows. In the second section we review the literature on the sources of regional and industrial externalities. The role of what have been termed external inputs is well illustrated in the literature on economic growth, and thus no further discussion is provided here. Section three presents the conceptual model based on the duality theory including external effects. In section four we suggest an empirical framework to be used in testing for the existence of external effects and estimating their impact. Section five describes the database. In section six we apply the theoretical and empirical framework to the case of the manufacturing industries in the Spanish regions from 1980 to 1991. Finally, section seven concludes.

## **2. SOURCES OF REGIONAL AND INDUSTRIAL EXTERNALITIES**

Evidence of the spatial concentration of economic activity has been widely reported (Krugman, 1991; Glaeser *et al*, 1992; Henderson, 1992). A simple look at a map depicting density of activity reveals how its spatial distribution is neither random nor homogeneous. Rather, firms tend to cluster spatially depending on the previous location of other firms in the same (*Marshall-Arrow-Romer* and *Porter* externalities) or in different (*Jacobs* externalities) industries. Although a firm can freely select its geographical location, the probability of each possible location in a given territory of being selected is not equally distributed (Ellison and Glaeser, 1997). There is a tendency to concentrate economic activity in locations that offer advantages due to the existence of large, specialized markets. Marshall (1920) explained the concentration of industries in a territory through the concept of external economies operating as a centripetal force. Specifically, Marshallian externalities explain the geographical concentration of economic activity due to the presence of highly specialized markets for labor and intermediate inputs, forward and backward linkages in the production process and the quicker and easier diffusion of ideas, technology and information. These first two factors have been

considered as pecuniary externalities by Scitovsky (1954) and incorporated in the new theories of industrial location and trade as engines for agglomeration. Examples of the latter are provided by Krugman (1991), Krugman and Venables (1995), Puga and Venables (1996), and Martin and Ottaviano (1999), who explicitly address the role of agglomeration economies as the main engine for endogenous growth. Similarly, technological innovation, which has been considered as a central element not only for the individual firm but also as an explanatory factor in aggregate growth, is supposed to diffuse easily and quickly across closely located firms.

While recognizing the importance of proximity, our assumption here is that external effects may spill across economies. This being the case, two types of externalities should be considered, across industries and across geographical units (regions or countries).

### **Industrial externalities**

Several mechanisms justify the existence of externalities across firms within a geographical area. For instance, when investing in physical capital, one firm is accumulating knowledge from which the other firms might benefit, increasing their own productivity, without incurring any costs (Arrow, 1962). In other words, when one firm buys intermediate goods from another, it is paying less than all the information embodied in these goods since the innovative firm is not able to internalize the whole benefit the innovation implies. This phenomenon is known as knowledge spillover. Further, there is another externality mechanism linked to physical capital based on the existence of complementarities between activities and firms, developing advantages of within-industry specialization (Durlauf, 1991).

Even though most of the externalities in the paragraph above focus on economies external to the firm though internal to the industry (so-called industry-specific externalities), of greater interest to us here is the assumption of spillovers across industries, as reported in studies by Chang (1981), Diamond (1982) and Herberg *et al.* (1982). In these papers externalities correspond to transaction or thick-market effects arising from easier matching between agents during expansions. Firms in the industrial sector are linked by input-output relationships that create forward and backward linkages. If transport costs are assumed to exist, proximity to suppliers allows costs to be reduced, thereby generating forward linkages. Similarly, proximity to customers

generates backward linkages. In this sense, Bartelsman *et al.* (1994) find a clear prevalence of the customer-driven externality in the short run whereas the linkage with suppliers is the dominant factor in the long run. Further evidence is provided by Keller (1997). He estimates the elasticity of total factor productivity with respect to own-industry R+D investments and other industries' investments. His results show how elasticity for investments in other industries is strongly significant, representing between a fifth and a half of the elasticity to own R+D investments. As a consequence, if R+D investments adequately proxy for the improvement in technology levels, it is worthwhile considering externalities across industries.

To end with this brief summary on previous evidence of spillovers across industries, we return to the papers by Caballero and Lyons (1990, 1992). They proxy the externality through the introduction in the production function for each industry of output at one aggregation level higher.<sup>1</sup> They show that, for a given input level, an industry's output is significantly higher on average when the aggregated output is high. Furthermore, they give evidence that, for instance, the estimate of the degree of returns to scale is larger for the manufacturing sector as a whole than for the two-digit industries. This difference is due to the externality that is only internalized at the most aggregate level. When considering aggregated data, returns to scale external to the industry cannot be identified, since external economies become internal as the aggregation level rises. A similar reasoning when the units of analysis are aggregate economies, such as regions or countries, suggests the importance of considering spillovers across them. However, this being the case, evidence of the existence of externalities across regions or countries needs to be provided.

### **Spatial externalities**

Up to this point, we have focused on externalities in terms of spillovers across industries within one economy. However, the world economy has undergone a major globalization process during recent decades. Inventions and innovations generated anywhere are easily and quickly absorbed and adapted elsewhere. Undoubtedly, among other factors, direct

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<sup>1</sup> As the authors explicitly state, this way of considering the external effect may cause endogeneity problems when estimating by ordinary least squares (OLS).

foreign investments and trade of intermediate and final goods play an important role in such a process. Indeed, trade relationships are much more important nowadays, particularly between countries belonging to integrated trade areas such as the EU and the NAFTA. Countries trade with each other, establish links with each other and learn from each other more than ever before. But empirically each economy has been treated as an island so that economic growth depends solely on its own factors. However, it is logical to think that there are growth sources that spill over the scope of an economy. The increasing exchange of goods and knowledge at an international level has led to an increasing interdependence in growth in different countries (Coe and Helpman, 1995; Ciccone, 1996).

If we consider regional economies these interdependence mechanisms are expected to increase in importance. The existence of common output and input markets is more likely at a regional level within a single country than among countries. Another reason why externalities may flow easily across geographically close regions is the existence of local social conditions that play a significant role in the way each economy incorporates and adapts innovations (Rodríguez-Pose, 1999). If the regions of a country share similar local conditions, knowledge spillovers between them may be more intense. In this sense, Kollmann (1995) observed that productivity growth is more strongly correlated across the states of the US than across the G7 countries.

Several authors have considered external effects, and particularly innovation diffusion, to be more important among groups or clubs of economies. Durlauf and Quah (1999) consider that if groups of economies were generated naturally, the average income to which they would converge would change, in general, for the different groups. One might also state that the closer the regions, the more intense the role of trade and technological diffusion. The importance of the geographical proximity of the units of production for innovation transmission has been widely pointed out (Henderson, 1992; Glaeser *et al.*, 1992). Thus, we should think of diffusion of innovations and ideas across geographically close units rather than across distant economies.

Even though theoretical and empirical evidence seems to support the existence of externalities across industries and regions, it is not clear as to which are stronger. Costello (1993) shows how total factor productivity growth is more strongly correlated across industries within one country than across countries within one industry. Conversely, Kollmann (1995) concludes that correlations across industries within a



region are weaker than across regions within an industry. While López-Bazo *et al.* (1998) observe how both sources of externalities are similar in magnitude in the Spanish economy. These results support the relevance of transfers of technology across regions. The high degree of integration among the US states or the regions in Spain may explain why technology and growth spread more intensively than across heterogeneous countries.

Despite these arguments, studies explicitly considering such externalities across economic areas are few. We can point out those by Barro and Sala-i-Martin (1995, ch.12), Ciccone (1996) and Ales and Chua (1997) in the case of countries, and Quah (1996), López-Bazo *et al.* (1998), Fingleton and McCombie (1998), Vayá *et al.* (1998) and Rey and Montouri (1999) in the case of regions. The remaining sections follow the line of argument adopted in these studies in an attempt to assess simultaneously the significance and strength of both types of spillovers in the cost of production.

### 3. THEORETICAL FRAMEWORK: DUALITY THEORY AND EXTERNAL EFFECTS

This section aims at summarizing the key points in a cost function that is extended to consider external inputs and spillovers across economies. Given the main objective of this paper, we will focus on the development of the elasticities measuring such effects, omitting the derivation of the traditional elasticities regarding private inputs and output.<sup>2</sup>

Let's consider an aggregate production function, where  $Y_{it}$  is the output in the  $i$ -th economy (region or industry) at time  $t$ , and  $X_j$  ( $j=1,...,r$ ) the  $j$ -th input:

$$Y_{it} = f(X_{lit}, X_{2it}, ..., X_{rit}) \quad (1)$$

According to the ideas advocating the role of external inputs and the existence of across-region and across-industry externalities, the output in an economy would also depend on the stock of the external inputs and the amount of inputs and output in the neighboring economies.<sup>3</sup> As a result, the specification of the production function should include a measure of such external effects in order to separate internal from external returns to

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<sup>2</sup> See Berndt (1991) and Morrison and Schwartz (1996) for a description of the usual elasticities.

<sup>3</sup> In the paper we use a broad concept of neighborhood. In the regional case it is referred to as geographical proximity, while in the sectoral case it is based on trade flows across industries.

scale. Thus, we obtain the following expression:

$$Y_{it} = f(X_{lit}, X_{2it}, \dots, X_{rit}, E_{it}, E_{pit}) \quad (2)$$

where  $E_{it}$  is a measure of the external input under consideration and  $E_{pit}$  the externalities across regions and industries according to what the index  $i$  refers to.

It is assumed that the firm is constrained to accept a vector of input prices,  $P_1, \dots, P_r$ , so that the optimization problem that firms face consists in determining the amount of inputs that minimizes the cost for producing a given output,  $\bar{Y}$ . Thus, the technology of the firm depicted by equation (2) can be represented by a variable cost function that will also include external effects:

$$VC_{it} = \sum_j P_{jit} \cdot X_{jit} = g(P_{lit}, \dots, P_{rit}, \bar{Y}_{it}, E_{it}, E_{pit}) \quad (3)$$

where  $VC$  is the level of variable costs and  $X_j$  the amount of input  $j$ -th, at the optimum.<sup>4</sup>

Specifically, taking into account the presence of externalities, the variable cost function used in this paper can be specified as follows:

$$VC_{it} = VC(P_{Lit}, P_{Mit}, \bar{Y}_{it}, Kp_{it}, E_{it}, E_{pit}) \quad (4)$$

where we consider two variable private inputs, labor ( $L$ ) and intermediates ( $M$ ) which appear in the cost function through their prices,  $P_L$ , and  $P_M$  respectively; and a quasi-fixed input, private capital ( $Kp$ ).<sup>5</sup> Therefore, this cost function permits the combination of internal scale economies in the production process due to private inputs (both variable and quasi-fixed) and the external scale economies, where there exist, provided by, different types of external inputs on the one hand, and across-economy spillovers, on the other. Besides, it overcomes one of the criticisms raised against empirical evidence on across-industry spillovers using the production function: the fact that significant externalities are due to variations in the use of internal inputs. Here, we consider  $Kp$  as an input that might not be at its optimum level in each time period. Thus, we can isolate the external effects on production from the over- or underutilization of capacity.

Assuming that variable input prices are exogenous to the producer, Shephard's Lemma (Shephard, 1953) states that it is possible to obtain the unique vector of the

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<sup>4</sup> See Chambers (1988) for detailed description of cost function properties.

<sup>5</sup> In order to test the assumption that private capital is a quasi-fixed input, the test developed in Shakerman and Nadiri (1986) can be used. The quasi-fixity of the private capital for the Spanish economy cannot be rejected (Moreno et al, 1998).

different variable inputs that minimize costs (cost-minimizing demands), and hence, their factor share ( $z_j$ ), that is, the percentage of the cost implied by the  $j$ -th input:

$$z_j = \frac{P_{ij} \cdot X_j}{VC} = \frac{\partial \ln VC}{\partial \ln P_j} = f(P_L, P_M, \bar{Y}, K_p, E, E_p) \quad j = L, M \quad (5)$$

For ease of notation, the variables in equation (5) and in subsequent equations do not carry indices for the period of time or the economy. Equations (4) and (5) constitute the solution to the equilibrium related to variable factors. Testing the validity of Shephard's Lemma is therefore equivalent to testing the validity of the restrictions on the parameters of the cost function and the share equations for variable inputs.

Once an empirical specification for the variable cost function has been estimated, the usual cost-private input elasticities and the elasticities of substitution between inputs can be obtained. However, here we focus on computing the effect on costs of the external input,  $E$ , on the one hand, and the spillovers across economies,  $E_p$ , on the other. It is important to note that, despite imposing constant parameters for all the individuals and time periods, general empirical functional forms allow a separate elasticity for each region/sector and time period to be obtained.

Concerning the first effect, in order to find out whether a marginal addition to the stock of an external factor decreases the cost per unit of output, the elasticity of production cost with respect to this input can be obtained as:

$$\epsilon_{VCE} = \frac{\partial \ln VC}{\partial \ln E} = \frac{\partial VC}{\partial E} \frac{E}{VC} \quad (6)$$

This elasticity will be negative as long as the external factor represents efficiency changes in terms of decreases in variable input utilization, and thus in costs. These effects can be computed as the elasticity of the conditional demand for private inputs with respect to  $E$ :

$$\epsilon_{X_j E} = \frac{\partial \ln X_j}{\partial \ln E} = \frac{\partial X_j}{\partial E} \frac{E}{X_j} \quad j = L, M \quad (7)$$

Second, we are interested in the quantification of the changes in manufacturing costs due to the presence of spillovers, in other words, due to the manufacturing performance in the neighboring economies (regions or industries). This elasticity is obtained as:

$$\epsilon_{VCE_p} = \frac{\partial \ln VC}{\partial \ln E_p} = \frac{\partial VC}{\partial E_p} \frac{E_p}{VC} \quad (8)$$

According to the literature of externalities, we can expect  $\epsilon_{VCE_p}$  to be negative in the

case of externalities enhancing production, indicating that the greater the interdependencies across economies, the greater the efficiency and hence, the lower the costs.

#### 4. SPATIAL ECONOMETRICS IN THE DETECTION OF SPATIAL AND SECTORAL EXTERNALITIES

As previously mentioned, various external inputs can affect the production process. Given that our empirical exercise illustrates the results obtained for the stock of publicly provided capital ( $K_g$ ), from now on we will use  $K_g$  instead of  $E$ . There are also a number of ways of accounting empirically for spillovers across economies. We present evidence for the case in which they are proxied by the level of output in the neighboring regions or sectors ( $Y_p$ ) as a measure of thick-markets. In addition, when analyzing the regional case we also include public capital in the neighbors ( $K_{gp}$ ) as another source of spillovers. Obviously, the method described can be applied to other measures in a straightforward manner.

##### Empirical cost function

In order to implement the duality theory, we assume a translog cost function, with the following form:<sup>6</sup>

$$\begin{aligned} \ln \frac{VC}{P_M} = & \beta_0 + \beta_L \ln \frac{P_L}{P_M} + \beta_Y \ln Y + \beta_{Kp} \ln Kp + \beta_T t + 0.5 \left[ \beta_{LL} \ln^2 \frac{P_L}{P_M} \right. \\ & \left. + \beta_{YY} \ln^2 Y + \beta_{KpKp} \ln^2 Kp + \beta_{TT} t^2 \right] + \beta_{LY} \ln \frac{P_L}{P_M} \ln Y + \beta_{LKp} \ln \frac{P_L}{P_M} \ln Kp \\ & + \beta_{LT} \ln \frac{P_L}{P_M} t + \beta_{YKp} \ln Y \ln Kp + \beta_{YT} \ln Y t + \beta_{KpT} \ln Kp t \end{aligned} \quad (9)$$

where  $t$  denotes a time trend that captures exogenous technical change. Applying Shephard's Lemma to equation (9) we obtain the share equations for variable inputs associated to the variable cost function above.

Following the reasoning in section 3, the variable cost function in (9) should be

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<sup>6</sup> This functional form permits the consideration of a great range of substitution possibilities and can be fitted to any production technology. We have introduced intermediates price as a relative factor to ensure that the function is homogeneous of degree one in factor prices. Besides, no kind of a priori returns to scale are imposed.

modified in order to include both the external input and the across-economy spillovers. In relation to the external input, in the regional case we consider the stock of public capital in the region itself. In the sectoral case, however, the stock of infrastructure is computed for each industry according to its importance in the whole manufacturing sector, that is the aggregate public capital stock is weighted in accordance with the proportion of the output of each industry. Thus, the potential utilization that each industry makes of the national public infrastructure endowment is accounted for.

Concerning the across-economy spillovers, we introduce output in the closest economies (regions or industries) together with its quadratic term and the cross-product with private capital. The former allows for a marginal effect of the externality and the latter picks up the fact that the more capitalized the economy, the more able it is to benefit from spillovers. Alternatively, this cross-product might indicate that private capital could be more profitable in an economy as externalities increase, as argued in Azariadis and Drazen (1990). In the regional case, we also consider the effect of the infrastructure stock in the neighboring regions as another source for spillovers. This kind of effect has been considered by Mas *et al.* (1996) and Kelejian and Robinson (1997) as another production input. However, we propose using a specification that allows a global effect for the whole notion of public capital through a geometric mean of own and neighboring regions' capital to be considered, that is,  $G_{it} = K_{g_{it}}^{\theta} \cdot K_{g_{pit}}^{1-\theta}$  where  $\theta \in [0,1]$ .<sup>7</sup> In this specification, the weight on the region's own public capital stock,  $\theta$ , is parameterized and estimated simultaneously with the other parameters in the model. The parameter  $\theta$  measures the contribution of the region's own public capital stock on manufacturing costs in the region, and  $(1-\theta)$  measures the importance of public capital in the neighboring regions on the costs in this region. This type of specification has two advantages. First, it implies a complementary relation between a region's own capital and that of its neighbors, reflecting the network characteristics of most transport and communication infrastructure. Thus, when considering the technology of production of a firm, what is included is a composite of infrastructures in the region in which the firm is

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<sup>7</sup> As far as we know, this specification has only been used in the literature concerning R&D spillovers (Jovanovic *et al.*, 1992, and Nadiri and Kim, 1996).

located and those in the neighboring regions, rather than both magnitudes separately. Besides, it avoids the addition of new regressors in the empirical model as a result of the interaction of each argument in the function with the others. This is important due to the problem of collinearity that characterizes the translog functional form, even though the inclusion of  $G_{it}$  in our empirical model necessitates the application of nonlinear estimation techniques. In contrast, it is worth noting that in the industrial case, the inclusion of the stock of public capital in the closest industries is pointless.

Therefore, when the external input as well as the two sources of across-economy externalities are introduced in the variable cost function given in (9) we obtain the following expression:

$$\begin{aligned} \ln \frac{VC}{P_M} = & \beta_0 + \beta_L \ln \frac{P_L}{P_M} + \beta_Y \ln Y + \beta_{Kp} \ln Kp + \beta_{Kg} \ln(Kg^\theta \cdot Kg_\rho^{1-\theta}) + \beta_T t \\ & + 0.5 \left[ \beta_{LL} \ln^2 \frac{P_L}{P_M} + \beta_{YY} \ln^2 Y + \beta_{KpKp} \ln^2 Kp + \beta_{KgKg} \ln^2 (Kg^\theta \cdot Kg_\rho^{1-\theta}) + \beta_{TT} t^2 \right] \\ & + \beta_{LY} \ln \frac{P_L}{P_M} \ln Y + \beta_{LKp} \ln \frac{P_L}{P_M} \ln Kp + \beta_{LKg} \ln \frac{P_L}{P_M} \ln(Kg^\theta \cdot Kg_\rho^{1-\theta}) + \beta_{LT} \ln \frac{P_L}{P_M} t \\ & + \beta_{YKp} \ln Y \ln Kp + \beta_{YKg} \ln Y \ln(Kg^\theta \cdot Kg_\rho^{1-\theta}) + \beta_{YT} \ln Y t + \beta_{KpKg} \ln Kp \ln(Kg^\theta \cdot Kg_\rho^{1-\theta}) \\ & + \beta_{KpT} \ln Kp t + \beta_{KgT} \ln(Kg^\theta \cdot Kg_\rho^{1-\theta}) t + \beta_{Yp} \ln Y_p + \beta_{Y_p Y_p} \ln^2 Y_p + \beta_{Y_p Kp} \ln Y_p \ln Kp \end{aligned} \quad (10)$$

The estimation of expression (10) in the regional case must be carried out by nonlinear least squares (NLLS) as a result of the nonlinearity caused by the interaction of  $\theta$  with the parameters measuring the effect of public capital. Given that the columns in the matrix of pseudo-regressors are linearly independent, the identification is guaranteed, although a high degree of collinearity may still exist characterizing such cost functions (see Berndt and Hanson, 1992, for a discussion). In the sectoral case, as argued above, we will deal with a simplified version of (10) in which  $\theta = 1$ .

### **Across-region externalities: Spatial Econometrics**

Were the external effects to be erroneously omitted, the estimation of expression (9) would suffer from spatial dependence, affecting the standard estimation and inference. In such a case, spatial econometrics provides the necessary tools to deal with this problem (Anselin, 1988). Using the concept of spatial lag we can rewrite the terms picking up the spillovers in expression (10). Thus,  $\ln Y_p$  can be expressed as  $W \ln Y$ , where  $W$  is a matrix defining across-region linkages. If we suppose that the information refers to a panel data

set with  $N$  regions and  $T$  time periods, and assuming there is only contemporaneous spatial dependence (that is, the effect of the externality is exhausted within the period in which it is generated), we can define a weight matrix  $W$  as a  $(N \times T) \times (N \times T)$  block diagonal matrix:

$$W = I_T \otimes C \quad (11)$$

where  $I_T$  is the  $(T \times T)$  identity matrix and  $C$  is a  $(N \times N)$  row-standardized weight matrix according to the physical contiguity criteria (1 for contiguous regions and 0 otherwise). Thus,  $W \ln Y$  is the weighted average of output in the contiguous regions as defined by  $W$ . The same idea is applied to obtain  $Kg_\rho$ ,  $W \ln Kg$ . It is important to note that we are working with the same set of parameters for the spatial effects throughout the period. That is, we think of an average for the spatial effects in the  $T$  time periods, as stated for the other parameters in the model.

Once the terms picking up the spillovers are quantified through the weight matrix, it can be observed that our empirical model results in a mixed regressive-spatial crossregressive model (Anselin, 1988) in which only some of the regressors enter with their spatial lags. Thus, taking into account that this model is built on a theoretical background, the logical procedure is to estimate expression (10) before checking the global significance of the proposed external effects. Further, it is sensible to check if spatial dependence remains in that specification. In this sense, it is worth noting that the nonlinearity of the empirical model should be taken into consideration when deriving the expressions of the Lagrange multiplier spatial statistics. It is not difficult to prove that the expression of the Lagrange multiplier test for spatial error dependence (LM-ERR) is not affected by the nonlinearity in the parameters of the exogenous variables. In contrast, the test for spatial lag dependence (LM-LAG) for this case follows the expression:

$$LM - LAG^0 = \left( \frac{e_*' W Y}{\sigma^2} \right)^2 / RJ_{\rho-\beta}^0 \quad (12)$$

where  $e_* = Y - h(X, \beta_*)$  is the vector of residuals in the nonlinear estimation under the null

hypothesis, and  $RJ_{\rho-\beta}^0 = T_1 + \frac{1}{\sigma^2} (W X_0 \beta_*)' M_0 (W X_0 \beta_*)$ , with  $T_1 = \text{tr}(W^2 + W' W)$  and

$M = I - X_0 (X_0' X_0)^{-1} X_0'$ , where  $X_0 = \frac{\partial h(X, \beta_*)}{\partial \beta_*'}$  is the  $(N \times T) \times K$  matrix of pseudo-

regressors. Thus, expression (12) only differs from that of the linear case in the use of the matrix of pseudo-regressors rather than the regressors themselves, and the residuals from the nonlinear model under the null. Summing up, should the spatial Lagrange multiplier statistics point to the existence of any kind of remaining spatial dependence in our specification, we would consider the estimation of the various forms of spatial dependence, either a substantive or a nuisance process (see Florax and Folmer, 1992, and Anselin and Florax, 1995).

Additionally, it is important to bear in mind that most empirical studies in this field directly estimate expressions such as (9), that is, without considering any kind of external effects. Given that its erroneous omission will affect the inference, we suggest checking for spatial dependence in models of this kind. Should the null hypothesis of non spatial dependence be rejected, our proposal would be to correct such misspecification by considering measures for spillover effects across the units of observation.

### **Across-industry externalities: An extension of the spatial dependence problem to the case of sectoral interdependencies**

As in the spatial case where regions are related to the closest regions, so industries are related to each other according to their input-output links. Therefore, when estimating with cross-sections of industries, one could face sectoral autocorrelation as well. This sectoral dependence causes the same econometric consequences as spatial autocorrelation. This is why, when working with industrial disaggregated data, testing sectoral dependence, as well as including measures of such links in the model, is of utmost interest.

As pointed out in section 2, several studies have sought to include spillovers across industries within an economy in order to identify returns to scale that are external to the industry. However, authors differ as to how these external effects might be modeled. When working with four and two-digit SIC-level manufacturing industry data, Caballero and Lyons (1989) and Burnside (1996) use aggregate manufacturing inputs as an index for the external effect, whereas Caballero and Lyons (1992) use output. However, in our opinion there are several limitations implicit in their consideration of across-industry externalities. First, they do not explicitly test for the existence of external effects. Second, they use output at one aggregation level higher as the measure for the



externality, without considering the strength of the dependence across industries. Third, the standard methods used for the estimation of these models suffer from endogeneity problems that may cause the estimates to be biased.

Spatial econometrics transferred to a sectoral context can help to overcome these limitations. Thus, we can explicitly test for the presence of across-industry externalities, while the use of the dual approach avoids the problem of endogeneity when including  $Y_p$ . The issue is how to reflect sectoral dependence. We suggest the transfer of the idea depicted in the weight matrix to a sectoral context, in which sectoral linkages are not explained by any kind of physical proximity but, for instance, by the input-output relations between industries (for a similar reasoning, see Bartelsman et al., 1994, and Keller, 1997). The general expression for the direct-requirements matrix of an Input-Output table is

$$\Lambda = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \cdots & \alpha_{1J} \\ \alpha_{21} & \alpha_{22} & \cdots & \cdots & \alpha_{2J} \\ \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & & \ddots & \vdots \\ \alpha_{J1} & \alpha_{J2} & \cdots & \cdots & \alpha_{JJ} \end{bmatrix} \quad (13)$$

where the element  $\alpha_{lm}$  reflects the value of products from industry  $l$  used as an intermediate in industry  $m$ .

Thus, if we think of externalities via technology diffusion through purchases of intermediates (supplier-driven externalities), the weights for the industrial connexion could be represented by the rates of purchases from all other industries. This weight is the  $lm$ -th element of the  $\Lambda$  divided by the sum of the  $l$ -th column:

$$c_{lm} = \frac{\alpha_{lm}}{\sum_{l=1}^J \alpha_{lm}} \quad l \neq m \quad (14)$$

In contrast, when considering externalities derived from sales to other industries (customer-driven externalities), the accurate weights could be the rates of sales to all other industries. This weight is the  $lm$ -th element of the  $\Lambda$  divided by the sum of the  $m$ -th row:

$$c_{lm} = \frac{\alpha_{lm}}{\sum_{m=1}^J \alpha_{lm}} \quad l \neq m \quad (15)$$

In our case we are interested in evaluating the significance and size of sectoral linkages affecting cost levels in each industry. Then, the externalities exerting the strongest influence on a priori grounds are those that are supplier-driven. Thus, we can consider how industries supplying industry  $l$  exert an influence on its cost level and structure, through a weight according to the importance of the purchases that industry  $l$  makes from each industry.<sup>8</sup> The resulting sectoral matrix is as in (11), where  $W$  is a  $(J \times T) \times (J \times T)$  block diagonal matrix, with  $J$  the number of industries and  $T$  the time periods, and the characteristic element for row  $l$  and column  $m$  being  $c_{lm}$  as in (14).

Once the sectoral weight matrix is defined, it is possible to use the concept of sectoral dependence, in the same way as spatial dependence, to test for the presence of these types of externalities. The strategy to follow is similar to the one given in the regional case. The only difference is that we do not have to face nonlinearities in the model for the sectoral case since in this case a counterpart for the stock in the neighbors is less straightforward.

## 5. DATA

For the empirical implementation we used annual data for manufactures in the Spanish regions from 1980 to 1991. For the spatial analysis we consider 15 regions in Spain (NUTS II level, without the island regions), whereas in the sectoral case the data refer to 12 manufacturing industries. The data were obtained from two main sources: first, output, intermediates, labor costs and number of workers were obtained from the Encuesta Industrial (Industrial Survey) produced by the Instituto Nacional de Estadística (INE, Spanish Statistical Office);<sup>9</sup> second, series of private and public capital stocks were taken from “El Stock de Capital en la Economía Española” (The Capital Stock in the Spanish Economy, Fundación BBV, 1995). The twelve manufacturing sectors considered in the analysis are shown in Table 1.

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<sup>8</sup> Compare this idea with that in Coe and Helpman (1995) where the relevance of international spillovers in R+D investments depends on the trade volume economies maintain with each other.

<sup>9</sup> Data provided by the Encuesta Industrial are given in nominal values. The use of sector-specific producer price indices were necessary to deflate the regional and sectoral magnitudes. Thus, the deflators are region-specific given that they pick up the sectoral characteristics of each region. The Programa de Investigaciones Económicas (Economic Research Program) supplied us with these deflators.

Price for employment ( $P_L$ ) was obtained by dividing labor costs by the number of jobs. The index price of intermediate inputs ( $P_M$ ) was measured by dividing the nominal intermediate input series by the constructed real intermediate input series. Private capital was measured by the total net capital stocks of manufacturing industry. Public capital stock included the net monetary stock of core infrastructures, that is, roads and highways, railway, harbors and maritime signaling, airports, water and sewage facilities and urban structures.<sup>10</sup> Since public infrastructures are not supposed to have an immediate effect on industrial activity, and taking into account the method used for the computation of public capital in the Spanish regions, it seems reasonable to follow the recommendation of entering the public capital stock variable with one period lag. Finally, data used to obtain the elements of the sectoral weight matrix were taken from the input-output table for the Spanish economy available for 1990.

## 6. EMPIRICAL RESULTS

Here, we present the main results for the regional and the sectoral cases. In both exercises, the restrictions between the parameters implied by Shephard's Lemma did not fit our data. Thus, we compute the relevant elasticities by estimating the variable cost function for the two empirical exercises. The results in this section were obtained using codes in Gauss v3.2.8.

### Regional case

Although our primary concern was to test the significance of externalities and to estimate their cost effects, we first estimated equation (9) with the aim of checking for spatial dependence in the traditional variable cost function. This also acted as a benchmark for assessing the bias in the traditional effects when externalities are neglected. The estimation was carried out for the pooled data. Several studies (e.g. Seitz and Licht, 1995, and Morrison and Schwartz, 1996) have estimated a fixed effect model to account for unobservable economy effects on the cost level. This is because these

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<sup>10</sup> Basic public infrastructures have been demonstrated to have a positive impact on regional productivity in the Spanish regions (e.g. Mas *et al.*, 1996; Moreno *et al.*, 1997), in contrast to social public infrastructures whose effect is not as clear.

effects are assumed to be correlated with the arguments in the cost function, which means the random effect model cannot be considered. As a result, a Hausman test always leads to the fixed effect model being chosen as the most appropriate. However, it causes an incidental parameter problem when the maximum likelihood (ML) principle needs to be applied in the spatial context (both for the tests and the estimation procedure in the presence of spatial dependence).<sup>11</sup> So, given that spatial effects were our main concern, we tried to consider exogenous economy-wide heterogeneity by means of a dummy that separated regions with a high share of manufactures in total output from those specialized in other activities. This variable was significant in all the estimates and, as expected, indicated lower exogenous cost levels in regions specialized in manufactures. The results for the spatial autocorrelation tests are shown in Table 2. The LM-LAG test clearly rejects the null hypothesis, so that some kind of externalities takes place in the explanation of the manufacture cost level. However, neither Moran's I nor LM-ERR rejected the null of non spatial autocorrelation in the residuals.

With the aim of obtaining the effect of the external input on the manufacturing cost, we first introduced the infrastructure stock.<sup>12</sup> A likelihood ratio (LR) test for the significance of all the terms related to Kg rejects its null hypothesis (35.82, p:0.000), revealing the necessity of including such a variable. Since it is difficult to analyze the plausibility of the signs and the significance of the estimates given that there are quadratic and cross-product terms that refer to each variable, the results for this estimation are not presented and the relevant effects are summarized by the elasticities.<sup>13</sup> With these estimates, we obtained the elasticities concerning the effects of public capital as shown in Table 3. The results show that the elasticity of cost with respect to public capital presents a negative average (weighted by the share of regional output in total national) of -0.034, indicating that from this specification Spanish manufactures benefited only slightly during the eighties from cost reductions when public capital increased. This negative average sign for infrastructure elasticity implies a global net substitutive relationship between public capital and private inputs. So, analyzing the elasticity of the

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<sup>11</sup> We are grateful to the editors for pointing this out to us.

<sup>12</sup> This implies the inclusion of the restrictions  $\theta = 1$  and  $\beta_{Yp} = \beta_{YpYp} = \beta_{YpKp} = 0$  in (10).

<sup>13</sup> The results of the estimations can be provided upon request.

conditional demand for labor and intermediates, it can be concluded that, on average, infrastructure is labor using (0.179) and intermediates saving (-0.064). Finally, we obtained returns to scale ( $RTS = 1/\varepsilon_{VCY}$ ) that were practically constant (1.073),<sup>14</sup> as have been reported in other Spanish studies of manufactures, including Suárez (1992) and Velázquez (1993).

As observed in Table 2, the inclusion of the external input reduces the magnitude of the LM-LAG statistic, although this remains significant. Therefore, following the "classical" specification search approach adopted in the spatial econometric literature, we estimated the spatial lag model. When estimated by ML, the spatial lag of the endogenous variable was significant (LR=9.689, p:0.002), indicating the adequacy of considering the variable costs in the neighboring regions.<sup>15</sup> In this specification there does not seem to be any remaining spatial dependence. However, although the consideration of the spatial lag model results in an econometric solution for the spatial dependence problem, it does not identify the sources of these across-region externalities. This is why, considering our theoretical sources of externalities across economies as described in section 4, equation (10) is estimated by NLLS to deal with the nonlinearity caused by the functional form for the composite of public capital. The LR test rejects the non significance of all the terms related to  $Y_p$  (22.859, p:0.000), so the thick-market externality needs to be considered. Further, Table 2 shows that the inclusion of these externalities completely removes spatial autocorrelation.

With regard to the estimates, the parameter  $\theta$  presented a value of 0.58, indicating that although the public capital endowment in the region under consideration was the most relevant, the endowment in the neighboring regions also play an important role, in all likelihood as a result of the network characteristic of most public infrastructures (Rietveld, 1995). The elasticity of costs with respect to the composite of

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<sup>14</sup> To test the significance of all these measures would require knowing their standard errors. It should be noted that this is a non-straightforward function of the estimated standard error for the parameters in the model. Alternatively, we could test the hypothesis on these elasticities by using the dispersion in the values for each individual and time period. Constant returns to scale cannot be rejected in this case.

<sup>15</sup> For reasons of space, the elasticities concerning the effect of the external input when including a spatial lag of the endogenous variable are not presented. However it is worth noting that as a result of expressing the spatial lag model through its reduced form, all the elasticities are obtained by means of pre-multiplying their usual expressions by  $(I-\rho W)^{-1}$ .

public capital (first column in Table 4) now presented an average of 0.282. That is, public capital has not meant a reduction in manufacturing costs in the Spanish regions during the eighties. This result agrees with other studies conducted in developed economies (Holtz-Eakin, 1994, and Garcia-Milà *et al.*, 1996, for the United States and de la Fuente, 1996, for the Spanish economy) that have cast some doubt on the effectiveness of public capital investment in enhancing productivity. This result can be explained by the fact that, in this period (the eighties), Spanish regions already had a substantial stock of public capital suggesting a threshold level for infrastructures that had already been reached.<sup>16</sup> Whatever the case, this positive cost elasticity of infrastructures is the opposite to that obtained in the model without externalities across economies, and warns of the erroneous conclusions that might be drawn in case of spatial misspecifications. What is also surprising is that in our sample the output of the neighbors increased the cost in the region. Although low in magnitude, it seems that Spanish regions suffered from proximity to regions of high manufacturing output. This might indicate some kind of competition during a period of major restructuring in the manufacturing industry in Spain. Whatever case, these results are obviously conditioned by the particular definition of the matrix of weights. Weighting regional output in another way might well result in different conclusions being drawn.

### **Sectoral case**

As with the regional case, we estimated expression (9) by OLS introducing a dummy in order to allow separate levels of exogenous costs in a group of sectors characterized by higher technology levels<sup>17</sup> and another that included mature activities. As shown in Table 5, the spatial statistics reveal the existence of sectoral dependence (in contrast to the regional case, all the spatial tests are significant). Before including the externalities across industries, and in order to analyze the effect of public capital on manufacturing costs, we first introduced the public capital stock. A LR test showed the joint significance of all the

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<sup>16</sup> In several studies analyzing the effect of public capital stock on economic growth in the Spanish regions (e.g. Mas *et al.*, 1996; Moreno, 1998), it has been shown that the impact of infrastructure decreased during the eighties. This was partly due to the existence of decreasing returns to scale for public capital, indicating that it is a factor with a threshold level that once reached reduces its effects.

new terms (16.459,  $p:0.011$ ). The cost elasticity with respect to public capital is shown in Table 6, and reveals a positive industry-weighted average (0.305). Besides, as can be seen, there is a strong across-industry variation both in the sign and value of this elasticity. This might reflect differences in the capacity of industries to take advantage of available public capital in the Spanish economy, as proposed in a number of theoretical models (e.g. Holtz-Eakin and Lovely, 1996). As for the relationship between public capital and each variable factor, once again we reached the conclusion that infrastructure capital is labor using (2.289) and intermediates saving (-1.197). Finally, average returns to scale are increasing, 1.849, with large across-industry variability which, on the other hand, is similar to the results obtained in studies analyzing returns to scale at the industry level (for instance, Caballero and Lyons, 1990, and Burnside, 1996).

As depicted in Table 5, the introduction of the external input did not eliminate sectoral dependence, with the LM-LAG being the most significant test. As in the regional case, if we follow a "classical" strategy in seeking the best model, we must estimate the sectoral counterpart to the spatial lag model by ML. Although the lag of the endogenous variable was significant (the value for the LR test is 24.747,  $p:0.000$ ) and it completely removed any form of sectoral autocorrelation, it did not provide us with an explanation of the origin of the externalities across industries. Thus, we estimated our empirical model given in (10) for the sectoral case. As shown in Table 5, introducing the spillover across industries also removed sectoral dependence completely. This result as well as the global significance of all the parameters including the supplier-weighted product according to a LR test (20.900,  $p:0.000$ ) supports our hypothesis as to the source of external effects (those due to thick-market of intermediates).

Finally, Table 7 displays the results of the elasticities once the across-industry externality was included. The value for the cost elasticity with respect to public capital changed to an average of -0.341, with both positive and negative effects. Thus, it seems that manufactures in Spain benefited from infrastructure increases during the eighties. However, industrial variability was high, which is in line with the different effects of public capital on activities as shown in Holtz-Eakin and Lovely (1996). It is worth noting

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<sup>17</sup> This group includes: Chemistry (s3), Metallic products and metalwork (s4), Electric machinery and

that this cost-reduction effect of public capital appears when we allow for externalities across economies. Similarly, returns to scale seem more reasonable in this latter case indicating that those observed in Table 6 might be strongly biased due to the omission of the externality (in line with that advocated in studies that have applied the primal approach). As for the cost elasticity with respect to the across-industry externality, this was negative in global terms, with an average of -0.325, that is, the higher the output in the supplier industries, the greater the technological diffusion embodied in goods and the higher the supplier-driven externalities, with correspondingly lower manufacturing costs.

## 7. CONCLUSIONS

This paper has addressed the relevance of external effects on the economic performance of firms. We have defined two sources for these effects: those derived from inputs within the economy but external to the firm, and those due to externalities that cross the industry or the geographical area in which they are generated. The latter case contributes to the debate on the scope of externalities across economies. While one strand of the literature argues that externalities with respect to firms do exist, albeit only for firms within the same industry, other authors emphasized the linkages between firms from different sectors. The same reasoning can be applied to firms located in different geographical areas (i.e. regions or countries). Unlike most studies conducted in this area, our analysis has been carried out within the duality framework. This overcomes some of the shortcomings of an analysis in the frame of the production function. First, it allows internal and external returns to be disentangled from variations in input utilization. Second, measures of externalities, such as those from thick- markets proxied by output, do not cause problems of endogeneity. Finally, potentially it should give more information about the effects of the externalities through the different substitution effects with internal inputs.

Spatial econometric techniques have been proposed in considering external effects. The concept of spatial dependence has been shown to capture empirically the notion of spillovers across economies. While traditional definitions of weight matrices

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material (s6), Transport material (s7), and Paper and derivatives and printing (s10).



can be used in the case of externalities across regions, proper counterparts for the sectoral case need to be defined. We propose the use of input-output linkages as a measure of *neighborhood* for the empirical analysis of externalities across industries. Besides, given the nonlinearity affecting the parameters of certain exogenous variables of the proposed empirical model, we obtain the expressions of the Lagrange Multiplier test for spatial dependence when this nonlinearity is accounted for.

We have applied this framework to the case of the stock of publicly provided capital (external input) and to the output in the *neighboring* economies (across-economy spillovers) for the manufacturing sectors in the Spanish regions. Although the results might be sensitive to problems of collinearity that characterize estimation of low restrictive cost functions, we can conclude that externalities had a significant impact in reducing costs in the sectoral case (acting in an opposite direction to that in the regional case), whereas the effect of public capital is unclear. Furthermore, it is shown how the omission of external effects biases the estimation of the parameters referring to the traditional inputs and the measures of internal returns to scale.

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**Table 1.** Description of the industrial groupings

1	Metallic minerals and first transformation of metals
2	Non metallic minerals and products
3	Chemistry
4	Metallic products and metalwork
5	Agricultural and industrial machinery and equipment
6	Electric machinery and material
7	Transport materials
8	Food products, alcohol, drinks and tobacco
9	Textiles, leather and shoes
10	Paper and derivatives and printing
11	Rubber and plastic derivatives
12	Wood, cork and derivatives and other manufactures

**Table 2.** Spatial dependence tests in the regional case

	<b>I MORAN</b>	<b>LM-LAG</b>	<b>LM-ERR</b>
Without external effects	0.895 (p:0.371)	16.759 (p:0.000)	0.161 (p:0.688)
Including external input (Kg)	1.507 (p:0.132)	9.339 (p:0.002)	1.119 (p:0.275)
Including external input (Kg) and across-region externalities ( $K_{g\rho}$ and $Y_{\rho}$ )	0.941 (p:0.347)	0.327 (p:0.567)	0.364 (p:0.546)

**Table 3.** Elasticities from the specifications with the external input in the regional case

	$\epsilon_{VCKg}$	$\epsilon_{LKg}$	$\epsilon_{MKg}$	RTS
<b>ANDALUCÍA</b>	-0.069	0.312	-0.069	1.035
<b>ARAGÓN</b>	-0.016	0.064	-0.060	1.140
<b>ASTURIAS</b>	0.010	0.190	-0.066	1.021
<b>CANTABRIA</b>	0.056	0.216	-0.062	1.065
<b>CASTILLA-LEON</b>	-0.034	0.143	-0.058	1.148
<b>CASTILLA-MANCHA</b>	-0.027	1.150	-0.066	1.109
<b>CATALUÑA</b>	-0.061	0.233	-0.066	1.027
<b>VALENCIA</b>	-0.049	0.338	-0.068	1.044
<b>EXTREMADURA</b>	-0.001	0.318	-0.067	1.131
<b>GALICIA</b>	-0.028	-0.150	-0.064	1.117
<b>MADRID</b>	-0.011	0.352	-0.055	1.143
<b>MURCIA</b>	0.020	0.031	-0.061	1.155
<b>NAVARRA</b>	0.032	0.539	-0.053	1.217
<b>PAIS VASCO</b>	-0.026	-0.790	-0.067	0.992
<b>RIOJA</b>	0.040	1.538	-0.054	1.280
<b>AVERAGE</b>	-0.034	0.179	-0.064	1.073

**Table 4.** Elasticities from the specification with the external input and the across-region externality in the regional case

	$\epsilon_{VCKg}$	$\epsilon_{LKg}$	$\epsilon_{MKg}$	RTS	$\epsilon_{VCYp}$
ANDALUCÍA	0.287	-0.091	0.024	1.063	0.037
ARAGÓN	0.253	0.219	0.021	1.121	0.058
ASTURIAS	0.306	0.129	0.023	0.931	0.050
CANTABRIA	0.298	-0.088	0.023	0.928	0.056
CASTILLA-LEON	0.252	-0.143	0.021	1.165	0.049
CASTILLA-MANCHA	0.245	-0.144	0.023	1.113	0.055
CATALUÑA	0.298	-0.084	0.025	1.097	0.053
VALENCIA	0.278	-0.078	0.025	1.095	0.057
EXTREMADURA	0.236	-0.244	0.022	1.028	0.058
GALICIA	0.259	-0.133	0.023	1.105	0.051
MADRID	0.276	-0.105	0.021	1.125	0.050
MURCIA	0.241	-0.171	0.022	1.086	0.058
NAVARRA	0.251	-0.241	0.020	1.101	0.053
PAIS VASCO	0.319	-0.103	0.024	0.979	0.043
RIOJA	0.221	0.052	0.020	1.127	0.057
<b>AVERAGE</b>	0.282	-0.084	0.023	1.084	0.050

**Table 5.** Spatial dependence tests in the sectoral case

	<b>I MORAN</b>	<b>LM-LAG</b>	<b>LM-ERR</b>
Without external effects	2.813 (p:0.005)	17.645 (p:0.000)	5.789 (p:0.016)
Including external input (Kg)	2.564 (p:0.010)	16.321 (p:0.000)	2.790 (p:0.095)
Including external input (Kg) and across-region externalities ( $Y_p$ )	1.139 (p:0.255)	0.160 (p:0.689)	0.108 (p:0.742)

**Table 6.** Elasticities from the specification with the external input in the sectoral case

	$\epsilon_{VCKg}$	$\epsilon_{LKg}$	$\epsilon_{MKg}$	RTS
s1	0.720	0.898	-2.146	5.724
s2	0.428	1.321	-1.213	1.680
s3	0.540	1.091	-1.606	2.721
s4	0.274	1.774	-0.992	1.206
s5	0.012	10.170	-0.594	0.855
s6	0.098	9.185	-0.686	0.927
s7	0.434	1.470	-1.220	2.513
s8	0.288	1.142	-1.415	1.569
s9	-0.005	3.606	-0.836	0.865
s10	0.337	2.090	-0.915	1.390
s11	0.301	3.521	-0.790	1.183
s12	-0.084	-1.620	-0.682	0.766
<b>AVERAGE</b>	0.305	2.289	-1.197	1.849

**Table 7.** Elasticities from the specification with the external input and the across-industry externality in the sectoral case

	$\epsilon_{VCKg}$	$\epsilon_{LKg}$	$\epsilon_{MKg}$	RTS	$\epsilon_{VCYp}$
<b>s1</b>	0.175	0.415	-1.102	1.046	-0.591
<b>s2</b>	0.042	0.672	-0.538	0.944	-0.375
<b>s3</b>	-0.244	0.565	-0.647	0.841	-0.490
<b>s4</b>	-0.202	1.060	-0.415	0.822	-0.280
<b>s5</b>	0.186	0.377	-0.283	1.134	0.279
<b>s6</b>	0.031	7.140	-0.316	0.989	0.076
<b>s7</b>	-0.492	0.883	-0.504	0.781	-0.413
<b>s8</b>	-1.086	0.958	-0.436	0.569	-0.612
<b>s9</b>	-0.368	-0.617	-0.320	0.713	-0.098
<b>s10</b>	0.096	1.002	-0.434	1.033	-0.134
<b>s11</b>	0.427	1.174	-0.403	1.293	0.030
<b>s12</b>	0.098	1.767	-0.292	0.893	0.082
<b>AVERAGE</b>	-0.341	1.148	-0.481	0.828	-0.325