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Vertical linkages, agglomeration and the organization of production in European regions

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VERTICAL LINKAGES, AGGLOMERATION AND THE ORGANIZATION OF PRODUCTION IN EUROPEAN REGIONS [a]

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ABSTRACT: In this paper we test for the presence of localisation economies due to input-output linkages between vertically related firms located in the same region. To undertake this we estimate, by duality, a quadratic cost function using a sector by sector panel at the European regional level in the period 1985-1995. Vertical economies are derived from the concept of scope economies and associated to regional advantages of having in the proximity specialised providers of intermediate goods. Several specifications are tested and results indicate that the necessary conditions for the existence of economies of vertical disintegration are satisfied as well as the sufficient conditions for some sectors, showing that vertical diseconomies are stronger for the more geographically concentrated industries. These effects are not pervasive since there are also opportunities for efficiency gains from a more vertically integrated production for some sectors in several regions.

Keywords: vertical economies, cost function, agglomeration.
JEL Classification: L23, L60, R12, R15.

Resumen: En este trabajo se realiza una prueba para determinar la presencia de economías de localización debidas a encadenamientos input-output entre empresas verticalmente relacionadas localizadas en la misma región. Para ello, se estima, por dualidad, una función de costes cuadrática utilizando un panel para diferentes sectores industriales a nivel regional europeo en el periodo 1985-1995. Las economías verticales se derivan del concepto de economías de gama y se asocian a las ventajas regionales de tener en la proximidad proveedores de bienes intermedios especializados. Se prueban varias especificaciones econométricas y los resultados indican que las condiciones necesarias para la existencia de economías de la desintegración vertical se cumplen, así como las condiciones suficientes para algunos sectores, mostrando que las deseconomías verticales son más fuertes en las industrias geográficamente concentradas. Estos efectos no son generales ya que también se manifiestan oportunidades para ganancias de eficiencia de la producción verticalmente integrada para algunos sectores en varias regiones.

Palabras clave: Economías verticales, aglomeración, función de costes
JEL Classification: L23, L60, R12, R15.

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[a] Comments are welcome. The opinions expressed in the paper do not necessarily reflect the IEB's opinions.

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1. Introduction

International trade models that incorporate external economies and imperfect market structures show, among other things, that the existence of increasing returns increases productive efficiency and, therefore, industrial specialization is desirable. Also, these models consider that the associated advantages can be concentrated on few regions (or countries). In this sense, economic integration plays a fundamental role in spatial changes, since the reduction (and eventual elimination) of trade barriers, along with a greater factor mobility, will tend to alter the attraction forces of some regions and will cause the reduction of profits in others, that will not only impact industrial location but also regional welfare.

The combination of vertical industrial linkages and imperfect competition generates agglomeration forces that will be greater as trade costs decrease. If linkages are strong inside a specialized location but relatively weak among industries, the theory predicts that integration will promote agglomeration and specialization. In the European context this means a high sectoral relocation with potentially asymmetric adjustment costs. An alternative is that linkages among industries are strong. In this case, attraction and dispersion forces would cause the existence of very few agglomerations that, in turn, would have an impact on demand levels and, with labour as an immobile factor, wage differentials and income inequalities would be enlarged. Hence, when incorporating directly agglomeration economies in a model of international trade[1] a seemingly paradoxical result takes place: cost reductions are directly associated to a growing advantage in spatial concentration of economic activities. This generates, as a commendable result of the integration process, a greater industrial concentration in fewer regions.

This paper provides an analysis of the impact of European integration in the structure, organization and location of industry with a special emphasis in the vertical division of labour. For that purpose it is organised in the following way. The second section highlights some of the main results obtained in the literature that has analyzed the effects of economic integration, agglomeration of productive activities and the existence

[1] As in Krugman (1991) for example.

of demand and cost linkages that generate external economies. The third section is methodological. There, the analytical approach is explained and the concept of vertical economies is defined. These are approximated by means of the estimation of a cost function whose functional form is also explained. Moreover, in this section data, variables and other relevant estimation issues are also tackled. Finally, this section ends with an in-depth discussion of estimation results. In the fourth section, vertical economies are calculated and its role as localization economies is argued. The fifth section concludes.

2. European integration, location and the organization of industry

The growing empirical literature that tries to contrast the new economic geography hypothesis has usually used country-level data and the findings support a positive relationship between location and dependence of locally produced intermediate goods.

One of the first papers that considers the existence of vertical linkages explicitly is Hanson (1994) and shows that for a developing economy, trade liberalisation implies a transition of vertically integrated industries towards specialization as subcontractors for (multinational) companies of developed countries. In the specific case of labour intensive industries this transition implies an industrial restructuring towards assembling activities, impacting directly the spatial distribution of economic activities. The empirical results show that textile production in Mexico was concentrated in the centre of the country before trade liberalisation took place and with the opening process not only the industry turned towards assembling activities but also producers began to relocate along the US border.

On the other hand, Holmes (1999) combines information on purchases of intermediate goods at the regional level with data on employment by establishment to analyze the relationship between vertical disintegration and location. With this information, obtains estimates of the relationship between the intensity in the purchase of intermediate goods of an establishment and the employment level in the same activity of the neighbouring establishments. The results show that the intensity in the purchase of intermediate goods in the American manufacturing sector is of the order of 6% higher in those plants that are located in a region where firms of the same sector are located, and there is a tendency towards vertical disintegration in agglomerated areas.

A paper by Haaland et al. (1999) analyzes the patterns of geographical concentration of manufacturing activities in Europe estimating two models. In the first one, relative geographical concentration is related to a set of factors taken from the different theories that analyze this relationship. In this case, the authors conclude that the geographical distribution of expenditure is the most decisive factor in the relative spatial distribution of manufactures, followed by human capital. In this context, neither scale economies nor input-output linkages have a significant incidence in the agglomeration of activities in Europe. However, in a second model where absolute concentration is related to expenditure, industrial linkages, scale economies and the existence of non tariff commercial barriers, linkages not only have a positive impact in the determination of geographical concentration of industry, but in addition it is shown that this influence is growing in time, being higher since the completion of the single market.

In a set of papers oriented to the analysis of the patterns of geographical concentration and productive specialization, Midelfart-Knarvik et al. (2000a, 2000b) analyze their determinants introducing in a regression some characteristics of the regions considered, several industrial characteristics and some interactive terms among these, to capture the effects suggested by the new theories of international trade and new economic geography. In the first paper, backward linkages are captured by means of an interactive term between market potential and sales of goods in the same industry. This variable captures the fact that firms want to be located near their clients to minimize transport costs of their sales to final markets. The estimated coefficient is positive, statistically significant and increasing with time. This result points out that backward linkages are increasingly important in the determination of location decisions. Thus, industries that sell a big share of their production to other industries are becoming more sensitive to locations with a high market potential. The interaction between market potential and the share of intermediate consumption in total costs proxies forward linkages. The hypothesis behind this assumption is that firms that depend heavily on intermediate goods will want to locate near other producers; this is, in regions of high market potential. The results point out that this interactive term is not only positive and statistically significant but also growing in time so that forward linkages are relevant in the determination of location as the industries that depend on intermediate goods will locate in central regions with good access to intermediate goods markets.

On the other hand, in the second paper their results show that both demand and cost linkages are statistically significant. In this case and given the specification of the estimated model, they measure the elasticity of production with respect to location, the latter being defined as access to suppliers or by means of a relative market potential indicator, of an industry with an intensity in the use of intermediate goods (forward linkage) or a production share oriented towards industrial consumption (backward linkage) a standard deviation above the average. The results show that backward linkages are losing importance in time while forward linkages are becoming more relevant, confirming that highly intensive sectors in the use of intermediate goods move toward central locations to reach a better access to these goods.

From the analysis of vertically related industries, Midelfart-Knarvik and Steen (2000) measure the existence of externalities and the possibilities for agglomerations to be self-sustained. In the first place, the relationship between growth of production in a given sector and the growth and activity level of vertically related industries is analysed. In second place, the link between sales of intermediate producers and sales of final producers is studied. Finally, they show that when comparing the results of the correlation of intermediate and final goods sales, a proxy for demand linkages, with the evidence of localized external economies it is possible to identify vertical linkages that allow an agglomeration to be self-reinforced in time. The empirical analysis is based on information on several vertically related activities (transport, services) of the Norwegian marine sector. The authors find that productivity growth in marine transport is positively related to the size (activity level) in five out of the six intermediate sectors considered. In three of them (banking, insurance and consultancy), the domestic market effect has a significant impact in sales, causing vertical linkages between these and marine transport to promote self-sustained agglomeration.

Analyzing the most relevant papers that have studied the relationship between vertical linkages and agglomeration in a context of growing economic integration from an empirical point of view, it is possible to conclude that most of them use information at country level and that estimations have been carried out from reduced form specifications. Moreover, most of the existent empirical evidence is based on the estimation of production functions. In what follows an attempt is made to provide another approach to those observed in the literature. In this paper we consider a cost function to analyze the relationship between vertical disintegration and location.

3. Vertical linkages and agglomeration

The starting point is the assumption of a perfectly integrated economy that can be characterized by the conditions of the Hecksher-Ohlin (HO) model where factor endowments determine the pattern of trade, specialization and concentration in a framework of perfect competition and constant returns to scale[2] [Dixit and Norman (1980), Woodland (1982), Helpman and Krugman (1985)]. Under these circumstances it is well known that this integrated economy (in our case the UE) will maximize the value of production. A formulation of this problem is

$$\underset{p,y\in R^N, v\in R^M}{\text{Max}} \quad \text{s.a.} \qquad y \in Y(v)$$

where *y* is the final goods vector, *p* is the corresponding vector of prices and *Y(v)* is the convex production set for the factor endowments vector *v*. The solution to this problem gives the maximum value of production *Y=r(p,v)*, where r(.) is a revenue function that depends on goods prices and factor endowments. In Harrigan (1997) and Redding and Vera-Martin (2001), this approach is used to analyze the validity of the hypotheses of the neoclassical model of international trade, using a translog specification. Here we adopt a slightly different approach by means of duality theory. In equilibrium, associated to this revenue function a cost function exists that can be defined as

$$C(y,w,t) \equiv \min\left\{\sum w_j x_j : (y,x) \in T\right\} \tag{1}$$

[2] This general equilibrium formulation allows for other specifications, such as the presence of external economies or a partial equilibrium approach. See Helpman and Krugman (1985) for details.

being y the vector of outputs, w the factor prices vector, x their quantities and t a Hicks neutral technical progress index[3]. Since the interest lies on the analysis of two vertically related markets, it is possible to assume a multiproduct environment where the output vector has more than one component. Concretely, we will assume that there are two goods (stages): final and intermediate. In a multiproduct setting scale economies are defined as [Baumol et al. (1982)]:

$$S_n = \frac{C(y)}{y\nabla C(y)} = \frac{C(y)}{\sum_{i=1}^{n} y_i C_i(y)} \tag{2}$$

where $C_i = \dfrac{\partial C(y)}{\partial y_i}$. Returns to scale for each specific stage of production can be calculated as

$$S_i = \frac{IC_i(y)}{y_i \partial C / \partial y_i} = \frac{AIC_i}{\partial C / \partial y_i} \tag{3}$$

where IC and AIC are incremental costs and average incremental costs, respectively. Returns to scale can be increasing (> 1), constant (= 1) and decreasing (< 1). Finally, the degree of scope economies in y relative to the production subset A are defined as

$$SC_A = \frac{C_1(y_A) + C_2(y_{N-A}) - C(y)}{C(y)}$$

where y_A and y_{N-A} are partitions of the production set. If $SC_A > 0$, scope economies exist, meaning that it is cheaper (profitable) to produce goods jointly than separated. Transferring this concept to the case where two stages of production are considered instead of two goods, one obtains the concept of vertical economies. We use this concept to analyse the productive efficiency of integrated and specialized production and its relation to agglomeration of economic activities.

[3] This cost function can be modified to include external economies or can be formulated in terms of short run variable costs. See Morrison-Paul (1999).

3.1 Vertical economies from the concept of economies of scope

Vertical economies exist if the cost of vertical integrated production is smaller than that of producing the goods separately by specialized firms in each stage of production. For the cost function, it is required that for all $y_i>0$, $\partial C/\partial y_i$ exist. This requirement allows the calculation of the specific marginal costs for each stage without the necessity of imposing the property of global continuity that would invalidate fixed costs assumptions. Under these conditions, it is possible to interpret the multiproduct cost function as a multistage cost function, this is, referred to several stages of the production. This function is amenable to empirical estimation with some modifications [Kaserman and Mayo (1991), Kwoka (2002)].

There are three main approaches for the estimation of vertical economies. The first, which is used in this paper, is based on the subadditivity of a multiproduct cost function in which the output of one stage of production is used as an input in another stage [Kaserman and Mayo (1991), Gilsdorf (1994), Kwoka (2002)]. The second approach is based on a separability test for production or cost functions. If the intermediate stage is separable from the final stage, the benefits associated to vertical integration do not exist since both stages would be technologically equivalent [Lee (1995), Hayashi et al. (1997), Nemoto and Goto (2004)]. Finally, the third approach is based on non parametric methods, using the Wilcoxon range test [Azzam (1998)].

From the cost function (1), scale economies from multistage production are given by[4]

$$S_n = \frac{C(y)}{y\nabla C(y)} = \frac{C(y)}{\sum_{i=1}^{n} y_i C_i(y)} \tag{4}$$

where $C_i(y) = \dfrac{\partial C(y)}{\partial y_i}$. In a similar way, specific returns to scale for each stage, for example the i-th are given by

[4] As in Baumol et al. (1982).

$$S_i = \frac{IC_i(y)/y_i}{C_i(y)} \tag{5}$$

where $IC_i(y) = C(y) - C(y_{n-i})$ can be interpreted as the incremental cost and y_{n-i} is the output vector that has a zero in the i-th stage of production. Comparing equations (2) and (3) with (4) and (5), both overall and stage-specific scale economies are an image of those that would be obtained considering a multiproduct scenario instead of a multistage one.

The existence of vertical economies is critical for the determination of the optimal degree of vertical integration. To detect these economies, it is possible to modify the concept of scope economies for the case of a multiproduct firm (or industry) to the case of multistage production, as proposed in Kaserman and Mayo (1991) and Kwoka (2002). The required modifications are that, in the case of vertical economies, one should necessarily consider the sales of the intermediate good between successive stages of production when this happens in separated units. Therefore, economies of vertical integration exist when between two successive stages (i and j) of production,

$$C(y_i, y_j) \leq C(y_i, 0) + C(0, y_j, p_i) - p_i y_i(y_j, \overline{p}) \tag{6}$$

where y_i is the production of intermediate goods, y_j it is the production of final goods, p_i it is the market price of the intermediate goods, $y_i(y_j,p)$ is the derived demand for intermediate goods and p is the vector of factor prices in the final stage (including p_i).

The left hand side of equation (6) represents the cost of the vertically integrated production of stages i and j. The price of the intermediate good, pi, doesn't appear since in this cost function a completely integrated industry will produce its own inputs[5]. The first term of the right hand side of the equation is the cost of producing the intermediate good if this process is carried out in a specialised productive unit. The second term point out the costs of production in the final stage, including the expenses required to acquire intermediate goods and thus depends on their price. Finally, the third term of the

[5] In the case that integrated production takes place in separate divisions of the same profit maximising multidivisional firm, a transfer price equal to marginal cost will prevail and the argument is still valid.

right hand side of equation (6) takes into account the expenses of final stage firms in the acquisition of intermediate goods to avoid to double count these costs, since they are already included in $C(y_i,0)$. Besides, subtracting these terms also corrects for any possible margin above marginal cost that the intermediate companies can charge. The equation only reflects savings in real costs of production attributable to vertical integration, ignoring the monetary transfers that can result from pricing.

The expressions $C(y_i,0)$ and $C(0,y_j,p_i)$ reflect the transaction costs associated to the use of the market to transfer yi between intermediate and final firms. In addition, $C(0,y_j,p_i)$ reflects any inefficiency in production caused by a sub-optimal combination of productive factors. Therefore, the expression points out that economies of vertical integration exist when the costs of the combined production are smaller or equal to the costs of producing each product separately in the vertical chain of production. The degree of vertical economies (among stages i and j) are given by

$$S_{ij} = \left[C(y_i,0) + C(0,y_j,p_i) - p_i y_j(y_j,\bar{p}) - C(y_i,y_j)\right] / C(y_i,y_j) \qquad (7)$$

When

$S_{ij}(y) > 0$, economies of vertical integration exist

$S_{ij}(y) = 0$, the costs in both ways of organizing production are the same

$S_{ij}(y) < 0$, diseconomies of vertical integration exist[6].

The empirical implementation for the calculation of vertical economies is not exempt of complications, especially in what concerns the appropriate functional form.

3.2 Choice of the functional form

From the previous discussion and for the purposes of estimation, the selection of the most appropriate functional form is crucial. On the one hand, flexible functional forms have been increasingly used because of their econometric properties, mainly for not

[6] These can also be interpreted as economies of vertical disintegration.

imposing a priori restrictions onto the substitution elasticity. However, their implementation can be expensive in terms of information and the number of parameters to estimate. On the other hand, other functional forms are less flexible[7] but their information requirements and the reduced number of parameters to estimate make them also useful.

In the specific case of estimating scope economies as a proxy for localisation economies, it is necessary to use an appropriate functional form. Thus, although it usually doesn't fulfil the hypothesis of homogeneity of degree one in prices, the quadratic cost function is superior to others, mainly because it considers the existence of null values in the output vector, an essential condition to the calculation of scope economies. So, the specification of the quadratic cost function would be, omitting variables not directly associated to production:

$$C(y) = \alpha_0 + \sum_i \alpha_i y_i + \frac{1}{2}\sum_i \sum_j \alpha_{ij} y_i y_j \tag{8}$$

Equation (8) it is a quadratic form of the quantities augmented by lineal terms and a fixed cost parameter. It is considered a flexible form in production levels. As it is written, it ignores the role of input prices (w) and it simply considers that a_0, a_i and a_{ii} are not-specified functions of the w vector. From the previous equation, we can find multistage economies of scale by

$$S_n = \frac{\alpha_0 + \sum_i \alpha_i y_i + \frac{1}{2}\sum_i \sum_j \alpha_{ij} y_i y_j}{\sum_i \alpha_i y_i + \sum_i \sum_j \alpha_{ij} y_i y_j} \tag{9}$$

From equation (9) we know that Sn>1 whenever $\alpha_0 > \left(\frac{1}{2}\sum_i \sum_j \alpha_{ij} y_i y_j \right)$. Returns to scale specific for each stage are given by

[7] For example, Cobb-Douglas, CES and Stone-Geary among others.

$$S_i = \frac{\alpha_i y_i + \frac{1}{2}\alpha_{ii} y_i^2 + \frac{1}{2}\sum_{j \neq i} \alpha_{ij} y_i y_j}{\alpha_i y_i + \alpha_{ii} y_i^2 + \frac{1}{2}\sum_{j \neq i} \alpha_{ij} y_i y_j} \tag{10}$$

so that S_i>1 when a_{ii} < 0.

Finally, the degree of vertical economies is calculated from:

$$S_{ij} = \frac{\alpha_0 - p_i y_i (y_j, \bar{p}) - \frac{1}{2}\sum_{i \neq j} \alpha_{ij} y_i y_j}{C(y)} \tag{11}$$

The cost function (8) incorporates two possible sources of vertical economies. On the one hand, these may be due to the existence of some not perfectly divisible inputs used in the production of final and intermediate goods. On the other, there is a cost interaction (or complementarity) between production stages. In the equation, α_0 represents the cost of indivisible inputs, costs that would be duplicated due to the separated production of intermediate and final goods. Cost complementarity is captured by means of the interaction of the terms $y_i y_j$. A negative sign would indicate that total costs are smaller when the output is jointly produced in relation to the specialized production of each one of them. Therefore, the necessary and sufficient condition for the existence of positive vertical economies is defined by applying the condition for the existence of scope economies to equation (8),

$$\alpha_0 - \frac{1}{2}\alpha_{ij} y_i y_j > 0$$

In the case that this sum is negative, diseconomies of vertical integration would exist, providing enough incentives for specialized production or vertical disintegration. This condition forms the base of the econometric hypothesis that is analysed in the following sections.

To take into account the possibility that the regional variations of the prices of the factors, the existence of localised external economies and other decisive potential variables in the determination of costs functions, it is advisable to consider additional specifications that include other characteristics of factor prices, as well as regional and industrial characteristics that can impact the location decision of firms, agglomeration forces and, evidently, the incentives to the reorganization of industry. These specifications are detailed later on.

Starting from the equilibrium conditions of an integrated economy, the cost function that is estimated is

$$C(y) = \alpha_0 + \sum_i \alpha_i y_i + \frac{1}{2}\sum_i \sum_j \alpha_{ij} y_i y_j + \varepsilon_{ij} \tag{12}$$

for i,j=1,2 being 1 the production of final goods and 2 the production of intermediate goods. Equation (12) it is the general formulation of the cost function to be estimated, assuming that the errors are identically and independently distributed among regions and over time. This equation is considered separately for each industry.

The quadratic cost function is generally used when information on factor prices is not available. However, in this specification the parameters a_{ij} depend on these prices that are supposed exogenous. Spatial variations of factor prices can be important in the determination of the most efficient way of organising local production. Therefore, the specification should include multiplicative variables of the outputs with the input prices[8].

In case of not having factor prices data, or if they are subject to some measurement error, it is still possible to take into account their effects from the correlation between factor endowments and their prices. It is possible to control for the differences in the relative factor prices assuming that the factor price equalization theorem holds and

[8] The estimation of a cost function requires the inclusion of factor prices, independently of the time horizon (short or long run) because these prices are essential to analyse the relationship between optimal input quantities and optimal output. See chambers (1988).

introduce dummy variables to control for these differential effects at the regional level. Thus, the corresponding specification would be

$$C(y) = \alpha_0 + \phi_j d_j + \sum_i \alpha_i y_i + \frac{1}{2}\sum_i \sum_j \alpha_{ij} y_i y_j + \varepsilon_{ij} \tag{13}$$

In equation (13) the dummy variables also control for the existence of common macroeconomic effects in the error term. When including factor prices, dummy variables would only pick up this last effect.

The previous hypothesis is highly restrictive if we admit the possibility that some factors are immobile. The solution to this would require the addition of some other variables that allow controlling for these effects. Following Harrigan (1997), it is possible to capture the effects induced by the presence of immobile factors assuming that their prices are obtained from a probability distribution that can be estimated. An additional specification taking into account these effects would include a country fixed effect, time dummies and an independently distributed stochastic error term:

$$C(y) = \alpha_0 + \lambda + \phi_j d_j + \sum_i \alpha_i y_i + \frac{1}{2}\sum_i \sum_j \alpha_{ij} y_i y_j + \mu_{ij} \tag{14}$$

where $\mu_{ij} = \varepsilon_{ij} + u_{ij}$. The country fixed effect (λ) also controls for a common error component between regions and time for each country. Once again, when including factor prices explicitly, this specification would be controlling not only the possibility that some factors are geographically immobile but also specific effects coming from political and institutional differential characteristics among the countries in the sample.

Given that the variables affecting production conditions in different regions and among sectors are multiple, it is recommended to include a large set of related variables to capture them. So, the inclusion of other variables, directly or indirectly related to the productive process, could be useful to explain production costs differences in the different industries in the European regions. The inclusion of variables that represent regional as well as sectoral characteristics could have a direct impact on production costs and, hence, in the degree of vertical integration. These variables are listed in the next section.

3.3 Variables and data

The estimation of a cost function requires information about quantities produced and on prices and quantities of factors of production. Besides, as it was already explained, the characteristics of the regions and of the different sectors are fundamental when explaining specialization and concentration patterns, since they allow to determine more precisely the forces of attraction and repulsion that give place to agglomeration. In what follows, variables sources and the methodology to construct additional indicators are described.

The estimation of the cost function requires information on total costs, production of final and intermediate goods and factor prices whose elaboration is described next:

- **Total cost (CT):** following Kwoka (2002), total costs of production should be net costs, that is, not including the payments made by firms for the inputs used in the production of final goods. Therefore, total costs are the sum of labour costs and capital costs (CT = wL + rK).

- **Cost of labour (wL):** these is the compensation of employees, obtained of the REGIO database, by sector and region.

- **Labour (L):** employment (persons) in each sector in each region, from REGIO.

- **Price of labour (w):** the quotient of compensation of employees and employment, as an index 1985=1.

- **Cost of capital (rK):** is the product of the price of capital times the corresponding capital stock.

- **Capital (K):** is the capital stock for sector each sector and region, built by means of the permanent inventories method. The information used was the gross fixed capital formation data from REGIO. The initial value of the capital stock is calculated following Bloom et al. (2001) with the following methodology:

$$K_1 = \left[\frac{\sum_{i=1}^{n} \left(GFKF_i / VA_i \right)}{n} \right] \frac{VA_1}{\delta}$$

where K_1 represents the initial stock of capital, GFKF is capital formation and VA is value added. This quotient can be interpreted as the rate of investment of the sector, n represents the number of periods for which the calculation is made and δ is the depreciation rate that is assumed constant in time and identical for all sectors and regions. In this case, it has been assumed a depreciation rate of 5% and a four year for the calculation of the initial stock of capital (n=4). From this starting point, the permanent inventories method follows the rule:

$$K_{t+1} = I_t + (1-\delta)K_t$$

where I_t is investment in time t.

- **Price of capital (r):** to obtain an estimate of the price of capital, the methodology used is the one proposed by Berndt and Hansson (1991), in which it is not possible to take into account the regional component and it is considered at the country level by means of the following formula

$$r = [i + \delta] p_k$$

where r is the price of capital in one country, i is the long term nominal interest rate and p_k is the deflator of capital formation. All variables are obtained at the country level from the OECD Economic Outlook publications[9].

- **Production of final goods (Yf):** proxied by means of value added by sector and region, obtained from REGIO database.

- **Production of intermediate goods (Yi):** this variable is obtained from Duch (2004) where spatial disaggregation methods are used to distribute geographically both value of production and intermediate consumptions by sector at the national level for the 11 countries used in this paper. Given regional value added and the spatialised value of production, intermediate consumptions are calculated as the difference. Given that intermediate consumption is also allocated regionally, comparing both measures serves as a robustness check for the obtained data[10].

In addition to the variables that enter the cost function directly, other variables are used to control for the effects derived from the characteristics of the regions and sectors in the sample. These variables are explained next.

a) Regional characteristics

The characteristics of the regions, summarized in the following variables, were obtained from the REGIO and DAISIE databases or built from existing data in these sources.

- **Market size (TM):** measured by population density (total population of the region by km2). Both variables were obtained of the REGIO database.

- **Market potential (PM):** is measured by means of the population of contiguous regions to the reference region.

[9] Note that given the absence of regional deflators for capital formation, the price of capital only varies between countries. This implicit assumption is consistent with evidence showing that capital markets are more integrated than goods and factor markets in the EU. See Molle (2001).

[10] Results are invariant to the use of one or other measure of intermediate production.

- **R+D intensity (RD):** employment in R+D activities, obtained from the REGIO database.

- **Index of regional specialisation (IE):** this is a regional specialisation index calculated with an entropy index calculated with value added from REGIO database.

b) Industrial characteristics[11]

The characteristics of the different industrial sectors used are defined next.

- **Minimum Efficient Scale (EME):** calculated as the average firm size in each industry. The number of firms at the regional level is obtained from the DAISIE database and was complemented with information from the sixth report on companies in Europe.

- **Forward and backward linkages (FL, BL):** in the first case it refers to the share of intermediate consumption in total costs (Yi/CT) and in the second it refers to the share of intermediate consumption in total production (Yi/(Yf+Yi)).

- **Geographical concentration (G):** it is an entropy index for geographical concentration of production, measured by value added.

Given the nature of the data, that is, periodic observations for the same group of individuals, intuitively the most appropriate estimation method is the use of panel data with fixed coefficients for each region, since cross section units cannot be considered as random observations. Nevertheless, this is a hypothesis that should be tested by means of the appropriate statistical tests. In this case, in the first place it should be tested that indeed panel data techniques throw superior results to the classic regression model, independently of the nature of the data. This is carried out by means of a LM test, proposed by Breusch and Pagan (1980), being the null hypothesis the non significance of the specific effects.

[11] The industrial classification used is presented in table A.1 in the appendix.

Once the use of the panel techniques has been decided, the specification of fixed or random effects should be decided on the basis of a Hausman (1978) test, based on the existence or absence of correlation between the errors and the explanatory variables. The consequence of this tests is the preference of the panel techniques to the classic pooled regression, and among these, fixed effects are preferable to random effects.

The fixed effects model assumes that the presence of an individual effect for each cross section unit captures the whole correlation among the non-observable effects in different periods of time. If the vector of explanatory variables is strictly exogenous, the presence of autocorrelation in the errors doesn't necessarily imply the inconsistency of the estimators. However, it invalidates the standard errors and the associated statistical tests, meaning that the estimators are no longer efficient. The presence of heterosckedastic errors has similar consequences. In the context of the estimated model, where the individual units are regions that differ in size, error terms associated with larger regions can have greater variances than those of small regions. If the presence of heteroskedasticity is assumed among cross section units, the model should be estimated by means of the feasible generalized least squares (FGLS) adopting the methodology proposed by White (1980).

On the other hand, we know that the error term picks up the influence of all those variables that affect the dependent variable but that have not been included in the model. The persistence of effects of excluded variables is, therefore, a frequent cause of positive autocorrelation. If these excluded variables are observed and can be included in the model, the resulting autocorrelation can also be interpreted as an indication of an erroneous model specification, resulting from the use of inappropriate functional forms, omitted variables and or an inadequate dynamic specification.

The first estimations showed the existence of heteroskedasticity and autocorrelation, so that the results presented in the next section incorporate the corrections to these two problems. Thus, as it was required the specification of an autoregressive model of the errors, it has been preferred not to include time dummies and to use those specifications that incorporate regional and industrial characteristics to increase the robustness of the results[12].

3.4 Results[13]

To compare estimation results of the cost functions among the different sectors considered, table 1 offers a summary of the parameters of the first specification, that is, the one that only includes variables directly associated to production activities (quantities of final and intermediate goods and interactive terms between these and factor prices). We can see in the table that the estimated parameters associated to final goods production are positive and highly significant. It doesn't happen the same with the estimated effects of the production of intermediate goods, since for mineral and non metallic minerals, paper and printing products and other manufactured products, the parameters are negative (and significant), while in the case of chemical products and food, beverages and tobacco are positive but not statistically significant.

On the contrary, the quadratic terms of the function are negative (although some of them not significant), indicating that the costs increase to a decreasing rate. As it was already explained, this is a condition for the existence of stage specific scale economies. Since both groups of parameters are negative, it is expected that scale economies exist in the production of both final and intermediate goods.

The coefficients of the interactive term between the production of final and intermediate goods (Y_f*Y_i) are all positive and significantly different from zero, except in the case of food, beverages and tobacco, textiles, leather and footwear and paper and printing products that are not statistically significant. In this case, cost complementarity indicates

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[12] An alternative to obviate these problems could be the partition of the sample in concrete points in time, for example using the initial year, the final year and some intermediate observation. However, this solution would not take into account the full information of the panel, possibly throwing less consistent estimates.

[13] Because of space restraints, the whole set of results are not presented in what follows, but are available from the author upon request or can be consulted in Duch (2004).

that total costs are smaller in those regions where production takes place in separate stages[14].

However, as it has been explained the existence of vertical economies has two components. On the one hand, cost complementarity reflected by the coefficient of the interactive term. On the other hand, the existence of indivisible inputs common to both stages of production that is captured by means of the fixed effect associated to each region. Therefore, the existence of economies of vertical (dis)integration requires the computation of this net effect, as it will be seen later on. Regarding factor prices, most of the estimated parameters are positive, as expected, and highly significant. A remarkable exception is the interaction among the price of labour and the production of intermediate goods that has negative parameter estimates in seven out of nine analyzed sectors.

The second specification is summarized in table 2 and includes, in addition to the above-mentioned variables, the set of variables that capture regional characteristics as a way of approaching the presence of localised external economies. The parameter associated to the size of the local market is positive for five sectors and negative in the rest. Nevertheless, only six of these are significant. In the case of chemicals and other manufactured products the coefficient is negative and significant, indicating that production costs are smaller in bigger regions. On the contrary, mineral and non metallic minerals, metallic products, machinery and equipment, food, beverages and tobacco and textiles, leather and footwear have positive and significant coefficients, indicating that costs are higher in bigger regions.

The market potential variable shows a peculiar result. This variable is significant in seven out of nine sectors, being in all them positive and indicating that costs tend to be higher in those regions surrounded by big regions. This result can reflect the presence of congestion, high land prices or any other source of centrifugal forces. As for R+D, it is significant in seven out of nine sectors and of these, it is negative in six, indicating that those regions that make a bigger effort in R+D have lower total costs of production.

[14] This would also mean that join production increases total costs.

Finally, regional specialization throws contradictory information. This variable is only significant in four sectors and positive in three of these. It is necessary to remember that the specialization index is an inverse index, so a positive sign indicates a cost reduction. This means that specialized regions are able to produce with smaller costs.

The third specification includes exclusively variables that proxy industrial characteristics, to measure its impact on the cost minimising process of the different activities and are summarised in table 3. Minimum Efficient Scale, calculated as average firm employment in each industry is significant in four sectors, metallic minerals, chemicals, metallic products, machinery and equipment and transport material. In all these sectors, scale economies play an important role in the determination of the optimal plant size. Of these, their estimated parameters are negative in three, indicating that scale economies in production leads to smaller costs, tending to increase the average firm scale.

The second variable in the table refers to backward linkages, defined as the proportion of intermediates in total costs. This variable is positive for all sectors, although significant only in three. This result indicates that, as the quantity of intermediate goods used in production increases, total costs also increase.

On the other hand, all the estimated coefficients of forward linkages are negative, being significant in six out of nine sectors. Since these linkages have been specified as the share of intermediate consumption in total costs, this indicates that those regions that use a greater proportion of intermediate inputs produce with lower costs. Indirectly, this result throws evidence on the advantages of specialized production in the context of the geographical distribution of productive activities.

Finally, the last variable refers to the index of geographical concentration[15]. Table 3 indicates that this coefficient is significant in five sectors. In three of them (metallic products, machinery and equipment, transport material and foods, beverages and tobacco) the sign is negative indicating that geographical concentration tends to increase

[15] It is necessary to remember, as in the case of the specialization index, that this is an inverse measure calculated by means of an entropy index. Therefore, a positive result would indicate that costs are lower in agglomerated industries.

production costs. On the other hand, the estimated coefficients are positive in two sectors, metallic minerals and metallurgy and chemical products, in which geographical concentration has a direct impact in cost minimisation.

Table 4 shows the results of the estimates of two additional specifications. In the first of them (specification 4), apart from the components of the cost function, it only includes the indexes of regional specialization and of geographical concentration to analyze their effects on production costs, trying to disentangle the role they play in the cost competition process unchained by a greater European integration.

In this specification, only the index of regional specialization is statistically significant in two sectors, metallic minerals and metallurgy and metallic products, machinery and equipment. For the first of them, the coefficient is negative, indicating that a greater specialization tends to increase production costs, while for the second the coefficient is positive, indicating that specialized regions tend to produce with smaller costs.

On the other hand, the geographical concentration index is significant in four sectors, the previous two along with chemical products and other manufactured products. The greater geographical concentration seems to favour production with lower costs in the metallic minerals and metallurgy and chemical products, while causing a cost increase in the other two sectors. Considering specialization and concentration effects separately the estimation results seem to worsen with regard to previous specifications. So, an additional specification, summarised in the bottom of table 4 including other regional and sectoral characteristics, is estimated to see if in combination with the previous variables their impact is more clearly netted out.

Table 4 includes, as additional variables, market potential, to capture the effect of a greater accessibility of local industries to larger markets on production costs and the Minimum Efficient Scale, as a measure of the magnitude of scale economies in order to analyse if technology and scale considerations has an impact on cost competition at the regional level.

Contrarily to what intuition could suggest, the explanatory power of specialization and concentration indexes diminishes considerably when including these additional variables. As it could be appreciated in the table, both indexes are only significant for one sector (chemical products in the case of regional specialization and metallic minerals and metallurgy for the case of geographical concentration). In both cases the impact is positive, indicating that production costs are smaller in regions specialized in the production of chemicals and in regions with a high share of the production of metallic minerals.

Finally, a final specification includes all the regional and industrial characteristics. The results are presented in table 5, omitting the parameters associated to the specific components of the cost function.

When considering all the regional and sectoral characteristics jointly, the results don't differ considerably of those obtained previously. The most significant variable in the process of cost minimisation is forward linkages. This variable is always negative, indicating that a higher proportion of intermediates in total costs have an enormous impact in the ability of the regions to produce with lower costs. This variable is statistically significant in six out of nine sectors.

In second place, R+D intensity and market potential share importance, being both significant in five sectors. Nevertheless, the second variable shows positive values indicating that the greater the contiguous markets of the reference region the higher the production costs. This result indicates that access to markets is not a relevant variable for production and, consequently, for the location decisions of firms. This happens, following arguments of the new economic geography, when trade costs are sufficiently low so that accessibility is no longer relevant. This might be the case of a more integrated Europe.

A third group of variables ordered according to its importance in the determination of the production costs would be formed by minimum efficient scale and backward linkages. Both are significant in four sectors. Concerning the first variable, it is only positive in one sector (paper and printing products), indicating that a greater average firm size would lead to produce with higher costs. It is necessary to highlight that scale economies seem particularly relevant in the two sectors of strong demand and high technological content (chemical products and metallic products, machinery and equipment).

The size of the local market and regional specialization are significant in three sectors. The first characteristic throws positive parameters (although near to zero), indicating that costs are higher in bigger regions. The second indicates that specialized regions produce with smaller costs. This is so for the two sectors considered as high technology and strong demand.

Finally, the effects of geographical concentration of production on costs are only statistically significant in two sectors (metallic minerals and metallurgy and paper and printing products) indicating that in both activities a greater geographical concentration impacts directly in the ability to produce with lower costs thus indicating the presence of localised external economies (or agglomeration economies). This result contrasts with almost all previous specifications where the effects of spatial concentration seem to have a greater incidence and its influence manifested in more sectors. Possibly when controlling for other characteristics as scale economies or forward and backward linkages, this variable loses importance.

4. Vertical localisation economies

The estimated parameters for the components of the cost function, the quantities of final and intermediate goods, their quadratic terms and the interactions between factor prices and quantities, stay relatively stable independently of the specification. In the same way, the statistical significance of these parameters decreases when introducing additional (regional or industrial) variables. For this reason, the first specification has been used to calculate the corresponding scale economies, global and stage-specific, and more importantly, economies or diseconomies of the vertical integration.

From table 1 it comes out that the necessary conditions for the existence of scale economies in each stage of the process are satisfied, since the parameters associated to the quadratic terms of the quantities are negative. We can see that the necessary conditions for the existence of diseconomies of vertical integration are also satisfied as the estimated parameters of the interactive term of the quantities are positive, indicating that the combined production of final and intermediate goods cause an increase in total costs. Nevertheless, since fixed costs associated to indivisibilities that can be duplicated exist in case production is carried out separately, one should confirm that, indeed, economies of vertical disintegration exist. These fixed costs are captured by the fixed effects associated to each region in each one of the previously proposed specifications.

In general terms, the existence of multi-stage scale economies is confirmed. These economies become localised external economies or agglomeration economies when analyzing aggregated industrial sectors. Since the objective is the determination of localised external economies that can arise because of the presence of specialised input suppliers in the territory and derived from the existence of backward and forward linkages table 6 shows the cost savings that firms located in each region can enjoy in the event of carrying out production in a specialized way in each stage of the process, if the associate sign is negative. Cost savings will be observed for vertically integrated production in case the sign is positive.

To obtain more insights from this relationship, table 7 relates geographical concentration with an average measure of vertical economies by sector. The table shows that the more concentrated activities are in space, regions tend to be more efficient producing in a specialized way. For manufacturing activities as a whole, for example, the costs are around 1.2% smaller in the case of specialized production. The cost reduction could reach, on average, 5% in metallic products, machinery and equipment and would be near 4% in transport material. On the other hand, vertical integration allows to reduce production costs on average a 2% in mineral and non metallic minerals and in something less than 1.5% in food, beverages and tobacco. Finally, it is necessary to highlight two cases in those that this relationship is not completed. On one hand, the sector chemical products increases its degree of geographical concentration but it shows economies of the vertical integration, indicating a null sensibility to the presence of local specialised suppliers. On the other hand, other manufactured products are more geographically dispersed in 1995 than in 1985 and however, specialized production is more efficient than its vertically integrated counterpart.

Until now, the analysis has been strictly centred in the technological aspects of production, without considering market power effects or other types of market imperfections. We will not tackle these issues here, but it is important to highlight that some of the results obtained here might be misleading because of the considerations of strategic interactions between firms[16].

5. Conclusions

This paper presents an attempt to estimate the economies of vertical (dis)integration as a measure of localisation economies for several manufacturing industries at the European regional level. To do this, a quadratic cost function is specified and estimated through a panel of regional data for production factors as well as regional and industrial characteristics. The approach taken here is somehow similar to that used by Hayasi et al. (1997) and Kwoka (2002) but from a geographical perspective to complement the empirical results obtained by Hanson (1994), Holmes (1999), Haaland et al. (1999) and Midelfart-Knarvik et al. (2000a, b) where the intensity in the use of intermediate inputs is associated to geographic concentration of production. In this paper, however, we offer an alternative approach to such a relationship. The starting point is to consider that an industry can produce final and intermediate goods. The economies of vertical disintegration are defined as the cost savings that can exist if specialised production is more efficient than the vertically integrated. The definition of these economies is done modifying the classic concept of scope economies for the case of a productive unit that operates in two stages of the production process.

Some of the conclusions to be drawn from an examination of the results can be summarised as follows. Overall, total costs are smaller for those regions that produce in separate and specialised stages final and intermediate goods. The most significant variable in the process of costs minimisation is the associated to forward and backward linkages. Finally, relating the results obtained from the estimation of the cost function with those of the geographical concentration of manufacturing activities in the European regions considered show that, in aggregate terms, those activities more geographically concentrated tend to be more efficient producing in a specialized way but, nevertheless, some activities in some regions are more efficient by means of vertically integrated production.

[16] See Duch (2005) for a paper that considers explicitly these topics.

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Table 1. Multistage cost function estimation results – Specification 1

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
Yf	2,592	2,966	3.232	2.893	2.168	3.015	2.222	3.347	2,867
	(31.132)	(52.807)	(53.597)	(57.506)	(19.929)	(65.822)	(49.781)	(26.312)	(44.860)
Yf^2	-0,0001	-0,001	-0,00004	-0,00002	-0,001	-0,001	-0,001	-0,001	-0,001
	(-0.588)	(-3.291)	(-1.691)	(-3.523)	(-1.929)	(-5.803)	(-2.609)	(-3.128)	(-3.341)
Yi	0,889	-0,260	0,082	0,125	0.665	0.048	0,108	-0,174	-0,154
	(14.072)	(-6.286)	(1.717)	(3.267)	(5.48)	(1.168)	(2.810)	(-1.875)	(-3.214)
Yi^2	-0,0002	-0,001	-0,00002	-0,000006	-0,001	-0,001	-0,001	-0,001	-0,001
	(-1.635)	(-2.891)	(-2.260)	(-2.383)	(-2.905)	(-4.240)	(-1.050)	(-3.757)	(-2.796)
Yf * Yi	**0,0003**	**0,001**	**0,0001**	**0,00003**	**0,001**	**0,001**	**0,001**	**0,001**	**0,001**
	(2.445)	(2.216)	(2.732)	(4.087)	(2.479)	(0.834)	(1.553)	(1.845)	(2.831)
w * Yf	0,165	0,111	0,504	0,555	-0,013	0,293	0,087	0,345	0,275
	(20.503)	(7.612)	(15.251)	(25.995)	(-0.373)	(8.578)	(7.577)	(7.728)	(8.742)
w * Yi	-0,039	-0,005	-0,188	-0,171	0,226	-0,093	-0,012	-0,03	0,074
	(-13.147)	(-0.421)	(-6.438)	(-10.602)	(4.560)	(-2.646)	(-1.501)	(-0.939)	(2.786)
r * Yf	2,280	2,671	2.550	2,341	2,292	2,699	2,204	2,838	2,486
	(39.307)	(53.29)	(67.520)	(67.0)	(24.554)	(99.446)	(51.497)	(28.942)	(70.955)
r * Yi	0,901	0,275	0,182	0,12	0,473	0,194	-0,134	0,297	0,113
	(18.359)	(7.25)	(5.896)	(4.083)	(4.618)	(10.554)	(-3.424)	(3.618)	(3.464)

Source: Own elaboration.

Table 2. Mustistage cost function estimation results – Specification 2

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Local market size	-0,0004	0,007	-0,008	0,164	-0,009	0,104	0,009	0,011	-0,105
	(-0.759)	(3.604)	(-9.181)	(2.878)	(-0.270)	(6.038)	(3.085)	(0.681)	(-16.917)
Market potential	0,003	0,002	0,112	0,122	0,153	0,108	0,009	0,015	0,015
	(8.747)	(0.636)	(1.699)	(1.884)	(2.201)	(5.049)	(3.508)	(3.256)	(4.503)
R+D intensity	0,041	-1,500	-0,404	-2,957	-6,068	-3,211	1,714	-3,527	-2,848
	(1.095)	(-4.495)	(-4.148)	(-0.383)	(-2.822)	(-2.485)	(7.381)	(-3.182)	(-7.388)
Regional specialisation	2,412	-2,524	18,366	0,038	4,07	-2,459	-0,567	0,833	0,598
	(13.355)	(-5.325)	(8.531)	(0.004)	(3.189)	(-1.210)	(-1.240)	(0.634)	(0.592)

Source: Own elaboration.

Table 3. Multistage cost function estimation results – Specification 3

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Minimum efficient scale	-0,363	2,875	-0,149	-0,303	0,004	0,496	-4,474	0,033	-1,378
	(-10.122)	(0.763)	(-13.554)	(-5.549)	(0.473)	(15.885)	(-0.539)	(0.109)	(-0.217)
Backward linkages	0,637	106,046	0,454	130,808	6,794	26,454	55,928	25,035	70,399
	(0.144)	(0.728)	(1.259)	(5.619)	(4.297)	(15.000)	(0.112)	(1.068)	(0.061)
Forward linkages	-4,195	-134,977	-1,262	-82,256	-11,421	-70,671	-45,774	-30,294	-59,782
	(-4.896)	(-1.593)	(-5.027)	(-4.26)	(-8.28)	(-23.163)	(-0.221)	(-2.115)	(-0.208)
Geographic concentration	294,4	-6376,2	131,0	-2118,5	-99,953	-3488,1	-8393,625	749,661	-41171,82
	(7.902)	(-1.081)	(9.398)	(-3.891)	(-2.034)	(-20.932)	(-0.571)	(1.029)	(-0.552)

Source: Own elaboration.

Table 4. Multistage cost function estimation results – Specification 4

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Regional specialisation	-4,090	-6,120	-0,751	73.60	5,896	-0,975	-1,208	-9.135	23.150
	(-2.589)	(-1.122)	(-0.203)	(2.694)	(1.085)	(-0.059)	(-0.325)	(-0.620)	(0.390)
Geographic concentration	485,9	-1991,4	1276,6	-3731,9	-409,049	-7563,6	-442,837	1492,71	-36983,93
	(6.846)	(-0.967)	(5.198)	(-3.038)	(-0.989)	(-1.600)	(-1.387)	(0.877)	(-2.389)
Market potential	0,0008	0,017	0,032	0,188	0,165	0,172	-0,309	0,058	0,004
	(0.811)	(0.374)	(9.360)	(1.952)	(2.405)	(4.565)	(-0.479)	(0.573)	(0.016)
Regional specialisation	0,6402	-7,762	21,937	98,732	4,011	-6,902	-24,863	-32,101	-4.130
	(0.916)	(-1.218)	(15.023)	(1.627)	(1.517)	(-0.210)	(-0.285)	(-1.082)	(-0.031)
Minimum efficient scale	-0,134	-0,254	-0,361	-0,764	0,029	1,548	0,153	-0,484	-1,101
	(-20.497)	(-0.165)	(-11.961)	(-2.538)	(0.403)	(0.849)	(0.023)	(-0.261)	(-0.311)
Geographic concentration	45,1	184,3	-37,9	-2568,9	-227,132	-8388,0	-7553,308	2055,514	-32545,99
	(8.396)	(0.076)	(-0.935)	(-0.99)	(-0.491)	(-1.025)	(-0.604)	(0.490)	(-0.862)

Source: Own elaboration.

Table 5. Multistage cost function estimation results – Specification 5

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Local market size	0,001	0,008	0.010	0,214	0,011	0,099	-0,087	0,022	-0,095
	(2.8067)	(0.068)	(1.116)	(4.986)	(0.353)	(1.678)	(-0.229)	(1.218)	(-0.356)
Market potential	0,0002	0,020	0,061	0,095	0,137	0,216	-0,282	0,04	-0,007
	(0.1602)	(0.248)	(5.771)	(2.314)	(2.203)	(3.645)	(-0.388)	(1.750)	(-0.052)
R+D intensity	-0,5286	-2,362	-7,291	-3,017	-11,616	-4,796	-0,886	-5,023	-0,733
	(-7.2697)	(-0.394)	(-5.012)	(-0.89)	(-4.776)	(-3.173)	(-0.064)	(-2.287)	(-0.094)
Regional specialisation	1,1030	-3,039	13,343	100,995	21,546	-16,172	-17,111	-0,471	28,696
	(1.6639)	(-0.141)	(3.255)	(5.176)	(3.137)	(-0.400)	(-0.165)	(-0.129)	(0.297)
Minimum efficient scale	-0,126	3,021	-0,66	-0,484	0,088	0,984	0,521	0,193	-0.990
	(-24.075)	(0.518)	(-4.413)	(-5.653)	(1.486)	(0.743)	(0.064)	(1.781)	(-0.395)
Backward linkages	-0,074	139,894	43,105	192,836	42,903	158,426	95,859	19,144	68,342
	(-0.243)	(0.689)	(4.927)	(4.999)	(2.667)	(0.941)	(0.203)	(1.840)	(0.167)
Forward linkages	-0,781	-125,975	-14,265	-122,167	-31,407	-273,788	-38,148	-8,899	-67,758
	(-6.127)	(-1.301)	(-2.945)	(-3.553)	(-4.158)	(-1.958)	(-0.367)	(-2.209)	(-0.571)
Geographic concentration	38,1	-5407,2	-175,4	782,7	-262,608	-3535,387	-7177,071	513,331	-37432,29
	(7.971)	(-0.597)	(-0.634)	(1.011)	(-0.714)	(-0.661)	(-0.479)	(2.149)	(-1.340)

Source: Own elaboration

Table 6. Vertical economies and diseconomies by region and sector

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Baden-Württemberg	2,1	-14,1	-16,4	-3,7	-16,2	-4,0	-20,1	-7,9	-4,3
Bayern	3,7	-10,5	-9,6	-20,8	-8,3	2,1	-17,9	-5,3	-4,5
Berlin	1,0	-2,0	-2,0	-8,5	-1,2	-1,6	0,2	-5,5	-16,5
Bremen	-0,3	-19,6	-2,2	-3,8	-9,0	-11,3	-4,5	-2,4	-6,3
Hamburg	-3,7	3,3	-0,8	-18,2	0,2	-12,8	6,0	-2,3	-21,7
Hessen	2,7	-11,3	-4,6	-18,7	-6,3	-4,4	-10,0	-10,7	-4,5
Niedersachsen	-1,2	-10,9	-4,1	-14,5	-6,0	2,0	-4,9	-5,4	-18,5
Nordrhein-Westfalen	-11,3	-15,5	-2,4	-5,1	-14,5	2,3	-19,4	-7,3	-3,0
Rheinland-Pfalz	6,6	-3,1	3,0	-15,8	-3,7	-5,2	-1,8	-8,7	-2,3
Saarland	1,7	-7,7	-2,1	-11,2	-0,8	-8,9	-15,2	-14,3	-19,1
Schleswig-Holstein	2,4	-3,7	2,2	-9,1	-4,8	-6,1	0,2	-5,8	-12,3
Bruxelles	3,2	3,2	-9,4	-10,2	5,6	9,4	1,2	13,7	10,7
Antwerpen	3,0	2,9	19,0	0,2	-8,4	18,1	18,2	15,8	-1,0
Limburg (B)	2,8	4,2	3,1	5,2	20,0	-2,4	-7,0	7,8	16,4
Oost-Vlaanderen	12,6	3,6	20,3	16,6	-1,5	13,5	-0,8	3,4	15,9
Vlaams Brabant	2,4	2,2	2,5	-5,2	6,1	12,1	2,1	13,7	-4,3
West-Vlaanderen	-6,1	17,5	2,7	5,2	-6,0	12,3	1,0	19,2	7,8
Brabant Wallon	-2,4	4,0	3,0	-5,1	4,0	7,9	6,7	9,6	20,1
Hainaut	0,2	9,0	19,4	0,9	11,6	2,5	-3,5	5,0	3,8
Liège	5,5	2,6	4,1	-8,4	-9,1	4,2	12,4	4,5	12,5
Luxembourg (B)	10,3	6,9	2,5	-8,6	5,0	5,2	3,2	6,5	4,2
Namur	-4,4	3,1	16,5	2,3	11,4	5,8	2,0	2,2	12,0
Denmark	13,1	17,5	13,1	-2,4	-6,8	14,2	-3,0	16,1	9,6
Galicia	-16,5	-7,1	-15,7	-11,0	-19,5	-10,9	-6,8	-12,4	-8,4
Asturias	-12,3	-7,9	-6,1	-7,1	-10,8	-8,2	-8,3	-6,8	-6,0
Cantabria	-14,8	-4,1	-13,0	-10,3	-13,0	-8,1	-5,3	-10,9	-8,9
Pais Vasco	-18,9	-8,0	-14,8	-12,8	-17,1	-13,5	-8,0	-11,7	-9,5
Navarra	-5,2	1,4	-0,1	-1,1	-0,5	-3,0	1,1	-4,3	0,1
La Rioja	-3,7	-15,4	-20,8	-2,2	-3,1	-6,3	-14,9	-2,2	-18,5
Aragón	-6,7	4,0	-6,9	-2,7	-8,0	-4,6	-0,8	-3,4	-2,1
C. de Madrid	-10,6	-6,4	-12,6	-12,2	-20,9	-10,6	-7,5	-7,0	-6,8
Castilla y León	-9,1	-2,8	-7,4	-6,1	-12,7	-7,9	-3,9	-8,7	-3,9
Castilla-La Mancha	-13,4	-3,7	-4,9	-6,2	-7,2	-7,3	-3,4	-6,1	-2,5
Extremadura	-12,3	1,5	-8,0	-1,8	-5,8	-3,9	-2,1	-2,7	-0,5
Cataluña	-10,8	-4,6	-8,6	-7,6	-12,7	-2,8	-5,5	-4,9	-3,8
C. Valenciana	-12,0	-5,2	-4,9	-9,4	-15,5	-7,8	-7,9	-8,6	-6,3
Baleares	-8,6	-4,8	-15,6	7,3	-2,2	-2,3	-8,6	-18,1	-6,0
Andalucia	-20,8	-14,2	-18,7	-14,2	-2,6	-15,9	-11,5	-13,9	-9,2
Murcia	-19,7	-12,9	-21,6	-14,4	-3,1	-2,5	-9,5	-15,4	-12,1
Canarias	2,2	-4,0	12,2	-3,6	-2,7	-11,2	8,3	-9,5	-3,4
Ile de France	12,3	13,1	-9,6	-19,3	-2,6	18,4	-0,7	20,1	-0,6
Champagne-Ardenne	4,8	1,1	6,8	-3,3	12,9	11,3	-4,8	6,0	12,8
Picardie	14,9	14,8	6,8	1,3	-2,3	1,4	-0,7	2,3	8,6
Haute-Normandie	-18,1	11,7	12,2	-3,2	16,8	11,3	-5,6	-14,1	9,8
Centre	2,4	2,1	19,1	-2,2	-2,8	6,3	3,1	10,6	9,6
Basse-Normandie	-12,3	16,2	6,6	0,7	14,2	7,7	6,1	12,7	8,8
Bourgogne	6,5	4,8	6,6	-2,3	-1,9	4,2	-5,4	6,0	2,9
Nord - Pas-de-Calais	-7,0	9,6	14,7	-4,3	-9,9	11,0	-8,4	5,6	8,1
Lorraine	-6,7	9,8	7,1	2,7	-1,8	3,5	-6,4	14,7	12,3
Alsace	5,1	-3,1	13,3	2,9	5,6	7,6	-3,6	11,4	9,9
Franche-Comté	19,0	14,8	21,1	2,4	-12,8	10,7	-7,5	5,1	9,8
Pays de la Loire	-5,8	12,3	7,9	-0,4	1,5	8,5	-4,2	10,8	9,5

Continues….

Table 6. Vertical economies and diseconomies by region and sector

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Bretagne	2,0	6,9	17,7	0,8	0,6	11,4	2,9	7,6	7,4
Poitou-Charentes	21,6	2,1	-15,5	-1,8	-4,3	14,6	0,6	0,3	9,2
Aquitaine	2,4	3,9	18,0	-2,9	-5,4	0,3	-6,8	4,6	5,4
Midi-Pyrénées	0,2	8,0	11,6	0,8	-0,9	8,6	-6,6	14,2	6,2
Limousin	-1,0	7,4	4,3	0,8	13,6	11,6	1,3	3,0	14,8
Rhône-Alpes	1,2	5,0	-3,9	-8,6	-6,8	12,1	-0,5	6,3	-0,2
Auvergne	1,9	2,6	2,4	1,7	-3,8	1,2	2,0	19,5	2,4
Languedoc-Roussillon	-4,8	-2,0	18,7	4,3	-4,2	7,0	1,2	9,0	4,4
Prov-Alpes-C d'Azur	15,5	4,4	7,7	-10,3	-13,0	10,3	-5,8	5,1	4,6
Corse	-10,3	5,6	-18,6	-6,6	-20,1	10,0	12,8	10,7	3,2
Noord-Nederland	-4,3	-0,9	-4,2	-4,2	-7,7	4,8	0,5	0,9	0,3
Oost-Nederland	4,2	5,5	13,1	0,9	0,1	12,3	0,7	6,7	-7,8
West-Nederland	-10,2	-7,4	-17,8	-8,4	-11,3	0,8	-4,1	0,5	-4,9
Zuid-Nederland	2,9	10,1	4,6	0,1	-2,1	13,6	-0,4	7,8	-1,6
Ireland	18,3	6,3	5,6	18,5	-7,4	18,8	-2,1	17,1	20,9
Piemonte	6,7	17,8	8,9	-8,1	-2,8	2,1	-4,5	-2,1	-9,1
Valle d'Aosta	-9,7	6,3	-4,1	0,7	-6,8	4,7	-2,9	-12,2	-19,1
Liguria	-15,0	9,3	2,5	-19,7	-2,4	-0,9	-7,9	-5,1	-3,9
Lombardia	-8,9	2,6	-11,4	-14,3	-5,1	4,7	-3,8	-2,5	-3,5
Trentino-Alto Adige	-1,5	-2,2	-7,3	-0,1	-10,4	9,8	-9,1	-0,8	8,4
Veneto	2,4	8,2	9,3	-9,7	-17,7	3,0	-7,2	-0,2	-8,1
Friuli-Venezia Giulia	11,5	7,9	11,6	-7,0	-2,7	0,8	-3,7	14,4	-7,6
Emilia-Romagna	0,1	5,5	7,0	-13,2	-3,6	5,8	-16,0	-1,4	-6,1
Toscana	-5,1	2,6	-1,6	-15,0	-17,3	-4,1	-20,8	4,3	-14,9
Umbria	7,6	11,0	-1,4	-3,8	-14,3	3,5	-10,6	-1,2	-6,8
Marche	-4,5	3,6	-1,9	-0,8	-8,6	3,0	-16,9	0,5	-9,0
Lazio	-0,4	10,6	1,5	-8,1	9,3	-3,2	-20,2	-6,4	-11,9
Abruzzo	13,9	7,6	0,3	8,5	4,3	0,9	-7,7	4,5	7,5
Molise	3,5	3,3	10,2	-7,7	7,8	-4,9	6,4	-2,2	5,0
Campania	-5,4	6,4	14,0	-10,1	2,4	1,7	-6,1	-6,0	4,6
Puglia	-4,5	11,2	10,8	-7,9	-0,8	-0,9	-4,7	-1,8	-1,8
Basilicata	1,1	-4,1	3,8	9,9	5,6	14,7	-11,0	4,3	-4,8
Calabria	-2,3	8,6	2,2	-3,3	12,2	-4,6	4,8	2,9	8,9
Sicilia	3,5	17,2	5,9	-10,3	1,5	-7,0	1,3	-2,0	-16,5
Sardegna	4,6	19,1	19,9	-15,5	-12,7	3,4	6,8	-0,8	9,9
Luxembourg-GD	1,0	5,1	3,1	9,9	2,8	11,6	14,1	19,4	9,2
Norte	-12,8	13,4	-10,1	-11,3	-7,3	-6,6	2,5	-4,3	-5,9
Centro (P)	-1,7	3,5	-11,7	-2,2	-7,3	-5,6	-19,2	-20,2	-6,0
Lisboa e Vale do Tejo	-4,8	4,4	-6,7	-13,9	-19,9	-11,7	4,7	-12,4	-8,0
Alentejo	9,0	-9,5	-12,1	-2,3	-12,1	-15,8	2,5	4,4	-2,5
Algarve	-12,2	-8,4	-16,4	-2,6	-4,4	-8,6	3,3	-12,1	-16,4
North East	-11,4	-2,5	-10,4	-9,1	-1,1	3,9	-5,1	-1,2	2,1
Yorkshire	-7,5	2,6	2,1	-4,1	-5,1	0,3	-5,4	5,2	4,6
East Midlands	-7,0	3,1	9,8	-2,5	9,1	4,4	-1,5	4,6	9,3
East Anglia	-5,0	-4,7	-6,9	-7,0	-8,8	-4,2	-8,7	-0,3	-1,7
South East	-16,3	-6,7	-10,9	-19,4	-3,2	-1,7	-18,4	5,4	-11,3
South West	-7,3	-6,0	-5,3	-7,0	-15,1	-6,3	-8,6	-0,1	-4,3
West Midlands	-10,1	1,9	-6,2	-5,4	-8,0	-0,4	-1,3	3,1	3,9
North West	-8,0	0,5	-0,6	-5,8	-7,3	-5,4	-4,2	-1,0	-0,6
Wales	-3,7	-1,2	8,3	-1,8	-4,3	0,7	-2,4	8,6	8,3
Scotland	-5,3	3,1	-8,1	-3,9	-9,5	-2,5	-3,3	2,3	1,5
Northern Ireland	-0,7	2,6	-2,9	-2,3	1,1	-5,8	-2,1	0,0	2,0

Source: Own elaboration.

Table 7. Vertical economies and geographic concentration

	Concentration	Vertical Economies
Ferrous and non ferrous ores and metals	**-0,076**	**-1,931**
Non-metallic minerals and mineral products	0,005	1,975
Chemical products	**-0,007**	0,408
Metallic products, machinery and equipment	**-0,010**	**-5,004**
Transport material	**-0,016**	**-3,985**
Food, beverages and tobacco	**-0,017**	1,401
Textiles and clothing, leather and footwear	**-0,050**	**-3,645**
Paper and printing products	0,036	0,834
Other manufacturing products	0,009	**-0,401**
Total manufacturing	**-0,015**	**-1,150**

Source: Own elaboration.

Appendix

Table A.1 NACE RR-17 classification. Industry

Code	Sector
S1	Ferrous and non ferrous ores and metals
S2	Non-metallic minerals and mineral products
S3	Chemical products
S4	Metal products, machinery and equipment
S5	Transport equipment
S6	Food, beverages and tobacco
S7	Textiles and clothing, leather and footwear
S8	Paper and printing products
S9	Products of various industries

Source: Eurostat.

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