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The Spatial Distribution of Human Capital: Can It Really Be Explained by Regional Differences in Market Access?

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Abstract: This paper checks for the robustness of the estimate of the impact of market access on the regional variability of human capital, derived from the NEG literature. The hypothesis is that the estimate of the coefficient of the measure of market access is actually capturing the effect of regional differences in the industrial mix, and the spatial dependence in the distribution of human capital. Results for the Spanish provinces indicate that the estimated impact of market access vanishes and becomes non-significant once these two elements are included in the empirical analysis.

Keywords: human capital, geography, market access, spatial dependence

JEL Codes: C21, I21, R12,

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1. Introduction

Contributions to the literature in the last decades have shown that regional disparities are associated with differences in the endowment of some socio-economic characteristics in each region. Among them human capital, and in particular the educational attainment of the population, has been claimed to be an important ingredient of differences in regional economic growth. Endogenous growth models remark that human capital is the element that stimulates the diffusion of knowledge and technological development. Lucas (1988) and Romer (1990) emphasize the importance of human capital for explaining why some economies are more developed than others. In this sense, Barro and Sala-i-Martin (2004) also consider human capital as an important factor for explaining economic convergence across countries and across regions.

From a complementary perspective, the New Economic Geography (NEG), has suggested a connection between the endowment of human capital in each economy and the spatial distribution of economic activity. Initially, the two sector model of Krugman (1991) and the more recent augmented model of Fujita et al. (1999) focused just on the location of production and, hence, on the distribution of economic growth among localities. From these types of models it is possible to derive a relationship between the spatial concentration of economic activity and factor prices. Specifically, wages are associated with the so-called market access, which is the distance-weighted sum of the purchasing power of the system of economies. The model predicts that locating in high market access areas will allow firms to pay higher wages to their workers, since it allows them to face lower transport costs and cost savings from large-scale production. The existing empirical evidence supports the prediction of the theoretical model, given that results confirm a strong and significant impact of market access on wages, proxied by per capita income, both for samples of countries and regions (e.g. Redding and Venables, 2004; Breinlich, 2006).

However, the understanding of the endogenous accumulation of factors of production was not investigated in detail in these seminal papers. That is to say, the earlier contributions to the NEG analyzed the spatial distribution of economic activity without paying particular attention to the impact of agglomeration on the accumulation of the factors supposed to determine economic growth. It is more recently that the accumulation of human capital was endogenized within the framework of a NEG model by Redding and Schott (2003). Under the

assumption that the endowment of human capital will be larger in the areas offering higher returns to this factor, the model predicts a higher endowment in economies with a better access to markets and suppliers. This is so because in the model, the relative wage of skilled labor, and thus the economic incentive to invest in human capital, increases with market and supply access.

Following a similar empirical strategy than that in studies checking for the relationship between wages and market access, Redding and Schott (2003) provided evidence supporting the positive impact of market access on human capital for a sample of countries. In the same vein, López-Rodríguez et al. (2007) tested this hypothesis for a sample of EU regions, obtaining a positive and significant correlation between market access and different measures of educational attainment. However, these two exercises can be criticized as the empirical specification they used does not control for factors that are also likely to impact the spatial distribution of human capital. In fact, López-Rodríguez (2007) checked for the robustness of the estimate of the impact of market access in the case of the EU regions. He showed that the estimated impact decreased markedly (to less than one third, from around 0.9 to 0.3) but remained significant when additional control variables where included (employment in high-tech sectors, labor productivity, number of patents, and a dummy variable accounting for peripherality). Redding and Schott (2003) also included in the regression *indicators thought to be important in cross country studies of development* (the risk of expropriation by the government, the percent of countries' land that is tropical, and dummies for socialist rule and external wars). The estimate of the impact of market access diminished by the half (from about 0.6 to 0.3), being significant only at 5%.

In this paper, we aim at contributing to the robustness checking of the market access–human capital relationship in a regional setting. It is our belief that the estimate of the coefficient of the measure of market access is actually capturing the effect of regional differences in the industrial mix, and the spatial dependence in the distribution of human capital. Actually, our hypothesis is that the omission of such factors in previous studies biases the estimate of the coefficient associated to market access. Concretely, this will be the case if, as expected, the sectoral composition of each region is correlated to the measure of market access, and if this measure is capturing at least part of the spatial dependence that is likely to characterize the regional distribution of human capital. Niebuhr (2006) and Kosfeld and Eckey (2008) raised a similar criticism in the case of the relationship between wages and market access. Actually,

Niebuhr (2006) proved that controlling for additional conditioning variables decreases the power of market access in explaining regional wages.

We test our hypothesis using data for the set of Spanish provinces. In so doing, in section 2 we first study the dispersion of human capital among the provinces of Spain, using two proxies of the endowment of human capital, the average years of schooling and the per capita value of human capital. In both cases, the results of the spatial descriptive analysis confirm remarkable regional disparities and strong spatial dependence in the distribution of human capital. Next, we estimate the coefficient of a simple specification, which reveals the positive and significant effect of market access on both measures of human capital. The theoretical arguments from the NEG that support these empirical results are sketched in section 3, while in the fourth we discuss the effect of not controlling for regional differences in the sectoral composition, and for spatial dependence. Based on these arguments, the original NEG specification is augmented and the estimation obtained with alternative specifications is compared with those originally obtained from the baseline model. Finally, section fifth concludes.

2. The Geography of Human Capital in Spain

2.1 Preliminary Evidence

Spain is one of the successful examples of the Euro Area regarding the evolution of regional inequalities. However, disparities among regions in the major macroeconomic indicators still remain sizeable (e.g. Cuadrado et al., 1999; De la Fuente, 2002). Based on arguments from the New Economic Geography (NEG) literature, recent contributions have analyzed the connection between the spatial distribution of economic activity and regional disparities in some variables of interest. In the particular case of Spain, López-Rodriguez et al. (2008) reported evidence on the impact of geography on regional wages. The findings of this paper confirm that geography, measured by market access of provinces, has a positive effect on the dispersion of regional wages. In the same vein, López-Rodriguez et al. (2007) concluded that market access also shapes the distribution of human capital, in this case in the set of EU regions. The findings in these two papers motivate our interests in a deeper analysis of the relationship between market access and the endowment of human capital in Spain. In

addition, it should be taken into account that human capital has been proved to be a key ingredient for regional growth in Spain as well as in some other economies (e.g. Rodríguez-Pose and Vilalta-Bufí, 2005; Di Liberto, 2008; López-Bazo and Moreno, 2008; Bronzini and Piselli, 2009). Hence, the improvement of the knowledge on the determinants of the spatial distribution of human capital will contribute to the better understanding of the origin of regional inequality in productivity, income per capital and, thus, long-run welfare.

Despite the continuous increase in the level of schooling in the last decades, the Spanish provinces still show marked differences in the endowment of human capital. The evidence provided in this paper was obtained from data for the 47 continental provinces in Spain, for two different indicators of human capital in 1995 and 2007.[1] The first indicator is a traditional measure of human capital: the average years of schooling of the working population in each province. However, as this measure has been subject to different criticisms, results have been also obtained for a second measure of human capital: the per capita value of human capital, which shows the productivity level of a skilled worker with respect to an unskilled one (Mulligan and Sala-i-Martín, 2000). In both cases, the source of the data is the IVIE-Bancaja Human Capital Dataset for Spain (see Serrano and Soler, 2008 for the description of the methodology used to build the dataset).[2]

The spatial distribution of these two measures for 1995 and 2007 is depicted in Figure 1. The maps confirm the existence of marked differences in the endowment of human capital across the Spanish provinces, and how they persist over time despite the increase in the endowment for all the provinces. However, the most interesting feature for our analysis in this paper is that there is a geographical pattern in the dispersion of the human capital with, broadly speaking, higher levels in the North and with lower levels in the Southern provinces. Again such pattern seems to persist despite the general increase in the level of education over the period under analysis.

As stated above, the prediction of the NEG is that a big deal of the spatial pattern of the

distribution of human capital in the Spanish provinces has to do with the geographic location of each province. Geography, location or, in other words, relative remoteness can be proxied by the market access measure suggested initially by Harris (1954). As discussed in this seminal contribution and later revisited by influential NEG models, market access can be proxied by the distance-weighted sum of the purchasing power of the economies. Therefore, market access of a province in Spain will be positively associated with the purchasing power of the remaining provinces but negatively related with the distance between each other:

$$MA_i = \sum_{j=1}^{K} \frac{Y_j}{D_{ij}} \quad (1)$$

where Y_j is gross value added (GVA) in province j, and D_{ij} is the distance between each pair of provinces i and j. The internal distance of each province is calculated following the suggestion in Head and Mayer (2006), that is $D_{ii} = 0.66 \cdot \sqrt{\frac{Area_i}{\Pi}}$. Figure 2 depicts the values of the measure of market access in the Spanish provinces, for 1995 and 2007. It can be clearly observed that provinces differ with regards their access to the market. Moreover, as expected dispersion is persistent and there are no significant changes over the time period under consideration.

As for the relationship between the distribution of human capital and that of market access, the comparison of Figures 1 and 2 reveals a connection between the two magnitudes, that is however far from perfect. In general terms, provinces with large endowments of human capital are not in the economic periphery, while regions in the periphery tend to be those with the lower endowments. But figures for some provinces contradict this general statement in both cases. This is confirmed by the information depicted in Figure 3. In all cases (for both years and time periods) there exists a positive relationship between human capital and marked access, but the amount of dispersion in such relationship is far from negligible. As a matter of example, it can be observed how there are provinces with similar low values of market access that have rather different endowments of human capital. In addition, the distribution of both magnitudes is likely to be characterized by spatial dependence, something

[1] Considering their particular characteristics, we decided not to include in the analysis the three provinces in the Canary and the Balearic Island and the two cities in Northern Africa (Ceuta and Melilla). This decision had to do with the construction of the measure of market access and not with the ones for human capital.

[2] It can be downloaded from http://www.ivie.es/downloads/caphum/2007/metodologia.pdf

that must be also considered when analyzing formally the impact of market access on the endowment of human capital.

2.2 Estimation of the baseline model

As a first step in our study of the robustness of the estimated impact of market access on the spatial distribution of human capital, we estimate a simple specification that will be used as a benchmark:

$$\ln HK = \delta + \beta \ln MA + \varepsilon \quad (2)$$

where *HK* denotes the column vector with values of the measure of human capital in the economies under analysis, and ε is supposed to be (so far) a well behaved error term. β is the parameter that captures the impact of market access on human capital.

The OLS estimates of the parameters in (2) for the two alternative measures of human capital and for the two years under analysis are reproduced in Table 1.[3] Results are obviously in agreement with the pictures depicted in Figure 3, confirming the existence of a positive correlation between the two variables. Hence, the evidence from Spain also indicates that provinces with higher market access are endowed with higher levels of human capital. In other words, that remoteness plays again the incentive to accumulate human capital. The impact of market access was however decreasing over the period analyzed, as shown by the lower estimate of the coefficient in 2007 with respect to that for 1995, in both measures of human capital.

Table 1 also includes results for some diagnostic checks. While the Breusch-Pagan test indicates that there are no symptoms of heteroskedasticity in none of the estimated baseline models, the battery of spatial dependence tests clearly reveal that the baseline human capital-market access model is likely to be (spatially) misspecified. The results of these spatial dependence tests will be discussed in detail in section 4, as they will motivate our claim for

the estimation of a spatial specification of the human capital-market access model. But before, we frame the results of the baseline specification within a NEG model extended to account for the endogenous accumulation of human capital in each region.

3. NEG's Explanation: Human Capital and Geography

Not only the findings of the previous section are intuitively reasonable, but also the NEG framework allows deriving the link between human capital and remoteness quite straightforwardly from a theoretical perspective. The models of Krugman (1991) and Fujita et al. (1999) did not include the accumulation of human capital. It is in Redding and Schott (2003) where an endogenous mechanism for the accumulation of human capital was considered, that in conjunction with standard arguments of the NEG gave rise to a reduced form linking the skill wage premium in every economy to its market and supply access.[4]

Next, we briefly sketch the main elements of the model in Redding and Schott (2003) stressing the derivations that support the empirical specification in (2).[5] The economy is composed by $i \in \{1,\ldots,R\}$ regions. There are L_i consumers in each region, each having 1 unit of labour. This unit of labour is initially unskilled. Individuals choose endogenously whether or not to invest in becoming skilled. Consumer preferences are identical and homothetic, defined over the consumption of agricultural and manufacturing goods. The agricultural sector produces under constant returns to scale while the manufacturing industry operates with increasing return to scale.

The critical part of the model is constructed over the individuals' human capital investment choice, which is formulated as:

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[3] It would be possible to explode the information of a panel data set for the variables under analysis. However, we have preferred to show cross-section results to easy the comparison with results in the previous contributions to the literature. On the other hand, it should be mentioned that similar qualitative results were obtained when estimating the relationship in equation (2) using data for some other years. These results are available from the authors upon request.

[4] The theoretical model in Redding and Schott (2003) includes both market and supply access, although in the empirical application they only consider the impact of market access because it is far more cumbersome to measure supply access, and because of the likely high correlation between both measures. The same approach has been adopted in the other contributions to the literature.

[5] See also Redding and Venables (2004) for full details on the major elements of the model.

(3) $$w_i^S - w_i^U \geq \frac{h_i}{a(z)} w_i^U$$

where w_i^S and w_i^U represents the wage level of skilled and unskilled workers respectively. The gap in the left hand side of (3) is the wage premium, which should be higher than the cost of education defined in the right hand side for individuals to have incentives to invest in education. The cost of education has two components: $a(z)$ represents individuals' ability to become skilled, that decreases the cost of education, and h_i that accounts for the institutional environment and the public provision of education which is defined as an inverse measure, that is to say, increasing h_i raises the cost of private education. From equation (3), Redding and Schott (2003) derived a skill indifference condition:

(4) $$a_i^* = \frac{h_i}{(w_i^S / w_i^U - 1)}$$

Hence, a_i^* represents a critical ability level that makes individuals indifferent between becoming skilled or staying unskilled. When the relative wage rate between skilled and unskilled workers increases, the cut off for the critical level of ability becomes lower. In turn this means that the amount of individuals having an economic incentive for becoming skilled increases. Therefore, it is the magnitude of the relative wage rate what determines the individuals' decisions to invest in human capital.

Next, Redding and Schott (2003) make use of the NEG framework to link relative wages to the geography of economic activity. The wage equation is derived from the equilibrium in the manufacturing sector (zero profit condition):

(5) $$\left(\frac{\sigma}{\sigma-1}(w_i^S)^{\alpha}(w_i^U)^{\beta}G_i^{1-\alpha-\beta}c_i\right)^{\sigma} = \left(\frac{1}{\bar{x}}\right)\sum_{j=1}^{R} E_j G_j^{\sigma-1}/(T_{ij}^M)^{\sigma-1}$$

where α, β, and (1–α–β) are the factor shares of skilled workers, unskilled workers and intermediate goods respectively, σ represents the elasticity of substitution, c_i denotes the marginal input requirement, and G_j is the price index for manufacturing goods. On the right hand side of (5), E_j represents the total consumption of manufacturing goods in region j, whereas T_{ij}^M accounts for iceberg-type transportation costs (physical and non physical). The

wage equation in (5) "*pins down the maximum wages of skilled and unskilled workers that a firm in country i can afford to pay, given demand for its products … and given the cost of intermediate inputs*" (Redding and Schott, 2003 p. 523).

Defining market access (MA_i) and supply access (SA_i) of region *i* as:

$$MA_i = \sum_{j=1}^{R} E_j G_j^{\sigma-1} / (T_{ij}^M)^{\sigma-1}, \qquad (SA_i)^{\frac{1}{1-\sigma}} = G_i$$

the wage equation can be written as:

$$(w_i^S)^{\alpha} (w_i^U)^{\beta} = \xi \frac{1}{c_i} (MA_i)^{\frac{1}{\sigma}} (SA_i)^{\frac{1-\alpha-\beta}{\sigma-1}} \tag{6}$$

where ξ absorbs constant terms. Therefore, the wage equation can be expressed as a function of market and supply access. Manufacturing firms in regions with easy access to the market and to suppliers can increase the maximum wages that they can afford to pay.

Combining the zero profit conditions of the constant returns to scale sector (agriculture) and of manufacturing[6] with the skill indifference condition in (4), Redding and Schott are able to characterize the equilibrium relationship between geographical location and endogenous human capital investments. Taking logarithms and totally differentiating each profit condition results in:

$$0 = \phi \frac{dw_i^S}{w_i^S} + (1-\phi) \frac{dw_i^U}{w_i^U} \tag{7}$$

$$\alpha \frac{dw_i^S}{w_i^S} + \beta \frac{dw_i^U}{w_i^U} = \frac{1}{\sigma} \frac{dMA_i}{MA_i} + \frac{1-\alpha-\beta}{\sigma-1} \frac{dSA_i}{SA_i} \tag{8}$$

From these expressions it can be deduced that if a region becomes remote (decreasing its access to the market and to supplier) and assuming that manufacturing production is skill intensive, then the new equilibrium should be such that the relative wage of skilled workers should be lower.[7] Turning back to the critical ability condition, this decline in the relative

wage for skilled workers means a lower incentive to invest in human capital. Accordingly, the number of skilled workers is also expected to decline in that region. This is the argument that supports the connection between the spatial distribution of human capital and market access in equation (2), as the relative wage of skilled workers is predicted to be lower in the remote regions and, hence, the critical level of ability (a_i^*) to be higher, which means a lower incentive to accumulate human capital.

4. Missing Links: Sectoral Composition and Spatial Dependence

The NEG model by Redding and Schott (2003) sketched in the previous section provides a theoretical justification for the empirical evidence reported in section 2 about the fact that the endowment of human capital is higher in some specific locations (the core economic provinces in Spain) and less abundant in the peripheral areas. However, the baseline model in (2) does not account for other potential determinants of the process of accumulation of human capital at the regional level. Actually, the theoretical model includes also other mechanisms that impact on the critical level of ability. Besides the impact of *MA* and *SA*, the supply of skilled workers is monotonically decreasing in the level of productivity in the constant returns to scale sector, in the cost of the manufacturing production parameter (c_i), and in the cost of education (h_i). On the other hand, technology transfers to a less developed region *i* reduce their c_i, raising the maximum wage that its manufacturing firms can afford to pay to skilled and unskilled workers given its current market and supply access. Since manufacturing is skill intensive, this causes an increase in the relative wage of skilled workers, and then a higher endowment of human capital.[8] For that reason, empirical specifications such as that in equation (2), which does not include variables proxying for

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[6] The zero profit condition for the agriculture is given by $P_i^Y = 1 = \frac{1}{\theta_i^Y}\left(w_i^S\right)^{\phi}\left(w_i^U\right)^{1-\phi}$, whereas that for manufacturing is the one in equation (5).

[7] A fall in *MA* and in *SA* with the initial equilibrium market prices results in a decrease in the size of the manufacturing sector, and thus in an excess of skilled labour. Hence, the nominal skilled wage is lower and the nominal unskilled wage is higher in the new equilibrium.

[8] Given that technology transfers are closely connected to the institutional environment and the endowment of social capital, these two factors are also assumed to influence people's willingness to invest in human capital (Redding and Venables, 2004).

these other factors, are likely to produce biased estimates of the impact of *MA* (and *SA*) on human capital.

This concern has already been pointed out in the recent empirical literature investigating the impact of market access on the dispersion of regional wages. For instance, Breinlich (2006) controls for the direct distance between the capital of each region and Luxemburg, as the economic activity centre of Europe, and for human and physical capital stocks in his study of the relationship between regional wages and market access. Similarly Niebuhr (2006) and Kosfeld and Eckey (2008) mention that market access's impact on wage dispersion can be influenced by the sectoral composition of the labor force and also by spatial dependence.

However, despite the arguments derived from the theoretical model, and the evidence from studies focusing their attention on wages and market access, López-Rodríguez et al. (2007) only control for the direct distance between each region and Luxemburg in their analysis of the link between human capital and market access across the EU regions. Interestingly, in a closely related paper, López-Rodríguez (2007) showed that the estimate of the impact of market access remains significant (although decreasing in size) when some other variables are included in the model. In sharp contrast, in the rest of this section we show how simply controlling for the industrial mix (as a rough proxy for the factors described above) and for spatial dependence (that it is also likely to account for the impact of some of these factors) in the baseline human capital equation modifies the conclusion on the impact of market access on the regional distribution of human capital.

4.1. Sectoral composition

It is well known that different economic activities tend to demand workers with distinct education levels. Accordingly, our hypothesis is that the industrial mix conditions the regional distribution of human capital, as some sectors are skilled intensive while some others employ low skilled workers. In the case of the Spanish provinces, there are strong disparities in the share of each sector in the economy. Therefore, we expect provinces specialized in some particular industries to show higher endowments of human capital. This is confirmed by Figure 4, which maps the spatial distribution of the employment share of the manufacturing and the service sector.[9] The picture revealed by the maps is already well known: the

manufacturing sector is more important in the Northeast of the country (along the Mediterranean coast and the Ebro Valley), and in some provinces in the centre. Meanwhile, the share of the service sector is higher in the Southwest (because of large employment in the public sector), in Madrid, and in some other provinces such as Barcelona and Valencia (in this case related to the employment in market services).

In any case, what we want to stress is that when Figures 1 and 4 are compared, it can be concluded that the spatial pattern of human capital and manufacturing employment is quite similar. In the case of the service sector, it can also be observed a connection with the endowment of human capital, although in this case we should take into account the above-mentioned intensity of the employment in the public sector in the Southwest provinces, and also the contribution of employment in some low added value services linked with tourism in those provinces.

4.2. Spatial dependence

Our second concern is related with spatial dependence. An Exploratory Spatial Data Analysis (ESDA) reveals that the two human capital indicators are characterized by significant spatial dependence. Global spatial autocorrelation has been tested by means of the Moran's *I* (see for instance Anselin, 1993):

$$I_i = \frac{n}{s}\frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum z_i^2} \tag{9}$$

where n represents the number of provinces, z is the standardised value of the variable under analysis, s is the summation of all the elements in the weight matrix, and $w_{i,j}$ is the generic element of W, a spatial weight matrix defined as:

$$W = \begin{pmatrix} 0 & k_1 w_{1,2} & \dots & \dots & k_N w_{1,N} \\ k_2 w_{2,1} & 0 & \dots & \dots & k_2 w_{2,N} \\ \dots & \dots & \dots & \dots & \dots \\ k_{N-1} w_{N-1,1} & \dots & \dots & 0 & \dots \\ k_N w_{N,1} & \dots & \dots & \dots & 0 \end{pmatrix} \quad \text{where} \quad k_i = \frac{1}{\sum_{j=1}^{N} w_{i,j}} \tag{10}$$

[9] Data on employment for each sector in each province comes from the National Regional Accounts produced by the Spanish National Institute for Statistics (INE).

Two different matrices of spatial weights have been used in the ESDA. First, a contiguity weight matrix, where w_{ij}=1 if provinces i and j are neighbors, and w_{ij}=0 otherwise. Next, an inverse distance weight matrix with elements defined by:

$$w_{i,j} = \frac{1}{D_{ij}^2} \tag{11}$$

The first four rows of Table 2 reproduce the results for the Moran's test for each indicator of human capital in the two years under analysis, and using the two weight matrices. In all cases, the null of absence of spatial dependence in the human capital variables is strongly rejected. A more detailed analysis, by means of the computation of measures of local spatial dependence, reveals a clear North-South divide, where hotspots of high endowments of human capital appear in the North, and groups of provinces with much lower endowments appear in the South (Moran's Scatterplot in Figure 5).

A similar analysis for the market access variable shows that its spatial distribution is far from random as well. As shown in the last two rows of Table 2, the *I*-Moran test clearly rejects its null hypothesis of absence of spatial dependence in both years and for the two weight matrices. However, the contribution of each area to the global spatial dependence differs from the one observed for the human capital indicators. Values of the local Moran's *I* in Figure 6 reveal that there is not a clear North-South pattern in this case. Instead, there seems to be a sort of East-West divide that in any case does not match to the structure of dependence observed for the measures of human capital. As a consequence, we must not expect market access to be accounting for the pattern of spatial dependence detected in the human capital indicators in a regression such as that in our baseline specification. On the contrary, spatial autocorrelation is likely to be present in the residuals of the OLS estimation of equation (2). This is confirmed by the results of the Moran's *I* and the battery of LM tests of spatial dependence reported in Table 1. In all the cases, the test concludes in favour of the presence of significant residual spatial dependence, which means that the results based on the OLS estimator would be providing an inefficient and even biased estimation of the coefficient that summarizes the relationship between human capital and market access.

4.3. Extended empirical specification

Considering the descriptive evidence provided so far, and the role played by the other elements in the theoretical model described in section 2, it is our belief that the empirical specification used for testing the connection between human capital endowments and market access must account for regional differences in the industrial mix and for spatial dependence. In the rest of this section, we show the effect of neglecting both phenomena in the case of the Spanish provinces.

As a first step, the baseline specification is augmented to control for the sectoral composition of each region:

$$\ln HK = \delta + \phi \ln SE + \beta \ln MA + \varepsilon \tag{12}$$

where *SE* is a matrix whose columns correspond to the share of the employment in each sector in total employment, excluding one (agriculture) to avoid the collinearity problem. ϕ is the corresponding vector of parameters associated to the effect of the sectoral composition.

Next, two specifications have been considered to control for spatial dependence: the spatial autoregressive model (SAR):

$$\ln HK = \delta + \rho W \ln HK + \phi \ln SE + \beta \ln MA + \varepsilon \tag{13}$$

and the spatial error model (SEM):[10]

$$\ln HK = \delta + \phi \ln SE + \beta \ln MA + \lambda W \varepsilon + \upsilon \tag{14}$$

where ρ and λ are the spatial coefficients, and υ a well behaved error term.

The results of the estimation of the parameters in (12) are reported in Table 3, while those for

the spatial models in (13) and (14) are shown in Table 4.[11] As for the impact of the inclusion of variables conditioning for the industrial mix, the results in Table 3 are quite clear. The magnitude of the coefficient associated to market access decreases for the two indicators of human capital and the two years under analysis. Actually, the non-significance of the effect of market access on the human capital endowment cannot be rejected at the usual significant level in 2007, while in 1995 it is only significant at 5% (for the per capita value of human capital) and 10% (for the average years of schooling). This finding confirms our concerns about the importance of the inclusion of a proxy for regional differences in the sectoral composition.

Nonetheless, the *I*-Moran test and the LM tests of the models estimated including the controls for the sectoral composition still reject their null hypotheses of no spatial dependence. That is to say, the addition of the sectoral composition does not account (at least fully) for the spatial autocorrelation in the human capital distribution in the Spanish provinces. Therefore, the estimation of a spatial specification (the SAR and/or the SEM models) is required to guarantee a robust inference on the effect of market access. Table 4 summarizes the estimation results of the two alternative spatial models, showing that the spatial parameter is strongly significant in all cases, and large in magnitude. We have also tested for the joint significance of the coefficients associated to the variables proxying for the sectoral composition and for the spatial effects. The results of the Likelihood Ratio tests are reproduced in Table 5. In building these tests, the logarithm of the likelihood (lnL) for the appropriate specifications in each case (from Tables 1, 3, and 4) has been used. It is observed that the null hypothesis of no joint significance is strongly rejected in all the cases, confirming that both the sectoral variables and the spatial effects are significant when explaining the variability in the regional distribution of the endowment of human capital.

[10] We decided to estimate these two traditional spatial specifications instead of selecting and estimating just one of the two. The reason is that we agree with Fingleton and López-Bazo (2006) in that selecting the spatial specification based on the results of the LM and the robust LM tests of spatial dependence can produce misleading results on the selection of the appropriate specification including spatial effects. On the other hand, modelling the source of the spatial dependence in the human capital-market access specification is beyond the scope of this paper, and should be addressed in a separate piece of research.

[11] Results in this section haves been obtained for the weight matrix based on the inverse distance. Similar qualitative results, not reported here to save space but available from the authors upon request, were obtained when using the contiguity weight matrix.

In addition, results of the LM tests of residual (in the SAR model) and of substantive (in the SEM) spatial dependence indicate that these models no longer exhibit significant spatial autocorrelation (the null is only marginally rejected for the SAR in the per capita value of human capital in 1995, and for the average years of schooling in 2007). As for the effect of market access, results strongly support our hypothesis as it can be observed that the change in its size and significance is even more intense when it is estimated considering spatial dependence, either by means of the SAR or the SEM specifications. Actually, these results suggest an almost negligible role of market access in explaining regional differences in human capital endowment, once the sectoral composition and spatial dependence are accounted for.

It could be argued, however, that market access is likely to be correlated with the proxies for the industrial mix, and also with the spatial lags in equations (13) and (14). As a result it could be the case that large collinearity causes the non-significance of the coefficient of our variable of interest. In other words, part of the explanation of market access could be absorbed by the additional control variables in our study. Recognizing this possibility, we would like to stress that the argument can be reversed, supporting our hypothesis that the favorable result to the NEG arguments in López-Rodríguez et al (2007) might be (at least partly) due to the omission of a proxy for the sectoral composition and of spatial effects in their analysis. To try to shed some more light in this issue, we compare the values for the Akaike and the Schwartz Information Criteria (AIC and SC respectively) as statistical measures that can help us in selecting the most appropriate specification. These two measures are reproduced in the bottom panel of Tables 1, 3, and 4. In all cases, the values are lower for the specifications including controls for the sectoral composition and the spatial effects, supporting our claim that the inference on the effect of market access on human capital should be based on an expanded model including these two elements.

5. Conclusion

The hypothesis in this paper has been that the inference on the impact of market access on the regional distribution of human capital provided in previous contributions to the literature is likely to be non-robust because it is based on a rather simple specification that does not account for regional differences in the sectoral composition, and for spatial dependence in the distribution of human capital.

Our results for the Spanish provinces confirm that once we include the sectoral composition of employment as well as control for spatial dependence, the role of market access decreases sharply, and even vanish and become statistically insignificant. Indeed, we can even conclude that spatial effects and differences in the demand of human capital across sectors play a much more prominent role than the traditional measure used to proxy for the accessibility to the market of each region. In this regard, our conclusion is in line with that in Fingleton (2006 and 2011). He indicates that there are alternative (or at least complementary) plausible theories to those from the NEG when explaining local wage variations. It is also consistent with the smaller role played by the NEG elements at the regional level when compared to the country scale, derived from results in Brakman et at. (2009). In any case, it is our belief that additional elements should be combined with those from the NEG model in order to obtain empirical specifications that provide robust inference on the real impact of market access on the regional differences in human capital endowments. In this regard, the consideration of regional spillovers within the theoretical framework sketched in section 3 and the derivation of its empirical counterpart is in our research agenda.

It will be also of interest the implementation of a more direct test of the connection between the regional differences in the incentives to invest in human capital and market access, based on the use of the returns to education instead of its endowment. In our opinion, this will be a more appropriate way of testing the implication given by the wage equation in the NEG model (equation 6 in section 3), where the estimated return to education in each region would be capturing the skill wage premium.

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Table 1. Results of the estimation of the baseline model – Human capital and market access.

	Per Capita Value of Human Capital		Average Years of Schooling	
	1995	**2007**	**1995**	**2007**
Market Access	0.091***	0.060***	0.102***	0.049***
	(0.027)	(0.027)	(0.026)	(0.023)
Breusch Pagan Test	0.774	0.119	0.076	0.039
	[0.38]	[0.73]	[0.78]	(0.843)
Residuals Moran´s I	0.233***	0.316***	0.205***	0.188***
	[0.00]	[0.00]	[0.00]	[0.00]
LM-ERR	12.099***	22.129***	9.333***	7.856***
	[0.00]	[0.00]	[0.00]	[0.00]
LM-LAG	12.543***	20.674***	12.236***	6.571**
	[0.00]	[0.00]	[0.00]	[0.01]
Robust LM-ERR	0.327	1.461	0.025	1.576
	[0.56]	[0.23]	[0.87]	[0.21]
Robust LM-LAG	0.771	0.006	2.930**	0.292
	[0.380]	[0.938]	[0.08]	[0.59]
lnL	71.408	70.611	72.896	77.790
AIC	-138.82	-137.22	-141.79	-151.58
SC	-135.12	-133.52	-138.09	-147.88
Obs.	47	47	47	47

Notes: **, **, *** represent significance at 10%, 5% and 1% respectively.*
Standard errors for coefficient estimates in ( ). P-values for the statistics in [ ].

Table 2. Results of the global spatial autocorrelation test (Moran's *I*) for human capital and market access.

	Inverse Distance^2	1st Order Contiguity
Per Capita Value of Human Capital, 1995	0.218***	0.418***
	(0.060)	(0.094)
Per Capita Value of Human Capital, 2007	0.316***	0.401***
	(0.059)	(0.096)
Average Years of Schooling, 1995	0.312***	0.431***
	(0.059)	(0.094)
Average Years of Schooling, 2007	0.183***	0.229***
	(0.059)	(0.094)
Market Access (GVA), 1995	0.299***	0.413***
	(0.059)	(0.093)
Market Access (GVA), 2007	0.306***	0.422***
	(0.058)	(0.093)

Notes: **, **, *** represent significance at 10%, 5% and 1% respectively. Standard errors in ( ).*

Table 3. Results of the estimation of the model including controls for the sectoral composition

	Per Capita Value of Human Capital		Average Years of Schooling	
	1995	**2007**	**1995**	**2007**
Market Access	0.074**	0.031	0.045*	0.012
	(0.032)	(0.024)	(0.025)	(0.019)
Manufacturing Empl (%)	0.013	0.043	0.055***	0.081***
	(0.025)	(0.026)	(0.020)	(0.021)
Service Empl (%)	0.172**	0.210**	0.268***	0.303***
	(0.074)	(0.089)	(0.059)	(0.071)
Construction Empl (%)	-0.034	-0.112**	-0.042	-0.021
	(0.042)	(0.046)	(0.033)	(0.036)
Energy Empl (%)	0.017	0.018	0.013	0.007
	(0.010)	(0.011)	(0.008)	(0.008)
Breusch Pagan Test	3.675	12.194	6.137	3.215
	[0.59]	[0.04]	[0.29]	[0.66]
Residuals Moran´s I	0.285***	0.318***	0.163***	0.215***
	[0.00]	[0.00]	[0.00]	[0.00]
LM-ERR	18.171***	22.526***	5.931**	10.330***
	[0.00]	[0.00]	[0.01]	[0.00]
LM-LAG	16.901***	24.883***	10.700***	7.137***
	[0.00]	[0.00]	[0.00]	[0.00]
Robust LM-ERR	1.953	1.207	0.008	3.214**
	[0.16]	[0.27]	[0.93]	[0.07]
Robust LM-LAG	0.683	3.564	4.777**	0.021
	[0.41]	[0.06]*	[0.03]	[0.88]
lnL	75.920	81.996	86.597	92.848
AIC	-139.84	-151.99	-161.19	-173.69
SC	-128.74	-140.89	-150.09	-162.59
Obs.	47	47	47	47

Notes: **, **, *** represent significance at 10%, 5% and 1% respectively.*
Standard errors for coefficient estimates in ( ). P-values for the statistics in [ ].

Table 4. Results of the estimation of the model including controls for the sectoral composition and spatial dependence.

	Per Capita Value of Human Capital		Average Years of Schooling		Per Capita Value of Human Capital		Average Years of Schooling	
	1995	**2007**	**1995**	**2007**	**1995**	**2007**	**1995**	**2007**
Market Access	0.059**	0.028	0.033	0.013	0.052**	0.023	0.025	0.016
	(0.024)	(0.017)	(0.020)	(0.016)	(0.025)	(0.020)	(0.022)	(0.018)
Manufacturing Empl (%)	-0.001	0.028	0.032**	0.072***	-0.001	0.033*	0.024	0.075***
	(0.019)	(0.019)	(0.017)	(0.018)	(0.019)	(0.019)	(0.016)	(0.017)
Service Empl (%)	0.184***	0.258***	0.257***	0.330***	0.276***	0.327***	0.341***	0.383***
	(0.058)	(0.064)	(0.050)	(0.061)	(0.061)	(0.061)	(0.053)	(0.057)
Construction Empl (%)	-0.036	-0.094***	-0.044	-0.012	-0.018	-0.076***	-0.033	-0.003
	(0.032)	(0.033)	(0.027)	(0.031)	(0.029)	(0.027)	(0.025)	(0.026)
Energy Empl (%)	0.017**	0.016**	0.013**	0.007	0.014*	0.018**	0.009	0.008
	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
ρ	0.767***	0.796***	0.625***	0.536***	-	-	-	-
	(0.127)	(0.112)	(0.151)	(0.182)				
λ	-	-	-	-	0.899***	0.926***	0.883***	0.814***
					(0.067)	(0.050)	(0.076)	(0.114)
Breusch Pagan Test	4.184	7.151	3.259	1.975	2.906	7.204	3.351	3.687
	[0.52]	[0.21]	[0.65]	[0.85]	[0.71]	[0.21]	[0.64]	[0.60]
LM Residual/Lag Spatial Dep	3.500*	1.214	0.390	3.065*	0.432	0.124	0.255	0.409
	[0.06]	[0.27]	[0.53]	[0.07]	[0.51]	[0.72]	[0.61]	[0.52]
lnL	83.119	91.937	91.731	95.944	85.715	94.426	92.791	98.637
AIC	-152.23	-169.87	-169.46	-177.88	-159.43	-176.85	-173.58	-185.27
SC	-139.28	-156.92	-156.51	-164.93	-148.33	-165.75	-162.48	-174.17
Obs.	47	47	47	47	47	47	47	47

Notes: **, **, *** represent significance at 10%, 5% and 1% respectively. Standard errors for coefficient estimates in ( ). P-values for the statistics in [ ]*

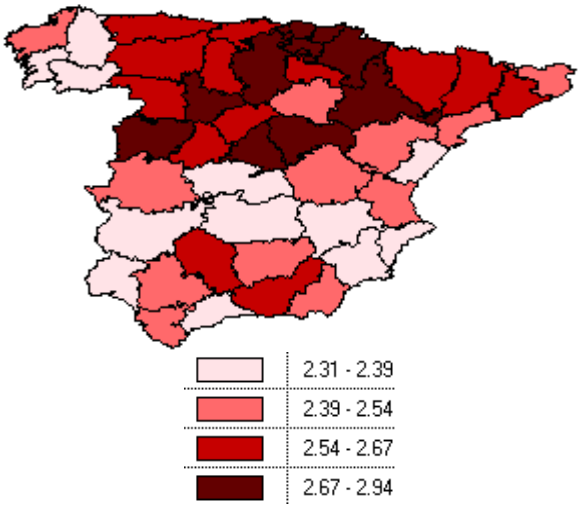
Table 5. Results of the tests for the joint significance of the sectoral and spatial coefficients.

	Per Capita Value of Human Capital		Average Years of Schooling	
	1995	**2007**	**1995**	**2007**
Sectoral Composition	9.024*	22.770***	27.402***	30.116***
	[0.06]	[0.00]	[0.00]	[0.00]
Sectoral Comp & Spatial Eff–SAR	23.422***	42.652***	37.670***	36.308***
	[0.00]	[0.00]	[0.00]	[0.00]
Spatial Effects–SAR	14.398***	19.882***	10.268***	6.192***
	[0.00]	[0.00]	[0.00]	[0.00]
Sectoral Comp & Spatial Eff–ERR	28.614***	47.630***	39.790***	41.694***
	[0.00]	[0.00]	[0.00]	[0.00]
Spatial Effects–EER	19.590***	24.860***	12.388***	11.578***
	[0.00]	[0.00]	[0.00]	[0.00]

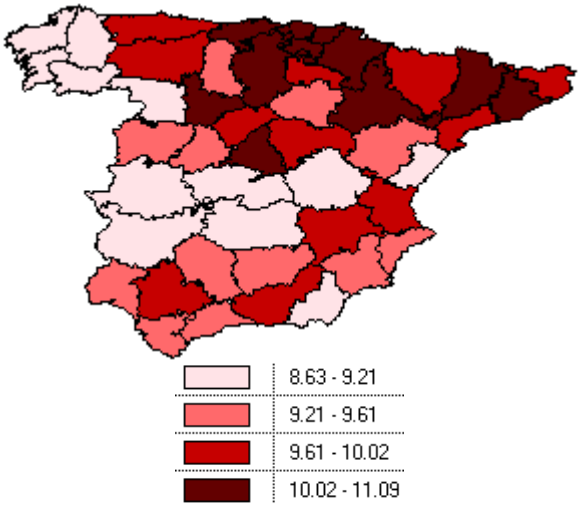
Notes: *Values of the Likelihood Ratio test for the significance of the sectoral composition variables and/or the spatial effects.*
, **, * represent significance at 10%, 5% and 1% respectively.*
P-values for the statistics in [ ].

Figure 1. Spatial distribution of human capital in Spain.

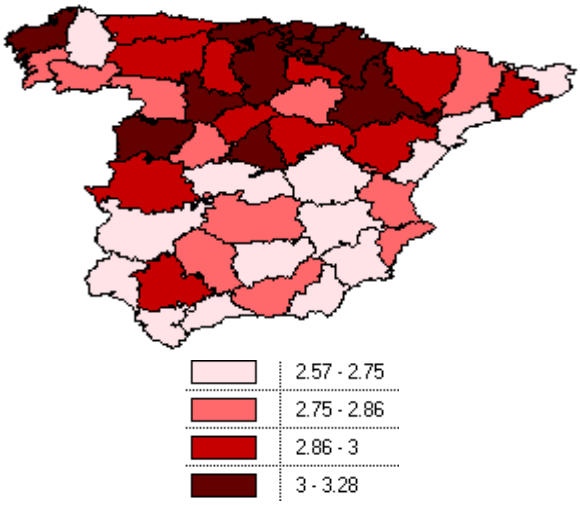
Per capita value of human capital – 1995



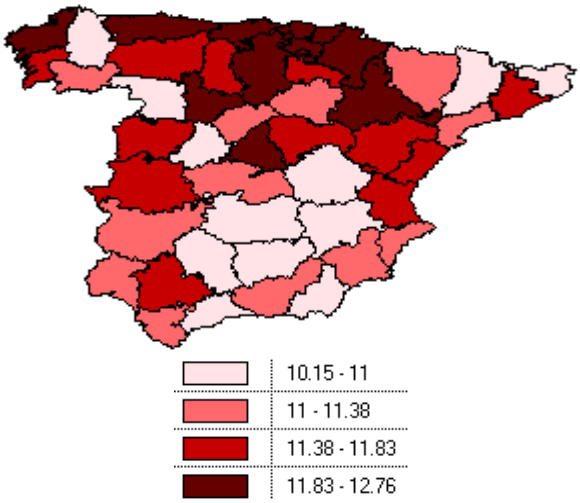
Average years of schooling – 1995



Per capita value of human capital – 2007

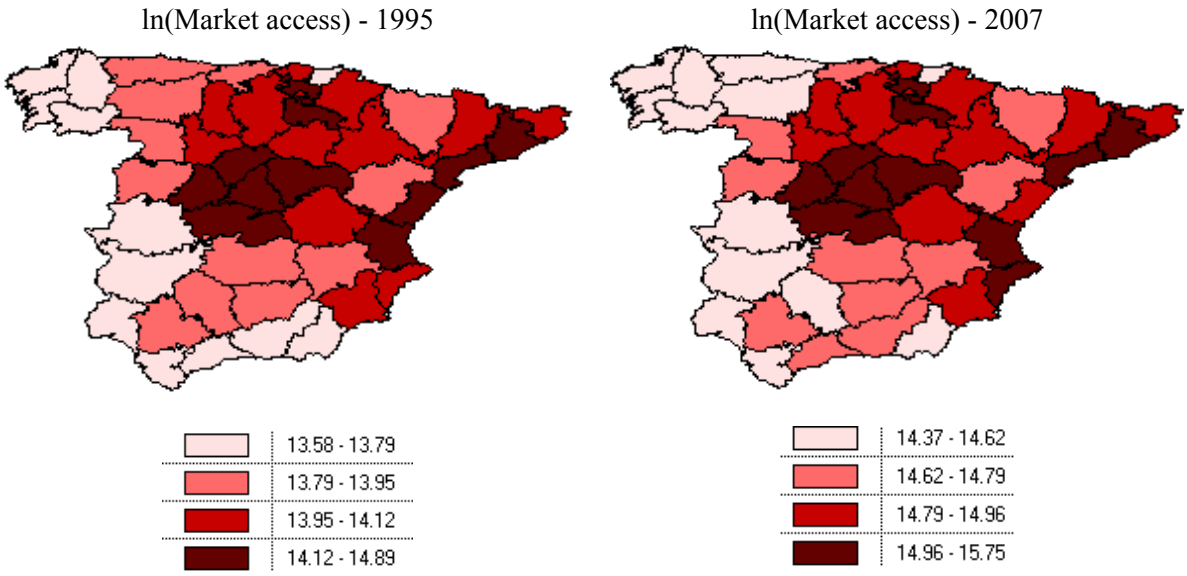


Average years of schooling – 2007



Note: The per capita value of human capital is measure in number of equivalent unskilled workers.
Source: IVIE

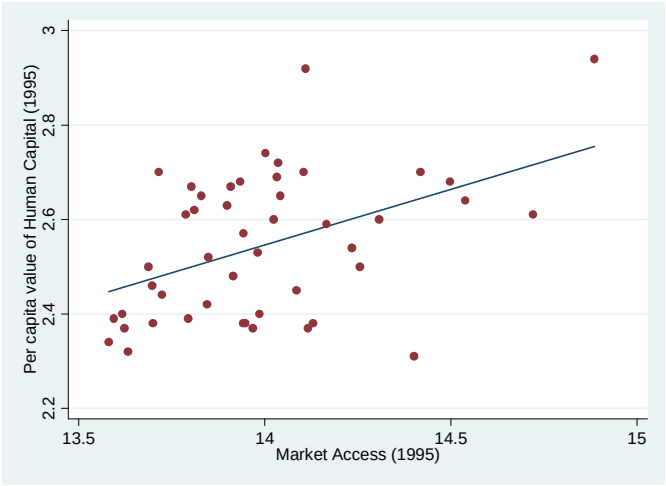
Figure 2. Spatial distribution of market access in Spain.



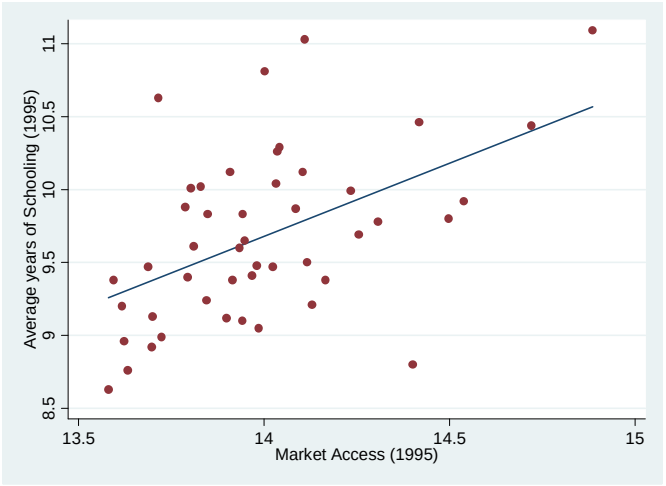
Source: INE and authors' calculations.

Figure 3. Relationship between human capital and market access in the Spanish provinces.

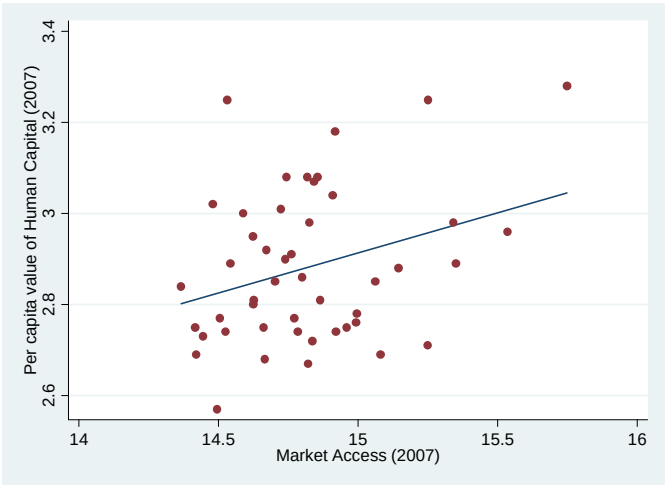
Market access and pc value of human capital – 1995



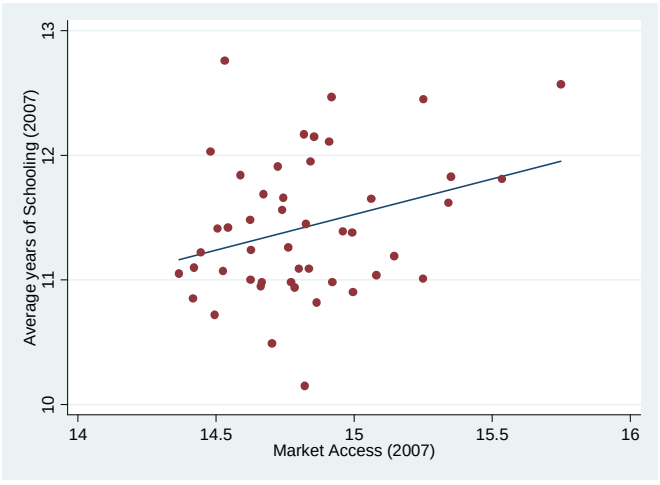
Market access and average years of schooling – 1995



Market access and pc value of human capital – 2007



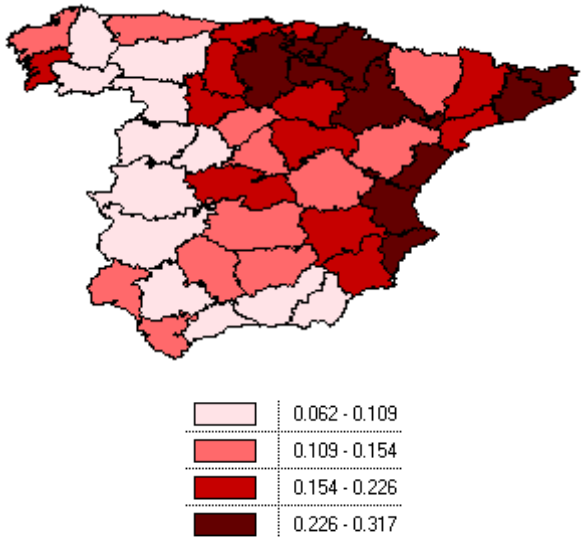
Market access and average years of schooling – 2007



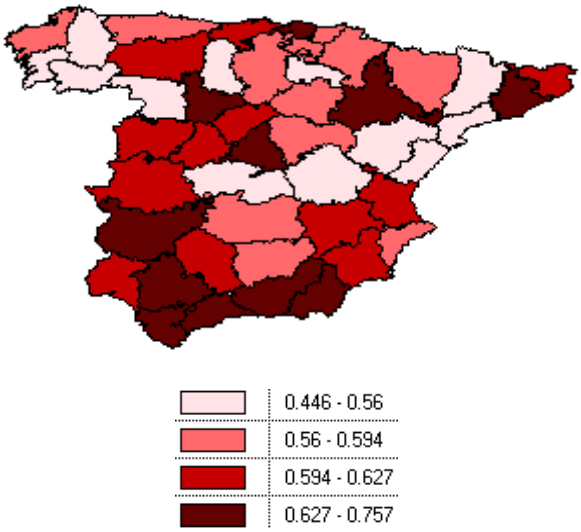
Source: INE, IVIE, and authors' calculations.

Figure 4. Spatial distribution of the sectoral composition in Spain (% over total employment).

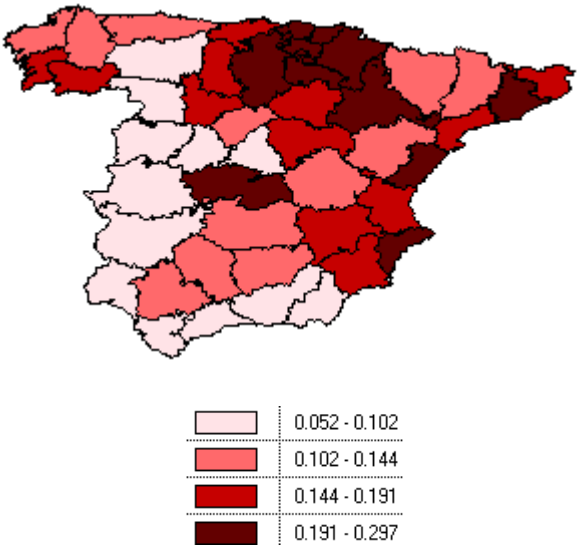
Manufacturing employment – 1995



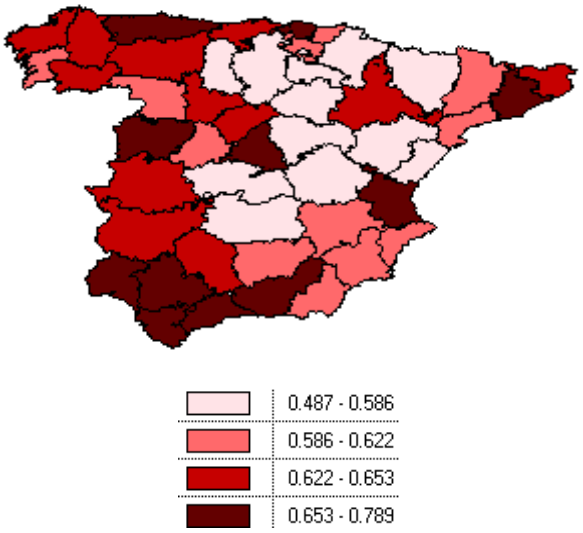
Service employment – 1995



Manufacturing employment – 2007



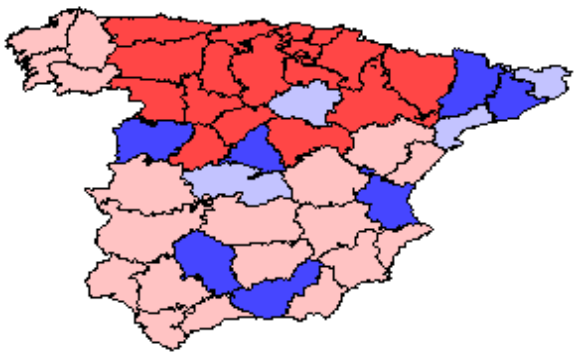
Service employment – 2007



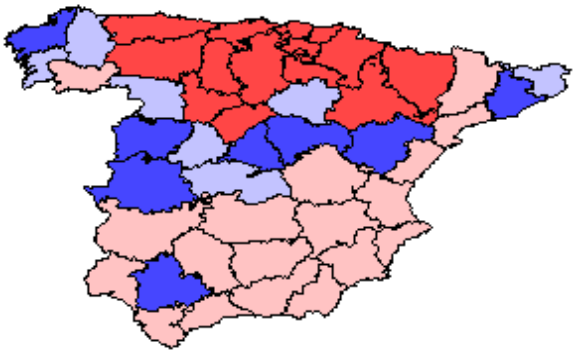
Source: INE

Figure 5. Moran Scatterplot for human capital in Spain.

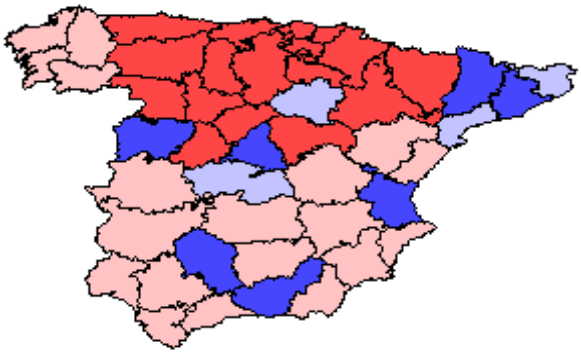
pc value of human capital – 1995



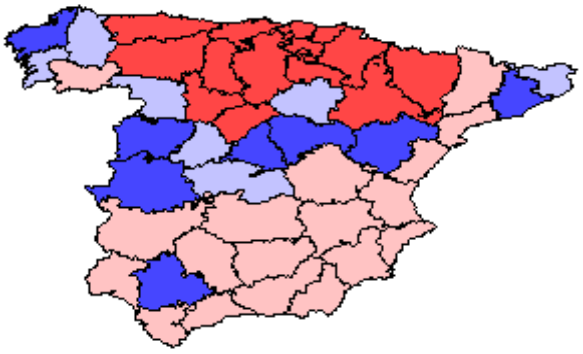
pc value of human capital – 2007



Average years of schooling – 1995



Average years of schooling – 2007



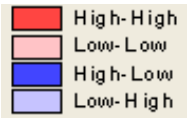


Figure 6. Moran Scatterplot for market access in Spain.