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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 tests the robustness of estimates of market access impact on regional variability in human capital, as previously derived in the NEG literature. Our hypothesis is that these estimates of the coefficient of market access, in fact, capture the effects 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,

Acknowledgments: BC-K acknowledges the scientific research support from the Scientific and Technological Research Council of Turkey (TUBITAK), grant code BIDEB-2214. EL-B acknowledges financial support from the Spanish Ministry of Science and Technology, National Program of R&D, ECO2008-05314/ECON. The views expressed here are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

1. Introduction

Contributions to the literature in recent decades have shown regional disparities to be associated with differences in the endowment of the socio-economic characteristics of each region. Among these, human capital, and in particular the educational attainment of the population, has been reported as being a key factor in accounting for differences in regional economic growth. Thus, endogenous growth models highlight the fact that it is human capital that stimulates the diffusion of knowledge and technological development, while Lucas (1988) and Romer (1990) stress the importance of human capital for explaining why some economies are more developed than others. Likewise, Barro and Sala-i-Martin (2004) also consider human capital an important factor for explaining economic convergence across countries and across regions.

From a complementary perspective, New Economic Geography (NEG) identifies a connection between the human capital endowment of an economy and the spatial distribution of economic activity. Initially, Krugman's (1991) two-sector model and Fujita et al's. (1999) augmented model focused solely on the location of production and, hence, on the distribution of economic growth among localities. From such models, a relationship between the spatial concentration of economic activity and factor prices can be derived. Specifically, wages are associated with market access - the distance-weighted sum of the purchasing power of the system of economies. The model predicts that by locating in high market access areas, firms will be able to pay higher wages to their workers, as such a location means lower transport costs and entails the cost savings of large-scale production. Existing empirical evidence supports the prediction of this theoretical model, given the confirmation of 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, these seminal papers did not examine in detail the endogenous accumulation of factors of production. Thus, while these early contributions to NEG analyzed the spatial distribution of economic activity, they did so without paying any great attention to the impact of agglomeration on the accumulation of the supposed determinants of economic growth. Only recently has the accumulation of human capital been endogenized within the framework of an NEG model (Redding and Schott, 2003).

Assuming that human capital endowments will be larger in areas offering higher returns on this factor, the model predicts greater endowments in economies with better access to markets and suppliers. This prediction holds because the relative wages of skilled labor, and hence the economic incentive to invest in human capital, increase with market and supply access.

Adopting a similar empirical strategy to that used in studies seeking to verify the relationship between wages and market access, Redding and Schott (2003) provided evidence of the positive impact of market access on human capital for a sample of countries. Similarly, López-Rodríguez et al. (2007) tested this hypothesis for a sample of EU regions and reported a positive and significant correlation between market access and measures of educational attainment. However, in both exercises the empirical specification did not control for factors that are equally likely to impact on the spatial distribution of human capital. López-Rodríguez (2007) did, however, test the robustness of the estimated impact of market access for the EU regions. He reported that the estimate decreased markedly (to less than a third, from around 0.9 to 0.3), but remained significant when additional control variables (i.e. employment in high-tech sectors, labor productivity, number of patents, and a dummy variable accounting for peripherality) where included. Redding and Schott (2003) also included *indicators thought to be important in cross country studies of development* (i.e. the risk of expropriation by the government, the percent of countries' land that is tropical, and dummies for socialist rule and external wars) in their regression. In this case, the estimate of the impact of market access fell by half (from around 0.6 to 0.3), being significant only at the 5% level.

In this paper, we seek to contribute to the testing of the robustness of the market access–human capital relationship in a regional setting. It is our belief that the estimate of the coefficient of the market access measure in fact captures the effects of regional differences in the industrial mix and of the spatial dependence in the distribution of human capital. Our hypothesis is that the omission of such factors in previous studies has biased estimates of the market access coefficient. Specifically, this holds true if, as expected, the sectoral composition of each region is correlated to the measure of market access, and if this measure captures at least part of the spatial dependence that seems likely to characterize the regional distribution of human capital. Niebuhr (2006) and

Kosfeld and Eckey (2008) raised similar concerns in the relationship between wages and market access. Indeed, Niebuhr (2006) showed that controlling for additional conditioning variables reduces the power of market access to account for regional wages.

We test our hypothesis by drawing on data for the Spanish provinces. In section 2, we study the dispersion of human capital among the provinces of Spain, using two proxies of human capital endowment: the average number of years of schooling and the per capita value of human capital. In both cases, the spatial descriptive analyses confirm sizeable regional disparities and a marked 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 of NEG supporting these empirical results are outlined in section 3, while in section 4 we discuss the effect of failing to control for regional differences in sectoral composition, and for spatial dependence. Building on these arguments, the original NEG specification can be augmented, and the estimation obtained with these alternative specifications can be compared with those originally obtained from the baseline model. Finally, section 5 concludes.

2. Spain's Geography of Human Capital

2.1 Preliminary Evidence

Spain's is one of the success stories of the Euro Area in terms of the evolution recorded in its regional inequalities. However, disparities in key macroeconomic indicators between regions remain sizeable (see, for example, Cuadrado et al., 1999; De la Fuente, 2002). Drawing on arguments from New Economic Geography (NEG), recent contributions have analyzed the connection between the spatial distribution of economic activity and regional disparities in certain variables of interest. In the case of Spain, López-Rodriguez et al. (2008) reported evidence of the impact of geography on regional wages. These findings confirm that geography, measured by the market access of provinces, has a positive impact on the dispersion of regional wages. Similarly, López-Rodriguez et al. (2007) concluded that market access also shapes the distribution of human capital (in this case for the set of EU regions). These respective findings suggest the need for a more rigorous analysis of the relationship between market access and Spain's endowment of human capital, particularly as human capital has been shown to be a key factor in this and other countries' regional growth (see, for example, Rodríguez-Pose and Vilalta-Bufí, 2005; Di Liberto, 2008; López-Bazo and Moreno, 2008; Bronzini and Piselli, 2009). Therefore, an enhanced understanding of the determinants of the spatial distribution of human capital should shed light on the origin of regional inequalities in productivity, per capita income and, hence, long-term welfare.

Despite the constant improvement in the level of schooling in recent decades, the Spanish provinces still show marked differences in their endowment of human capital. The evidence presented herein was obtained from data for Spain's 47 continental provinces[1] and for two indicators of human capital, in the years 1995 and 2007. The first indicator is a traditional measure of human capital: the average number of years of schooling of the working population in each province. However, as this measure has been subject to certain criticism, results were 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 compared to that of an unskilled one (Mulligan and Sala-i-Martín, 2000). In both cases, the data were drawn from the IVIE-Bancaja Human Capital Dataset for Spain (see Serrano and Soler, 2008, for a description of the methodology used in constructing the dataset).[2]

The spatial distribution of these two measures for 1995 and 2007 is shown in Figure 1. The maps confirm the existence of marked differences in human capital endowment across the Spanish provinces and their persistence over time, despite the overall increase in endowment in all provinces. However, of greatest interest to us here is the geographical distribution of human capital with, broadly speaking, higher levels in the north and lower levels in the south. Here again this pattern seems to persist despite the general increase in the level of schooling between 1995 and 2007.

As outlined above, NEG predicts that the spatial distribution of human capital in the Spanish provinces is largely attributable to 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, the 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 them:

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

where Y_j is the 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 in line with Head and Mayer (2006), that is $D_{ii} = 0.66\sqrt{\frac{Area_i}{\Pi}}$. Figure 2 shows the values of the market access measure for the Spanish provinces for 1995 and 2007 and it is evident that the provinces differ as regards their market access. As expected, the dispersion is persistent and no significant changes are recorded in the time period under consideration.

The relationship between the respective distributions of human capital and market access (Figures 1 and 2) reveals a connection between the two magnitudes, albeit that it is far from perfect. Generally, provinces with large endowments of human capital do not lie in the economic periphery, which tends to be occupied by those with the smallest endowments. However, a number of provinces contradict this general trend as is confirmed by Figure 3. In all cases (for both years and time periods) there exists a positive relationship between human capital and market access, but the amount of dispersion in the relationship is far from negligible. Note, for example, that there are provinces with similar, low market access values that have quite different endowments of human capital. In addition, the distribution of both magnitudes seems likely to be characterized by spatial dependence, a factor that must also be considered when formally analyzing the impact of market access on the endowment of human capital.

2.2 Estimation of the baseline model

The initial step in our study of the robustness of the estimated impact of market access on the spatial distribution of human capital involves estimating a simple specification for use as a benchmark:

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

where *HK* denotes the column vector with the values for the human capital measure in the economies under analysis, and ε is supposedly (at least 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 shown in Table 1.[3] The results are obviously in agreement with the depiction in Figure 3, thereby confirming the existence of a positive correlation between the two variables: Spanish provinces with greater market access are endowed with higher levels of human capital. In other words, remoteness acts as an incentive to accumulate human capital. The impact of market access, however, declined over the period analyzed, as shown by the lower coefficient estimate in 2007 for both measures of human capital.

Table 1 additionally includes the results for further diagnostic tests. Thus, the Breusch-Pagan test indicates that there are no symptoms of heteroskedasticity in any of the estimated baseline models, while the battery of spatial dependence tests indicates that the baseline human capital-market access model is likely to be (spatially) misspecified. The results of these spatial dependence tests are discussed in greater detail in section 4, as they lend support to our claim for the estimation of a spatial specification of the human capital-market access model. However, first, we frame the results of the baseline specification within an NEG model that is extended to account for the endogenous accumulation of human capital in each region.

3. The NEG Explanation: Human Capital and Geography

Not only are the findings reported in section 2 intuitively reasonable, but the NEG framework allows for the relatively straightforward, theoretical derivation of the link between human capital and remoteness. Krugman (1991) and Fujita et al's. (1999) models did not include the accumulation of human capital. It was in Redding and Schott (2003) that an endogenous mechanism for the accumulation of human capital was first considered and which in conjunction with standard NEG arguments gave rise to a reduced form linking the skill wage premium in every economy to its market and supply access.[4]

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

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

(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 so that individuals have incentives to invest in education. The cost of education comprises two components: $a(z)$ represents individuals' ability to become skilled, which lowers the cost of education, and h_i, which accounts for the institutional environment and the public provision of education defined as an inverse measure, i.e., 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 level of ability at which individuals are indifferent to becoming skilled or remaining unskilled. As the relative wages of skilled workers increase, the cut-off for this critical level of ability falls. In turn, this means that the number of individuals with an economic incentive for becoming skilled increases. Therefore, it is the magnitude of the relative wage that determines the individuals' decision to invest in human capital.

Next, Redding and Schott (2003) employ an 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 manufactured 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 the market access (MA_i) and the 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:

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

where ξ absorbs the earlier 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 therefore 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:

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

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

From these expressions it can be deduced that if a region becomes remote (in the sense that market and supplier access fall) and assuming that manufacturing production is skill intensive, then the new equilibrium will be characterized by a lower relative wage of skilled workers.[7] Returning to the critical level of ability, this decline in the relative wages of skilled workers means a lower incentive to invest in human capital. Accordingly, the number of skilled workers can also be expected to fall in that region. This is the argument underpinning the connection between the spatial distribution of human capital and market access in equation (2), as the relative wages of skilled workers are 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

Redding and Schott's (2003) NEG model (as outlined above) provides a theoretical justification for the empirical evidence reported in section 2 whereby the human capital endowment is higher in Spain's economic core 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. Indeed, the theoretical model includes other mechanisms that impact on the critical level of ability. In addition to the impact of *MA* and *SA*, the supply of skilled workers monotonically decreases 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). By contrast, technology transfers to a less developed region *i* reduce their c_i, thereby raising the maximum wage that its manufacturing firms can afford to pay to skilled and unskilled workers given the current market and supply access. Since manufacturing is skill intensive, this leads to an increase in the relative wages of skilled workers, and hence a higher endowment of human capital.[8] For this reason, empirical specifications such as the one included in equation (2), which has no variables proxying for these other factors, are likely to produce biased estimates of the impact of *MA* (and *SA*) on human capital.

This concern has 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 (considered the economic 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) recognize that the impact of market access 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 obtained from studies that focus 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 (albeit decreasing) when other variables are included in the model. In marked contrast, in the rest of this section we show how by controlling simply for the industrial mix (as a rough proxy for the factors described above) and for spatial dependence (which is also likely to account for the impact of some of these factors) in the baseline human capital equation, this modifies the conclusion regarding the impact of market access on the regional distribution of human capital.

4.1. Sectoral composition

Different economic activities require workers with different levels of education. Accordingly, it is our hypothesis that the industrial mix conditions the regional distribution of human capital, as some sectors are skill intensive while others employ low skilled workers. In the case of the Spanish provinces, there are major disparities in the share each sector has in the economy. Therefore, we expect provinces specialized in a particular industry or industries to present higher endowments of human capital. This is confirmed by Figure 4, which maps the spatial distribution of the employment share in the manufacturing and services sectors.[9] The picture described by the maps is well known: the manufacturing sector is most important in the northeast of the country (along the Mediterranean coast and the Ebro Valley), and in some central provinces. Meanwhile, the services sector is most important in the southwest (because of greater employment in the public sector), in Madrid, and in some other provinces such as Barcelona and Valencia (reflecting high rates of employment in market services).

Thus, Figures 1 and 4 show that the spatial patterns of human capital and manufacturing employment are quite similar. In the case of the services sector, a connection can also be observed with the endowment of human capital, although in this case we should take into account the aforementioned intensity of employment in the public sector in the southwest provinces, and also the proliferation of some low value-added services linked to tourism in these provinces.

4.2. Spatial dependence

Our second concern is related to the spatial dependence of human capital. An exploratory spatial data analysis (ESDA) reveals that the two human capital indicators are characterized by significant spatial dependence. Global spatial autocorrelation was tested by means of Moran's *I* statistic (see, for instance, Anselin, 1993):

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

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:

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

Two matrices of spatial weights were used in conducting 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 in which the elements are defined by:

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

The first four rows of Table 2 show Moran's *I* test results for each indicator of human capital in the two years under analysis and for the application of the two weight matrices. In each case, the null hypothesis of absence of spatial dependence in the human capital variables was strongly rejected. A more detailed analysis, involving the computation of measures of local spatial dependence, revealed a clear north-south divide, with hotspots of human capital endowment in the north, and groups of provinces with much lower endowments in the south (see, the Moran scatterplot in Figure 5).

A similar analysis conducted for the market access variable also reveals a far from random spatial distribution. As shown in the last two rows of Table 2, Moran's *I* test clearly rejects the 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 that observed for the human capital indicators. The values of the local Moran's *I* statistic in Figure 6 reveal that in this instance there is no clear north-south divide. Rather, there would seem to be a roughly east-west divide, which does not, however, match the structure of dependence observed for the human capital measures. Thus, we cannot expect market access to account for the pattern of spatial dependence detected in the human capital indicators in a regression such as that employed 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 Moran's *I* and the battery of Lagrange Multiplier (LM) tests of spatial dependence reported in Table 1. In all instances, the test points to the presence of significant residual spatial dependence, which means that the results based on the OLS estimator provide 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 up to this point, 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 ought to account for regional differences in the industrial mix and for spatial dependence. In the rest of this section, we show the effect of ignoring both phenomena in the case of the Spanish provinces.

Initially, the baseline specification was augmented to control for the sectoral composition of each region:

(12) $$\ln HK = \delta + \phi \ln SE + \beta \ln MA + \varepsilon$$

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

Next, in order to control for spatial dependence, two specifications were considered: 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 with market access decreases for the two indicators of human capital and for the two years under analysis. In fact, the non-significance of the effect of market access on human capital endowment cannot be rejected at the usual significance level in 2007, while in 1995 it is only significant at the 5% (for the per capita value of human capital) and 10% (for the average number of years of schooling) levels. This finding confirms our concerns about the importance of including a proxy for regional differences in sectoral composition.

Nonetheless, Moran's *I* test and the LM tests of the models estimated, including the controls for sectoral composition, still reject their null hypotheses of no spatial dependence. In other words, the addition of 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 of the imapct 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 also tested for the joint significance of the coefficients associated with the variables proxying for sectoral composition and for spatial effects. The results of the likelihood ratio tests are shown 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) was used. It was observed that the null hypothesis of no joint significance is strongly rejected in all cases, confirming that both the sectoral variables and the spatial effects are significant when explaining the variability in the regional distribution of human capital endowment.

In addition, the results of the LM tests of residual (the SAR model) and substantive (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 number of years of schooling in 2007). As for the effect of market access, the results strongly support our hypothesis as 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. In fact, these results suggest an almost negligible role of market access in explaining regional differences in human capital endowment, once sectoral composition and spatial dependence are accounted for.

It might be argued, however, that market access is likely to be correlated with the proxies for industrial mix, and also with the spatial lags in equations (13) and (14). As a result, it might be that a high degree of collinearity results in 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 should stress that the argument could just as easily be reversed, thereby supporting our hypothesis that the favorable result reported in support of the NEG arguments in López-Rodríguez et al. (2007) might (at least partly) be due to their omission of a proxy both for sectoral composition and for spatial effects. In an effort to shed more light on this question, we compared the values for the Akaike and the Schwartz Information Criteria (AIC and SIC respectively) as statistical measures that can help in selecting the most appropriate specification. These two measures are included in the bottom panel of Tables 1, 3, and 4. In each case, the values are lower for the specifications including controls for sectoral composition and spatial effects, lending support to our claim that any inference of the effect of market access on human capital should be based on an expanded model including these two elements.

5. Conclusion

The hypothesis presented in this paper is that any inferences made regarding the impact of market access on the regional distribution of human capital in earlier studies are likely to be non-robust, because they are based on a somewhat simple specification that fails to account for both regional differences in sectoral composition and the spatial dependence in the distribution of human capital.

Our results for the Spanish provinces confirm that if we include the sectoral composition of employment and control for spatial dependence, then the impact of market access falls sharply, to the point that it actually disappears and becomes statistically insignificant. Indeed, it can even be concluded that spatial effects and differences in the demand for human capital across sectors play a much more prominent role than the traditional measure used to proxy for market accessibility in each region. In this regard, our conclusion is in line with that reported in Fingleton (2006 and 2011), who claims that there are alternative (or at least complementary) plausible theories to those defended by NEG for explaining local wage variations. This conclusion is also consistent with the smaller role played by NEG elements at the regional level than at the countrywide scale, as suggested by results reported in Brakman et al. (2009). Thus, it is our belief that additional elements need to be combined with those in the NEG model so that we might obtain empirical specifications that provide a robust inference of the real impact of market access on regional differences in human capital endowments. In this regard, the consideration of regional spillovers within the theoretical framework outlined in section 3 and the derivation of its empirical counterpart are high on our research agenda.

The use of a more direct test of the connection between regional differences in the incentives to invest in human capital and market access, based on returns to education rather than on endowment, is also required. This would appear to be a more appropriate way of testing the implications of the wage equation in the NEG model (equation 6 in section 3), where the estimated return on education in each region would capture the skill wage premium.

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[1] Given their characteristics, we chose not to include the three provinces of the Canary and Balearic Islands and the two cities of North Africa (Ceuta and Melilla). This decision was related to the construction of the market access measure and not to those of human capital.

[2] Available at http://www.ivie.es/downloads/caphum/2007/metodologia.pdf

[3] A panel data set could be used for the variables under analysis; however, we preferred cross-sectional results to facilitate comparison with published results. On the other hand, similar qualitative results were obtained when estimating the relationship in equation (2) using data for a number of 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 their empirical application only considers the impact of market access, given that it is considerably more cumbersome to measure supply access, and because of the likelihood of a high correlation between both measures. The same approach is adopted elsewhere in the literature.

[5] See also Redding and Venables (2004) for full details of the model's essential elements.

[6] The zero profit condition for 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 as shown 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).

[9] Employment data for each sector in each province are drawn from the National Regional Accounts produced by the Spanish National Institute for Statistics (INE).

[10] We chose to estimate both spatial specifications rather than selecting just one of the two. In line with Fingleton and López-Bazo (2006), we believe that selecting the spatial specification based on the results of the LM and the robust LM tests of spatial dependence can produce misleading results for the selection of the appropriate specification including spatial effects. Moreover, modeling the source of the spatial dependence in the human capital-market access specification lies beyond the scope of this paper, and needs to be addressed separately.

[11] The results in this section were obtained using a weight matrix based on the inverse distance. Similar qualitative results (not reported here for reasons of space, but available from the authors upon request) were obtained when using the contiguity weight matrix.

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** (0.032)	0.031 (0.024)	0.045* (0.025)	0.012 (0.019)
Manufacturing Empl (%)	0.013 (0.025)	0.043 (0.026)	0.055*** (0.020)	0.081*** (0.021)
Service Empl (%)	0.172** (0.074)	0.210** (0.089)	0.268*** (0.059)	0.303*** (0.071)
Construction Empl (%)	-0.034 (0.042)	-0.112** (0.046)	-0.042 (0.033)	-0.021 (0.036)
Energy Empl (%)	0.017 (0.010)	0.018 (0.011)	0.013 (0.008)	0.007 (0.008)
Breusch Pagan Test	3.675 [0.59]	12.194 [0.04]	6.137 [0.29]	3.215 [0.66]
Residuals Moran´s I	0.285*** [0.00]	0.318*** [0.00]	0.163*** [0.00]	0.215*** [0.00]
LM-ERR	18.171*** [0.00]	22.526*** [0.00]	5.931** [0.01]	10.330*** [0.00]
LM-LAG	16.901*** [0.00]	24.883*** [0.00]	10.700*** [0.00]	7.137*** [0.00]
Robust LM-ERR	1.953 [0.16]	1.207 [0.27]	0.008 [0.93]	3.214** [0.07]
Robust LM-LAG	0.683 [0.41]	3.564 [0.06]*	4.777** [0.03]	0.021 [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

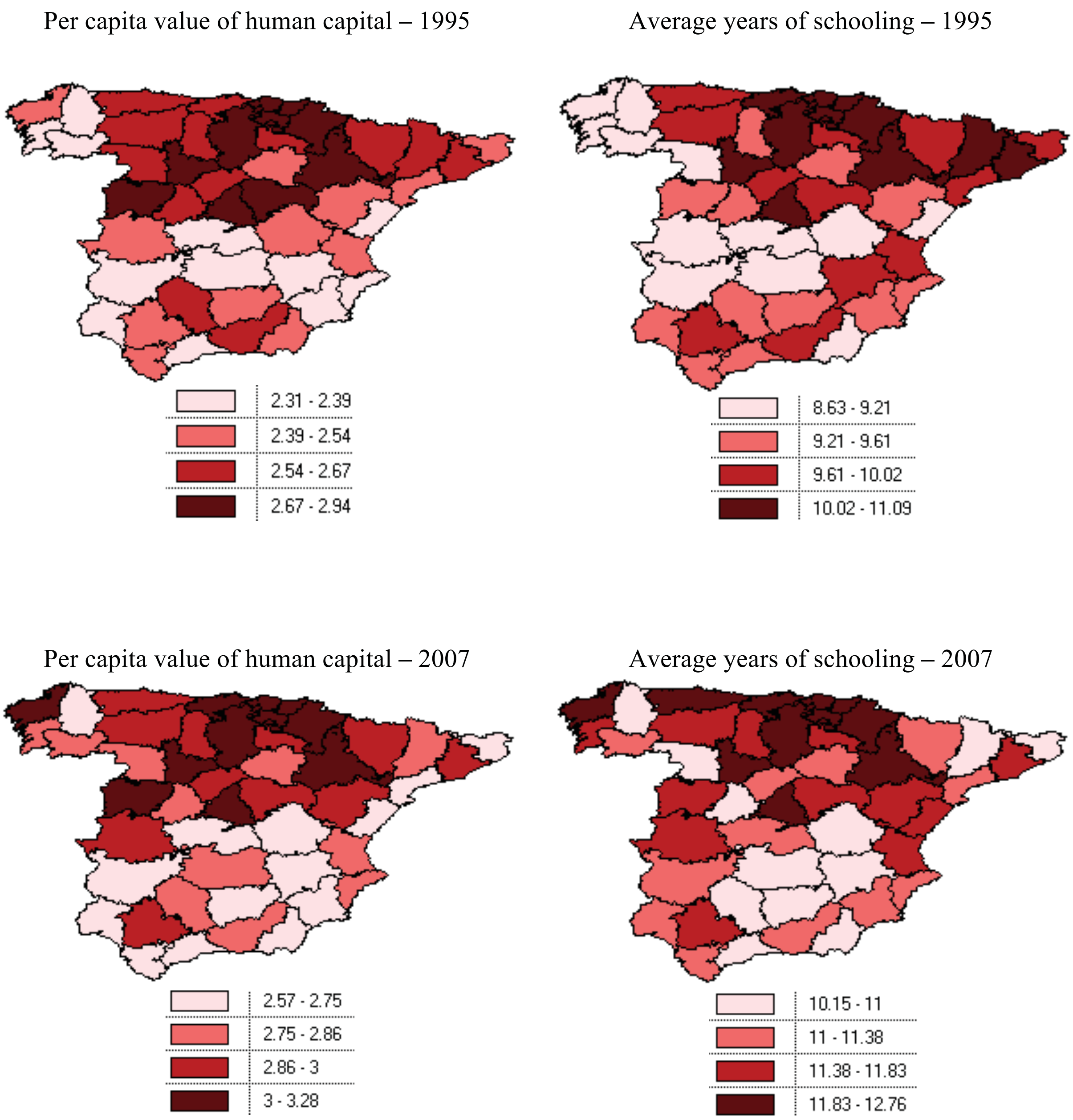
Notes: *, **, *** *represent significance at 10%, 5% and 1% respectively. Standard errors for coefficient estimates in ( ). P-values for the statistics in [ ]*

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]

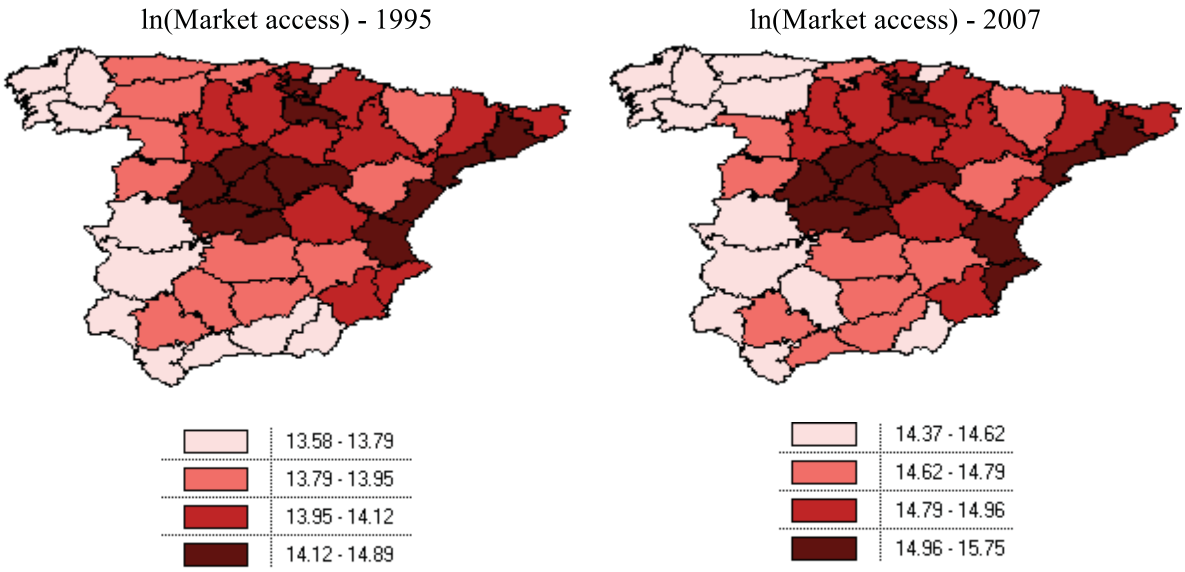
Notes: *Values of the Likelihood Ratio test for the significance of the sectoral composition variables and/or the spatial effects.*
, **, * represent significance at 10%, 5% and 1% respectively.*
P-values for the statistics in [ ].

Figure 1. Spatial distribution of human capital in Spain.



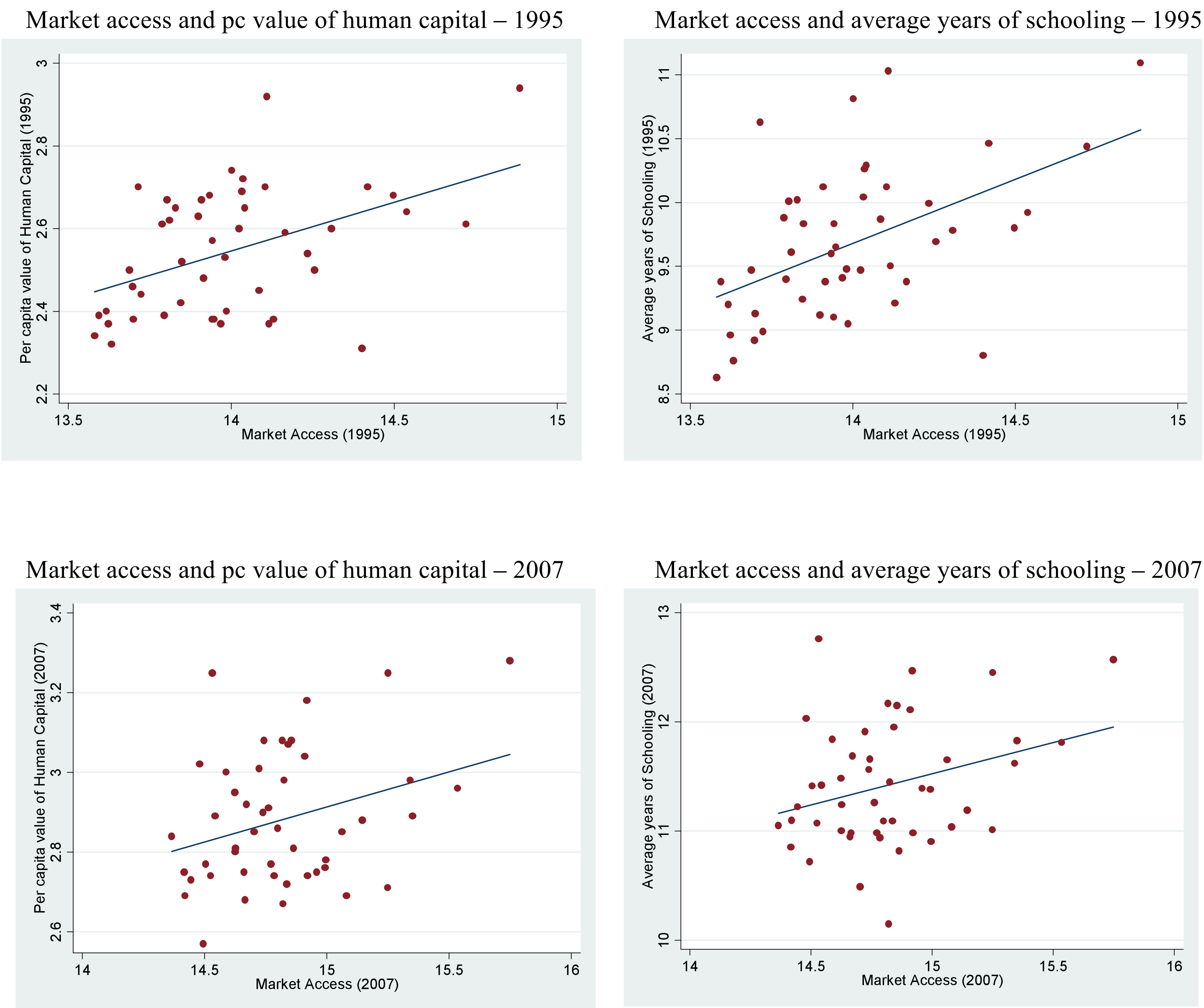
Note: The per capita value of human capital is measure in number of equivalent unskilled workers.
Source: IVIE

Figure 2. Spatial distribution of market access in Spain.



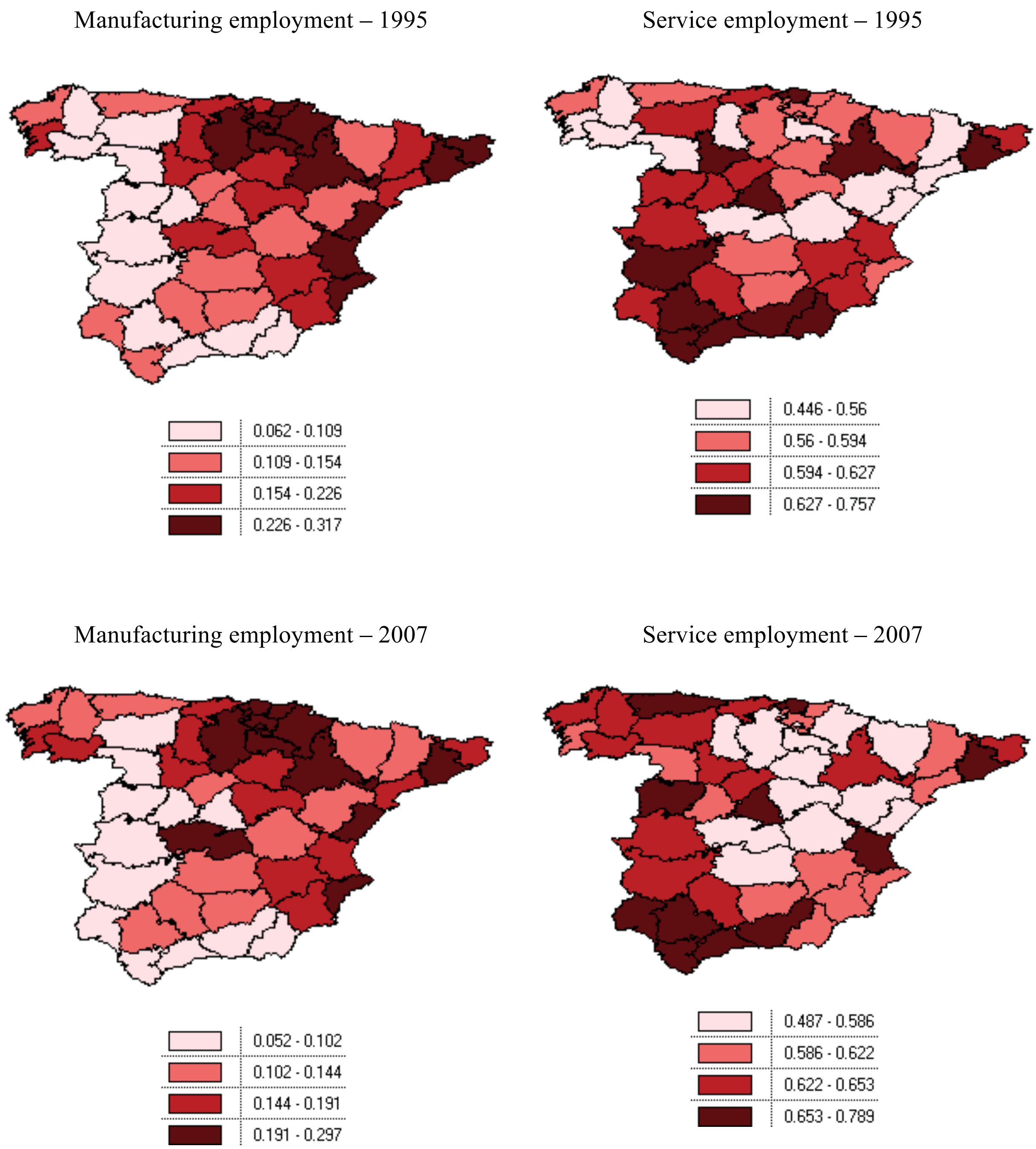
Source: INE and authors' calculations.

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



Source: INE, IVIE, and authors' calculations.

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



Source: INE

Figure 5. Moran Scatterplot for human capital in Spain.

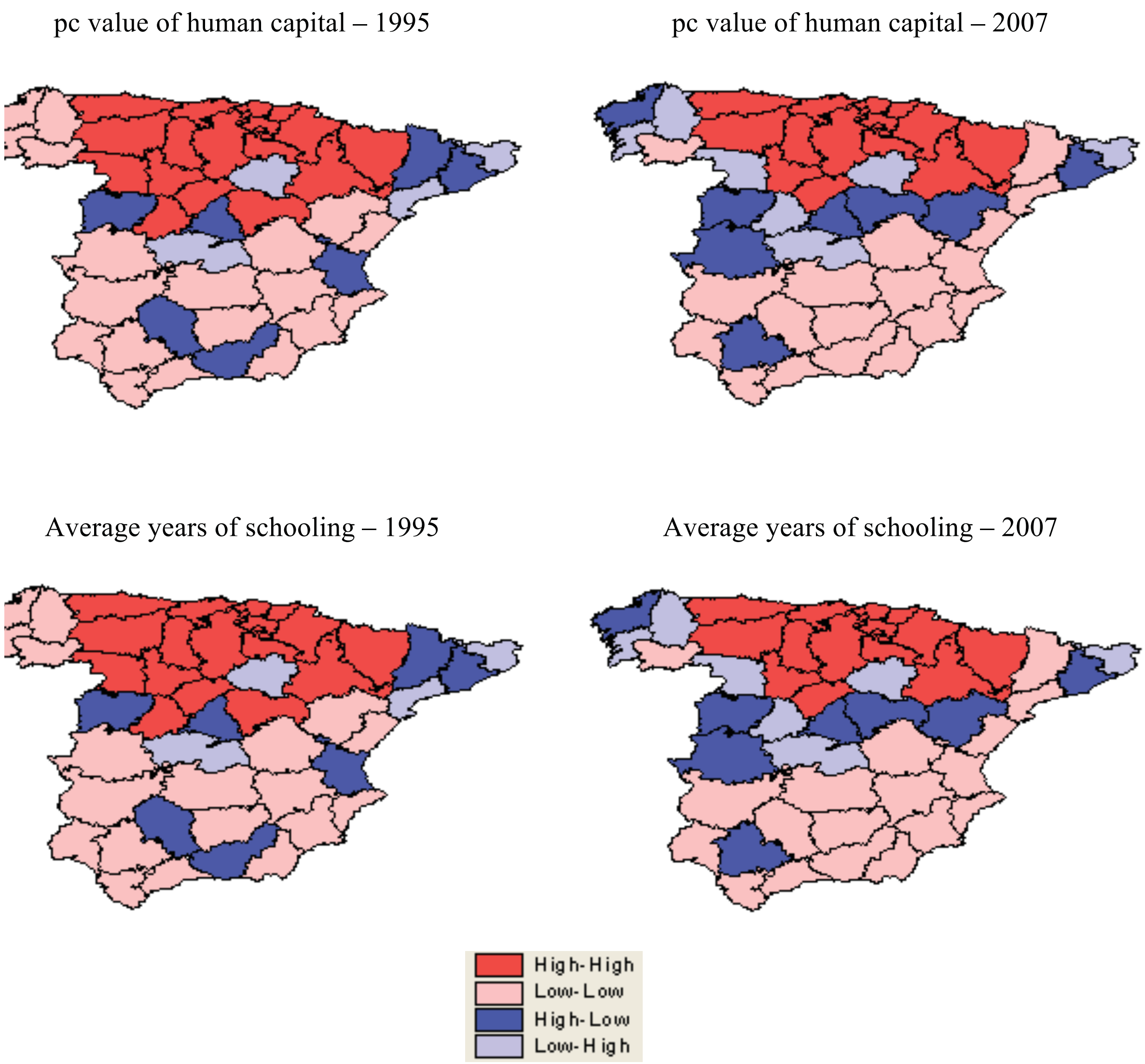
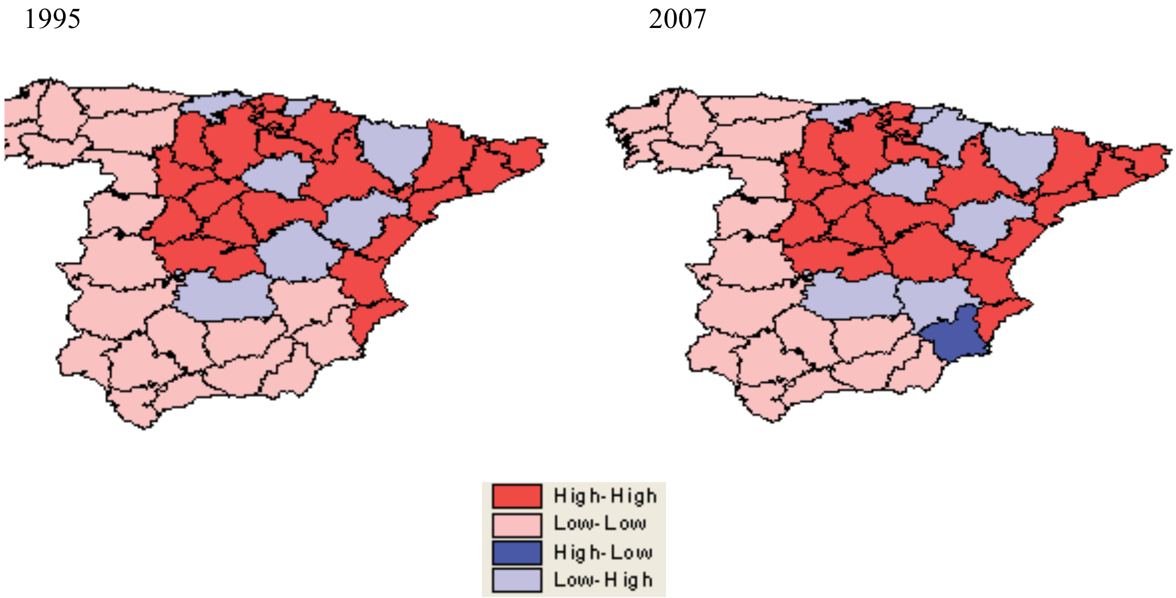


Figure 6. Moran Scatterplot for market access in Spain.



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