

**HUMAN CAPITAL ACCUMULATION AND GEOGRAPHY: EM-
PIRICAL EVIDENCE IN THE EUROPEAN UNION**

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HUMAN CAPITAL ACCUMULATION AND GEOGRAPHY: EMPIRICAL EVIDENCE IN THE EUROPEAN UNION

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Abstract

This paper evaluates the role that geography plays in determining the spatial distribution of educational attainment levels among EU regions, based on an extension of the standard two sector (agriculture and manufacturing) Fujita et al. (1999) economic geography model. We provide evidence that, in the EU, educational attainment levels are higher in those regions with greater market access. This finding corroborates the theoretical predictions of the model and proves that remoteness is a penalty for the economic development and convergence of the European Union regions.

JEL classification: F12, F14, O10

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1. Introduction

In January 2003 the release of the 2nd intermediate report of the economic and social cohesion showed that in the year 2000 the regions with the highest GDP per head (PPS) accounting for 25% of the total population in the European Union were twice as rich as the regions with the lowest GDP per head (PPS) accounting for the 25% of the total population in the European Union. This ratio was the same in 1990¹. At the 10% percentile the situation was even worse, the ratio between the regions with the highest GDP per head levels and those with the lowest GDP per head levels was about 2.8 in 1990 and 2.6 in 2000². The persistence of such differences is surprising in light of the successive steps taken by the European Union towards higher levels of integration. The Single European Act, 1987 was conceived with the aim of fostering the integration process in the European Community. Integration was to be characterized by the twin dynamic of monetary union and regional expansion. The former process came about through the unification of European markets and the bases for monetary union which were set out in the EU Treaty, Maastricht (1992), and had the effect of intensifying integration and giving rise to economic and monetary union (EMU) by 1999. The deepening of economic integration was followed by a wide-scale reform in Regional Policy. Present Regional Policy has been shaped by the introduction of the Economic and Social Cohesion principle in the EEC Treaty by the Single European Act (SEA) in 1987. It was reinforced after the ratification of the EU Treaty and the creation of the new Cohesion Fund³. There are a number of reasons which may have prevented convergence of income levels such as sluggish technology diffusion, endowment disadvantages⁴ and trade costs⁵. At this point New Economic Geography (NEG) has reached a theoretical consolidation as a theory that explains the emergence of a heterogeneous economic space⁶. In NEG models agglomeration of economic activities and population bases on increasing returns to scale and transport costs. Firms that are far from large consumer markets pay greater transport costs and have less value added available to remunerate domestic factors of production. Although it is well documented the theoretical bases of NEG models, authors such as Neary (2001), Ottaviano (2002) and Head and Mayer (2003) pointed out that empirical research on NEG is lagging behind. Recently new empirical contributions came out (Brakman et al. 2000, 2002, Faina and Lopez-Rodriguez 2004, Hanson 1998, 2000, Niebuhr 2004, Mion 2003, Redding and Schott 2003, Redding and Venables 2004, Ross 2001).

The aim of the paper is to add to the empirical evidence on NEG. We investigate whether there exists a spatial educational attainment structure in the EU, i.e. whether there is a positive correlation between regional levels of educational attainment and distance from large consumer markets.

¹ Data refer to EU15 countries

² The figures of the 1st intermediate report on the economic and social cohesion comparing the years 1989 and 1999 for the 10% and 25% of population with the highest and lowest levels of GDP per head were the same as in the 2nd intermediate report on the economic and social cohesion.

³ With respect to the effectiveness of the European Union Regional Policy to boost regions whose development is lagging behind the opinions of the scholars are divergent (see Basile et al. 2001, Boldrin and Canova 2001, Faina and Lopez-Rodriguez 2004, Rodriguez-Pose and Fratesi 2004)

⁴ Studies examining the link between human capital and growth include Benhabib and Spiegel (1994), Bils and Klenow (2000), Eicher and Garcia-Penalosa (2001) Galor and Mountford (2001), and Mankiw et al. (1992)

⁵ See Hanson (1998, 2000), Redding and Venables (2004)

⁶ See Krugman, 1991, 1992

Our study departs from an extension of the standard two sector (agriculture and manufacturing) Fujita et al. (1999) economic geography model carried out by Redding and Schott (2003) in which they allowed unskilled individuals to endogenously choose whether to invest in education. The authors demonstrate that there is a penalty of remoteness in terms of return to skill, thereby reducing incentives for investment in human capital accumulation. In Redding and Schott words “This penalty magnifies the effect that economic geography can have on cross-country per capita income; increasing a country’s relative trade costs not only reduces contemporaneous factor rewards, but also lowers gross domestic product by suppressing human capital accumulation and decreasing the supply of high-income skilled workers”

Our investigation complements the work carried out by Redding and Schott (2003). It differs from them in geographical focus (European Union regions rather than World countries) and in the fact that we use an *ad hoc* measure of market access instead of using the theory-based measure.

The rest of the paper is structured as follows: Section 2 contains a brief description of the theoretical model that constitutes the theoretical framework of the empirical analysis. In section 3 contains the empirical framework, data and regional system use in our estimations. The results of the regression analysis are presented in section 4. Section 5 contains the main concluding remarks. In section 6 are the main references used.

2. The Theoretical Model

In NEG models, the interaction of transport costs and increasing returns to scale generates demand linkages and serves as explanation for agglomeration. Agglomeration is caused by a circular relationship in which the spatial concentration of manufacturing both creates and follows market access. In Krugman’s (1991a) words, *circular causation a la Myrdal* is present because these two effects reinforce each other: “manufactures production will tend to concentrate where there is a large market, but the market will be large where manufactures of production is concentrated”. These forces that are at work in any multiregional economy can be studied within a relatively simple general equilibrium model of monopolistic competition developed by Krugman (1991b), which has come to be known as the *core-periphery model*⁷. Krugman’s theoretical research on NEG has triggered a plethora of contributions⁸, which have been surveyed by Ottaviano and Puga (1998). Most recently a synthesis of the existing theoretical research on NEG can be found in Fujita et al. (1999) and Fujita and Thisse (2002).

The present analysis is based on an extension of the standard two sector (agriculture and manufacturing) Fujita et al. (1999) economic geography model carried out by Redding and Schott (2003) by introducing human capital accumulation. The structure of Redding and Schott’s model is as follows. The economic space is made of $i \in \{1, \dots, R\}$ countries. Each country is endowed with L_i consumers. Consumers have one unit of labour which is supplied inelastically with zero disutility and consumers choose endogenously whether or not to invest in becoming skilled. Preferences are identical across all consumers and described by a Cobb-Douglas utility function,

$$U_j = A_j^{1-\mu} M_j^\mu, \quad 0 < \mu < 1 \quad (1)$$

⁷ An earlier analysis that anticipated several aspects of Krugman’s work was developed by Faini (1984). Ideas close to economic geography have already appeared in Krugman (1979) but were not fully worked out.

⁸ See Krugman and Venables (1995), Venables (1996), Redding and Venables (2004) among others

Where μ is the share of expenditure on manufactures, A is the quantity of agricultural good consumed and M is a composite of symmetric product varieties given by:

$$M_j = \left[\sum_{i=1}^R \int_0^{n_i} m_{i,j}^C(z)^{(\sigma-1)/\sigma} dz \right]^{\sigma/(\sigma-1)} = \left[\sum_{i=1}^R n_i (m_{i,j}^C)^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} \quad (2)$$

We use j to denote a country that is demanding or importing a good and i to denote a country that is producing or exporting a good. σ is the constant elasticity of substitution between any pair of varieties (consumers have love for variety, with increasing σ , the substitutability among varieties rises, thus the desire to spread consumption over manufactured goods declines), n_i denotes the number of varieties produced in country i and $m_{i,j}^C$ denotes the amount of each variety produced in country i for final consumption in country j . The second equation exploits the fact that, in equilibrium all the products produced in country i are demanded by country j in the same quantity, so we can remove the index z and rewrite the integral as a product. Dual to manufacturing goods consumption index (M_j) is a price index (G_j) defined over the prices of individual varieties produced in i and sold in j (i.e) $P_{i,j}$.

$$G_j = \left[\sum_i^R \int_0^{n_i} P_{i,j}(z)^{1-\sigma} dz \right]^{1/(1-\sigma)} = \left[\sum_i^R n_i (P_{i,j})^{1-\sigma} \right]^{1/(1-\sigma)} = [SA_j]^{1/(1-\sigma)} \quad (3)$$

Equation (3) can also be interpreted as a measure of the country's overall access to sources of supply-supplier access (SA_j).

The agricultural sector produces a homogeneous good under constant returns to scale

$$Y_i = \theta_i^Y (S_i^Y)^\phi (L_i^Y)^{1-\phi}, \quad 0 < \phi < 1 \quad (4)$$

Y_i denotes the output in the agricultural sector which is endowed with L_i unskilled workers and with S_i skilled workers. θ_i stands for agricultural productivity. Here, we assume that the output of the agricultural sector is costlessly traded between any two countries⁹.

The manufacturing sector produces a differentiated good according to an increasing returns to scale technology such as the production of each variety requires primary factors of production (skilled and unskilled labour) and goods from the manufacturing

⁹ Redding and Schott (2003) also relax this assumption considering the possibility of trade costs involved in shipped the agricultural good.

sector (intermediate inputs). The costs that a firm in country i incurs to produce the differentiated good can be given by:

$$\Gamma_i = (w_i^S)^\alpha (w_i^U)^\beta G_i^{(1-\alpha-\beta)} c_i [F + x_i], \quad (5)$$

where w_i^S is the wage of skilled workers (input share α), w_i^U is the wage of unskilled workers (input share β), G_i is the price index for manufactures (input share $1 - \alpha - \beta$), c_i is a constant marginal input requirement, F is a fixed input requirement and

$x_i = \sum_{j=1}^R x_{ij}$ is the total output of the firm produced for all markets.

Manufactured goods are trade among countries incurring iceberg costs, i.e. a fraction of any good shipped from location i to location j melts away so in order to arrive at location j with one unit of good $T_{ij}^M > 1$ units must be shipped.

In order to introduce endogenous human capital accumulation in the model, Redding and Schott (2003) assume that one unit of unskilled labour in country i (z_i) can be converted in one unit of skilled labour by incurring in a fixed cost of education

$\Omega_i(z) = \frac{h_i}{a(z)}$ units of unskilled labour where h_i is an inverse measure of the extend of

public provision education and $a(z)$ is the individual ability that has an upper and lower bounds determined by human biology $[a, \bar{a}]$. Associated with this distribution of ability we can defined a probability density function $\lambda(a)$ and a cumulative distribution of ability¹⁰ $\Lambda(a) = \int_a^a \lambda(a) da$. Taking into account the features above mentioned the decision to become educated will be given by:

$$w_i^S - w_i^U \geq \frac{h_i}{a(z)} w_i^U \quad (6)$$

This expression tells us that there is incentives to invest in education when the differential wage between skilled workers and unskilled ones exceed the educational costs. Moreover from equation (6) it can be obtained the equilibrium supply of skills, i.e., the critical value for a (a_i^*) such that if $a(z) \geq a_i^*(z^*)$ all individuals choose to become skilled:

$$a_i^* = \frac{h_i}{\left(\frac{w_i^S}{w_i^U} - 1\right)} \quad (7)$$

¹⁰ For a rigorous analysis see Redding and Schott (2003)

The worker with ability (a_i^*) is indifferent between becoming skilled and remaining unskilled, so this equation is called *skill indifference condition* (S).

The equilibrium conditions on the consumer's side are obtained by maximizing their utility subject to their budget constraint.

If we denote by E_j^C total consumer expenditure on manufacturing goods in country j , its demand for each product is (Applying Shephard's lemma on the price index¹¹)

$$m_{ij}^C = (P_{ij}^M)^{-\sigma} E_j^C G_j^{\sigma-1} \quad (8)$$

The term $E_j^C G_j^{\sigma-1}$ is a measure of demand in the importing country j termed *market capacity* ($m_j^C = E_j^C G_j^{\sigma-1}$) and comprised of total expenditure on manufacturing goods in market j (E_j^C) as well as the number of competing firms and the prices they charge as summarized in the manufacturing price index (G_j).

With respect to the producers' equilibrium, in the agricultural sector profit maximization imply that price equals unit costs of production:

$$P_i^Y = 1 = \frac{1}{\theta_i^Y} (w_i^S)^\phi (w_i^U)^{1-\phi} \quad (9)$$

where the output of the agricultural good is chosen as the numeraire, and thus $P_i^Y = 1$ for all i . In the manufacturing sector, the profit function of a representative country i firm is:

$$\Pi_i = \sum_{j=1}^R \frac{P_{ij}^M x_{ij}}{T_{ij}^M} - (w_i^S)^\alpha (w_i^U)^\beta G_i^{1-\alpha-\beta} c_i (F + x_i) \quad (10)$$

Because varieties are equally weighed in the utility function, the equilibrium price is the same across all firms located in region i . Solving the first order condition yields the common equilibrium price:

$$P_i^M = \left(\frac{\sigma}{\sigma-1} \right) (w_i^S)^\alpha (w_i^U)^\beta G_i^{1-\alpha-\beta} c_i \quad (11)$$

¹¹ See also Dixit and Stiglitz (1977)

This means that the firm uses a relative mark-up over marginal costs. Substituting (11) into the profit function leads to:

$$\Pi_i = \left(\frac{P_i^M}{\sigma} \right) [x_i - (\sigma - 1)F] \quad (12)$$

Under free entry, profits are zero, and thus equilibrium output of a firm is a constant given by:

$$x = \frac{\sigma - 1}{F} \quad (13)$$

The price needed to sell this many units satisfies¹² (using demand function (4))

$$(P_i^M)^\sigma = \frac{1}{x} \sum_{j=1}^R E_j G_j^{\sigma-1} (T_{ij}^M)^{1-\sigma} \quad (14)$$

Introducing the equilibrium prices (11) in equation (14) we obtain the following zero-profit condition:

$$\left[\left(\frac{\sigma}{\sigma - 1} \right) (w_i^S)^\alpha (w_i^U)^\beta G_i^{(1-\alpha-\beta)} c_i \right]^\sigma = \frac{1}{x} \sum_{j=1}^R E_j G_j^{\sigma-1} (T_{ij}^M)^{1-\sigma} \quad (15)$$

This is the so-called nominal wage equation which is point of departure of most studies that investigate the existence of a spatial wage structure for different cross sections. According to equation (15), the nominal wage level in region i depends on a weighted sum of purchasing power in all accessible regions j , whereby the weighting scheme is a function declining with increasing distance between locations i and j . This sum we will refer to as the “*market access*” of country i (MA_i). As Hanson (2000) notes, equation (15) can be thought of as a spatial labour demand function in an economy with perfect labour mobility. Labour demand and wages increase with income of neighbouring regions and decline with rising transport costs to these locations. The nominal wage equation represents one of the main propositions emerging from NEG models mentioned by Head and Mayer (2003): access advantages raise local factor prices. More precisely, production sites with good access to major markets because of relatively low trade costs tend to reward their production factors with higher wage and land rentals. Moreover, the equation resembles the market potential concept introduced

¹²The transport cost term ($T_{i,j}$) enters with the exponent $(1 - \sigma)$ and not σ because total shipments to market j are $T_{i,j}$ times quantities consumed

by Harris (1954). The market potential concept states that the attractiveness of a region as a production site depends on its access to markets. The nominal wage equation can be rewritten as:

$$(w_i^S)^\alpha (w_i^U)^\beta = \xi \frac{1}{c_i} (MA_i)^\frac{1}{\sigma} G_i^{(\alpha+\beta-1)} \quad (16)$$

by making use of equation (3) we can express the skilled and unskilled wages as a function of the market access and supplier access.

$$(w_i^S)^\alpha (w_i^U)^\beta = \xi \frac{1}{c_i} (MA_i)^\frac{1}{\sigma} (SA_i)^\frac{(1-\alpha-\beta)}{(\sigma-1)} \quad (17)$$

where the constant ξ on the right-hand side combines constants from the equation (15). Equations (9) and (17) combined together give us the equilibrium wages for skilled and unskilled workers. Taking logs and differentiating equations (9) and (17) and combining them with the skill indifference condition-equation (7)-, it is obtained the equilibrium relationship between geographical location and endogenous human capital investments.

$$0 = \phi \frac{dw_i^S}{w_i^S} + (1 - \phi) \frac{dw_i^U}{w_i^U} \quad (18)$$

$$\alpha \frac{dw_i^S}{w_i^S} + \beta \frac{dw_i^U}{w_i^U} = \frac{1}{\sigma} \frac{dMA_i}{MA_i} + \frac{(1 - \alpha - \beta)}{(\sigma - 1)} \frac{dSA_i}{SA_i} \quad (19)$$

Taking into account equations (18) and (19) it can be shown that if the equilibrium market access (MA_i) and supplier access (SA_i) fall and if the manufacturing sector is skill-intensive relative to the agricultural sector and the country remains incompletely specialized (this will occur for relatively high values of trade costs), the new equilibrium must be characterized by a lower relative wage of skilled workers and therefore by using the skill indifference condition this new equilibrium implies a higher critical level of ability (a_i^*) above which individuals become skilled and a reduced (increased) supply of skilled (unskilled) workers.

The intuitive explanation is based on that the fall in the market and supplier access modifies the initial equilibrium conditions in the manufacturing sector which experiences a fall in size. This reduction in size releases more skilled labour than is demanded initially in the agricultural sector. To go back to the equilibrium point, the nominal skilled wage has to be lower and the nominal unskilled wage higher and therefore the relative wage of skilled workers is lower. Taking into account equation (7), a lower relative wage of skilled workers reduces the incentive to invest in education. Therefore, there is a positive (negative) correlation between market access and number of skilled (unskilled) workers.

3. Empirical framework, data and regional system

The results that are obtained from the theoretical model can be tested by using the following regression equation:

$$\ln(EA_{it}) = \alpha_{0t} + \alpha_{1t} \ln(MA_{it}) + \varepsilon_{it} \quad (20)$$

Equation (20) allows us to check if there is a spatial educational attainment structure in the EU, i.e. whether there is a positive correlation between medium and high levels of educational attainment and distance from large consumer markets, i.e. if high market access locations have relatively high levels of education.

EA_{it} stands for levels of educational attainment for different countries/regions and periods of time. In our analysis, the dependent variable in the regression analysis of European regions is de log of educational attainment. The corresponding data were taken from the Eurostat Regio databank -first and second intermediate reports on economic and social cohesion (dates of release 30-01-2002 and 30-01-2003) and the third report on economic and social cohesion (date of release 2004)-. The educational attainment is a three-level measure defined as persons aged 25-59 (as a % of total) with low, medium or high levels of education. The dependent variable is given for 203 European Union NUTS2 regions. The right-hand side of the equation contains the market access variable, a constant and the random disturbance. With respect to the market access measure (MA_i), we built an *ad hoc* measure of it, that is the *population potential* computed for every single place in the European space. The concept of population potential must be understood as the force or attraction which the population centre j would exert on an inhabitant located at location i in geographical space and conditioned according to the distance between them, T_{ij} . Therefore, this measure shows the influence each place exerts on all other places and in this sense it measures the proximity of a place to other places. This measure of market access is quite similar to the market potential concept proposed by Harris (1954) and also there is a natural link with the concept of demand cones due to Lösch (1954). Population potentials at a given location represent an index of the aggregate market potential from the whole structure of population weighing the number of inhabitants by their distance to this location. In order to make the computations we have to say that it is not possible to consider

all the points within a given territory, which is why the practical computation of the population potentials is carried out by using a dot or grid “net”. This net which, is placed over specific j places, defines a finite and manageable set of nodes for the calculations. The potential indices are calculated by going through each node on the net and assigning to it a corresponding “potential” value, that is, the value of its own population plus the inhabitants of each and every other node divided by the distance separating them to the original node.

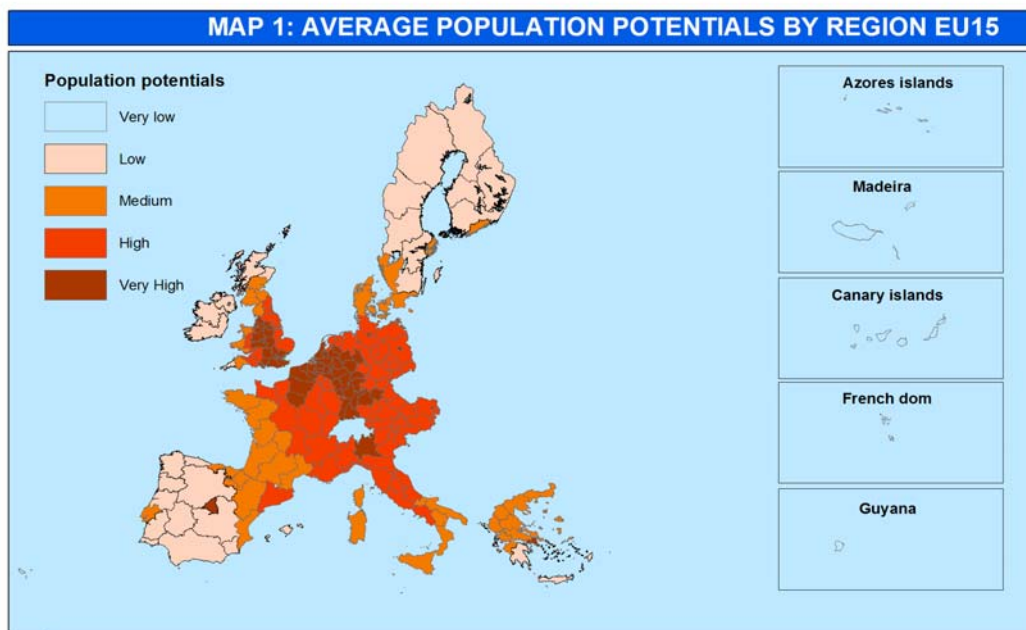
The calculations were carried out in the following way: for each “ i ” node in the net we add the population of each centre divided by:

The distance T_{ij} , measured in kilometers, if it is more than 1, or

One, if the distance is less than 1.

To this end, an algorithm or “loop” which goes through the whole of the net (i) is designed to complete the whole of the space and is computed in order to be able to compile the indices. The population data we used have been obtained from the statistics information service of the European Commission, Eurostat, and the cartographic data from GISCO. From the group of urban centers with more than twenty thousand inhabitants the potential index of each point of the net was calculated in ARC/INFO and then they have been plotted in a map by using ARC MAP. The next step in our computations was to assign a market access value to each of the NUTS2 regions of the European Union in order to have a comparable relationship between levels of educational attainment and these population potentials, i.e. the same geographical coverage. To this end the market access value assigned to each of the NUTS2 regions in the European Union is based on a weighted aggregation of the points’ population potential that belong to a particular region.

Before analyzing the regression results it is interesting to graphically see a map that displays a classification in five levels of our market access measure within the EU15¹³.



The value of the market access measure (population potential) is reflected in the relative shade of the colour used, that is, the darker the shade, the higher the market access (population potential) and visa versa. The map reflects a concentric distribution of the market access measure, which has its centre in an area in which the values are the highest, an area that is commonly known as the Golden triangle (Greater Manchester-London-Paris and the Rhur Valley). This area is surrounded by successive envelopes of decreasing market access values, which eventually reach the Atlantic periphery where the values are lowest.

¹³ For a detailed analysis of the spatial distribution of population potentials in the European space see (Faiña et al., 2001)

4. Economic Geography and Educational Attainment Levels: Empirical results

In this section we test econometrically expression (20), i.e. whether there is a positive correlation between human capital investments and market access. Consistent with the model, we provide evidence that educational attainment is higher in those regions that have greater market access.

Figures 1, 2 and 3 plot medium, high and medium+high educational attainments against market access for year 2000. It is clear from these figures that the relationship between regional levels of medium, high and medium+high educational attainments and regional market access are in line with the predictions of the model. The relationship is robust and is not due to the influence of a few individual regions.

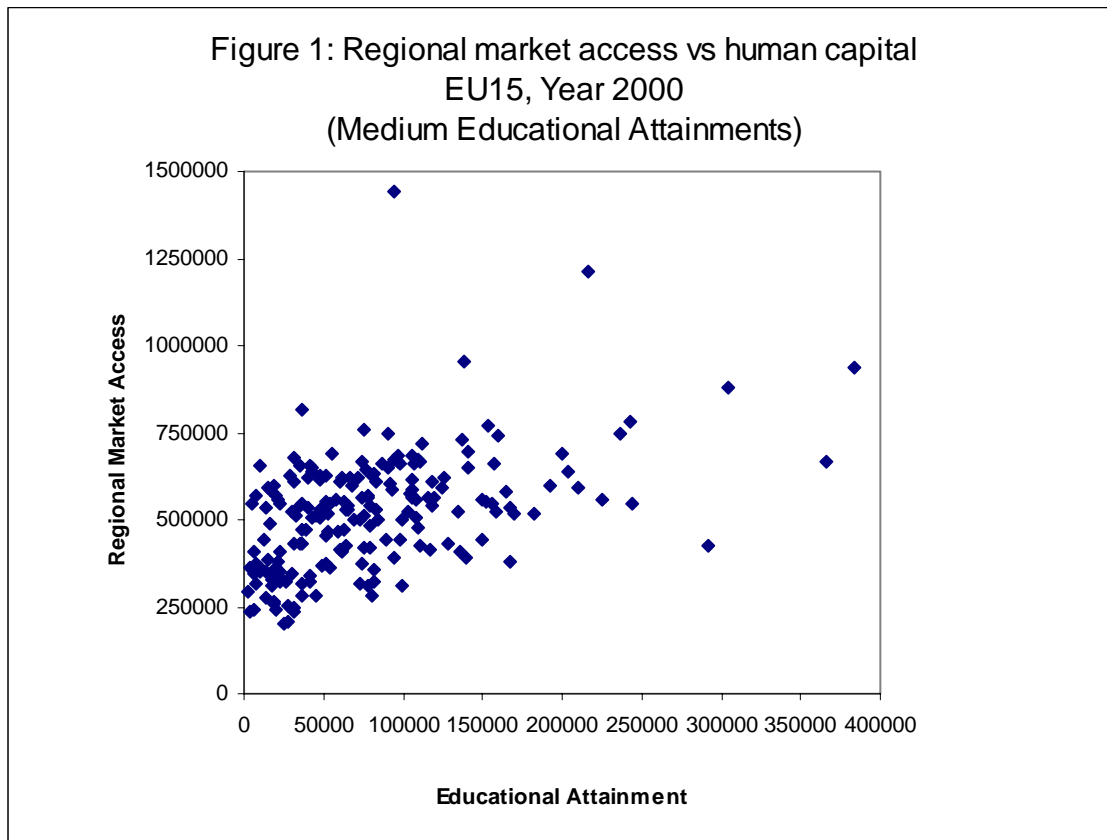


Figure 2: Regional market access vs human capital
EU15, Year 2000
(High Educational Attainments)

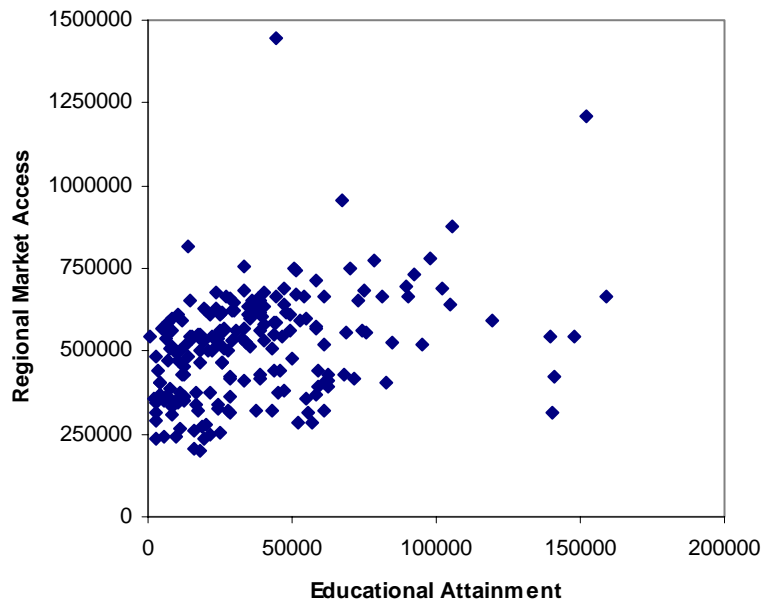
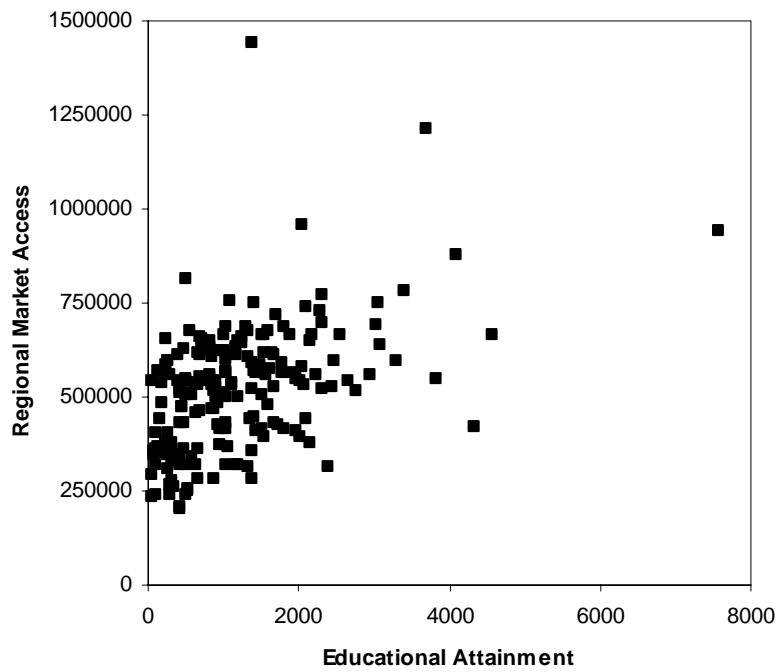


Figure 3: Regional market access vs human capital
EU15, Year 2000
(Medium+High Educational Attainments)



Tables 1-3 present the results of our econometric estimations for 203 EU NUTS2 regions. We regress log medium educational attainment, log high educational attainment and log medium+high educational attainment on log ad hoc measure of market access using OLS. The coefficients on market access are significant and the signs correspond with theoretical expectations.

Table 1: OLS Regression of Medium Educational Attainment on Regional Market Access, Year 2000
Dependent Variable: Log Medium Educacional Attainment
Included observations: 203 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.809588	1.887801	-3.607154	0.0004
Log (MA)	0.998549	0.143535	6.956853	0.0000
R-squared	0.194059	Mean dependent var		6.316829
Adjusted R-squared	0.190049	S.D. dependent var		0.956941
S.E. of regression	0.861221	Akaike info criterion		2.548873
Sum squared resid	149.0821	Schwarz criterion		2.581515
Log likelihood	-256.7106	F-statistic		48.39781
		Prob(F-statistic)		0.000000

Table 2: OLS Regression of High Educational Attainment on Regional Market Access, Year 2000
Dependent Variable: Log High Educational Attainment
Included observations: 203 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.262878	1.921406	-3.259529	0.0013
LNV	0.903618	0.146090	6.185365	0.0000
R-squared	0.159905	Mean dependent var		5.615624
Adjusted R-squared	0.155726	S.D. dependent var		0.953973
S.E. of regression	0.876552	Akaike info criterion		2.584162
Sum squared resid	154.4370	Schwarz criterion		2.616804
Log likelihood	-260.2924	F-statistic		38.25875
		Prob(F-statistic)		0.000000

Table 3 OLS Regression of Medium+High Educational Attainment on Regional Market Access, Year 2000
Dependent Variable: Log Medim+High Educational Attainment
Included observations: 203 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.913805	1.806912	-3.272879	0.0013
LN (MA)	0.963220	0.137384	7.011127	0.0000
R-squared	0.196501	Mean dependent var		6.748192
Adjusted R-squared	0.192504	S.D. dependent var		0.917330
S.E. of regression	0.824320	Akaike info criterion		2.461287
Sum squared resid	136.5801	Schwarz criterion		2.493929
Log likelihood	-247.8206	F-statistic		49.15591
		Prob(F-statistic)		0.000000

These results show that almost 20% of the variation in regional levels of secondary and tertiary education is explained by market access. However, the models given in tables 1-3 are marked by outlying observations. The outlying regions do not correspond with the spatial educational attainment structure determined by the majority of the observations.

Outliers will seriously affect the coefficients estimates, if they are influential leverage points, i.e. outlying observations with regard to our measure of market access. In order to control for effects of outlying observations, dummy variables for the outliers are introduced. The most significant outliers are the regions of Bruxelles and Inner London. Moreover, the regions of Wien, Andalucia and Denmark are outliers as well. To control for the latter observations, regional dummies were included.

Including dummies for outlying regions does alter the estimates considerably (see tables 4-6). In particular, the coefficient of the market access increases in all the regressions.

According to the results, market access has a positive effect on the educational attainment levels of the European Union regions. This effect is reinforced when dummy variables are included in the regressions. The models presented in tables 4 and 6 explain around 30% of the spatial variation in the educational attainment levels in the European Union¹⁴.

Table 4: OLS Regression of Medium Educational Attainment on Regional Market Access and Dummy Variables, Year 2000
Dependent Variable: Log Medium Educacional Attainment
Included observations: 203 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-12.86948	2.162430	-5.951395	0.0000
LN(MA)	1.461293	0.164746	8.869987	0.0000
DAT13	-1.549939	0.847773	-1.828249	0.0690
DBE1	-2.765784	0.840810	-3.289428	0.0012
DUK11	-3.568617	0.933999	-3.820793	0.0002
DDK	1.916596	0.813188	2.356891	0.0194
DES61	1.275771	0.816372	1.562733	0.1197
R-squared	0.303641	Mean dependent var	6.316829	
Adjusted R-squared	0.282324	S.D. dependent var	0.956941	
S.E. of regression	0.810680	Akaike info criterion	2.451988	
Sum squared resid	128.8117	Schwarz criterion	2.566237	
Log likelihood	-241.8768	F-statistic	14.24399	
		Prob(F-statistic)	0.000000	

¹⁴The market access variable remains statistically significant at conventional critical values including control variables thought to be important in the determination of educational levels (Gross Value Added Per capita, employment in high tech sectors and backwardness). Proofs can be sent by the authors upon request.

Table 5: OLS Regression of High Educational Attainment on Regional Market Access and Dummy Variables, Year 2000

Dependent Variable: Log High Educational Attainment

Included observations: 203 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.788321	2.273357	-4.305667	0.0000
LN (MA)	1.171900	0.173197	6.766288	0.0000
DAT13	-1.517650	0.891261	-1.702812	0.0902
DBE1	-1.162368	0.883942	-1.314983	0.1901
DUKI1	-1.639608	0.981911	-1.669814	0.0966
DDK	1.860134	0.854903	2.175843	0.0308
DES61	2.204463	0.858250	2.568557	0.0110
R-squared	0.225568	Mean dependent var	5.615624	
Adjusted R-squared	0.201861	S.D. dependent var	0.953973	
S.E. of regression	0.852266	Akaike info criterion	2.552038	
Sum squared resid	142.3661	Schwarz criterion	2.666287	
Log likelihood	-252.0319	F-statistic	9.514774	
		Prob(F-statistic)	0.000000	

Table 6: OLS Regression of Medium+High Educational Attainment on Regional Market Access and Dummy Variables, Year 2000

Dependent Variable: Log Medium+High Educational Attainment

Included observations: 203 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-10.86047	2.099596	-5.172646	0.0000
LN (MA)	1.340556	0.159959	8.380634	0.0000
DAT13	-1.512465	0.823138	-1.837437	0.0677
DBE1	-2.053054	0.816378	-2.514832	0.0127
DUKI1	-2.740392	0.906859	-3.021849	0.0028
DDK	1.866885	0.789559	2.364466	0.0190
DES61	1.676735	0.792650	2.115353	0.0357
R-squared	0.285602	Mean dependent var	6.748192	
Adjusted R-squared	0.263733	S.D. dependent var	0.917330	
S.E. of regression	0.787124	Akaike info criterion	2.393012	
Sum squared resid	121.4346	Schwarz criterion	2.507261	
Log likelihood	-235.8908	F-statistic	13.05947	

We also report the estimates of an ordered probit model (table 7). The dependent variable (Educational Attainment Level) was ranked for each region given to it the values 1 (low educational attainment), 2 (medium educational attainment) or 3 (high educational attainment) taking into account the relative importance of the educational attainment shares in each region.

In Table 7: Ordered Probit Model Regression of Educational Attainment Levels on Regional Market Access, Year 2000
 Included observations: 203 after adjustments
 Number of ordered indicator values: 3
 Convergence achieved after 6 iterations
 Covariance matrix computed using second derivatives

	Coefficient	Std. Error	z-Statistic	Prob.
LN (MA)	1.189026	0.228852	5.195600	0.0000
Limit Points				
LIMIT_2:C(2)	15.17475	2.994245	5.067973	0.0000
LIMIT_3:C(3)	18.14431	3.127138	5.802209	0.0000
Akaike info criterion	1.319453	Schwarz criterion	1.368417	
Log likelihood	-130.9245	Hannan-Quinn criter.	1.339262	
Restr. log likelihood	-145.1108	Avg. log likelihood	-0.644948	
LR statistic (1 df)	28.37269	LR index (Pseudo-R2)	0.097762	
Probability(LR stat)	1.00E-07			

Ordered Probit Models, the sign of the coefficient shows the direction of the change in the probability of falling in the endpoint rankings, in our case (Educational Attainment Level=1 or Educational Attainment Level=3) when Market Access changes. Probability of Educational Attainment level=1 changes in the opposite direction of the sign of the estimated coefficient and Probability of Educational Attainment level=3 changes in the same direction. So the results show that the probability that the educational attainment level of a region is high increases with market access. The coefficient estimated is statistically significant at the conventional critical values.

Our results are in line with those obtained by Redding and Schott (2003) for a world sample of countries. In their estimations market access itself explained 23% of the variation in educational attainment (105 countries) and excluding from the sample OECD countries, US, Japan and Belgium (66 countries) the explanatory power of the regression raised to 26%.

These results shed new light to the pioneering work initiated by Redding and Schott (2003), showing that at the EU level there is a positive correlation between countries' human capital investments and market access. As Redding and Schott (2003) pointed out fruitful avenues for future research include the analysis of the relationship between changes in educational attainment and changes in market access within countries and the exploitation of exogenous changes in market access associated with changes in policy regimes.

5. Conclusions

In this paper, we analyse the relationship between an *ad hoc* measure of market access (Population potential) and the levels of educational attainment in the European Union regions for the year 2000. Consistent with the predictions of the theoretical model, we provide empirical evidence of a spatial educational attainment structure in the EU, i.e. a positive correlation between regional medium and high levels of educational attainment and distance from large consumer markets. The inclusion of dummy variables alter the coefficient of market access considerably, changing from values around but below to 1 to values over 1.17. The augmented models explain around 30% of the spatial variation in the educational attainment levels in the European Union regions.

Taking into account that human capital accumulation is a key factor for regional development and to promote convergence among EU regions and the results of this analysis suggesting that there is a penalty of remoteness for human capital accumulation, one obvious policy implication is that the outlying regions in the EU should make bigger efforts to improve the quality of their infrastructures trying to reduce distance to the main centres of economic activity. An important role in this sense has been played by the European Union Regional Policy since its institutionalization (1989), devoting an important part of its resources to objective 1 regions (most of them in the outskirts of the EU and so facing the penalty of the remoteness) throughout its three programming periods (Delors I and II packages and Agenda 2000). The majority of resources were channelled to improvements in infrastructure, human capital and aids to production sectors.

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