POPULATION POTENTIALS AND DEVELOPMENT LEVELS: EMPIRICAL FINDINGS IN THE EUROPEAN UNION

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Abstract

In this paper we deal with the issue of the spatial structure of Europe. In order to carry out our study, we use the technique of gravity models to compute population potentials, and then plot potential maps, which allow us to represent the main lines of force in terms of the geographical distribution of the population and consequently the main economic activity in the area as well.

We also use the data which corresponds to the future acceding countries in order to better analyse the effects of European Union enlargement from a spatial perspective.

The concept of population potentials allows us to construct a "macroscopic cartography" and gives us a weighted representation of the influence of population on territory, and further enables us to highlight the structural characteristics of the European Union. The potential maps clearly illustrate the nature of the spatial structure of the European Union and its large central agglomeration area: Greater Manchester-London-Paris-Cologne-Rhur Valley. Moreover population potential contours allow us to highlight some policy guidelines for the European Spatial Development Perspective and for the future of the European Regional Policy.

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The findings about the spatial structure of Europe (employing the technique of gravity models to compute the population potentials) were carried out to a further stage. We tested econometrically the explanatory power that population potentials have on the levels of development. Using a logarithm specification for the relationship between population potentials and levels of development and estimating cross-section regressions for different time periods we evaluated if the explanatory power of the population potentials was hold constant over the time or if on the contrary it was decreasing as long as we move forward testing our model for the latest data available (1999).

To do this we had to assign a value of population potential to each of the NUTS II regions of the European Union (The value assigned was based on a weighted aggregation of the points´ population potential that belong to a particular region) in order to have a comparable relationship between levels of development and these population potentials based on the same geographical coverage. We proxy the levels of development by the regional (NUTS II) gross domestic product per capita (PPS at 1985 prices).

Having ready our data, we estimated our proposed relationship in different years, 1982, 1989, 1994 and 1997 for the EU12 regions and in 1999 for EU15 regions. Figures on income per capita are based on Eurostat data (ESA79) for the years 1982, 1989, 1994 and 1997 and Eurostat data (ESA95) for 1999. What we have found is that closeness to large consumer markets or in other words, market potential, was an important explanatory variable for regional income in the early eighties and that it has decreased its significance in determining regions income on the 1990´s. Thus dynamic income regions have also emerged in the periphery, and need not necessarily be close to rich regions. This fact lead us to think about the possible effects that the "new" European Union regional policy has exerted since the mid eighties. The regional policy of the European Union had an important effect in terms of boosting the growth of peripheral regions and therefore their income levels, so the results showed here could be a proof in that sense.

JEL classification: A12; J11; N30; R23

Keywords: Spatial structure; Population Potential contours; Spatial planning; Potential maps; Population settlements

2. Gravity models and economic theory

Gravity models, as the name suggests, are based on a physical analogy and utilize the formal outline of classical mechanics. Theoretically, the importance of the interrelations between two population centers is proportional to their size and consequently their incomes, or in Newtonian terms their combined mass. Similarly the further away from each other they are, the less important will be the said interrelations. This is roughly analogous to the theory of gravity introduced by Isaac Newton in 1686. Newton postulated that the gravitational force which acts between two bodies in space was in direct proportion to the mass of the two bodies and in inverse proportion to the square of the distance between the bodies.

It was not until the first half of the 19^{th} century that the theory of gravity was applied to human interaction. At that time, Carey (1858-59) theorized "*Gravitation is here, as* *everywhere, in the direct ratio of the mass and the inverse of the distance*". Work by Ravenstein (1885-1889) and later by Young (1924) confirmed the belief that gravitational function does apply to the migration of people from one area to another.

A key effort in this field is associated with Reilly (1931) in his study of the retail trade areas of moderately sized American towns. Reilly came to the conclusion that: "*Under normal conditions two cities draw retail trade from a smaller intermediate city or town in direct proportion to some power of the population of these two large cities and in an inverse proportion to some power of the distance of each of the cities from the smaller intermediate city*". Further examples of the use of the gravity model are available in the works of Stewart (1947-48-50) who presented three primary concepts based on Newtonian physics, demographic force, demographic energy and demographic potential. Zipf (1946-49) examined for pairs of cities interaction phenomena such as bus passenger trips, airline passenger trips, telephone calls etc and the $\frac{P_i P_j}{D_{i,j}}$ factor[2], finding a straight-line relationship between this factor and those phenomena where the entire factor is raised to some power. Isaard and Whitney (1949), Cavanaugh (1950) and Dod (1950) deal with demand and location according to product. Artle (1959) carried out an study on income groups and the interaction among them in the city of Stockholm.

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[2] The differences between Stewart and Zipf´s uses of the gravity model is that Zipf consider the entire $\frac{P_i P_j}{D_{i,j}}$ factor raised to some power and not only $D_{i,j}$ as it is considered by Stewart. Thus Zipf´s findings do not directly test the validity of Stewart´s concepts except in the nontypical case when the power of the $\frac{P_i P_j}{D_{i,j}}$ factor is unity. In this case Zipf´s use of his so-called $\frac{P_i P_j}{D_{i,j}}$ relationship becomes identical with Stewart´s use of demographic energy.

Finally the gravity model has been used widely as a model for estimating international trade flows and as a baseline model for estimating the impact of a variety of policy issues, such as regional trading groups, political blocs, patent rights, and various trade distortions[3].

From a microeconomic perspective, gravity models deal with the question of their theoretical foundations for optimizing the decisions of economic agents. The question is complex, because of the fact that there are connections that have yet to be analyzed in detail. These include the generic and formal minimal action principle associated with Hamilton´s formulation of movement equations.

Anderson (1979) and Bergstrand (1985) derived gravity models from models of monopolistic competition

From a perspective of International trade, Deardorff (1998) demonstrated that the gravity model can be derived within Ricardian and Hecksher- Ohlin frameworks. Other authors who works in the theoretical foundations of the gravity models are Feenstra et al. (1998) and Egger (2000).

Leaving aside these theoretical questions, the gravity formulations are basically empirical models, and their intrinsic value lies fundamentally in their ability, either to predict the interactions among the system's components, or to represent the relationships and structures of the said components. The explanations that follow attempt to do the latter and focus on the treatment of spatial information through the

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[3]See Tinbergen (1962), Pöyhönen (1963), Aitken (1973), Brada and Mendez (1983), Bikker (1987), Sanso, Cuairan and Sanz (1993) Oguledo and Macphee (1994), McCallum (1995), Helliwell (1996), Wei and Frankel (1997), Bayoumi and Eichengreen (1997), Mátyás (1997), Frakel and Wei (1998), Garman et al. (1998), Evenett and Keller (1998), Frankel et al. (1998), Fitzsimons et al. (1999), Fontagne et al. (1999), Smith (1999),Xu (2000) and Kalirajan (2000).

construction of potential maps, based logically on the calculation of potentials of population.

Two further important characteristics of this type of model are that they have a clearly defined structural perspective and are macroscopic in outlook.

- As far as structural perspective is concerned, potential maps constitute a common technique in the social sciences, and this technique assumes that the relationships between the components of a system are influenced by the arrangement of the permanent elements.
- The fact that the models are macroscopic in outlook really means that the gravity models are capable of providing us with an aggregate representation consisting of aggregates of contours of equipotentials of population and differing grades or strengths of the potential field, so that they produce a macroscopic representation of populations within a territorial structure.

3. The formulation and significance of population potentials

The formal expression of the gravity models is of the type:

$$F_{ij} = K \frac{A_i^{\alpha} . A_j^{\alpha}}{D_{ij}^{\beta}} \qquad (1)$$

where F_{ij} represents the frequency, intensity or force of the interaction between the places i and j to which are given, respectively, the masses (population, income, etc) A_i and A_j respectively.

D_{ij} refers to the distance (physical, economic etc..) between the points i and j, while K is a constant specific to the phenomena being studied; and alpha and beta are the corresponding exponentials of the variables, all of which are parameters, which are empirically estimated.

To obtain a "macroscopic cartography" of the economic territorial structure we can turn to the analogy of gravity models. In order to simplify the analogy and at the same time increase the model's efficiency, we assume the exponential for the "mass" to be 1 and the exponential for the distance to be 2. In this way the general expression in figure 1 is transformed into the following expression:

$$F_{ij} = K \frac{A_i \, . A_j}{D_{ij}^2} \tag{2}$$

which can be interpreted as the Stewart´s definition of demographic force. Later, Stewart also developed the concept of demographic energy, $E_{i,j}$ corresponding to the Newtonian gravitational energy, defining it as:

$$E_{i,j} = K \frac{A_i A_j}{D_{i,j}} \tag{3}$$

and demographic potential, ${}_iV_j$ corresponding to the gravitational potential as:

$${}_iV_j = K \frac{A_j}{D_{i,j}} \tag{4}$$

It can be seen immediately from equation (2.4) that ${}_iV_j$ only defines the potential created upon city i by one single city, j. It is very easy, however, to measure the total potential of i by merely summing over all different $j´s$; i.e.

$$_iV = K\frac{A_1}{D_{i,1}} + K\frac{A_2}{D_{i,2}} + ... + K\frac{A_n}{D_{i,n}} = K\sum_{j=1}^{n}\frac{A_j}{D_{i,j}} \qquad (5)$$

As $_iV$ can be computed for every single place, it becomes possible to use iso-lines for mapping the potentials. (as can be seen from Equation (2.5), the demographic potential $_iV$, is expressed as population per distance)

The concept of potential of population must be understood as the force or attraction which the population centre A_j would exert on an inhabitant located at the point i in geographical space and conditioned according to the distance between them, D_{ij}.

Therefore, potential maps show the influence each place exerts on all other places and that in this sense they measure the proximity of a place to other places. Intuitively the concept of population potential can be understood like a measure of the demand potential that the whole population exerts over every location in the space. 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.

4. The construction of potential maps

Population potentials, according to current formulas and formal interpretation, are indices of the influence or relative force that all the centres and population settlements exert at each of the points within the space being considered. In other words, the potential of population at a point may be regarded as a measure of the proximity of people to that point. In computing it we consider that every person makes a contribution which is less the farther away he lives. As we move from back-country rural areas toward a great city there is a rise in potential because of the concentration of people there.

The outcome of the computation of population potentials can be presented on a map of the surface by the device of contours of equipotential. The familiar contours on a topographic map which represent altitude above sea level are precisely contours of equal gravitational potential.

Potential maps are generated through a graphic representation of the various contours of equipotential, and they provide an overall view of the territorial structure of the population and human settlements within a given geographical space.

They provide us with a macroscopic cartography of the big population centres and a classification of territorial areas based on the influence and distribution of the principal conurbations.

Due to it is not possible to consider all the points within a given territory, the practical computation of the indices and potential mapping is carried out by using a dot or grid "net".

This net which, is placed over a specific space, defines a finite and manageable set of nodes for the $A_i, _iV$ 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 weighed against each and every other node and its corresponding population, and divided by the distance separating each node.

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

- The distance D_{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. By joining the points with the same potential index we obtain the population potential contours which form the potential maps, where the strong force lines and agglomeration areas which compose the spatial structure of the economy are reflected.

The population data we used was obtained from the statistics information service of the European Commission, EUROSTAT, and the cartographic data from GISCO. Nowadays, the possibility of enlarging the European Union in order to take in the countries of Eastern Europe is one of the most important European issues and has far reaching implications for this type of study.

The potential indices were calculated and the corresponding maps were made for Russia and for the fifteen present-day members of the European Union. From the group of urban centers in Europe with more than twenty thousand inhabitants the potential index of each point of the net was calculated in ARC/INFO and then, by means of interpolation, the potential population contours were computed in ARC VIEW, by using the SPATIAL ANALYST modulus.

5. Spatial structure in the European Union

5.1 Population contours in an enlarged European Union

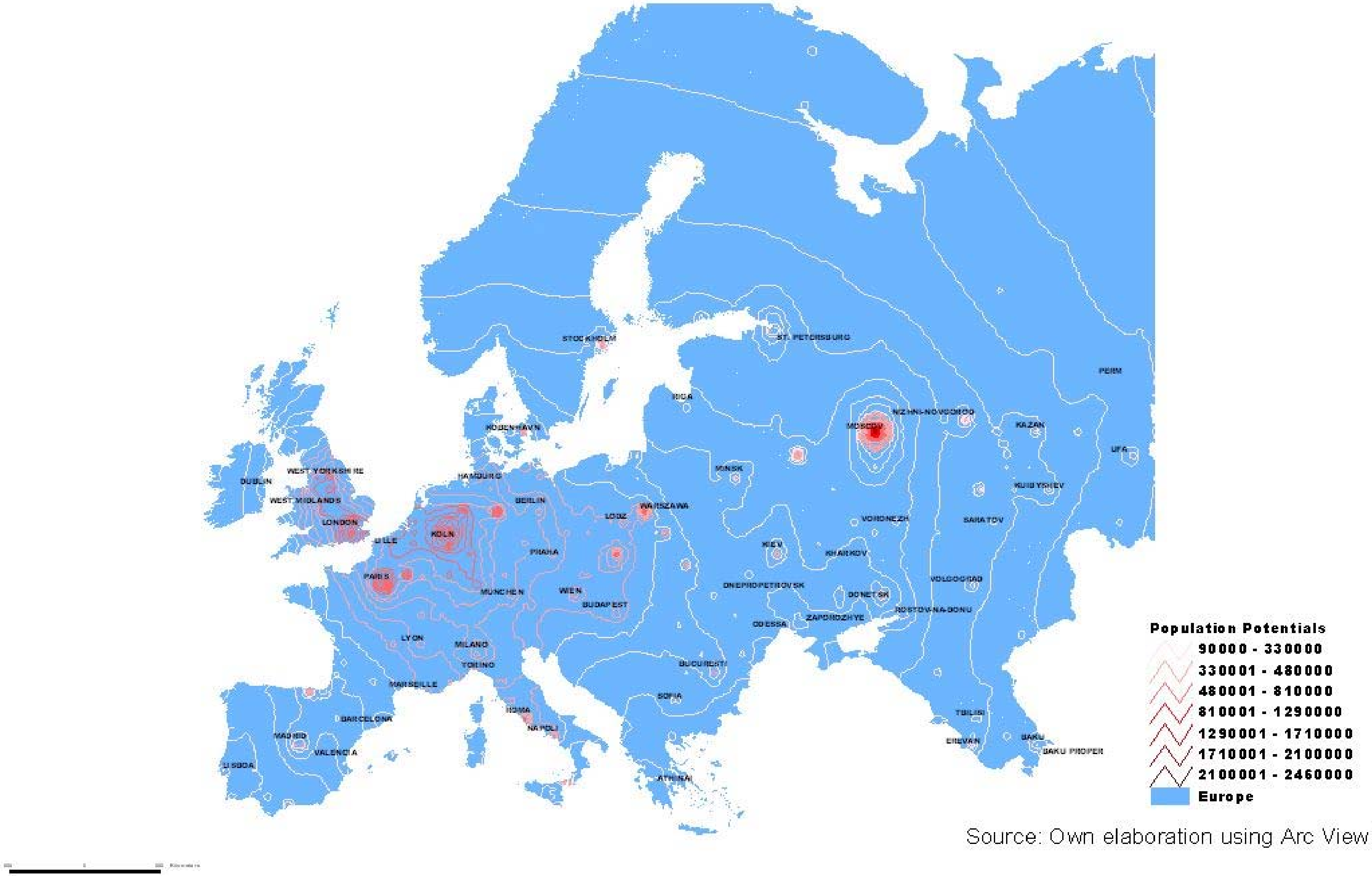
There are striking disparities in economic performance between different parts of Europe, particularly between the central and peripheral regions. GDP per head (measured in terms of purchasing power standards, PPS, to take account of differences in price levels) is typically half to two-thirds of the EU average in the Southern periphery (Greece, Southern Italy to Southern and Western Spain and Portugal, and around 60% of the EU average in most of Eastern Germany).

There are also clusters of poorer regions in the Northern periphery, particularly in Northern and Eastern Finland and the North and West of the UK. By contrast, GDP per head is well above average in the more central area extending from the North of Italy through Southern Germany to Austria as well as in the BENELUX countries and

Northern Germany. This central area of the EU including the metropolises of London, Paris, Milan, Munich and Hamburg shows an important concentration of the population. This situation can be seen with clarity in the territorial structural maps of Europe that has been plotted with the technique of gravity models.

The following maps reveal the spatial structure of the present-day fifteen-member-European Union plus the ten CEECs and were drawn up by using EUROSTAT data which deals with those centres of population with more than twenty thousand inhabitants. In these maps the value given to each point, i.e. its population potential index, represents the relationship expressed by its distance between the remaining urban centres and their populations.

MAP 2.1: EUROPEAN TERRITORIAL STRUCTURE



Source: Own elaboration using Arc View 8.1

Maps of the territorial structure of Europe and those of its fifteen member states are drawn up by joining together the equi-potentials with the same values in order to form equipotential contours or level curves. Over the blue, background of the maps, the highest population potentials are drawn in red and the darker the shade, the higher the value of the population potential contours and visa-versa. The very lowest population potential contours are drawn in white.

In the first map, which represents the European territorial structure, we find that the big conurbations of Leningrad, Moscow and Gorkij are to be found in the East. Perhaps the map´s most striking feature however is the relatively compact nature of the big central settlements of the European Union around which there are a concentric series of population potential contours with decreasing levels of potential. In order to test the validity of the resultant shape of this central concentration of the spatial structure of the European Union, the lines with the highest potential values are extended over sea-areas, particularly the English Channel and the North sea, as well as the Baltic sea and the Mediterranean sea.

The center of the European area, in terms of its population, is located among the three large central conurbations of London, Paris and Cologne-Düsseldorf-Rhur Valley, which have contour-lines with potential indices which are greater than 660.000 inh/Km, and form an area which we define as “the Central European triangle”. This area fits into a zone of high population potentials whose nearest population potential contour has a value of 480.000 inh/Km. This population potential contour takes in the region of Greater Manchester and London in the North and then drops towards the region of Paris in the South. From Paris the contour traces a line North East to enclose the region of the Rhur Valley before turning North West to cut the North Coast of Holland, taking in Amsterdam and Rotterdam and then joining up with the contour which embraces the conurbation of Greater Manchester.

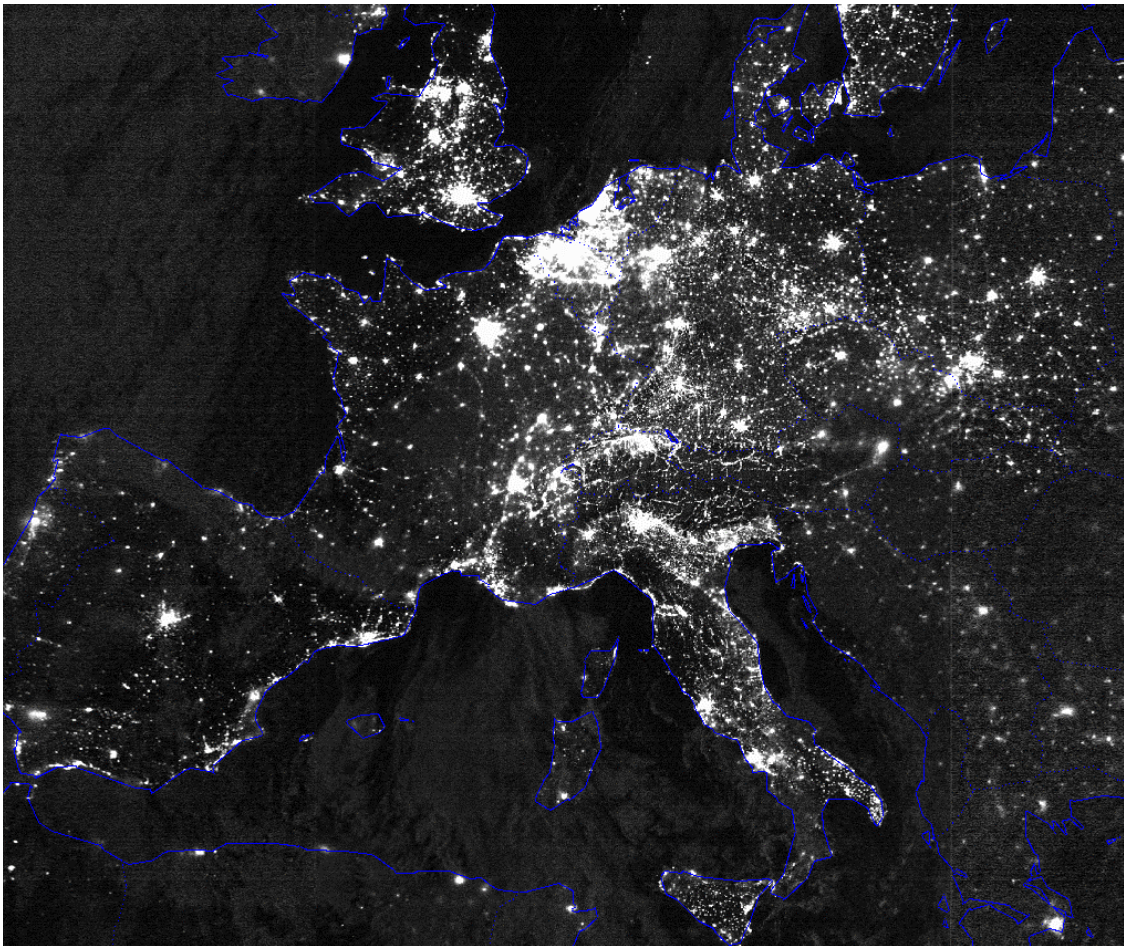
A population potential contour with a value of (390.000 inh/Km) begins in the North West of England, taking in the cities of Liverpool, Leeds and Greater Manchester, traces a line to the East round Hamburg and Copenhagen, where it becomes a gentle arc which falls in a North-South direction to take in Berlin, Prague and Viena and the North of Italy (Milan and Turin). After this the contour turns again, to the Northwest to Lyon (without taking in the Rhône Valley) and then absorbs the areas of influence of Paris and London, before linking up with Northwest England.

The largest central population potential contour i.e. the one which takes in the greatest geographical area, corresponds to that with a value of 330.000 inh/Km, and starts in the Northeast in the English area of Grand Manchester-London. From here the contour goes towards the East, taking in Copenhagen before turning in a North-South direction along the Varsovie-Budapest axis. After this, the contour crosses the Adriatic sea, taking in Naples, turns to the Northeast to take in Rome, the North of the Italian Peninsula and the Rhône and Marseille Valley. From here it turns again towards the Northeast before going on to enclose the region of Paris and the coast of Normandy before finally linking up with the southwest of the large English agglomeration area of London-Greater Manchester.

The population potential with a value of 290.000 inh/Km constitutes the widest catchment's area in terms of population space. The contour traces a band which takes in the Northwest of England, goes East to take in Copenhagen, before dropping to the Southwest to Warsaw, from where it moves in a Westerly direction to Budapest before turning sharply towards the West to reach the Adriatic coast. After absorbing the conurbations of Rome and Naples it continues to the West, roughly following the coast and the Gulf of Lion up to Catalonia, and then turns back to the north of England after bordering on the conurbations of the Basque country and Cantabria.

In a similar way, the heavy structural lines of the European territory can be seen on the following nocturnal-light map. This map presents us with a satellite view of the nighttime light emissions from cities, houses, industries and other light sources. The light emissions were captured and recorded using high sensitivity equipment.

Map 2.2: MAPPING CITY LIGHTS WITH NIGHTTIME DATA FROM THE DMSP OPERATIONAL LINESCAN SYSTEM



Although high sensitivity reception techniques make it difficult to distinguish between the distinct intensities of light emissions, there is still a broad similarity between the light emission images and the shape of a central European area based on population potential contours. The similarity is even greater when lower sensitivity nighttime light data are used. Low sensitivity light data do not reflect the variations in the strength of light emissions and as a consequence the characteristic shape of the Central European Area becomes more prominent. The population potential contours around the area that we define as, the "Central European Triangle" are clearly visible in the image below, and were provided by the Earth Viewer[4] system.

Map 2.3: NIGHTTIME LIGHT DIFUSION "EARTH VIEWER"

[4] Nighttimes lights diffusion "Earth Viewer, Nighttimes images composition system from "Earth Viewer" 100 Km. high on 50º North, 5º East. The light diffusion allows to appreciate the intensity differences.

5.2 The effect of Enlargement on Population Potentials

The fourth map illustrates the territorial structure of the European Community and was plotted using the same database as that used for map 2.1 “European territorial structure” but in this case was restricted to its fifteen present-day members.

The reduction in the size of the area, through excluding the countries of the east, produces a reduction in the levels of the potential indices. This reduction is derived from the contraction in the size of the spatial field and reinforces the accuracy of the description and the compactness of the areas included within the equipotential contours. Map 2.4 therefore, shows on the one hand, the inner structure of the central areas of population within the European Union, and on the other hand it provides us with the most characteristic features of the peripheral areas. Interestingly in map 2.4, Galicia and the North of Portugal stand out in the Atlantic area as a single homogeneous region. This region forms the southern extreme of an area that includes the west of Ireland, Cornwall and Brittany, spreads over to the Gulf of Biscay and joins the Atlantic side of the Iberian Peninsula.

Although the enlargement of the European Union to the Central and Eastern European Countries is a complex question, it is very interesting to do a first proof through the comparison of population potentials. To this end, the following table (table 2.1) shows the relative increased in the population potentials when we enlarge the potential field from the European Union countries to the whole countries of Europe.

The comparison between *column a* and *column b* shows quite remarkably the impact of population potentials among the different European Union areas.

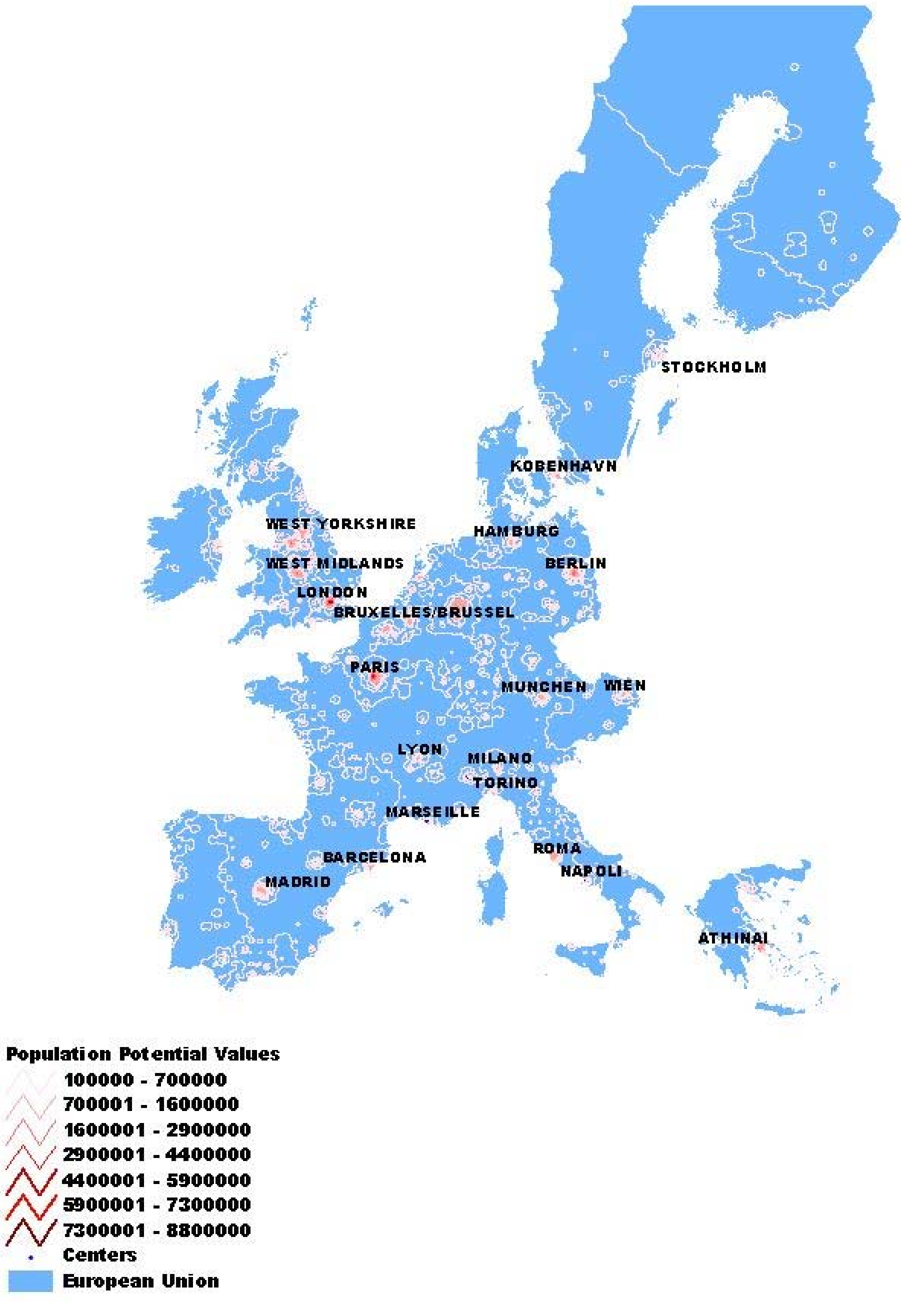
Galicia and Portugal and the same for London, have a very little increased in their population potentials that are around 6%. Madrid, Bilbao, Barcelona and Valencia have increased in their population potentials in the interval 6-7%, the same as central cities in the Western part of the continent such as París, Brussels, Amsterdam and Colonia.

Table 1: POTENTIALS OF POPULATION (measured in Inh/Km)

	European Union (a)	Europe (b)	Incr. (d) (b-a)/a
A Coruña	295	313	5.93%
Vigo	328	347	5.89%
Porto	525	556	5.91%
Lisbon	1.229	1.301	5.87%
Madrid	5.269	5.597	6.22%
Barcelona	3.967	4.238	6.82%
Bilbao	783	832	6.23%
Valencia	1.230	1.313	6.73%
Milán	2.414	2.634	9.12%
Roma	3.989	4.449	11.54%
London	13.207	13.978	5.84%
Venecia	496	555	11.92%
Ámsterdam	1.321	1.410	6.79%
Hamburgo	2.553	2.829	10.82%
Copenhague	1.906	2.170	13.84%
Estocolmo	1.284	1.500	16.79%
Helsinki	646	763	18.26%
Munich	2.012.6	2.258	12.2%
Berlin	4.439.7	5.162	16.27%
Dresde	750.3	884	17.77%
Viena	2.054.8	2.512	22.25%
París	13.990	14.963	6.95%
Brussels	2.327	2.486	6.86%
Colonia	2.162	2.299	6.34%
Amsterdam	1.321	1.410	6.79%

On the contrary, the increased in the population potentials are very important in the cities of Italy such as Rome and Venecia, achieving values around 11% and above all in the Eastern cities of Germany and Austria, where for instance Berlin is over 16% and Viena over 22%.

Map 2.4: Spatial Structure in the European Union



Source: Own elaboration using Arc view 8.1

6. Population Potentials and Levels of Development

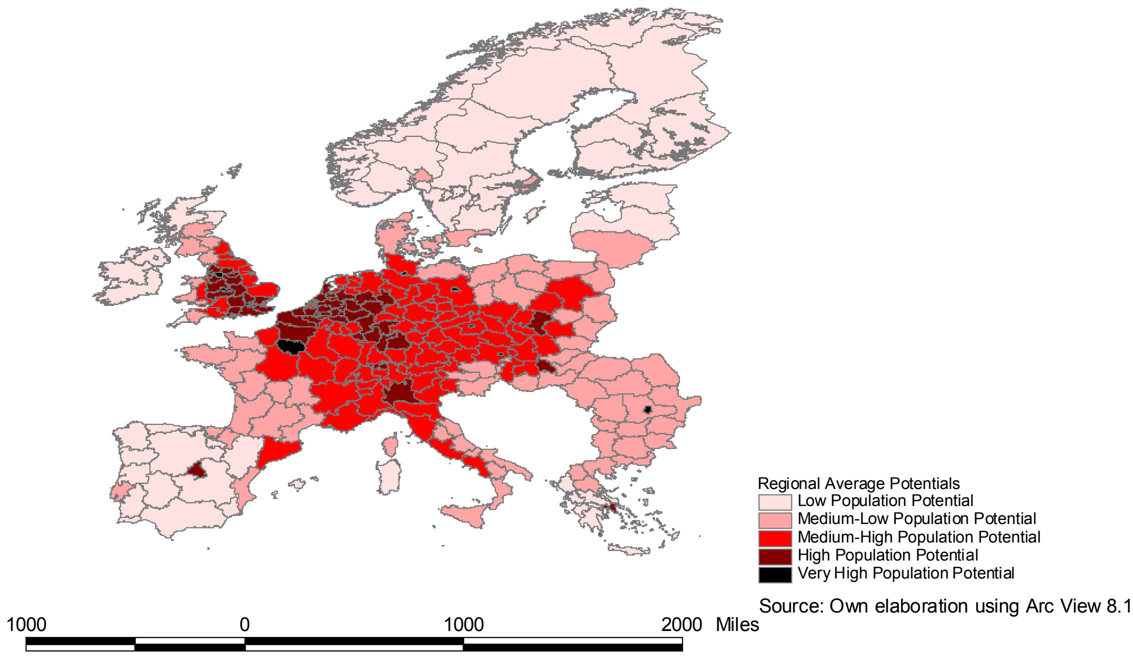
The previous findings about the spatial structure of Europe (employing the technique of gravity models to compute the population potentials) were carried out to a further stage. In this section we are going to test econometrically the explanatory power that population potentials have on the levels of development. Using a logarithm specification for the relationship between population potentials and levels of development and estimating cross-section regressions for different time periods we will evaluate if the explanatory power of the population potentials is hold constant over the time or if on the contrary it is decreasing as long as we move forward testing our model for the latest data available (1999).

As we mentioned above population potential data have been computed using a gravity model. This computation have been done using a geographical information system which basically consist of build a net of points for the European space and assign a value of potential for each of these points (see section 4 for more details about the computation of the population potentials). The next step in our computations was to assign a value of population potential to each of the NUTS II regions of the European Union[5] in order to have a comparable relationship between levels of development and these population potentials based on the same geographical coverage (see map 2.7).

[5] The value of population potential assigned to each of the NUTS II regions in the European Union is based on a weighted aggregation of the points´ population potential that belong to a particular region.

Map 2.5 displays a classification of five levels or weightings of population potentials within the EU25.

Map 2.5: Population Potentials in EU25



The value of the population potential is reflected in the relative shade of the colour used, that is, the darker the shade, the higher the population potential and visa versa. The population potentials reflect a concentric distribution of the population, which has its centre 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 population potential values, which eventually reach the Atlantic periphery where the values are lowest. It is worthwhile reiterating the striking similarity in the distribution of the illumination intensities shown in the night light maps with the distribution of potential values among the NUTS II regions shown in map 2.5. Another striking feature that can be seen in this map is the core position that the central and Eastern countries have. They are situated within an envelope of medium-high population potential values.

We proxy the levels of development by the regional (NUTS II) gross domestic product per capita (PPS at 1985 prices).

Having ready our data, we estimated our proposed relationship in different years, 1982, 1989, 1994 and 1997 for the EU12 regions and in 1999 for EU15 regions. Figures on income per capita are based on Eurostat data (ESA79) for the years 1982, 1989, 1994 and 1997 and Eurostat data (ESA95) for 1999.

A first intuition about the relationship between population potentials and levels of development is shown in figures 2.1 and 2.2.

Figure 2.1: Population Potentials and Levels of Development (UE12 1989)

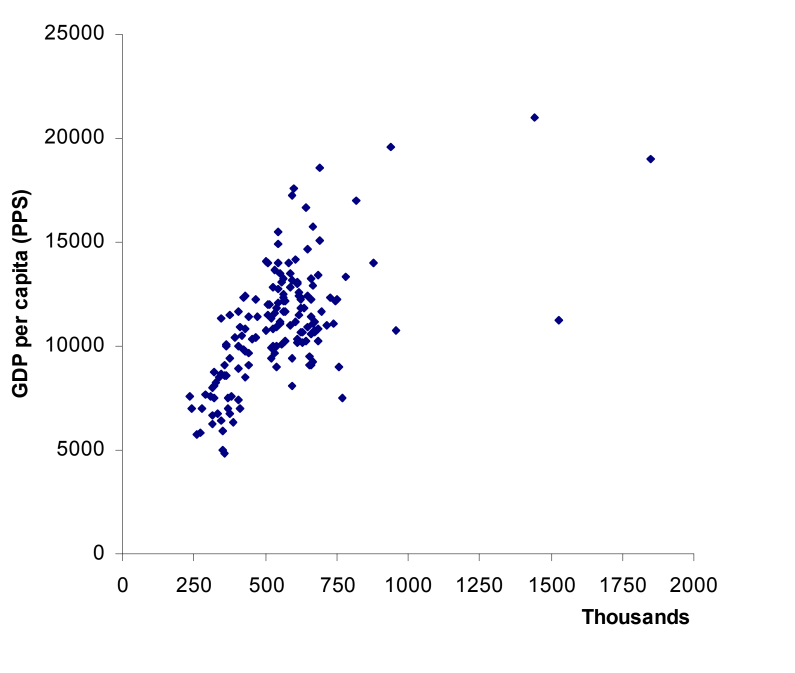
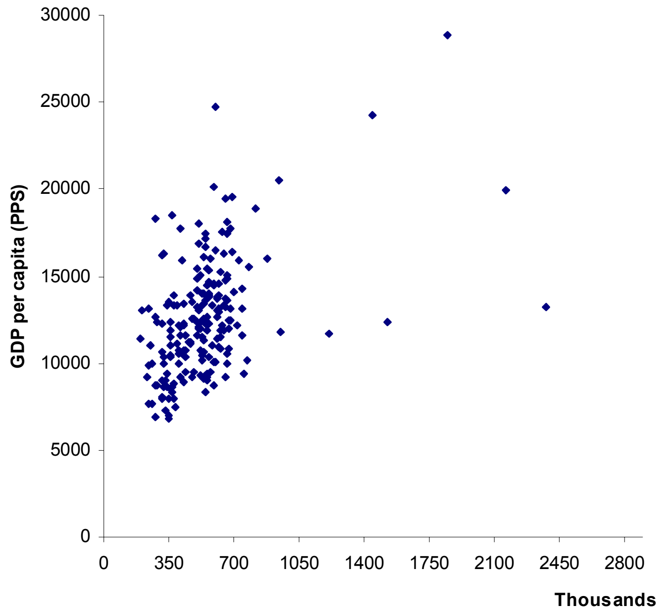


Figure 2. 2: Population Potentials and Levels of Development (UE15 1999)



The above scatter plots represent the relationship between the levels of development and population potentials for two single points in time. On the one hand we plot this relationship for the year 1989 (EU12) and on the other hand we plot the relationship 10 years later (EU15). A visual inspection on the dynamic evolution of the positive relationship between levels of development and population potentials shows a higher dispersion in 1999 than in 1989 indicating that this relationship is vanishing all over the time.

In order to give a more robust interpretation to the relationship between levels of development and population potentials we estimate the following model:

$$LnGDPpc_{i,t} = a + cLnV_{i,t} + u_{i,t} \qquad (6)$$

$GDPpc$ stands for gross domestic product in purchasing power parities at 1985 prices, V stands for population potentials and u is a random disturbance. This kind of specification has the advantage of a direct interpretation of the estimated coefficient c as the elasticity of the income per capita to the population potentials (in other words the change expressed in percentage terms of the income per capita to a 1% increase in the population potentials).

Tables 2, 3, 4, 5, 6 contain the cross-section estimations of the model (6) for the years 1982, 1989, 1994, 1997 and 1999.

Table 2: Population Potential and Regional Income EU12-1982

Dependent Variable: LNY82
Method: Least Squares
Included observations: 131

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.136282	0.694993	-0.196091	0.8448
LNV	0.708395	0.052933	13.38296	0.0000

R-squared	0.581310	Mean dependent var	9.161970
Adjusted R-squared	0.578064	S.D. dependent var	0.301394
S.E. of regression	0.195775	Akaike info criterion	-0.408551
Sum squared resid	4.944296	Schwarz criterion	-0.364655
Log likelihood	28.76011	F-statistic	179.1037
		Prob(F-statistic)	0.000000

Table 3: Population Potential and Regional Income EU12-1989

Dependent Variable: LNY89
Method: Least Squares
Included observations: 161

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.944067	0.614355	3.164404	0.0019
LNV	0.556469	0.046651	11.92837	0.0000

R-squared	0.472262	Mean dependent var	9.270123
Adjusted R-squared	0.468943	S.D. dependent var	0.261802
S.E. of regression	0.190785	Akaike info criterion	-0.463000
Sum squared resid	5.787397	Schwarz criterion	-0.424722
Log likelihood	39.27149	F-statistic	142.2860
		Prob(F-statistic)	0.000000

Table 4: Population Potential and Regional Income EU12-1994

Dependent Variable: LNY94
Method: Least Squares
Included observations: 169

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.364388	0.514051	6.544848	0.0000
LNV	0.449592	0.038998	11.52861	0.0000

R-squared	0.443164	Mean dependent var	9.288080
Adjusted R-squared	0.439830	S.D. dependent var	0.264769
S.E. of regression	0.198165	Akaike info criterion	-0.387672
Sum squared resid	6.557967	Schwarz criterion	-0.350632
Log likelihood	34.75831	F-statistic	132.9089
		Prob(F-statistic)	0.000000

Table 5: Population Potential and Regional Income EU12- 1997

Dependent Variable: LNY97
Method: Least Squares
Included observations: 169

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.502148	0.506481	6.914668	0.0000
LNV	0.444498	0.038424	11.56837	0.0000

R-squared	0.444864	Mean dependent var	9.358730
Adjusted R-squared	0.441540	S.D. dependent var	0.261268
S.E. of regression	0.195246	Akaike info criterion	-0.417345
Sum squared resid	6.366234	Schwarz criterion	-0.380305
Log likelihood	37.26565	F-statistic	133.8271
		Prob(F-statistic)	0.000000

Table 6: Population Potential and Regional Income EU15-1999

Dependent Variable: LNY99
Method: Least Squares
Included observations: 204

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.129120	0.477704	10.73701	0.0000
LNV	0.326139	0.036328	8.977634	0.0000

R-squared	0.285204	Mean dependent var	9.415562
Adjusted R-squared	0.281665	S.D. dependent var	0.258615
S.E. of regression	0.219188	Akaike info criterion	-0.188014
Sum squared resid	9.704801	Schwarz criterion	-0.155484
Log likelihood	21.17746	F-statistic	80.59792
		Prob(F-statistic)	0.000000

From the output of the estimations, it can be seen that the significance of the parameters is very high (t-statistic) and that the effects of population potentials on the levels of development are decreasing over time. This fact is reflected in the values that the coefficient c takes in the different periods of analysis. The coefficient c changes from 0.77 in 1982 to 0.444 in 1997 and to 0.326 in 1999. One possible interpretation of this result is the following one:

Population potential is a concept that has an interpretation in terms of market potential. One spatial factor that determines regional income is the closeness to large consumer markets as it is emphasized in demand oriented models of regional growth (Kaldor 1970) and the agglomeration effects of the new economic geography models (NEG). This effect can be captured by our population potentials.

What we have found is that closeness to large consumer markets or in other words, market potential, was an important explanatory variable for regional income in the early eighties and that it has decreased its significance in determining regions income on the 1990´s. Thus dynamic income regions have also emerged in the periphery, and need not necessarily be close to rich regions. This fact call us to think about the possible effects that the “new” European Union regional policy has exerted since the mid eighties. The regional policy of the European Union has an important effect in terms of boosting the growth of peripheral regions and therefore their income levels, so the results showed here could be a proof in that sense.

7. Conclusions

The heavy "structural" lines of potentials in the European territorial space structure studied through the technique of population potentials, clearly shows a similarity with the satellite observations of night-time light emissions from cities, houses, industries, etc., captured by the Earth Viewer Satellite. This similarity highlights the usefulness of the technique of population potentials (based on an analogy with classical mechanics) for providing a graded image of the population distribution within a particular territory. Population Potentials offer a means to condense a large quantity of information by plotting maps of population contours which expand from the main agglomeration areas, where the highest peaks of population potentials are reached.

When applied to Europe this technique emphasizes an area in which the European population is particularly dense. This area is based around the large population centers of Manchester – London – Paris – Cologne – Düsseldorf – Ruhr Valley, around which there are further concentric population potential contours of decreasing strength. This research provides us with a clear-cut alternative to what is commonly known as the "Blue Banana"-a large growing area which includes most of the regions of Germany, Austria and Benelux, as well as the more developed urban regions which form part of the UK, France and the North of Italy.

This alternative concept of the European population as a nuclear structure with successive concentric lines of potentials, correlates quite remarkably with nighttime light diffusion images which depict the population centered around what we define as the "Central European Triangle" (UK, Manchester, London, Paris, Cologne, Düsseldorf, Ruhr Valley). Around this area, successive population potential contours take in Berlin and the Prague and a North Italian axis.

Moreover, population potentials highlights the important effects enlargement will cause on the different parts of the spatial structure of Europe. Potential countours show a displacement of the gravity center of Europe towards the East.

Eastern parts of the current EU members like East and Central Germany, Austria and West of Italy will enjoy important competitive advantages due to the high relative increase in their population and market potentials that will be caused by the enlargement. CEECs will also enjoy important competitive advantages due to their central location within a high potential contour (330.000 inh/Km). After the enlargement they will be integrated in a big market area and their peripheral position will be strongly reduced. CEECs will also benefit from reinforced regional and local authorities cooperation in the framework of new cooperation spaces like the Central European, Adriatic, Danubian and South Eastern European Space (CADSES). However they will be border regions in the Eastern frontier that will probably need special policy measures.

Enlargement will be also beneficial for the central areas of the EU and probably will not affect the strong tendency to big agglomeration in the real core of the European spatial structure: The central triangle compound by the big metropolitan areas of Great Manchester-London/Paris/Colonia-Dusseldorf-Rhur Valley that concentrates more than 40% of EU population and more than 50% EU GDP.

On the contrary the Atlantic periphery will be affected by an important comparative decrease in population potentials. That must be faced by developing new measures in the context of future European Regional Policy and within the European Spatial Development Perspective. The Atlantic periphery need to be reinforced with new policy measures to compensate the outlying location and to encourage a polycentric and more balanced development with the improvement of the efficiency of small and medium size agglomerations in the framework of urban networks in these areas Europe as it is stated in the ESDP This, in the future, after the enlargement, implies for the Atlantic regions a risk of loosing the connections with the more developed regions of Europe.

In last section of the paper, we analyse the relationship between population potentials and the levels of development in the European Union for different periods of time. In this way we check if the relationship holds all over the time. We find clear evidence to support the positive effect of population potentials in determining the levels of development although its explanatory power decreases in the nineties.

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