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 using the technique of gravity models.

What we have found is that closeness to large consumer markets 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. The main reasons for this tendency reside in a trend towards the delocalisation of economic activities driven by technical advances in transport, information and communication, together with tendencies towards convergence in a unified economic space and the impulse generated by the new EU regional policy which began in 1987 after the European Single Act

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1. 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. 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).

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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.

[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).

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 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.

2. 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.

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

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.

3. 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 map of average population potential for EU15 was plotted (see next section). Computations have been carried out by taking the group of urban centers in Europe with more than twenty thousand inhabitants. For those urban centers and for the remaining points in the grid, the potential index was calculated in ARC/INFO and then, by means of interpolation, the population potential contours were computed in ARC VIEW, by using the SPATIAL ANALYST modulus.

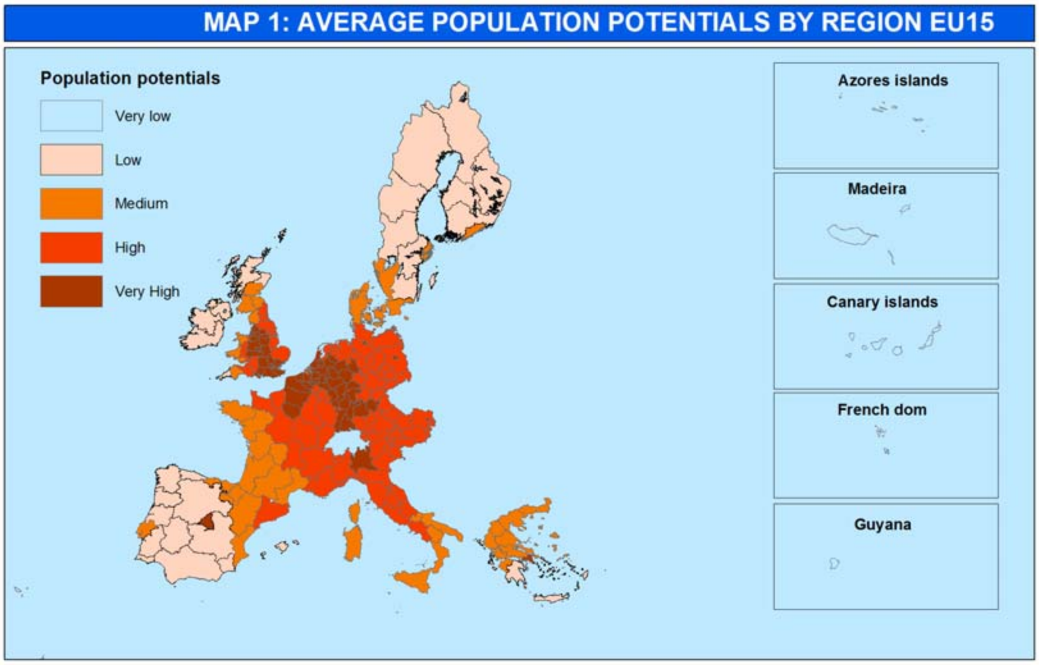
4. Population Potentials and Levels of Development

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[4] 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).

Map 1 displays a classification of five levels or weightings of population potentials within the EU15.



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.

[4] 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.

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 1 and 2.

Figure 1: Population Potentials and Levels of Development (UE12 1989)

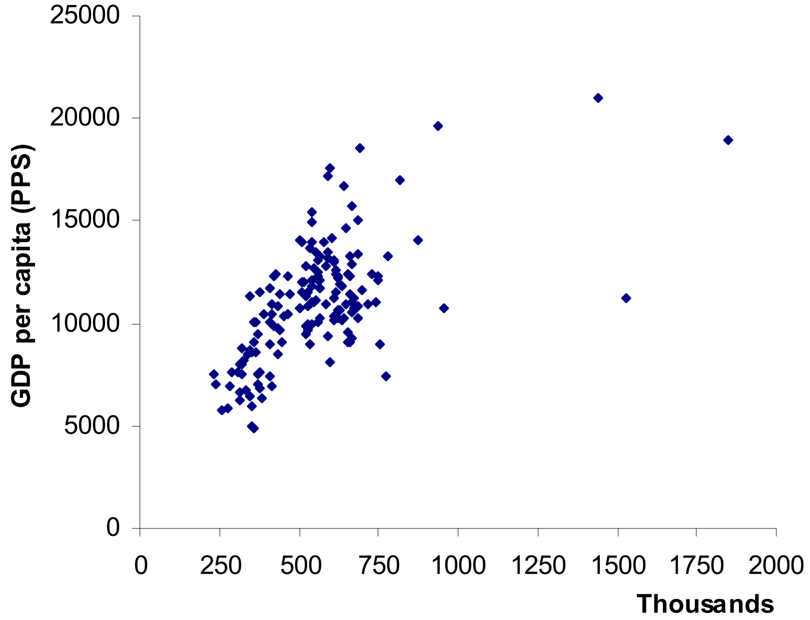
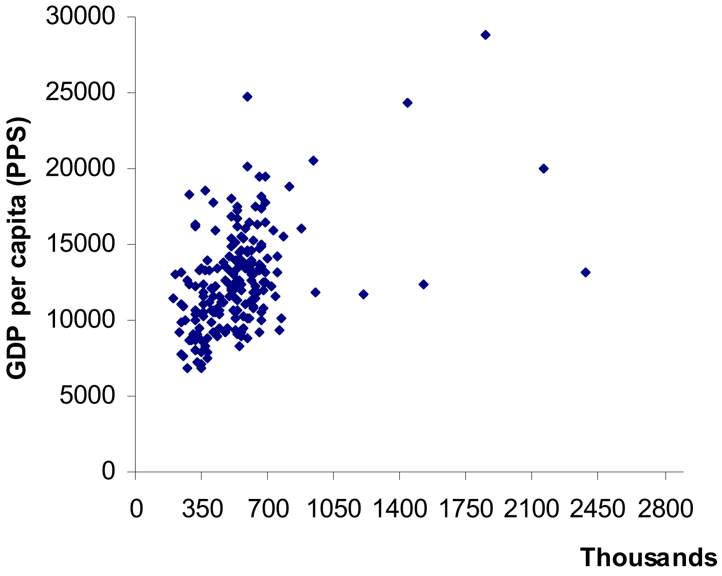


Figure 2: Population Potentials and Levels of Development (UE15 1999)



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 1: 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 2: 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 3: 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 4: 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 5: 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.

5. Conclusions

In this paper, we analyzed the relationship between population potentials and the levels of development in the European Union for different periods of time. By using a logarithm specification for the relationship between population potentials and levels of development and by estimating cross-section regressions for different time periods we evaluated if the explanatory power of the population potentials was hold constant over time or if on the contrary it was decreasing as long as we move forward testing our model for the latest data available (1999). Our proposed relationship was estimated in different years, 1982, 1989, 1994, 1997 and 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. The main reasons for this tendency reside in a trend towards the delocalisation of economic activities driven by technical advances in transport, information and communication, together with tendencies towards convergence in a unified economic space and the impulse generated by the new EU regional policy which began in 1987 after the European Single Act.

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