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Urban Clusters as Growth Foci: Evidence from the Analysis of European Urban System

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Abstract

Urban clusters are geographic concentrations of urban places, some of which may include major cities. Unlike agglomerations, whose geographic boundaries are clearly delineated, urban clusters have 'variable' boundaries, with each urban settlement being part of its 'own' cluster of populated places, located within its commuting range. As our study indicates, the effect of clustering on urban growth is not uniform: It appears to be positive in low density clusters, and negative in densely populated ones. In particular, outside densely populated areas, towns surrounded by other localities tend to evince higher rates of population growth than their 'lone' counterparts.

Key words: Urban clustering, population growth, location

JEL codes: O18; R11

1. INTRODUCTION

In contemporary urban literature, several terms are used, often interchangeably, in referring to urban concentrations: agglomerations, conurbations, metropolitan areas, urban clusters, etc. (Lowry, 1990). 'Agglomeration' is apparently the most commonly used term, although not the most inclusive. Agglomerations are formed around major cities, which function as their cores (Storper and Venables, 2004). The term 'metropolitan area' basically refers to the same phenomenon as 'agglomeration', but is 'geo-functional;' it implies both dependence on the metropolitan *core* and proximity to it (Fujita et al., 2001). Metropolitan areas usually combine one or several major cities and their hinterlands (Fig. 1A), all of which depend on the core - for employment, physical infrastructures, commerce, and sometimes governance (Fujita et al., 2001; Pastor et al., 2000). A 'conurbation' includes several large cities, surrounded by towns and villages, which, through population growth and expansion, merge into a continuous built area; being polycentric (Fig. 1B), a conurbation lacks a specific core, unlike metropolitan areas (Parr, 2004a,b).

<<< Figure 1 about here >>>

A general term for urban concentrations, whether they include major cities or not, is 'urban clusters' (Portnov and Erell, 2001). In this study, an *'urban cluster' (UC) is defined as a group of urban settlements located within commuting range of each other, which include major cities or, alternatively, is formed by localities of similar size.* In essence, agglomerations and conurbations are specific forms of UCs, found in densely populated core areas, where urban settlement is mature and major cities are dominant.

An important distinction between agglomerations and urban clusters pertains to the delineation of their borders. Although an agglomeration may spread a long way from its core, sometimes as much as 50-100 or even 150 km (Bode, 2008), the 'rip' between its geographic domain and areas beyond it is usually crisp: a town may either be inside or outside an agglomeration (Cheshire and Hay, 1989; Karlsson and Olsson, 2006). In contrast, *every town or city may be said to belong to some UC*: The cluster may be restricted to the town itself, if the area is sparsely populated and there are no other localities within commuting range, or it may include additional places, if local urban settlement is more mature. UCs thus have 'moving' boundaries, with *every* urban settlement being part of its 'own' cluster of places located within its commuting reach (see Fig. 1D).

Clustering and agglomeration have been objected to in-depth analysis in classical studies of urban and industrial location (Weber, 1909; Christaller, 1933; Lösch, 1938; Isard, 1956; Beckmann, 1968). In recent years, *clusters of industries* have attracted extensive research (Rogerson, 1998; Shilton and Craig, 1999; Wallcott, 1999; Boddy, 2000; Gordon and McCann, 2000). Yet studies of *urban clustering* remain rare. The few which have been carried out, mainly refer to five aspects of the phenomenon: a) the physical expansion of UCs (Fujita and Mori, 1997; Schweitzer and Steinbink, 1997; Portugali, 1999); b) the provision of services and facilities in UC's (Wellar, 1982, 1988; McNiven et al., 2000); c) preconditions for the sustainable growth of small and medium-size towns in UCs (Portnov and Erell, 1998, 2001; Portnov et al., 2000), and e) proximity between cluster members as a factor of development similarities (Portnov, 2006). Regional development issues pertinent to urban clustering and agglomeration have also been investigated in the literature dealing with 'spread' and 'backwash' effects occurring around major population centers and affecting their rural hinterlands (Henry et al., 1997; Partridge et al., 2007).1

As development differentials between densely populated metropolitan areas and peripheral regions are increasing, overcoming inequalities in socio-economic development has become a key issue for urban and regional planners worldwide (Mera, 1995; Puga, 1999; Felsenstein and Portnov, 2005). In many sparsely populated peripheral areas, the inhabitants are denied access to social amenities, which are available in denser populated regions. As the population of a community increases, it crosses the threshold for higher-level services, and starts offering richer opportunities for employment, education and leisure. In this respect, knowledge about the effect of *urban clustering* on the development of urban areas may have important policy implications. For instance, it may guide regional development policies aimed at enhancing urban growth in priority development areas.

Is population growth likely to be faster in urban clusters than in geographically scattered urban settlements? Does the effect of urban clustering on the population growth of towns differ between densely populated metropolitan areas and sparsely populated peripheral regions?

The present paper attempts to answer these questions on the basis of population growth data on ca. 4,700 localities in 40 European countries. According to our findings, a town surrounded by neighboring localities is likely to grow faster than its isolated

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1 For an extensive review of theories and studies of urban clustering, see Portnov and Erell (2001).

counterparts. This is especially relevant for the periphery, where being a part of a cluster may make the difference between a growing place and stagnating one.

The rest of the paper is organized as follows. We start with a brief discussion of the processes whereby UCs are formed and then discuss some mechanisms which would explain why their growth rates are faster than those of dispersed urban settlements. In the following sections, empirical data on Europe's urban system are used to compare population growth rates across settlements characterized by different levels of urban clustering.

2. FORMATION OF URBAN CLUSTERS

There are three distinctive (and often interrelated) processes whereby urban clusters are formed. First, they may form in response to diseconomies of concentration in overgrown population centers. Second, such clusters may make their appearance through the simultaneous growth and eventual merging of adjacent peri-urban localities and villages. Finally, urban clusters may be formed through deliberate planning, such as that which has led, in several countries, to the establishment of new towns around major population centers (Galantay, 1975). In the following subsections, these 'cluster-generating' processes will be discussed in brief.

Urban Spillover

As a city grows, the positive effects of agglomeration are likely to decline (Fujita et al., 2001; Parr, 2004b). As a result, locations distant from the urban centre may become increasingly attractive to new firms, due to high inner-city rents, while the growing number of firms in the central city may intensify competition (Krugman, 1999; Fujita et al., 2001). If the overall population keeps growing, new urban localities may emerge in the expanding urban hinterland, generating new town clusters, or enlarging existing ones (Fujita and Mori, 1997). The establishment of such new towns around major population centers is often affected by the institutional framework and by land conservation policies. Thus, the 'green belt' policy in the U.K. effectively prevents the creation of new communities around London and other major population centers (Cowan and Mac Donald, 1980). Furthermore, public ownership of land (e.g., in countries of the former Soviet Union), or land deficit (Hong Kong, Israel and South Korea) may render the establishment of new communities around existing population centers rather unfeasible, causing developers to opt for more remote hinterland areas. On the other hand, infrastructure investments, and especially highway rings built around major cities (e.g., in the U.S.A in the 1960's), may effectively facilitate the creation and expansion of new urban communities in the metropolitan fringes, due to improved access (Friedrichs, 1985).

Simultaneous Growth

New urban clusters may start forming *before* the central city is 'overloaded.' In particular, demographic growth may affect several rural communities located near large cities, turning them into urban places. When such a process occurs, clusters are formed, until the municipal authority of the large city is extended to the new urban places. Historically, such a process has happened to the villages which have ultimately become neighborhoods of Paris, London, New York City, etc. Small communities established around coal mines and other *loci* of mineral deposits may also follow a path of 'growth and merging'. Starting as small villages or hamlets, such mining communities expand into urban clusters (e.g., the *Norilsk* region of Russia) or 'blend' into uninterrupted urban contiguities (such as the *Ruhr* region in Germany). Recently, tertiary industries (i.e., banking, knowledge-intensive high technology industries, culture, entertainment and services) have expanded in developed economies, evincing a strong preference for major cities (Boddy, 2000; Andersson et al., 2006). Cities with such industries may cast a 'development shadow' or the so called 'Upas Tree' effect on other urban places and thus limit any significant inter-regional spillover effect. Such a 'Upas' effect has been noted for Helsinki, Tel Aviv, and Dublin (Roper and Grimes, 2005). The expansion of the knowledge economy, coupled with its increased need for 'face-to-face' communication (Storper and Venables, 2004), is also likely to work in the same direction, i.e., towards limiting the expansion of small urban communities in hinterland areas around metropolitan cores.

Establishment of New Towns

New settlement clusters may be formed to facilitate the co-ordination of communal activities, such as the operation of a complex irrigation system (Fedick, 1997). In pre-modern societies, clusters of urban and rural settlements were often nucleated around a monastery or a castle, or, at other times, formed from settlements of tribal groups sharing a common ancestor (Aston 1999). In modern societies, the factors leading to the establishment of new towns include the 'pull' of exploitable resources, and the 'push' of overcrowding (Galantay, 1975). Those established in response to the latter are often satellite towns, clustering around older population centers, sometimes built as a government response to the failure (real or perceived) of market forces to 'counteract' the over-concentration of population and economic activity in a few major cities (Fouchier, 1998).

3. CLUSTERING AND URBAN GROWTH

The large distances often separating peripheral towns are likely to cause a shortage of intra-regional educational and recreational infrastructures, as well as limiting job opportunities available within daily commuting range. Conversely, being part of a cluster of towns may widen employment opportunities and even limit out-migration during economic downturns (Portnov and Erell, 2001).

Another growth-enhancing advantage of clustering may stem from the tendency of migrants to choose their destinations hierarchically: first, between clusters of localities, and second, between individual localities in a preferred cluster. The reason is that ordinary migrants, unlike those with political, business or other connections, often lack inside information on possible destinations or else lack the capacity to process it, and thus tend to treat neighboring localities as clusters of opportunities (Fotheringham, 1991; Fotheringham et al., 2000).

In the process of location decision-making, firms and individual entrepreneurs may also prefer clusters to isolated settlements. Within such clusters, they may expect to find a wider pool of skilled labor and more consumers than in isolated towns. Everywhere, but especially in sparsely populated areas, in which individual urban localities tend to be small and distant from each other, clusters of neighboring towns may offer a 'safety net' for local residents based on joint infrastructures and employment opportunities (Portnov and Erell, 2001).

However, once the density of urban settlement has risen above a given threshold, the establishment of additional urban communities may be detrimental to all of them, due to overcrowding and to increasing diseconomies of agglomeration (Weber, 1909; Krugman, 1999; 1995; Fujita et al., 2001).

4. RESEARCH METHOD AND DATA SOURCES

To test our research hypothesis that *the spatial clustering of urban localities helps explain their population growth*, we used data on Europe's settlements. As of 1999, Europe hosted close to 16,000 settlements with populations of 5,000+ residents; ca. 1,600 localities with more than 50,000 dwellers and nearly100 cities of more than 500,000 residents (Geonames, 2007). This analysis only covers urban localities for which population growth rates are available (ca. 4,700 municipalities). The places are spread over 40 countries and range between 2,000 and 7,000,000 residents (see Appendix 1).2

The data on the longitude and latitude of the settlements, and on their elevation above sea level, were obtained from the Geonames Database, which contains such data on urban and rural settlements worldwide (Geonames, 2007). Data on population growth rates of urban localities of Europe were obtained from the City Population Database (Brinkhoff, 2007), whereas proximity of individual urban localities to location landmarks (the sea shore, and the closest city larger than 500,000 residents) was calculated in the ArcGIS™ software, using geographic layers obtained from the geo-coverage database maintained by ESRI (2000).

5. STATISTICAL ANALYSIS

The effect of several factors on the *annual population growth* of urban localities was analyzed by multiple regression analysis (MRA), using both Ordinary Least Squares (OLS) and Spatial Lag (SL) models. Annual population growth was measured in two ways: a) as absolute (i.e., unstandardized) rate of population growth (per 1,000 residents) and b) as country-standardized population growth rate, i.e., the difference between the population growth rate in a locality and that of the country as a whole. (The latter transformation was required to take into account country differences in population growth rates, which are most notable between the countries of northern and southern Europe).3

The following factors served as explanatory variables: population size of localities (ln); distance to the sea shore (km); distance to the closest major city (km), and the interaction term between a place's latitude (decimal degrees) and its elevation above the sea level (meters). [In the absence of more specific climatic data the latter variable served as proxy for climatic harshness].

To measure the *clustering of localities*, the Index of Clustering (IC), similar to that proposed by Portnov et al. (2000), was used. This index was calculated in two separate ways. First, in line with the definition suggested in the introductory section (see p. 2), the Index of Clustering (IC) was calculated as the total population of the localities residing within a given distance from a given town (after subtracting the town's own population). In the following discussion, this index will be referred to as IC1. As an alternative, the index of clustering (termed hereon IC2) was calculated as the logarithm of the ratio be-

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2 Nearly all cities and towns of Europe with a population of 20,000+ residents are covered by the study. Smaller localities are less fully represented, due to incomplete data on population growth. This limitation will be further discussed in the concluding section. For most countries covered in this study, population data are available for 1990/91 and 2000/2001. However, for some countries, the time span covered by the analysis differs slightly. Thus, population data for Belorussia are only available for 1989 and 1998, whereas the data on French urban settlements can be obtained for 1990 and 1999, etc. To facilitate comparative analysis, we annualized population growth rates.

3 The results of regression modelling for country-standardized and unstandardized rates of population growth were found to be similar. In the following discussion, only models for absolute population growth rates are reported, for brevity's sake.

tween the aggregate population of all towns and cities (*j*) located within commuting range of urban place *i* (including the town's own population), and the urban place's 'remoteness', IR_{ik}, measured as the aerial distance from the town in question to the closest major urban centre (*k*):4

$$IC2_i = \ln[(\sum_{j=1}^{n} P_j) / IR_{ik}],$$

where P_j is population size of town *j* located within commuting range from locality *i*, and *n* is the number of localities in *i*'s 'commuting field.'5

IC2 thus has high values in central, densely populated areas, where distances from major cities are small and the urban field - dense, while it has lower values in peripheral areas, where towns are more scattered, often lying at considerable distances from each other.

Two clarifications are required. At first sight, IC2 looks similar to the accessibility index commonly used in urban and regional studies (see *inter alia* Tschopp and Axhausen, 2006; Andersson et al., 2006).[6] The difference between the two measures is nevertheless considerable. The Accessibility Index emphasizes the access of a subject locality to residents of other towns, that is, it considers the locality in question as an opportunity available to residents of other urban places. In contrast, the Index of Clustering, used in this study, emphasizes on the *opportunities available to the residents of the subject town within their commuting reach.* Furthermore, IC2 adjusts for the *geographic location* of the town in relation to major population centers, assuming that if a centrally located town lacks urban places of similar size in its vicinity, its relative isolation may be compensated by proximity to a major urban centre. However, such 'compensation' is clearly unavailable to residents of a similar town located in a more remote peripheral area. Thus, despite its apparent simplicity, the IC2 index combines three important dimensions of urban location, viz. intraregional isolation, remoteness, and commuting range.

Similar values of the IC2 index may exist for *both* densely populated areas distant from population centers and sparsely populated areas close to such centers. Although these two cases *are not* identical, the index suggests similarities these localities may exhibit with respect to population growth.

The values of IC1 and IC2 for each locality under study (ca. 4,700) were calculated in the ArcGIS9™ software, using geographic layers of cities separated into the layer of major cities (500,000+ residents) and those of smaller cities and of towns.

Although access time may seem to be the most accurate measure of inter-urban proximity, we opted for *aerial distances*, which are commonly used in urban and re-

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4 The definition of 'major city' depends on the function the city performs, and may thus vary by country, depending on its land area, population size etc. In the analysis, we decided that 500,000 residents would be our population threshold for the 'major city' group. In calculating the IC2 index, all distances were measured from the centers of individual localities. To avoid division by zero, for all major cities (i.e., localities with 500,000+ residents), IR_{ik} value was conditionally set to 1.

5 In calculating the IC index, we set the 75 km range (ca. one decimal degree (dd)) as commuting threshold. It corresponds to the findings of previous studies of commuting patterns on the continent (see *inter alia* Schwanen, 2002; Karlsson and Olsson, 2006).

6 In its general form, the accessibility of location *i* (A_i) is given to the following formula: $A_i = ln(\Sigma X_j f(c_{ij}))$, where X_j is the number of residents at location *j*, C_{ij} is the generalized costs of travel between locations *i* and *j*, and *f* is the weighting function for the generalized costs of travel, e.g., $e^{-\lambda c_{ij}}$ (Tschopp and Axhausen, 2006).

gional studies (see *inter alia* Henry et al., 1997; Partridge et al., 2007). Our decision was motivated by the shortcomings of travel time between any two given places, such as considerable variation by season of the year (especially in countries with rainy and snowy winters), and even by time of the day. Concurrently, if the infrastructure and quality of service are more or less uniform throughout the study area, aerial distance may be a fairly accurate measure of inter-urban proximity.

It is also noteworthy that in addition to being important development indicators in their own right, each of the aforementioned development measures (i.e., population size of localities, clustering etc.) may reflect more development aspects than it directly measures, as demonstrated in brief by the following argument.

The Index of Clustering (primarily IC1, but also IC2), we calculated as the total population of places located in the *fixed* commuting range from a given locality, is in fact, a direct measure of *population density.* Thus, according to Rappaport (2006), population density itself is a proxy for other development parameters, including quality of life and local productivity. Actually, it is an especially important development measure because individuals are willing to endure severe crowding and high housing costs so as to enjoy better commercial services and higher wages. In this sense, varying local population density may be perceived as the primary mechanism whereby local wages and house prices adjust to equate utility and profits across localities.

The *population size* of localities affects their attractiveness and growth rates, because, quite often, they have to reach a given threshold, to ensure sufficient employment diversity and adequate services (Alonso, 1971; Portnov and Erell, 2001).

Seashore proximity may also facilitate regional and international trade, allowing urban localities to grow in a more sustained way and improve their overall economic performance (Fujita and Mori, 1997). Seashore proximity may be especially important in countries lacking a developed inland transportation network (Gallup et al, 1999).

Large distances to major population centers, which tend to be the major markets and sources of employment, often imply economic weakness and limited job opportunities (Ades and Glaeser, 1995; Fujita and Mori, 1997). Thus, remote localities tend to grow slowly, being relatively unattractive to migrants and investors (Duranton, 1999).

The *harsh climate* of some geographic areas places limitations on interurban exchanges, as well as on human comfort and access to urban amenities. Moreover, towns located on high elevations in northern latitudes, are often hindered in their access to national *loci* of employment and cultural life (Cheshire and Magrini, 2006).

The inclusion of these variables in the analysis thus makes the entire variable set (restricted, due to data availability, to a relatively small number of explanatory variables) fairly parsimonious.

In addition, individual countries were represented in the analysis by country dummies, i.e., dichotomous variables taking on the values 1 if a locality is in a given country and 0 otherwise. The inclusion of these dummies helps adjust for intra-country differences, which may not be fully covered by the above 'global-level' variables (for brevity's sake, regression estimates for countries' dummies are omitted in the following discussion).

Analysis Procedure

Normal distribution of the dependent variable is an important prerequisite for valid regression analysis. The analysis of regression residuals confirmed that their distribution was fairly normal. The linearity of the relationship between dependent and independent variables was also verified, and logarithmic transformation was used when required (e.g., for population size, IC1 and IC2), to improve the model's fit and generality. We also checked for multicollinearity and found the results satisfactory (Tol.>0.3).

We conducted the analysis in two stages. In the first, we estimated the regression models using all our explanatory variables *but* the Index of Clustering. In the second stage the Index of Clustering (IC) was added and the analysis was rerun. Our underlying assumption was that if the proximity of a locality to its neighbors does matter, then adding IC to the list of predictors should improve the explanatory power of our population growth models.

The investigation of regression residuals for the OLS models revealed significant autocollinearity within up to the 80-90 km inter-town proximity range (Moran's I> 0.02; P<0.05; see Fig. 2). This required the use of spatial dependency models. Three types of such models – conditional autoregression (CAR), simultaneous autoregression (SAR) and moving averages (MA) – were used in the analysis. (In the following discussion only the best performing SL model of the SAR covariance family is reported). The analysis was performed in the S+SpatialStats^{TM} software.

<<< Figure 2 about here >>>

The effect of individual location attributes (e.g., topography, proximity to networks, etc.) may depend on how much they stand out in their regional or national contexts. In a region or country where a given advantage or disadvantage are commonplace, they are likely to have lesser effects than where they are uncommon (Polese and Shearmur, 2006; Portnov and Schwartz, 2007). To assess the importance of this relativity of location attributes, location variables (proximity to the coast, proximity to major cities, and climatic harshness) were successively represented in the analysis first by their 'absolute' and then the by their 'relative' values. To estimate the latter, 'absolute' values were divided by the average values observed in each country and the quotient was used in rerunning the analysis.

We also estimated *separate* regression models for settlements in high density clusters (IC2(ln)≥12) and for localities with lower values of clustering (IC2(ln)<12).7 In line with our initial hypothesis, we expected that clustering would foster urban growth in peripheral areas with low levels of clustering, while having no effect or even hindering such growth in more densely populated metropolitan regions.

6. RESULTS

The list of variables and the resulting models are reported in Tables 1 and 2, while the descriptive statistics of the research variables are given in Appendix 2. In Model 1 the location of the settlements is represented by absolute values of location variables (that is, distance to the shore, proximity to major cities, etc.). The index of clustering (IC) is not included in this model. Models 2 and 3 preserve the same 'setting', while IC1 (Model 2) and IC2 (Model 3) are added as additional explanatory variables (see Table 1).

Models 4-6 (Table 1) are based on relative (i.e. country standardized) values of location variables and calculated first excluding the IC (Model 4) and, second, including it (Model 5). Model 6 (Table 1) is calculated using the stepwise regression procedure and reports only highly significant explanatory variables (P<0.01).

7The rationale for setting this particular inter-group break threshold is discussed in the following section.

Models 7-12 (Table 2) are calculated for settlements in dense clusters ((IC2(ln)≥12)), and for those with lower values of clustering (IC2(ln)<12), respectively. In the first model set (Models 7-8; Table 2), the IC is included, while in the second and third sets, either IC (Models 9-10) or 'distance to the major' city (Models 11-12) are omitted, to analyze how that affects the models' fit and generality. Lastly, Model 13 (Table 2) is a spatial lag model, estimated by the simultaneous autoregression (SAR) method.

<<Tables 1-2 about here >>

Comparison of the first two sets of models (Model 1 vs. Models 2-3; Table 1) indicates that the inclusion of the Index of Clustering (IC) enhances their explanatory power, with the effect of IC2 being more significant than that of IC1 (R^2-adjusted=0.344 (Model 1) vs. R^2-adjusted=0.346 (Model 2), and R^2-adjusted=0.358 (Model 3). Although the R^2 change appears marginal, the F test of regression residuals confirms that the improvement of the regression fit attributed to the inclusion of IC as an additional explanatory variable (especially in the case of IC2), is statistically significant (P<0.01). Notably, both IC1 and IC2 emerge as highly significant (albeit the significance level of IC1 is much lower than that of IC2: t=3.967; Model 2 vs. t=10.197; P<0.001; Model 3).

Characteristically, most location-related variables (proximity to the seashore, major cities, etc.) turn out to be highly significant when their absolute values (Models 1-3; Table 1) are replaced by country-standardized ones (Models 4-5; Table 1). However, this change fails to affect the performance of the IC, which retains its significant positive sign in the new models as well (t=6.856; P<0.001; Table 1). This result confirms our initial hypothesis that for an urban place, cluster membership is generally conducive to growth.

Although multicollinearity levels among explanatory variables were monitored and found to be within tolerable limits (Tol.>0.3), even this, relatively low, level of collinearity may adversely affect regression estimates. To rule out this possibility, we reran the analysis using stepwise regression, which makes it possible to include only highly significant variables and minimize collinearity between them. The results are reported in Table 1 (Model 6). Importantly, the distance to major cities was filtered out in these models as statistically insignificant (P>0.10), while the index of clustering was retained and increased its significance level, compared to the previous model run (t=7.858 (Model 6) vs. t=6.856 (Model 5; Table 1).

The scatter plot of IC2 *vs.* population growth rates of towns, shown in Figure 3, indicates, however, that in line with the initial research hypothesis, the relationship between the two variables is *non-linear*. In particular, if town growth rates appear to increase initially as clustering increases (see Fig. 3). However, upon reaching a certain threshold (IC2=ca.160,000 (see Fig. 3); IC2(ln)=ca.12), the trend is reversed, i.e. further increases in clustering lower population growth rates. The Chow test of regression residuals, reported in Table 4, confirms that the slopes of regression lines before and after the IC2(ln)=12 break point are significantly different (Chow test=8.218; P<0.001; Table 3).8

8 Although several cutoff thresholds for the IC2 index were tested, the results were found to be inferior to the IC2(ln)=12 threshold, eventually used in the analysis. In particular, alternative thresholds showed less difference between IC2 coefficients in the 'high' – 'low' density models. The results of these tests are *not* reported in the following discussion for brevity's sake.

<<< Figure 3 and Table 3 about here >>>

Running the models separately for settlements located in dense urban clusters (Models 7, 9 and 11; Table 2) and those located in less densely populated ones (Models 8, 10 and 12: Table 3) sheds additional light on the clustering phenomenon. Strong differences appear in the effects of several variables, namely, distance to the closest major city, latitude, and index of clustering (see Table 2). Thus, all else being equal, close proximity to the major city has a negative effect on the population growth of individual towns which are part of dense clusters (b= 0.664; P<0.01; Model 9) and a positive effect (albeit statistically weak) on the performance of towns whose clusters are scattered (b=-0. 034; P>0.10: Model 10). This trend change is, in fact, not surprising, considering that most towns located in the former group appear to be close to major population centers (D(mean)=21.85 km; D(max)=74.80 km; see Appendix 2), and are thus likely to experience the adverse effects of agglomeration, such as overpopulation, high rents, etc.

The effect of 'climatic harshness' appears to be weak for cities and towns located in dense urban clusters (b=0.008; t=0.130; P<0.01; Model 7; Table 2) and strongly negative for towns in less dense clusters (b= -0.069; t=-3.467; P<0.01; Model 8; Table 2). This difference implies the existence of a 'compensatory' mechanism, whereby highly developed all-weather infrastructures around densely populated metropolitan centers help reduce adverse climatic effects on the daily life of urban dwellers (e.g., long periods of low winter temperatures associated with e.g., high elevations and northernmost latitudes).

Notably, the effect of *clustering* on the population growth of individual towns appears to be *negative* in dense clusters (IC(ln): t=-0.323; t=-5.427; P<0.01; Model 11; Table 2) and positive elsewhere (t=0.064; t=5.001; P<0.01; Model 12; Table 2). This supports our initial hypothesis that urban clustering *does not* always favor the population growth of individual towns. That is, in sparsely populated areas, clustering may contribute to each town's attractiveness to potential newcomers by offering a 'safety net' based on joint infrastructures and employment opportunities. However, in densely populated areas, especially around major population centers, additional communities might be detrimental to previously established ones, due to overpopulation and inter-town competition for potential migrants and businesses.

To quantify the effect of clustering on population growth of towns, we performed a sensitivity test of the population growth models to plausible changes in the values of the IC2 variable. The test was based on Models 11-12 (Table 2) and its results are reported in Table 4. As Table 4 shows, in 'high density clusters,' the annualized rates of population growth of individual towns appear to drop, *ceteris paribus*, in line with increasing values of clustering (from 1.614% for IC2=10.800 to 1.094% for IC2=12.409). Concurrently, in 'low density clusters,' the opposite trend is observed, viz., population growth rates tend to increase with increasing values of clustering: from 1.295% for IC2=8.038 to 1.387% for IC2=9.473.

<<< Table 4 about here >>>

In general, the use of spatial lag models (Table 2: Model 13) *does not* substantially change the outcome of the analysis. In particular, the index of clustering retains its statistical significance (P<0.001) even after taking the spatial dependency of residuals into account.

7. CONCLUSIONS

The positive effect of clustering on the population growth of individual towns may be due to several reasons. First, both private investors and migrants may make their location decisions hierarchically: initially between town clusters, and then, between individual towns in a 'preferred' cluster. Second, a town's membership' in a cluster may widen employment opportunities for its residents, limiting out-migration during economic downturns.

According to Christaller's (1933) Central Place Theory (CPT), development processes are not necessarily linked to location externalities, with the centrality of an urban place being determined solely by retailing functions it contains. The proposed approach to understanding of the effect of clustering on urban growth leads us to a different conclusion. In particular, as our study indicates, the effect of clustering on urban growth is *not* uniform: *It appears to be positive in low density clusters, and negative in densely populated ones.* This conclusion is in line with the findings of country-specific studies (Portnov and Erell, 1998, 2001; Portnov et al., 2000), which indicated that increased clustering *does not* always foster urban growth: The performance of towns appears to improve initially with increased clustering and then decline as the density of the urban field increases further. In our analysis, this trend was indicated by is switching of the IC2 coefficient from positive to negative with an increase in IC2. The explanation may be straightforward: initial clustering in a region enhances urban growth, but further clustering may lead to over-concentration, thus limiting the growth potential of individual towns.

The relationship between urban clustering and the population growth of individual towns resemble Weber's (1909) agglomeration function, according to which, after a critical point is reached, and diseconomies of concentration (congestion costs, and the bidding-up of land and labor prices etc.) come into play, generating centrifugal forces, which stir economic development and migration away from established population centers towards less densely populated areas (Fujita *et al.* 2001). However, the difference between the 'agglomeration-based' approach, advocated by the 'new economic geography,' and the 'cluster-based' approach remains substantial.

Although an agglomeration may spread a long way from its core, the 'rip' between its geographic domain and areas beyond it is usually crisp: a town may either be inside or outside an agglomeration (Cheshire and Hay, 1989; Karlsson and Olsson, 2006). In contrast, according to the cluster-based approach we advocate, *urban clusters have 'variable' boundaries, with each urban settlement being part of its 'own' cluster of populated places, located within its commuting range.* The cluster may be restricted to the town itself, if the area is sparsely populated and there are no other localities within commuting range, or it may include additional places, if local urban settlement is more mature.

The Index of Clustering, we used in this study to measure the effect of clustering on urban growth, may look similar, at least at first glance, to the Accessibility (Market Potential) Index, commonly used in urban and regional studies (see *inter alia* Tschopp and Axhausen, 2006; Andersson et al., 2006). However, the difference between the two measures is nevertheless substantial. While the Accessibility Index emphasizes the access of a subject locality to residents of other towns (that is, it considers the locality in question as an opportunity available to residents of other urban places), the Index of Clustering, puts an emphasis on the *opportunities available to the residents of the subject town within their commuting reach.*

Furthermore, the Index of Clustering adjusts for the geographic location of the town in relation to major population centers, assuming that even if a centrally located town lacks urban places of similar size in its vicinity, its relative isolation may be compensated by proximity to a major urban center. Thus, despite its apparent simplicity, the

IC index combines three important dimensions of urban location, viz. intraregional isolation, remoteness, and commuting range.

Although further studies of time-related changes in UCs are needed to confirm the generality of the observed trends, and additional indicators of urban development (e.g., export-based employment, ratio of manufacturing employment to total employment, housing prices, etc.) may be well worth considering in future studies, our initial findings suggest that focusing development resources on selected urban clusters, particularly in under-populated peripheral areas, may be useful in the promotion of urban growth.

Finally, we need to acknowledge that geographic location, in general, and urban clustering, in particular, are *not* the sole factors of urban growth. Other factors, such as population makeup, availability of local natural resources, agricultural hinterland, physical infrastructures, development policies, and macro-economic situation in the country as a whole, may affect the long-term performance of individual towns. However, urban clustering does appear to affect urban development, as demonstrated by the present analysis.

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TABLE 1: Factors Affecting the Annual Rates of Population Growth of Urban Localities in Europe (Model – MRA; Country-normalized Location Variables)

Variable	Model 1	Model 2	Model 3	Model 4	Tol.[a]	Model 5	Tol.[a]	Model 6	Tol.[a]
(Constant)	5.285	4.549	4.389	6.080		5.069		4.528	
	(12.402**)	(9.802**)	(10.196**)	(13.520**)		(10.759**)		(12.345**)	
Population size (ln)	-0.103	-0.099	-0.147	-0.114	0.794	-0.145	0.738	-0.141	1.246
	(-6.301**)	(-6.085**)	(-8.765**)	(-6.983**)		(-8.593**)		(-8.709**)	
Distance to sea shore	0.005	6.94E-05	1.55E-04	0.054	0.715	0.042	0.709	-	1.405
	(0.448)	(0.446)	(1.006)	(2.620**)		(2.022**)		-	
Distance to major city	-0.245	1.68E-04	0.002	-0.092	0.975	0.110	0.323	-	-
	(-1.015)	(0.930)	(6.752)	(-4.432**)		(3.045**)		-	
Climatic harshness	-0.004	-0.004	-0.004	-0.077	0.952	-0.067	0.698	-0.049	1.029
	(-1.928)	(-1.740)	(-1.777)	(-4.096**)		(-3.605**)		(-3.055**)	
Latitude	-0.066	-0.063	-0.067	-3.525	0.701	-3.371	0.947	-3.338	1.017
	(-9.912**)	(-9.304**)	(-10.151**)	(-10.836**)		(-10.388**)		(-10.456**)	
Index of clustering (ln)	-	0.040	0.132	-		0.106	0.198	0.067	1.543
	-	(3.967**)	(10.197**)	-		(6.856**)		(7.858**)	
Country dummies (39)									
No of cases	4667	4667	4667	4667		4667		4667	
R^2	0.350	0.352	0.364	0.355		0.362		0.356	
Adjusted R^2	0.344	0.346	0.358	0.349		0.355		0.352	
Std. Error of the Estimate	1.001	0.999	0.990	0.997		0.992		0.995	

[a] Tolerance (collinearity diagnostic); *0.05 significance level; ** 0.01 significance level; *t*-statistics are in parentheses.

Model 1: Unstandardized rates of population growth; non-standardized location variables;
Model 2: Unstandardized rates of population growth; non-standardized location variables (Index of Clustering (IC1) added);
Model 3: Unstandardized rates of population growth; non-standardized location variables (Index of Clustering (IC2) added);
Model 4: Unstandardized rates of population growth; country-normalized location variables;
Model 5: Unstandardized rates of population growth; country-normalized location variables (Index of Clustering (IC) added);
Model 6: Unstandardized rates of population growth; country-normalized location variables (model – stepwise regression).

TABLE 2: Factors Affecting the Annual Rates of Population Growth Across Localities with High (IC2(ln)≥12) and Low (IC2(ln)<12) Values of Clustering (Models 7-12) and Spatial Lag Regression (Models 13: All Sample; Dependent Variable - Absolute Rates of Population Growth)

Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13
(Constant)	7.670	4.811	4.771	6.262	7.752	5.603	5.385
	(4.499**)	(9.077**)	(3.004**)	(13.098**)	(4.777**)	(11.413**)	(10.173**)
Population size (ln)	-0.127	-0.103	-0.248	-0.093	-0.126	-0.098	-0.146
	(-2.855**)	(-5.274**)	(-7.068**)	(-4.726**)	(-2.869**)	(-5.012**)	(-9.128**)
Distance to sea shore	0.042	0.028	0.018	0.035	0.043	0.029	0.028
	(0.755)	(1.188)	(0.315)	(1.502)	(0.770)	(1.266)	(1.192)
Distance to major city	0.040	0.152	0.664	-0.034	-	-	0.128
	(0.158)	(3.916**)	(3.182**)	(-1.390)	-	-	(3.059**)
Climatic harshness	0.008	-0.069	0.045	-0.075	0.007	-0.071	-0.086
	(0.130)	(-3.467**)	(0.745)	(-3.726**)	(0.112)	(-3.545**)	(-4.497**)
Latitude	-1.332	-3.612	-1.160	-3.888	-1.339	-3.764	-3.573
	(-1.137)	(-10.450**)	(-0.980)	(-11.287**)	(-1.145)	(-10.939**)	(-9.573**)
Index of Clustering (ln)	-0.316	0.125	-	-	-0.323	0.064	0.091
	(-4.370**)	(6.204**)	-	-	(-5.427**)	(5.001**)	(5.662**)
Country dummies							
No of cases	840	3837	840	3837	840	3837	4667
R^2	0.319	0.386	0.303	0.380	0.319	0.383	
Adjusted R^2	0.289	0.379	0.273	0.373	0.290	0.376	
rho	-	-	-	-	-	-	0.032
Log-likelihood	-	-	-	-	-	-	-19500
SEE[a]	0.879	1.003	0.889	1.008	0.879	1.005	0.967
F	10.749**	52.817**	10.273**	52.622**	11.078**	53.467**	

* Indicates a 0.05 significance level; ** Indicates a 0.01 significance level; *t*-statistics are in parentheses; [a] standard error of the estimate.
Model 7: 'High density clusters' (IC2(ln)≥12);Unstandardized rates of population growth; country-normalized location variables;
Model 8: 'Low density clusters' (IC2(ln)<12); Unstandardized rates of population growth; country-normalized location variables.
Model 9: 'High density clusters' (IC2(ln)≥12); Unstandardized rates of population growth; country-normalized location variables (IC2 excluded);

Model 10: 'Low density clusters' (IC2(ln)<12); Unstandardized rates of population growth; country-normalized location variables (IC2 excluded).
Model 11: 'High density clusters' (IC2(ln)≥12); Unstandardized rates of population growth; country-normalized location variables (Distance to major city excluded);
Model 12: 'Low density clusters' (IC2(ln)<12); Unstandardized rates of population growth; country-normalized location variables (Distance to major city excluded).
Model 13: All sample of localities (Method - Simultaneous autoregression (SAR)).

TABLE 3: Chow's Test of Similarity of Regression Coefficients (Model – Two-variable Regression; Dependent Variable – Annualized Population Growth Rates; Predictor – Index of Clustering (IC2))

Set	No of cases	B_0	t	B_1	t	Chow test
All clusters	4667	0.631	33.795**	-6.36E-008	-1.914*	8.218**
'High density clusters' [a]	840	0.827	21.615 **	-1.37E-007	-4.397**	
'Low density clusters' [a]	3837	0.573	21.370**	6.23E-007	0.930	

** Indicates a .01 significance level; * indicates a .05 significance level;
[a] see footnote to Table 2 (Models 7-8)

TABLE 4: Sensitivity Test of the Population Growth Models to Plausible Changes in the Values of IR and IC2

'High density clusters'				'Low density clusters'			
IR_{ik} (km)[a]	IC2	Growth rate, %	% change	IR_{ik} (km)[a]	IC2	Growth rate, %	% change
20	12.409	1.094		100	9.473	1.387	
30	12.004	1.225	11.970	140	9.136	1.365	-1.553
40	11.716	1.318	7.585	180	8.885	1.349	-1.178
50	11.493	1.390	5.469	220	8.684	1.337	-0.952
60	11.310	1.449	4.237	260	8.517	1.326	-0.800
70	11.156	1.499	3.436	300	8.374	1.317	-0.691
80	11.023	1.542	2.878	340	8.249	1.309	-0.608
90	10.905	1.580	2.467	380	8.138	1.302	-0.544
100	10.800	1.614	2.154	420	8.038	1.295	-0.492
	Cumulative percent:		40.196		Cumulative percent:		-6.817

Note: Based on Models 11-12 (Table 2). The values of 'control' variables are set to their mean levels in the dataset, viz.: Population size (ln) =10.8 ('High density clusters'); Population size (ln) =10.37 ('Low density clusters'); Cluster size= 4,900,000 residents ('High density clusters'); Cluster size= 1,300,000 residents ('Low density clusters'); Distance to sea shore = 1 (country normalized); Climatic harshness = 1 (country normalized); Latitude = 1 (country normalized).

[a] Index of Remoteness (distance from the center of town *i* to the center of the closest major city (*k*) with 500,000+ residents).

APPENDIX 1

Number of localities under study, their population sizes and average annualized rates of population growth

Country	No of localities	Population of localities, residents			Annual mean rate of population growth (%)
		Mean	Minimum	Maximum	
Albania	15	70,657	14,848	374,801	1.78
Austria	79	44,890	5,851	1,569,316	0.45
Belgium	113	51,859	19,696	1,019,022	0.31
Bosnia and Herzegovina	23	73,936	3,613	696,731	0.96
Bulgaria	38	100,439	19,958	1,152,556	-0.42
Byelorussia	27	168,647	19,135	1,742,124	0.66
Croatia	27	66,979	4,725	698,966	0.41
Cyprus	10	70,795	7,835	200,452	2.81
Czech Republic	67	69,523	1,776	1,165,581	-0.31
Denmark	103	30,764	4,909	1,089,957	0.56
Estonia	24	35,604	3,763	394,024	-0.37
Finland	45	52,141	5,580	558,457	2.25
France	377	57,208	1,087	2,138,551	0.24
Germany	896	50,881	1,007	3,383,782	0.58
Greece	56	71,704	1,131	729,137	1.14
Hungary	61	72,694	18,580	1,708,087	-0.08
Iceland	18	12,513	1,059	113,906	0.91
Irish Republic	22	79,442	9,164	1,024,027	1.38
Italy	426	64,857	1,268	2,563,241	0.34
Latvia	32	42,893	2,264	742,572	0.05
Lithuania	39	53,382	9,867	542,366	-0.37
Luxembourg	19	6,825	1,508	76,684	1.14
Macedonia	27	37,952	16,267	474,889	3.61
Malta	17	10,297	5,053	21,676	0.92
Moldova	35	37,064	3,829	635,994	-0.18
Netherlands	160	59,884	17,144	741,636	0.72
Norway	37	55,702	9,561	811,688	0.85
Poland	189	86,652	18,677	1,651,676	0.61
Portugal	76	41,785	4,066	517,802	1.07
Romania	104	85,502	1,841	1,877,155	0.88
Russia[a]	270	112,613	1,473	4,039,745	0.52
Serbia	15	95,833	1,379	1,273,651	1.38
Slovakia	33	57,295	21,343	423,737	0.11
Slovenia	35	20,711	1,064	255,115	0.31
Spain	251	86,308	19,172	3,117,977	1.75
Sweden	95	50,429	10,168	1,253,309	0.25
Switzerland	115	23,603	1,277	341,730	0.44
Turkey	135	178,389	14,137	3,517,182	3.26
Ukraine	130	106,478	2,467	2,514,227	-0.64
United Kingdom	426	83,007	1,136	7,421,209	0.36
Total:	4,667				

[a] only urban settlements located in the westernmost part of the country are covered by the analysis

APPENDIX 2

Descriptive statistics of the research variables

Variable	All localities				'High density clusters'				'Low density clusters'			
	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
Population growth rate (un-standardized)	-4.56	13.40	0.62	1.24	-3.80	8.73	0.75	1.07	-4.56	13.40	0.59	1.27
Population growth rate (country-standardized)	-4.02	13.14	0.51	1.17	-3.78	8.60	0.60	1.08	-4.02	13.14	0.49	1.20
Population size (ln)	6.91	15.82	10.46	1.00	7.35	15.82	10.80	1.09	6.91	13.10	10.37	0.96
Distance to sea shore (km)	0.00	1285.04	133.47	153.47	0.03	1217.96	100.49	100.94	0.00	1285.04	142.21	163.51
Distance to major city (km)	0.00	1517.55	114.37	128.77	0.00	74.80	21.85	16.74	6.52	1517.55	138.90	134.29
Climatic harshness	-0.29	76.35	8.19	9.07	-0.26	40.86	5.74	6.65	-0.29	76.35	8.84	9.50
Latitude (dd)	27.92	69.97	48.84	5.90	36.72	60.18	48.97	4.45	27.92	69.97	48.81	6.23
Distance to sea shore*	0.00	7.20	1.00	0.83	0.00	4.47	1.08	0.86	0.00	7.20	0.98	0.82
Distance to major city*	0.00	11.33	1.00	0.71	0.00	1.17	0.30	0.26	0.03	11.33	1.19	0.67
Climatic harshness*	0.71	1.28	1.00	0.05	0.83	1.11	1.01	0.03	0.71	1.28	1.00	0.05
Latitude*	-0.46	13.33	0.99	0.93	-0.46	7.55	0.83	0.76	-0.37	13.33	1.04	0.96
IC1 (ln)	0.00	16.37	13.98	2.06	0.00	16.37	15.43	1.12	0.00	16.03	13.59	2.08
IC2 (ln)	0.35	16.37	9.92	2.12	11.78	16.37	12.79	0.80	0.35	11.78	9.16	1.66
Number of cases	4667				978				3689			

* Country-normalized values

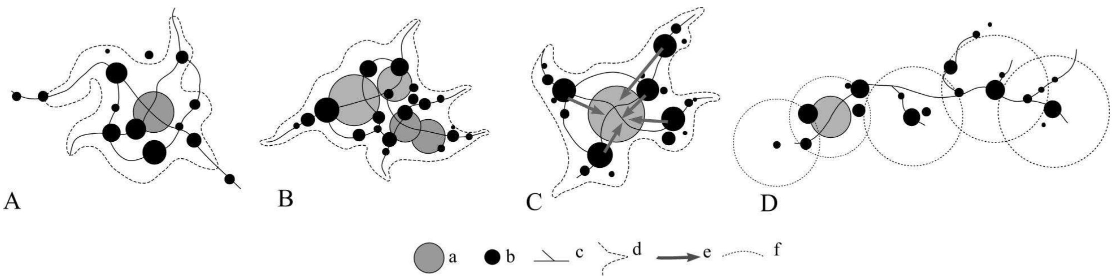

FIGURE 1: Basic Concepts Pertinent to Geographic Concentrations of Urban Settlements.

A – Agglomeration; B – Conurbation; C- Metropolitan area; D – Urban clusters
A – major city; b – local town; c – road network; d – agglomeration/conurbation boundary; e - functional dependency; f – urban clusters

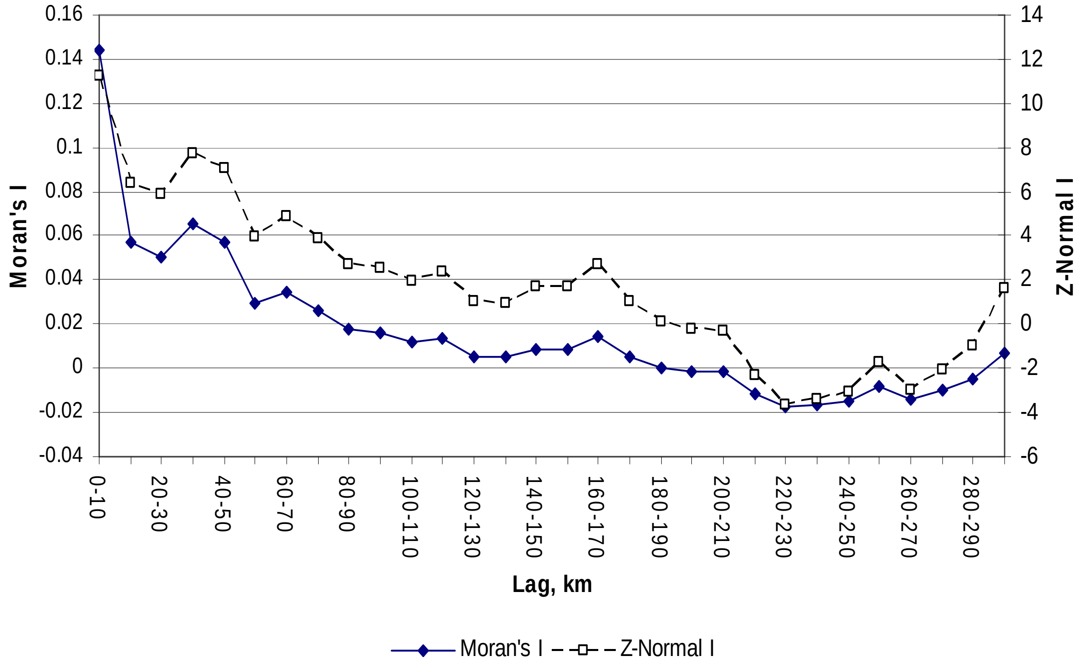

FIGURE 2: Spatial Autocorrelation of Population Growth Rates (Moran's *I* Index and its *Z*-statistic)

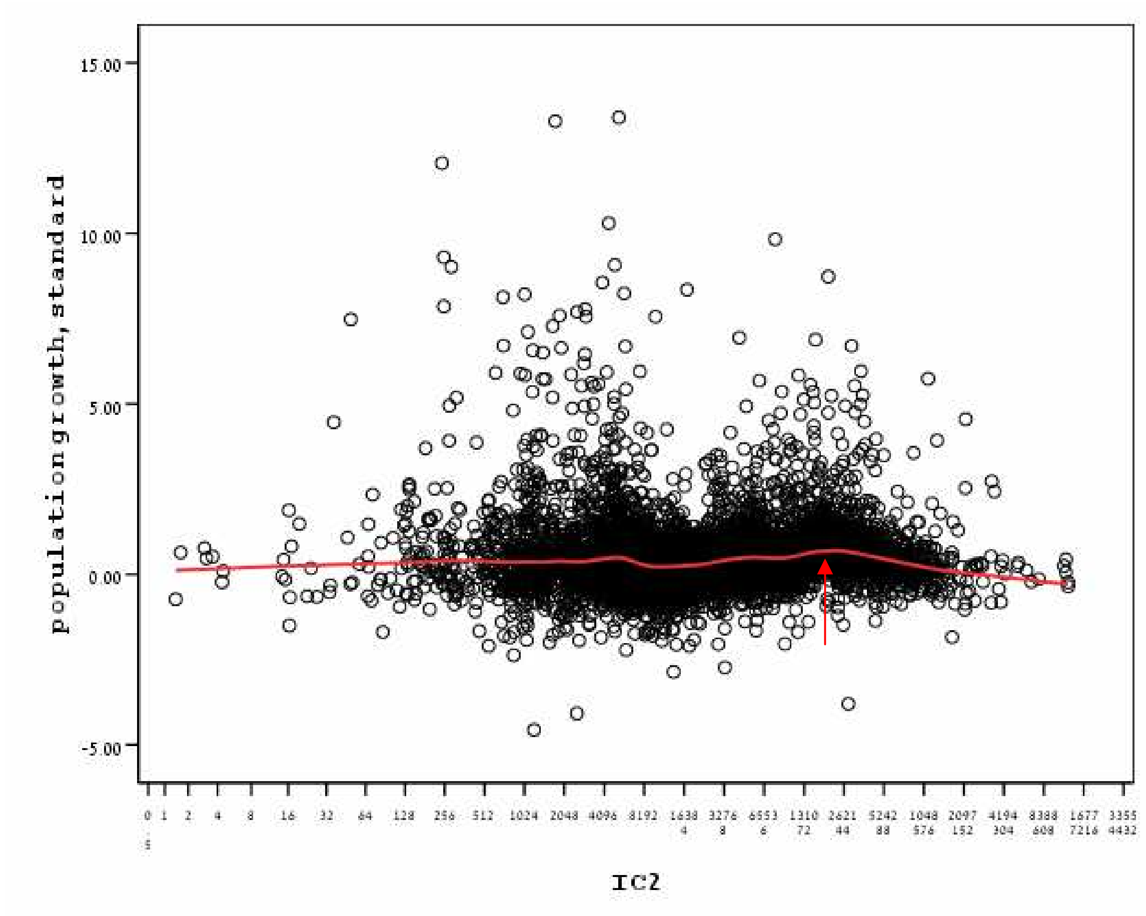

FIGURE 3: Index of Clustering (IC2) vs. Population Growth of Towns

(Trend line is estimated by the Loess fit method - 20% point *Epanechnikov* kernel)