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The Improbable Nature of the Implied Correlation Matrix from Spatial Regression Models*

Abstract

Spatial lag dependence in a regression model is similar to the inclusion of a serially autoregressive term for the dependent variable in a time-series context. However, unlike in the time-series model, the implied covariance structure matrix from the spatial autoregressive model can have a very counterintuitive and improbable structure. A single value of spatial autocorrelation parameter can imply a large band of values of pair-wise correlations among different observations of the dependent variable, when the weight matrix for the spatial model is specified exogenously. This is illustrated using cigarette sales data (1963–1992) of 46 US states. It can be seen that that two "close" neighbours can have very low implied correlations compared to distant neighbours when the weighting scheme is the first-order contiguity matrix. However, if the weight matrix can capture the underlying dependence structure of the observations, then this unintuitive behaviour of implied correlation is corrected to a large extent. From this, the possibility of constructing the weight matrix (or the overall spatial dependence in the data) that is consistent with the underlying correlation structure of the dependent variable is explored. The suggested procedures produced very positive results indicating further research.

Keywords: Spatial Dependence, Variance-Covariance matrix, Implied Correlation Structure, Weight Matrix.

Introduction

The key idea of modelling spatial data is that a set of locations can characterise the dependence among the observations. One of the many general ways to do this is to define a neighbourhood structure based on the shape of a lattice. Among others, this measures the distance between centroids of the regions. Once this spatial dependence structure is determined or assumed based on distance (social/economic/physical) or adjacency, models resembling time-series autoregressive structures are considered. The two very popular models that take into account such spatial dependence structure are simultaneously

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autoregressive (SAR) and conditionally autoregressive (CAR) models. The SAR and CAR models were originally developed by Whittle (1954) and Besag (1974), respectively, mainly on the doubly infinite regular lattice. On a regular lattice, these models resemble the well-understood stationary time-series model defined on the integers. On an irregular lattice, however, which is most common in economic applications, the effect that the exogenously defined arbitrary neighbourhood structure and spatial correlation parameter have on implied covariance structure is not well understood. Wall (2004) was probably the first to carry out a systematic analysis of the impractical nature of the correlation structure implied by the SAR and CAR models, and this issue has spurred some further inquiries, see for instance Martellosio (2009).

This paper highlights the problem of implied structure of the SAR model in case of an irregular lattice and suggests a possible solution. Although the proposal is for the SAR model, it can be easily extended to the CAR model. Section 2 provides a summary of the existing literature. Section 3 sets up the notations and states the SAR model. Section 4 presents a spatial regression example on cigarette sales data on 46 US states where the spatial model is compared with ordinary least square case and highlights the unintuitive and impractical behaviour of the implied correlation structure when the usual neighbourhood matrix is used. The findings reconfirm the results of Wall (2004). Section 5 first gives the basic idea behind the authors W matrix construction and then estimates W using the Levenberg-Marquardt nonlinear optimization procedure. Section 6 demonstrates how the developed W matrix helps to correct the implied correlation structure and gives a more intuitive result using the same dataset as in Section 4, Section 7 concludes the paper.

Summary of relevant previous work

Although the implied correlation structures of the spatial models have such a peculiar pattern, it is quite surprising that this issue has received relatively little attention in the literature, given that these models are so widely used in a variety of applications. Haining (1990) and Besag and Kooperberg (1995) mentioned resulting heteroscedasticity from the SAR model with homoscedastic error term. They also pointed out about the unequal covariance between regions that are at same distance apart. The very first systematic treatment of this problem was probably done by Wall (2004). She provided a detailed description of the implied structure of SAR and CAR models, and in particular, considered the dependence and covariance structures on an irregular lattice. Using the US state level summary data of SAT verbal score for the year 1999, she investigated the relationship between the correlation ρ and the implied pair-wise correlations among the scores of various states when W was based on first-order neighbours. The implied spatial correlations between the different states using the SAR and CAR models did not seem to follow an intuitive or practical scheme. For example, Wall (2004) found that for the SAR model Missouri and Tennessee are constrained to be the least spatially correlated states, than Tennessee and Arkansas, although all of them are first-order neighbours. Martellosio (2009) shed some further light on how the correlation structure of the SAR model depends on W and ρ and explained this inconsistency using graph theory. He showed that implied correlation between two spatial units depends on a particular type of walks (in a graph theoretic sense) connecting the units. When $|\rho|$ is small, the correlation is largely

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determined by short walks; however, for large values of $|\rho|$, longer walks have more importance. Since ρ can be estimated only after W has been chosen, one cannot control the correlation properties by specifying W. Defining W based on graph, his work explains the inconsistency of ranking of implied correlations between pair of locations as ρ changes.

The SAR model

Let $\{y(A_i): A_i \in (A_1 \dots A_n)\}$ be a Gaussian random process where $(A_1 \dots A_n)$ are n different locations. The value of the variable y in location A_i depends on the values in its neighbouring locations A_j. One way to model this dependence is by the simultaneous autoregressive (SAR) model:

$$y=\rho Wy+X\beta+\varepsilon \qquad (1)$$

where y is a n×1 vector observation on the dependent variable, ρ is the spatial autoregressive parameter, $W \equiv ((w_{ij}))$ is n×n spatial weight matrix representing degree of potential interactions between neighbouring locations (geographic/economic/social), X is n×k matrix of observations on the explanatory (exogenous) variables, β is k×1 vector of regression coefficients and ε is a n×1 vector of error term with $\varepsilon \sim (0, \sigma^2 I_n)$.

Spatial effects are incorporated using the row-standardised weight matrix W. One common way to do this is to define $W = (w_{ij})$ is

$$w_{ij} = \begin{Bmatrix} 1 \text{ if } A_i \text{ shares a common edge or border with region } A_j \ (i \neq j) \\ 0 \text{ otherwise} \end{Bmatrix}$$

The other ways to define the neighbourhood structure W is to express weights as functions of the distance between two points or as functions of the length of borders. For ease of interpretation, the weight matrix is often standardised so that the elements of each row sum to one. Ensuring that all the weights are between 0 and 1, facilitates the interpretation of operations with the weight matrix as an averaging of neighbourhood values. It also ensures that the spatial parameters of different models are comparable. This is not intuitively obvious, but relates to constraints imposed in a maximum likelihood estimation framework, specifically the spatial autocorrelation parameter must be in the interval $[1/\omega_{min}, 1/\omega_{max}]$, where ω_{min} and ω_{max} are, respectively, the smallest and largest eigen values of W [Cliff and Ord (1980)]. For a row-standardised matrix, the largest eigen value is always +1, and this facilitates the interpretation of ρ as "correlation" coefficient.

It is easy to see that the implied covariance matrix of y for model (1) is given by

$$Var(y) = \sigma^2 (I-\rho W)^{-1} (I-\rho W)^{\prime -1} \qquad (2)$$

Using (2), the pair-wise correlations $corr(y_i, y_j) = \rho_{ij}$, $i, j=1,2,\dots, n, i\neq j$ can be calculated. However, these ρ_{ij} values can apparently have "no connection" with the values of w_{ij} and ρ. To demonstrate this, we use the widely applied cigarette sales data on 46 US States. We show that a single value of ρ can imply a large band of values of ρ_{ij} with the same w_{ij} values. The findings confirm the results of Wall (2004). We then construct a W matrix that is "consistent" with the underlying correlation structure of y. Finally, we further investigate the behaviour of implied correlations for the same model using the constructed W matrix, and show that the use of the weight matrix eliminates all the unintuitive behaviour of implied correlations.

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An example

In order to analyse the spatial interaction and implied correlation structure of the SAR model, the 1963–1992 cigarette sales data on 46 US States, that has been widely used for panel data analysis by Baltagi and Levin (1992) and Baltagi, Griffin and Xiong (2000), and later by Elhorst (2005) for spatial panel analysis, is considered. The underlying model is:

$$\log(C) = \alpha + \rho W \log(C) + \beta_1 \log(P) + \beta_2 \log(Y) + \beta_3 \log(Pn) + \epsilon, \qquad (3)$$

where C is real per capita sales of cigarettes to persons of smoking age (14 years and older), measured in packs of cigarettes per capita; P is the average retail price of a pack of cigarettes measured in real terms; Y is the real per capita disposable income, and Pn denotes the minimum real price of cigarettes in any neighbouring state. This last variable is a proxy for the casual smuggling effect across state borders, and acts as a substitute price attracting consumers from high-tax states to cross over to low-tax states. As in Elhorst (2005), we follow the conventional form of row-standardised first-order neighbourhood weight matrix, and in Table 1 present the estimation results based on 1992 cross-section data of the 46 states.

Table 1

Estimation Results of Model (3) (Standard errors are in parentheses)

Parameters	OLS	SAR(W=row-standardised first-order contiguity)
β_1	−1.24(0.31)	−1.15 (0.29)
β_2	0.17(0.32)	0.27(0.30)
β_3	1.03(0.19)	0.74(.15)
Ρ	N/A	0.28(0.14)
σ^2	0.05	0.04
Log Likelihood		25.78
R^2	0.15	0.18

To illustrate the behaviour of the implied correlation structure from the estimated SAR model, in Figure 1, the histogram covers of all the implied *first-order* neighbour correlations and demonstrates a wide variation. The smallest correlation is 0.09 that occurs between Missouri and Tennessee and the largest correlation, equal to 0.37, occurs between New Hampshire and Maine. Wall (2004) also noted smallest and largest implied correlations *exactly* for these states, although she used *different* data (1999 US statewide average SAT verbal scores) and model. The common feature between Wall's and this example is the W matrix, more specifically, Maine has only one neighbour, i.e., New Hampshire, and Tennessee and Missouri have 7 and 8 neighbours, respectively. Also, the qualitative nature of the histograms of Wall (in her Figure 3 with ρ =0.60) and this paper are very similar. Therefore, it can be stated that implied correlation is simply a function of the first-order neighbours each state has.

To elaborate further on the implied correlations of Missouri and Tennessee with their 8 and 7 neighbours, respectively, from Table 2 it should be noted that Missouri is more correlated with Kansas than with Tennessee, and Tennessee is more correlated with its neighbour Alabama than with Missouri. Such peculiarity arises mainly due to the nature of covariance matrix (2) that involves inversion of the sparse matrix $(I - \rho W)$.

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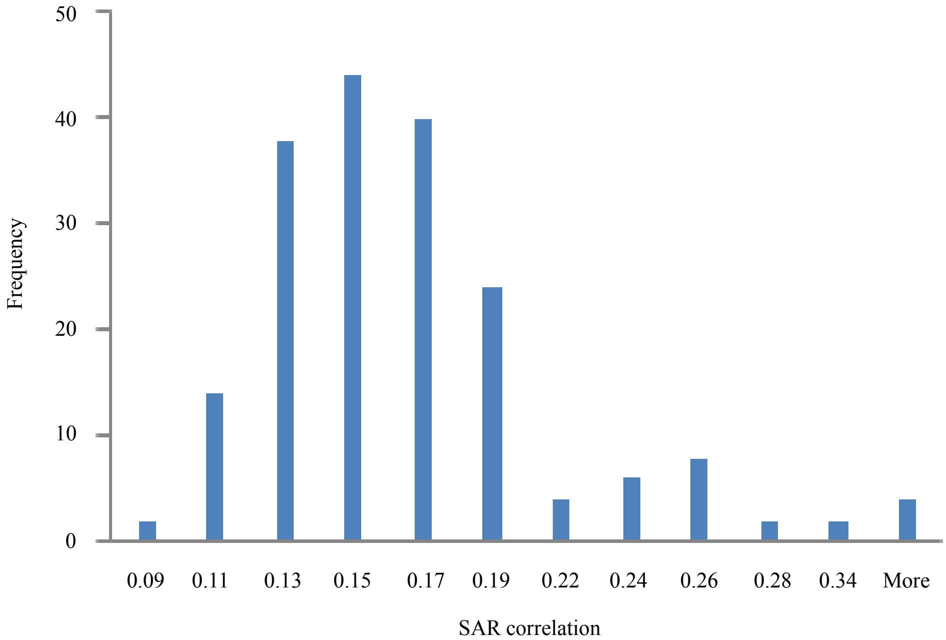
Figure 1

Histogram of implied correlations



The relative ranking of the states using implied spatial correlation almost coincides with that of Wall (2004). These two datasets have no connection economically, and ranking of implied spatial correlation is determined by the prior fixed weight matrix.

Table 2

Implied correlation between first-order neighbours of Missouri and Tennessee

Missouri		Tennessee	
1st order neighbours	Implied correlation	1st order neighbours	Implied correlation
Arkansas	0.0965	Alabama	0.1354
Illinois	0.1062	Arkansas	0.1036
Iowa	0.0977	Georgia	0.1256
Kansas	0.1516	Kentucky	0.0931
Kentucky	0.0879	Mississippi	0.1325
Nebraska	0.1108	Missouri	0.0873
Oklahoma	0.1110	Virginia	0.1044
Tennessee	0.0873		

Figure 2 demonstrates that the relationship between the implied correlation and number of neighbours is not that simple. If number of neighbours is less, then implied correlation is strong. There is a band in which the implied correlations vary for a given number of neighbours, with less heterogeneity for an extreme number of neighbours.

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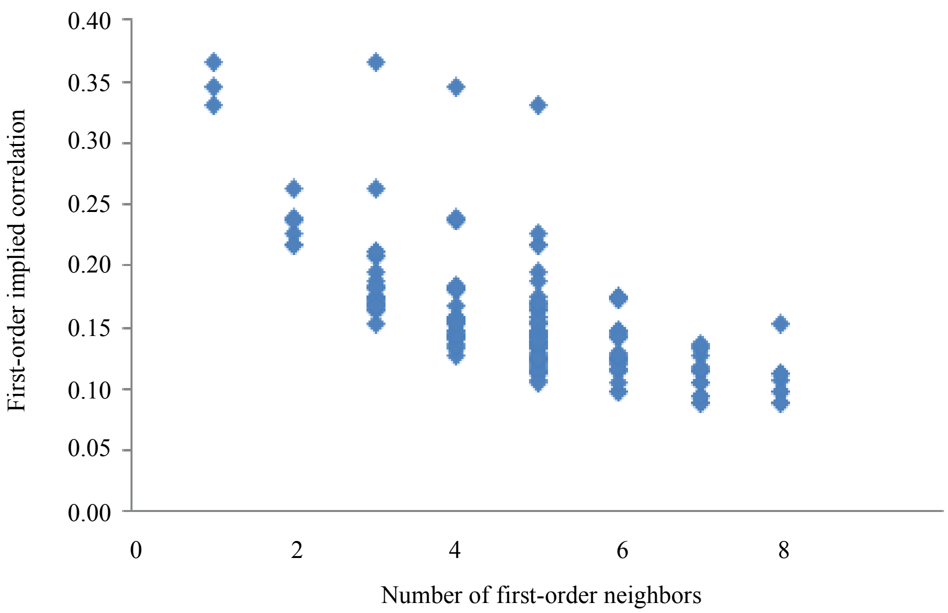
Figure 2

Implied correlations of SAR model



The paper now focuses on how implied correlations behave as functions of true parameter ρ (i.e., irrespective of data). From Figures 3a and 3b, it can observed that for any given ρ, there is a high variability in correlations among all the pairs of observations. For example, when ρ=0.1, the implied correlations vary from 0.03 to 0.13; while for ρ=0.6, they vary from 0.25 to 0.73. From Figure 3a, this can be observed from the red arrows as marked. As ρ increases, the implied correlations of all locations increases monotonically, which matches the behaviour of autoregressive models in a time series, i.e., correlation increases with the autoregressive parameter. However, as observed in Figure 3b, the most unintuitive behaviour is that as ρ changes, there are many lines that *cross each other*, implying the inconsistency of ranking of relative implied correlations. For example, when ρ=0.2 the correlation (Missouri, Arkansas) =0.17 and correlation (Tennessee, Arkansas) =0.24. However, when ρ=0.7, then correlation (Missouri, Arkansas) =0.33 and correlation (Tennessee, Arkansas) = 0.26. Wall (2004) reported the same phenomenon. Therefore, the implied correlations of SAR model with first-order neighbour *W* matrix do exhibit some unintuitive and impractical behaviour. The marked area in the Figure 3b shows the crossing of implied correlation lines.

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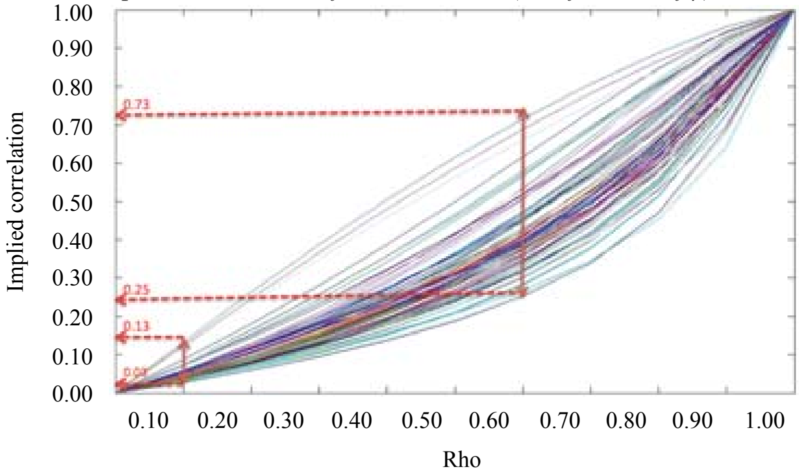
Figure 3a

Implied correlations of the SAR model (as a function of ρ)

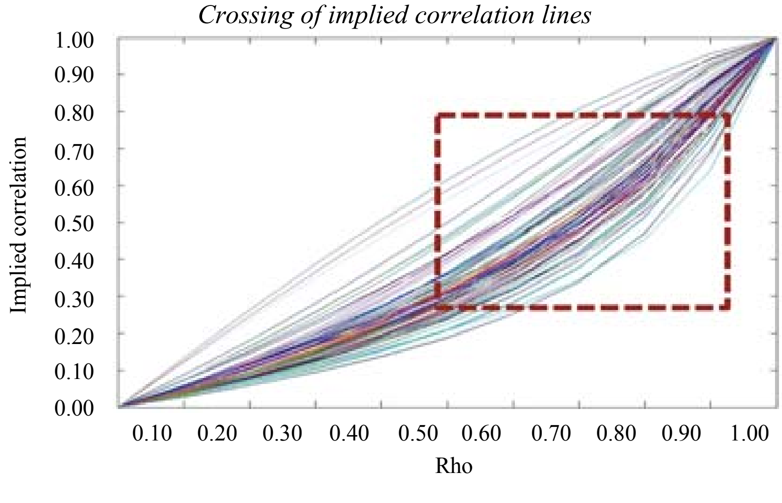


Numerical optimization

It is a general understanding that the weight matrix captures the "spatial dependence" of the observations as Ord (1975) stated that the (i, j)th element of W "represents the degree of possible interaction of location j on location i". However, each element of $(I\text{-}\rho W)^{-1}(I\text{-}\rho W)'^{-1}$ provides the correlation structure of y. As evident from Wall (2004) and from Fig. 3a, if one expresses the spatial dependence in terms of neighbourhood matrix W, then the covariance from $(I\text{-}\rho W)^{-1}(I\text{-}\rho W)'^{-1}$ does not have a strong connection to the spatial correlation.

Figure 3b

Crossing of implied correlation lines



The choice of spatial weights is a central component of spatial models as it imposes a priori structure on spatial dependence. Although the existing literature contains an implicit acknowledgement of the issues of choosing an appropriate weight matrix, most empirical

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studies treat W to be a known, fixed and arbitrary spatial weight matrix (Giacomini and Granger 2004). It is proposed to construct the weight matrix using *past* time-series data to remove the odd features of implied correlations discussed previously.

Suppose the dependent variable y_i is observed over n locations, where i=1…n for t=1,…,T in the *past* T periods. Given y_i for T periods, we estimate the variance-covariance matrix $V(y) = \Sigma$, whose (i,j)th element is given by $\frac{1}{T}\sum_{t=1}^{T}(y_{it} - \bar{y}_i)(y_{jt} - \bar{y}_j)$, where $\bar{y}_i = \frac{1}{T}\sum_{t=1}^{T} y_{it}$ and $\bar{y}_j = \frac{1}{T}\sum_{t=1}^{T} y_{jt}$. Our objective is to investigate the implied correlation structure of a SAR model at the current time, therefore, construction of the weight matrix based on *past* T periods helps us to avoid the endogeneity issue.

We solve the following system for W

$$\sigma^2(I - W)^{-1}(I - W)^{-1'} = \Sigma,$$

We can take $\sigma^2 = 1$, which will have no consequence for our solution to W. Also, since W is row standardised, the solution will be invariant to ρ. Therefore, without loss of generality we solve

$$(I - W)^{-1}(I - W)^{-1'} = \Sigma,$$

i.e.,

$$(WW') - (W + W') = \Sigma^{-1} - I. \qquad (4)$$

We need to find W that solves the equation (4) subject to

i) $w_{ii} = 0$

ii) $w_{ij} \geq 0$

iii) $\sum_j w_{ij} = 1$

ii) and iii) imply the range of w_{ij}, i.e., $0 \leq w_{ij} \leq 1$. Alternatively, our objective is to find a solution to a constrained system of nonlinear equations:

$$F(w) = I + (w * w') - (w + w') - \Sigma^{-1} = 0, \quad w \in \mathrm{W}, \qquad (5)$$

where $W \subseteq R^{m+}$ is a nonempty, closed and convex set and $F: O \longrightarrow R^m$ is a given mapping defined on an open neighbourhood O of the set W. Here $m = n^2$, where n is the number of locations. W^* is the set of solutions to (5). To solve (5) we consider the related optimization problem:

$\min f(w)$ subject to the constraints as above, where $f(w) := ||F(w)||^2$, and $\|.\|$ is the Euclidean norm.

The Levenberg (1944) and Marqaurdt (1963) algorithm (LM) that interpolates between the Gauss-Newton algorithm and method of gradient descent is used, as in many cases, the LM algorithm is more robust than Gauss-Newton as it finds a solution even if it starts very far off from the optimal values. It is an iterative procedure where in each step *w* is replaced by *w+d*. To determine the increment vector *d*, the function *F(w+d)* are approximated by their linearisation using Taylor Theorem i.e., $F(w + d) \approx F(w) + J * d$, where

$J = \partial F(w)/\partial w$ is the gradient of *F* with respect to *w*. At its minimum, the gradient of *f* with respect to *d* will be zero. The above 1st order approximation gives

$f(w + d) := ||F(w + d)||^2 \approx ||F(w) + J * d||^2$.

Taking derivative with respect to *d* and setting the result equal to zero gives

$(J^T J)d = -J^T F(w)$, where *J* is the Jacobian term. This gives us a set of linear equations that can be solved for the increment vector *d*. The Levenberg-Marquardt contribution is to replace this equation by a '*damped version'*,

$$\left(J^{T}J + \mu * diag\left(J^{T}J\right)\right)d = -J^{T}F(w).$$

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The main difference between Gauss-Newton and the LM algorithm is in terms of normal equations. In the LM algorithm, the normal equations are modified in such a way that the increment vector *d* is always rotated towards the direction of steepest descent.

In a more formal way, LM type method for this system of equations generates a sequence $\{w^k\}$ by setting $w^{k+1} = (w^k + d^k)$, where d^k is the solution to the linearised sub-problem:

$$min\ \theta^k(d) = ||F(w^k) + J_k d||^2 + \mu_k ||d||^2, s.t \qquad w^k + d \in W \qquad (6$$

Here, J_k is an approximation of Jacobian of $F'(w^k)$ and μ_k is the positive parameter. Note that $\theta^k(.)$ is a strictly convex quadratic function; hence the solution d^k of (6) always exists uniquely. Since our constraints are of box constraints type, any iterate w^k can be projected easily into the feasible region *W*. The feasible region of *W* is such that any w ∈ W has the structure defined by the above constraints. Therefore, we set $w^{k+1} = P_W(w^k + d_u^k),\ k = 0,1, \ldots,$ where P_W is the projection matrix and d_u^k is the unique solution to the *unconstrained* sub-problem:

$$min\ \theta^k(d_u),\ d_u \in R^m.$$

We call this the projected LM method since the unconstrained step gets projected onto the feasible region *W*. The projected version of LM algorithm needs significantly less time per iteration since the strict convexity of the function $\theta^k(.)$ ensures that a global minimum is reached at d_u^k if and only if $\nabla\ \theta^k(d_u{}^k) = 0$, i.e., if and only if $d_u{}^k$ is the unique solution of the system of linear equations [For detailed discussion on the Levenberg-Marquardt Method, see Numerical Optimization by Nocedal and Wright (2006)]:

$$\left(J_k{}^T J_k + \mu_k diag(J_k{}^T J_k)\right) d_u = -J_k{}^T F(w^k). \qquad (7)$$

The step-by-step algorithm is as follows:

S1) Choose $w^0 \in W, \mu > 0,\ v > 1, \gamma > 0$ and set $k = 0$, tolerance = $1e - 10$.

S2) If $F(w^k) <$ tolerance, then Stop, otherwise go to S3.

S3) Compute $J_k = F'(w^k)$.

S4) $Set\ \mu_k = \mu/v^k$ and compute $d_u{}^k$ as a solution to (7).

S5) If $||F(P_W(w^k + d_u^k)|| \leq \gamma ||F(w^k)||$, then set $w^{k+1} = P_W(w^k + d_u^k)$, update k to k+1 and go to S2; Otherwise go to S6.

S6) Set $\mu_k = \mu * v^k$ and compute $d_u{}^k$ as a solution to (7).

S7) If $||F(P_W(w^k + d_u^k)|| \leq \gamma ||F(w^k)||$, then set $w^{k+1} = P_W(w^k + d_u^k)$, update k to k+1 and go to S2.

Note, if any k^{th} iteration comes to S6, then for k+1th iteration onwards, it will flow as S2 → S3 → S6 → S7. This is due to the choice of dampening factor as suggested by Marquardt (1963). If there is no reduction in residual by setting $\mu_k = \mu/v^k$, then the dampening factor is increased by successive multiplication by v until a better point is found with the new dampening factor $\mu_k = \mu * v^k$ for some k. However, if the use of $\mu_k = \mu/v^k$ results in the reduction of residuals, then this is taken as a new value of μ and the process continues. In other words, as μ_k gets small, the algorithm approaches the Gauss-Newton algorithm, if μ_k becomes large with successive iterations, it approaches the steepest gradient algorithm. The Levenberg-Marquardt technique is a "blending" between these two extremes, and uses a steepest descent type method until our objective function approaches a minimum, and then gradually switches to the quadratic rule. It tries to guess the proximity to a minimum by how the error is changing. The intuition is simple; i.e., if error is increasing, then our quadratic approximation is not working well and we are likely not near a minimum, so we should increase μ_k in order to blend more towards simple gradient descent. Conversely, if error is decreasing, our approximation is working well, and we expect that we are getting closer to a minimum so μ_k is decreased to bank more on the Hessian. The algorithm we used is very similar to the projected LM algorithm of Kanzow-Yamashita-Fukushima (2002). As long as F is affine and twice continuously differentiable, any accumulation point of the sequence $\{w^k\}$ generated by our algorithm is a stationary point of (6).

Application of the proposed solutions

The SAR model for the year 1992 is estimated using the proposed weight matrix in Section 5.1. In order to avoid endogeneity problem, the *W* matrix using the data on *C* (Cigarette sales) from 46 states for the period 1963-1991. The model is the same as in Equation (3).

Table 3 provides the estimates of the SAR model using the standard *W* matrix, and the numerically solved *W* using the Levenberg-Marquardt algorithm.

Table 3

Estimation Results of Model (3) (Standard errors are in parentheses)

Parameters	SAR(*W*=Constructed using the LM algorithm)	SAR(*W*=row-standardised first-order contiguity)
β_1	–1.10 (0.29)	–1.15 (0.29)
β_2	0.18 (0.29)	0.27 (0.30)
β_3	0.55 (0.17)	0.74 (0.15)
P	0.45 (0.16)	0.28 (0.14)
σ^2	0.03	0.04
Log Likelihood	26.37	25.78
R^2	0.27	0.18

It is clear that the estimated SAR model using the proposed *W* matrix is as good as (if not better than) the standard *W* in terms of log likelihood values.

Figure 4 plots the first-order implied correlation as a function of weights from the estimated *W*. Out of 46*46=2116 pairs of locations, the 188 first-order neighbour correlations are plotted. First, arrange the weights of 188 pairs of first-order neighbours are arranged in ascending order, and then the implied correlations are sorted out in ascending order as well. From Figure 4, note that the implied correlations have a very slow increasing trend with weights. There is also little variation in contrast to Figure 2 (where number of neighbour increases means weight decreases), which displayed much higher variation.

Implied correlations of the SAR model for different values of ρ are plotted in Figure 5. In contrast to Figure 3, now for each value of ρ, the band of variation of implied correlations is very narrow in Figure 5. For example, when ρ=0.1, the implied correlations vary only between 0.004 and 0.006; while for ρ=0.6, they vary from 0.09 to 0.11. Also now there is no crossing, and thus the inconsistency of the ranking of implied correlations seen in Figure 3, is absent in Figure 5.

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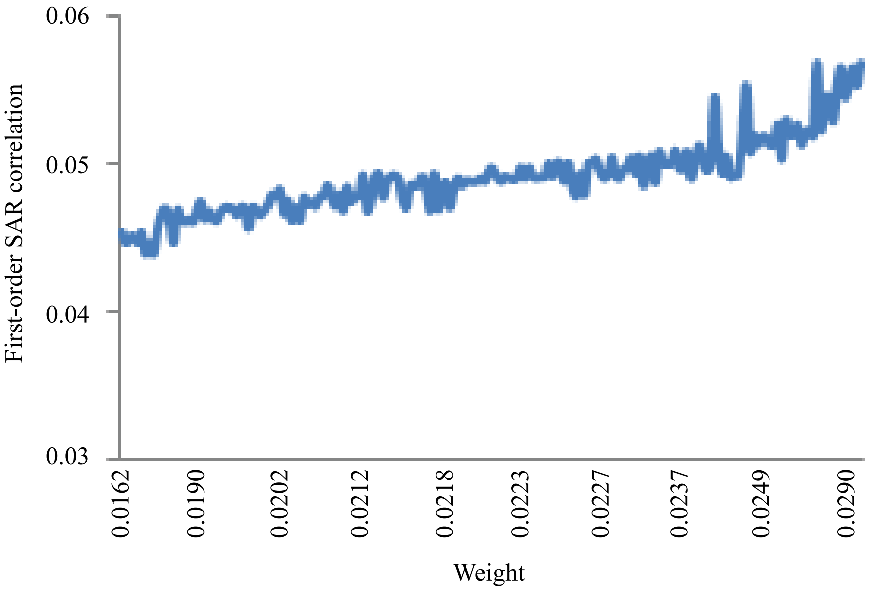
Figure 4

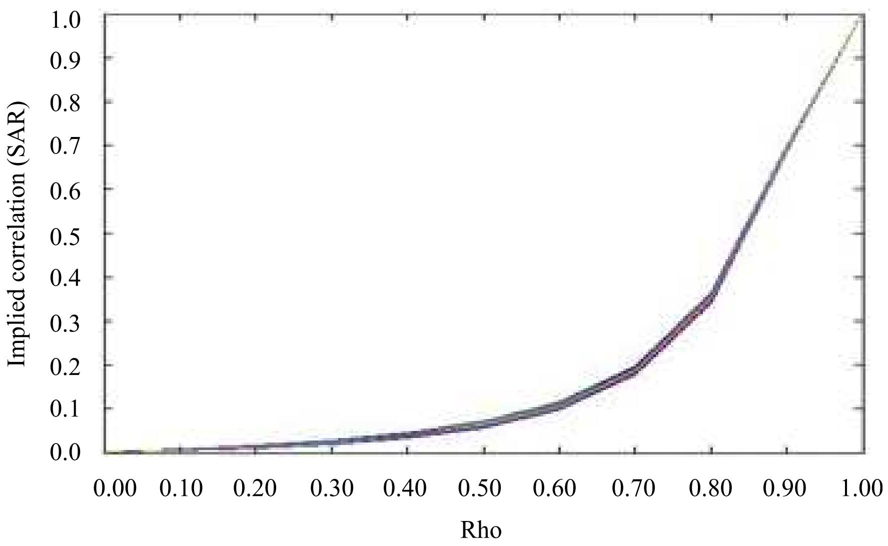
First-order correlations of SAR model (W=Constructed)



How implied correlations behave as function of ρ is examined in Figure 5.

Figure 5

Implied correlations of SAR model (as a function of ρ)



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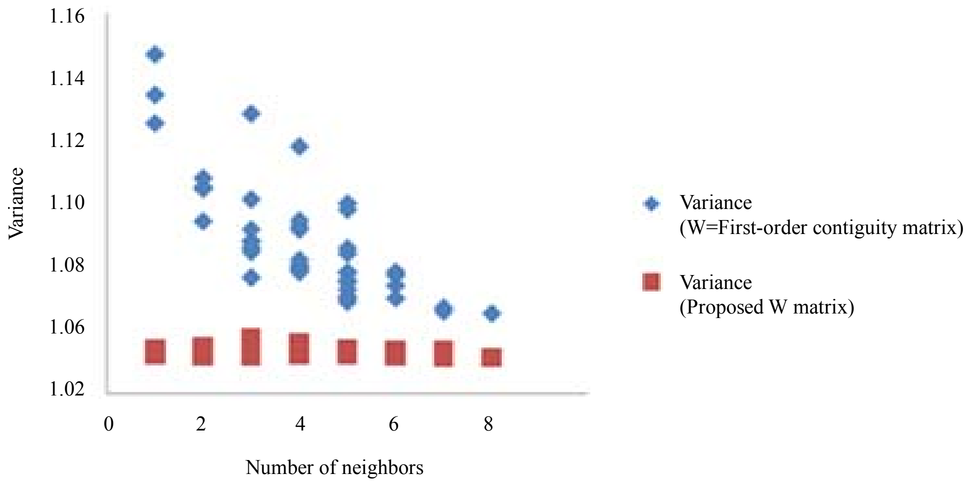
To address the implied heterogeneity of the SAR model, in Figure 6, the 46 diagonal elements of Σ as a function of the number of first-order neighbours are plotted. Using the first-order contiguity matrix leads to substantial variation of implied variances of y_i (that decreases with the number of neighbours). In contrast, the proposed W matrix leads to much less variation.

Figure 6

Variance comparison of 46 US States



Conclusion

The paper first demonstrates the unintuitive and impractical nature of the implied correlations implied by the estimated SAR models with row-standardised neighbourhood matrix. It then proposes a simple methodology for estimation of spatial weight matrix that yields very intuitive results in terms of implied correlations. Finally, the proposed methodology is illustrated using real data on cigarette sales. Although the methodology is applied only for the SAR model, it can be easily extended to the CAR model. For CAR, Var(y) $=\sigma^2(I-\rho W)^{-1}$, which is a variation of Equation (2). Therefore, the procedure can be applied to yield a W that is consistent with the underlying dependence structure. Another interesting extension that the authors would like to address in future is the influence of W on the impact (direct and indirect) factor, which can be obtained from Equation (1) as $\frac{\partial y_i}{\partial x_{jk}} = g_k(i,j)$, where $g_k = (I-\rho W)^{-1}\beta_k, i,j = 1,2,\dots,n$ and $k = 1,2,\dots,K$. This has a simpler structure than the implied covariance matrix in Equation (2), and thus, as the referee conjectured, the two W matrices (binary contiguity and the "estimated" one) may give similar results.

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Economies of Scale in Local Communal Services in Hungary*

Abstract

Knowledge of whether, and over what range of output, there are economies or diseconomies of scale in providing local communal services is an important question from a theoretical, practical and regional political point of view. The theoretical side of the question is connected to the primary research regarding the optimal city size. If an optimal city size can actually be established, then a valid policy argument can be made for fostering its approximation. However, theoretical considerations are sometimes based on those types of assumptions, which are often not valid in reality. Therefore, empirical investigations are essential in this research area.

After a short theoretical overview, the paper initially gives a general outline of previous controversial empirical evidence on economies of scale regarding community size and the provision of local communal services. In the second part, the empirical findings are presented; these concern economies of scale in local communal services based on a large and detailed database, which consist of almost 300 Hungarian settlements. During the research, a number of methodological questions have occurred. For example, there are several solutions for the organisational structure providing local services, from a large holding to the smaller individual companies. Considering this and some other issues, the main results suggest that on a community level, there are moderate economies of scale in water supply, sewage disposal and district heating and a moderate diseconomy of scale in refuse collection until 5 thousand inhabitants. Above this level there is no connection between the settlement size and the average cost of services. The results are mainly consistent with the previous findings: there are economies of scale under a certain threshold, but after this, unit cost reduction is not feasible. This threshold can be different in the different types of services.

Keywords: economies of scale, local communal services, Hungary.

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Introduction

Knowledge of whether, and over what range of output, there are economies or diseconomies of scale in providing local communal services is an important question from theoretical, practical and regional political point of view. The theoretical side of the question is connected to the primary research concerning the optimal city size. If optimal city size can actually be established, then a valid policy argument can be made for fostering its approximation. However, theoretical considerations are sometimes based on those types of assumptions, which are often not valid in reality. Therefore, empirical investigations are essential in this research area.

This paper will be organised as follows. After a short theoretical overview, it gives a general outline about the previous controversial empirical evidences on economies of scale in the community and providing local communal services. In the second part, we present our empirical findings concerning to economies of scale in local communal services based on a large and detailed database which consist of almost 300 Hungarian settlements. The main results suggest that on a community level there are moderated economies of scale in water supply, sewage disposal and district heating and moderated diseconomies of scale in refuse collection until five thousand inhabitants. Above this level, there is no connection between the settlement size and the average cost of services. This result is mainly consistent with the previous findings: there are economies of scale under a certain threshold, but after this, unit cost reduction is not feasible. This threshold can be different in the different types of services.

Theoretical background

Classic economies of scale relate to the effect on average costs of production of different rates of output. Economies of scale or scale economies exist if increased output goes hand in hand with lower average costs. The sources of economies of scale can be manifold, most of them can be classified either as technical or organisational reasons: mechanization, specialization, division of labour, vertical and horizontal integration and so on.

Economies of scale is a simple concept on a conceptual level but its measurement is very difficult in practice, where the measurement of "output" and "cost" can be highly complicated. The simplest case, the homogenous quality of only one output is extraordinarily rare in reality. The vast majority of the controversial results of the empirical investigations in a wide range of various activities (industrial activities and services) can be traced back to the definitional and measurement problems of output and costs and/or to the treatment of quality considerations. Measuring the output of a school, hospital or public administration is extremely difficult. Cost of production can also be very different, not only due to problems of non-monetary costs elements, but when taking into consideration the costs that arise for the consumer (for example transportation cost, quality considerations), not just from the side of the producer. Analysis and comparison of local communal services has to cope with other difficulties besides the pure qualitative problems: the significant institutional variation between local government administration in the same country, different population densities, and geographical environment and

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settlement structure variations between the same size settlements. However, quantitative analysis must choose some form of measurement.

There is an important practical difference between the private enterprises of industries and services and the communal services of the public sector. As a result of competition, there is a permanent pressure on private enterprises to take advantage of the potential economies of scale and to avoid uneconomic solutions. This is one motivation for mergers and disintegration or outsourcing. Public communal enterprises have three constraints to achieving the optimal organisational size: regulation, the fixed size of settlements and the fixed locality as an outer condition. The third constraint is the most severe. Regulation can also facilitate the utilization of economies of scale. Joint services are a feasible opportunity in many cases, which can manage at least partly the constraints of settlement size.

Theoretically, city size may lead to economies and diseconomies of scales. Larger city size may enable the spreading of overhead costs over a large number of people, reducing unit costs and thereby achieving economies of scale. Besides these factors, larger cities have a more varied public sector, with units of services beyond the optimum scale. However, among smaller local government units, the competition becomes more intensive, which leads to greater efficiency and lower costs. Empirical investigations are necessary to discover the real connections between city size and average cost of services.

Previous studies

There are few empirical studies about the economies of scale in local communal services and the cost of local administration in Hungary, despite that the question is often mentioned theoretically and in political discussions, both on settlement level and higher-level reorganisation of spatial structures. On a settlement level, the fragmented structure with several very small autonomous settlements is criticized as inefficient (Verebélyi 1993). Empirical investigations of local public services, such as nursery, elementary school, and cost of general administration suggest that the average cost of various activities is slightly different between the various size categories of settlements, but the difference cannot be interpreted as an economy of scale. For example, the lowest average cost of administration can be detected in large villages (population above 5000 inhabitants); both smaller villages and larger cities have higher average costs, but the difference is very small (Fekete et al. 2002, p. 51–57.). Other papers in this publication deal with Poland, Slovakia and Bulgaria and have found slight economies of scale in administration costs (Swianiewicz 2002).

There are economies of scale in solid waste and sewage-water management (Hermann et al. 1998, Kerekes 2002). However, the increasing transportation cost was not taken into consideration in these results. Bálint Koós and Mihály Lados conducted research about the size and number of settlements. According to their results, the number of settlements is not too large; however, the large number of various tasks of the settlement and the lack of joint services between settlements is a real problem (Koós–Lados 2008). György Budaházy's (2013) analysis regarding economies of scale in land registry offices was conducted on a county level. His results show that there is a linear connection between the size of the county and the cost of the land registry office: simply, a twice the size county has twice the costs.

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The number and time horizon of empirical investigations in various other countries is, of course, enormous and cannot be reviewed in a short paper. It is worth stressing the contradictory character of various results. General statements without any empirical evidence are quite common in reports of various advisory boards. Size of a school district in USA is a classic example. School district consolidation in USA from the 1930s was motivated by the belief that economies of scale existed in this service. "Although the validity of this assumption was never tested, 'Bigger is Cheaper' became the mantra of the profession as future generations of administrators were taught to believe" (Robertson 2007, p. 620). However, the growing empirical literature suggests that administrative efficiencies can be increased by merging small districts into larger ones, but only within limits, which lies somewhere between 500 and 1000 students. When this threshold is crossed, it will often result in decreased administrative efficiencies (Hanley 2007).

Local government reforms in many countries focus on compulsory council consolidation, amalgamation of smaller administrative units into larger ones under the slogan of efficiency, and enhancing the planning and administrative capacities. This is true, for example, for Australia (Dollery et al. 2010), Greece (Hlepas 2010), Denmark (Vrangbaek 2010), Germany (Wollmann 2010) and Macedonia (Kreci–Imeri 2010). However, empirical proofs of the slogans are rare and mixed. In "Moderning Local Government" by the Committee for Economic Development in USA the following quote is telling: "The most pressing problem of local government in metropolitan areas may be stated quite simply. The bewildering multiplicity of small, piecemeal, duplicative, overlapping local jurisdictions cannot cope with the staggering difficulties encountered in managing modern urban affairs. The fiscal effects of duplicative suburban separatism create great difficulty in the provision of costly central city services benefitting the whole urbanized area. If local governments are to function effectively in metropolitan areas, they must have sufficient size and authority to plan, administer, and provide significant financial support for solutions to area-wide problems" (cited by Hutcheson–Prather 1979, p. 166). According to this, increasing the size of jurisdictions would supposedly allow economies of scale to accrue to local governments and enhance the efficiency of service delivery systems. However, empirical evidence shows little sign of economies of scale. A pioneering work by Hirsch, using data from 149 local governments around St Louis and in Massachusetts, found that growth and consolidation appear to have little, if any, significant effect on per capita expenditures for fire protection, police protection, refuse collection, and other similar services. These make up the vast majority (80–85%) of all city expenditures. Consolidation of water and sewage services, accounting for approximately 10% of total expenditure, leads to a decline in per capita expenditures until a very large scale is reached. After this point, there are no further economies of scale (Hirsch 1959).

Gabler's paper analysed the connection between settlement size and average cost for several functions, such as highways, police, fire service, sewerage and sanitation, parks and recreation, general expenditures. In most cases the per capita expenditures are larger in larger towns, that is, diseconomies of scale exist, except for highways (Gabler 1971). Hutcheson and Prater (1979) show that 1% increase of population goes hand in hand with 1.2% increase in the size of administration. Andrews and Boyne (2009) have opposite results in their paper about English local authorities: the relationship between population size and back office cost is negative; economies of scale might be achieved by

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amalgamating smaller councils into larger units. Knapp's paper deals with the economies of scale of crematoriums in England. This analysis is particularly interesting, because the cost structure and the output can be accurately measured. Economies of scale exist until 3000 cremations, above this level there are diseconomies of scale due to the more complex coordination (Knapp 1982).

The interpretations and comparisons of results are not easy, because almost every local government service unit has a variety of quality dimensions. "In assessing the influence of population size on urban public sectors, however, it is necessary to note that the concepts of diseconomies and economies of scale assume a constant level of service quality" (Gabler 1971, p. 131). For example, increasing the size of the schools leads to loss of personalisation, lower motivation of teachers, parents and students. Growing service units means larger distances from the consumer and greater transportation costs. In residential refuse collection, the frequency and the manner of collection, the care and reliability of the removal services, cleanliness, quietness and courtesy of collection crew are important factors. Provision of water and sewer service is influenced by natural conditions.

Almost every service is influenced by the population density. Some writers emphasize the spatially explicit economies of density instead of spatial economies of scale (Walls et al. 2005, Nauges–van der Berg 2008). Drew et al. (2012) point out that when areas are decomposed into subgroups (in the Australian research area) on the basis of density, the evidence of scale economies largely disappears. Buettner et al. (2004) show that on a regional level, there are no connections between population density, the size of population and public expenditure. "Per capita expenditures tend to be almost constant in response to changes in the size of population, indicating that most of the goods provided by the state governments tend to be quasi-private goods" (Buettner et al. 2004, p. 510). According to Holcombe and Williams (2009), municipal government expenditures are characterised by constant returns to scale (examining 487 municipalities above 50 thousand inhabitants in the USA), but population density and various demographic factors influence the level of expenditure of local governments. Ladd argues that a U-shaped relationship exists between population density and the cost of providing public services: average cost is highest in sparsely populated areas and at higher density. Ladd's data set consisted of 247 large counties in the USA, 59 percent of the population of the USA (Ladd 1992).

In a recent survey, Saal et al. summarised the results of more than 20 examinations on the efficiency of the water industry. Typically, there are economies of scale up to certain output level, and diseconomies of scale after the optimal point. However, the optimal is situation-dependent and differs largely from country to country. (Saal et al. 2013)

Database of the analysis

The analysis intended to build a temporal database with company-level business data in the following areas of communal services: water supply, sewage disposal, refuse collection, district heating, general communal services, property and real estate management. In building the database, several practical problems were confronted: correct identification of activities, frequent temporal changes in organisational structure, mixed and holding structure of companies. Each company was checked individually. Due to the temporal matching problems, the database is static. Each year from 2002 to 2011 has its

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unique classification. Because of the abundance of data and the similarity of the results, only the results of the latest year, 2011 are shown.

The division according to sectors and settlement size can be seen in Table 1 and Table 2. The only city above 250 thousand inhabitants is Budapest, which is an outlier with its 1.7 million inhabitants. Every large city (above 50 thousand inhabitants) is represented in the database as well as the majority of medium sized settlements. In smaller settlements categories, the rate of investigated settlements is smaller. Mixed services category means integrated companies with every local public service. There is duplication in the table, because some companies provide more than one service, typically water supply and sewage disposal.

Table 1

The number of settlements and companies

Size of the settlement (thousand inhabitants)	Number of settlements in the analysis	District heating	Water supply	Sewage disposal	Refuse collection	Mixed services (holding structure)
250.0–	1	5	2	5	1	1
100.0–250.0	8	10	13	13	15	5
50.0–100.0	12	7	13	13	14	3
30.0– 50.0	21	7	20	12	13	5
20.0– 30.0	18	6	12	8	11	3
15.0– 20.0	24	10	21	14	16	8
10.0– 15.0	35	12	20	14	15	3
7.5– 10.0	27	0	25	16	7	3
5.0– 7.5	32	3	20	17	8	5
2.5– 5.0	55	1	34	22	10	5
– 2.5	60	1	24	26	10	0
Total	*293*	*62*	*204*	*160*	*120*	*41*

Table 2

The number of settlements

Size of the settlement (thousand inhabitants)	Number of settlements in Hungary	Number of settlements in the analysis
250.0–	1	1
100.0–250.0	8	8
50.0–100.0	12	12
30.0– 50.0	21	21
20.0– 30.0	21	18
15.0– 20.0	29	24
10.0– 15.0	52	35
7.5– 10.0	46	27
5.0– 7.5	100	32
2.5– 5.0	332	55
– 2.5	2,535	60
Total	*3,157*	*293*

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Analysis

Economies of scale could be best analysed according to the average cost, namely the ratio of total cost and the output. Yet for the output, data is not available in real terms, only monetary data. Therefore, six proxies are used. These can be seen in Table 3. Four of them use the number of inhabitants as denominator. Population is not the best measure for four reasons: settlement borders are sometimes arbitrary, some services (water and sewage) serve several neighbouring settlements, the number of inhabitants and the number of served persons can be different, and the composition of inhabitants (age structure, income level, unemployment rate and other socio-economic factors) can also vary. However, without other data, population figures provide the best available solution. The other ten indicators use only company level data (number of employees and various fiscal indicators). The first indicator can be treated as the primary index of economies of scale: a smaller value indicates more cost efficient activities, although, as mentioned previously, quality and other differences are disregarded. Other indicators are supplements for the broader view and rather show the effect of size on organisational structure and labour/capital ratio.

Table 3

Proxies for economies of scale

Number of proxy	Short description of indicator
1 (basic indicator)	Revenues/production costs
2 (secondary indicator)	Production costs/inhabitants
3 (secondary indicator)	Production costs/employees
4 (secondary indicator)	Revenues/inhabitants
5 (secondary indicator)	Revenues/employees
6 (secondary indicator)	Employees/inhabitants

The calculations can be seen in Tables 4–9 for all services together and for each service separately. The general results can be broadly summarised: there is no systematic connection between settlement size and the average cost of the various services. Only the largest settlement (Budapest with 1.7 million inhabitants) and the settlements under five thousand inhabitant show minor economies or diseconomies of scale. Budapest has the smallest average costs in water supply and sewage disposal. The smallest settlements have the lowest average costs in refuse collection, but highest in district heating. These results can be readily explained by the fact that refuse collection is not capital intensive; however central heating and water supply and sewage disposal are capital intensive activities with large fix costs. Large fix costs are the explanation for the absence of district heating in the vast majority of smaller settlements. However, between five thousand and 250 thousand inhabitants there are no clear tendencies in of either economies of scale or diseconomies of scale.

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Table 4

Indicators for all services (continued)

Settlement size	Number of indicators (see Table 3)					
	1	2	3	4	5	6
250.0–	0.88	9.06	32.08	10.30	36.47	0.28
100.0–250.0	0.97	21.15	15.80	21.83	16.32	1.34
50.0–100.0	0.96	51.60	18.40	53.80	19.19	2.80
30.0– 50.0	0.96	28.58	10.36	29.76	10.78	2.76
20.0– 30.0	0.98	53.73	9.92	54.77	10.11	5.41
15.0– 20.0	0.99	40.54	12.02	40.85	12.11	3.37
10.0– 15.0	0.95	25.00	10.30	26.24	10.81	2.43
7.5– 10.0	0.96	22.49	7.85	23.49	8.19	2.87
5.0– 7.5	0.94	32.42	10.50	34.43	11.15	3.09
2.5– 5.0	0.99	31.36	7.74	31.62	7.81	4.05
– 2.5	0.87	42.59	11.62	49.08	13.39	3.67
Total	*0.94*	*17.48*	*16.62*	*18.67*	*17.75*	*1.05*

Source: Own calculation based on company level data.

Table 5

Indicators for district heating

Settlement size	Number of indicators (see Table 3)					
	1	2	3	4	5	6
250.0–	0.97	13.62	113.02	13.98	115.98	0.12
100.0–250.0	1.05	44.94	30.98	42.95	29.61	1.45
50.0–100.0	0.98	155.09	60.29	158.94	61.79	2.57
30.0– 50.0	1.00	30.30	19.52	30.31	19.52	1.55
20.0– 30.0	1.07	55.64	18.11	52.07	16.94	3.07
15.0– 20.0	1.03	79.81	30.12	77.64	29.30	2.65
10.0– 15.0	1.05	27.42	32.17	26.14	30.67	0.85
7.5– 10.0	0.97	28.60	11.52	29.59	11.92	2.48
5.0– 7.5	1.24	39.43	14.00	31.71	11.26	2.82
2.5– 5.0	1.36	31.85	9.74	23.44	7.16	3.27
Total	*1.00*	*25.27*	*49.64*	*25.35*	*49.79*	*0.51*

Source: Own calculation based on company level data.

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Table 6

Indicators for water supply

Settlement size	Number of indicators (see Table 3)					
	1	2	3	4	5	6
250.0–	0.85	6.93	18.58	8.17	21.89	0.37
100.0–250.0	0.93	22.61	11.46	24.26	12.30	1.97
50.0–100.0	0.97	57.34	11.23	59.36	11.62	5.11
30.0– 50.0	0.96	39.68	9.48	41.36	9.88	4.19
20.0– 30.0	0.98	86.49	9.90	88.17	10.09	8.73
15.0– 20.0	0.96	42.29	9.24	43.85	9.58	4.58
10.0– 15.0	0.92	26.57	8.56	28.93	9.32	3.11
7.5– 10.0	0.95	24.00	7.04	25.23	7.40	3.41
5.0– 7.5	0.96	27.48	7.98	28.51	8.28	3.44
2.5– 5.0	0.99	25.10	6.09	25.27	6.13	4.12
– 2.5	1.09	29.16	8.48	26.73	7.77	3.44
Total	*0.94*	*24.43*	*10.66*	*25.91*	*11.31*	*2.29*

Source: Own calculation based on company level data.

Table 7

Indicators for sewage disposal

Settlement size	Number of indicators (see Table 3)					
	1	2	3	4	5	6
250.0–	0.70	3.30	23.52	4.72	33.67	0.14
100.0–250.0	0.93	18.12	10.67	19.51	11.49	1.70
50.0–100.0	0.95	50.15	11.55	52.71	12.14	4.34
30.0– 50.0	0.95	52.75	9.75	55.47	10.26	5.41
20.0– 30.0	0.98	107.31	10.73	109.11	10.91	10.00
15.0– 20.0	0.98	41.39	7.43	42.08	7.56	5.57
10.0– 15.0	0.93	31.22	8.67	33.60	9.34	3.60
7.5– 10.0	0.92	28.84	9.47	31.29	10.28	3.05
5.0– 7.5	0.98	36.54	14.79	37.39	15.13	2.47
2.5– 5.0	1.03	19.41	8.22	18.78	7.95	2.36
– 2.5	1.05	29.96	9.66	28.52	9.19	3.10
Total	*0.90*	*13.95*	*11.32*	*15.47*	*12.56*	*1.23*

Source: Own calculation based on company level data.

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Table 8

Indicators for refuse collection

Settlement size	Number of indicators (see Table 3)					
	1	2	3	4	5	6
250,0–	0.83	19.19	11.72	23.13	14.13	1.64
100,0–250,0	0.92	16.66	11.74	18.16	12.80	1.42
50,0–100,0	0.90	18.40	12.67	20.52	14.13	1.45
30,0– 50,0	0.84	19.36	8.48	23.00	10.08	2.28
20,0– 30,0	0.91	30.11	7.80	33.13	8.58	3.86
15,0– 20,0	0.93	26.53	9.20	28.57	9.91	2.88
10,0– 15,0	0.93	27.77	8.46	29.71	9.06	3.28
7,5– 10,0	0.97	25.67	9.75	26.45	10.05	2.63
5,0– 7,5	0.84	42.84	12.44	51.05	14.83	3.44
2,5– 5,0	0.94	76.39	9.97	80.87	10.56	7.66
– 2,5	0.70	119.69	16.22	171.71	23.27	7.38
Total	*0.88*	*20.12*	*10.81*	*22.85*	*12.28*	*1.86*

Source: Own calculation based on company level data.

Table 9

Indicators for mixed services (holding structure)

Settlement size	Number of indicators (see Table 3)					
	1	2	3	4	5	6
250.0–	0.83	19.19	11.72	23.13	14.13	1.64
100.0–250.0	0.95	33.25	12.34	35.04	13.00	2.69
50.0–100.0	0.87	30.41	11.09	34.84	12.71	2.74
30.0– 50.0	1.01	25.58	10.01	25.27	9.89	2.56
20.0– 30.0	0.88	43.07	6.19	48.89	7.03	6.96
15.0– 20.0	1.08	28.55	7.06	26.42	6.53	4.05
10.0– 15.0	1.08	51.40	8.61	47.55	7.97	5.97
7.5– 10.0	1.43	19.05	4.29	13.30	2.99	4.44
5.0– 7.5	1.02	28.30	5.61	27.86	5.52	5.04
2.5– 5.0	0.95	20.52	7.72	21.64	8.14	2.66
Total	*0.90*	*25.19*	*10.64*	*27.96*	*11.81*	*2.37*

Source: Own calculation based on company level data.

Summary and further research

In the paper, an overview was taken of the connection between settlement size and the average cost of communal services, referring also to the perennial question of optimal settlement size. The results suggest that there is no optimal settlement size from the point of view of communal services. Only the small settlements (under approximately five thousand inhabitants) have some minor cost disadvantages in activities with high fixed

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capital costs (water supply, sewage disposal, central heating). The next stage of the research will include some of those factors that were mentioned in the broader introduction: the cost structure, the effect of settlement structure and population density, the number of served individuals and furthermore some demographic and socio-economic factors, which have potential influence on the economic status of communal service companies. The explanation of the significant differences in secondary indicators (such as revenues/inhabitants, assets/employees) will also be examined.

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ESZTER SIPOSNÉ NÁNDORI[a)]

The Role of Economic Growth and Spatial Effects in Poverty in Northern Hungary

The study examines how the recent economic crisis and the related unfavourable economic features affect poverty. As economic crisis is usually associated with many economic and social problems, it tries to determine to what extent it influences poverty. The paper attempts to prove that economic recession contributes not only to the impoverishment of a significant section of society, but also increases the depth of poverty significantly. If the research supports this hypothesis, it is worth examining to what extent one percent economic growth or economic decline can decrease or increase the rate of the poor and the depth of poverty. Besides the effect of economic growth on the given area, the paper also analyses the effect of the economic growth of the neighbouring areas. The initial hypothesis states that the economic growth of the neighbouring regions can also alleviate poverty. As for spatial effects, spatial autocorrelation is examined in the average income level to reveal how the economic growth of the neighbouring areas affects a given region.

The study examines Northern Hungary, one of the most backward regions in Hungary (based on GDP per capita). Eurostat (2010) reports this region is among the poorest twenty regions within the European Union (based on GDP per capita PPP, Northern Hungary is the 259th among the 271 regions of the European Union).

Poverty

There is no exclusive definition for poverty. According to the general definition, one is considered to be poor if (s)he lacks the minimal resources necessary to make ends meet, that is his/her income level falls below a minimal level (Bokor 1987).

Three main concepts of monetary poverty can be distinguished. Absolute concepts of poverty assume that minimum material needs can be defined regardless of space and time. Those who fail to satisfy these minimum needs can be considered poor. The relative conceptions define poverty as living below some relative poverty line (Siposné Nándori 2012). People can be considered to be poor if they fall behind some average wealth level in the society to a certain extent (for example 50, 60 or 70 percent of the mean or median equivalised income level). The other approach of the relative poverty concept defines poverty threshold as an income level below which a predefined part (10 or 20%) of the population lives (Hegedűs and Monostori 2005).

The subjective poverty concept was worked out by two research groups. Van Praag (1971) elaborated the Income Evaluation Question (IEQ) to collect data on subjective well-being. Deleeck and his staff defined the so-called Subjective Poverty Line. Subjective poverty concept can be used in two different meanings. On the one hand, poverty can be

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defined by finding out who people consider to be poor. On the other, it can be defined by collecting peoples' beliefs about their own position in the system of inequalities (Spéder 2002).

Besides its monetary definition, multidimensional concepts of poverty can also be defined that take into consideration non-material socio-economic circumstances that can influence well-being. In this sense, deprived is the person who is in an unfavourable position from different aspects. Therefore, handicaps are accumulated. Accumulated poverty and social exclusion do not, however, refer to the same phenomena. In the case of accumulated poverty, emphasis is put on the output, namely on the deprivation from certain goods and services. Exclusion, however, primarily concentrates on the process leading to poverty (Havasi 2002). This complex view of poverty is important because more people seem to be affected by deprivation if more socio-economic dimensions are taken into consideration rather than defining poverty only by the income level (Bokor 1987).

The European Union elaborated the system of Laeken indicators in 2001, which defines different – mainly relative – measures of poverty. Its application makes it possible to compare different level NUTS regions. The study uses the most common measure of poverty defined by the EU for the calculation: the 60 percent of the median equivalised income.

Provided that the poverty threshold is defined, the most important measures of poverty can be calculated. The most common measure is the poverty rate or headcount index (H) that expresses the ratio of those living below the poverty line within the population (Ravallion 1996).

$$H = \frac{p}{n}, \qquad (1)$$

where p is the number of persons living below the poverty threshold and n is the number of population. This measure describes the extent of poverty. However, it does not provide any information about the depth of poverty. When the financial position of a poor person worsens, the value of the poverty rate will not change at all.

That is why it is also worth computing poverty gap, which measures the distance between the average income of the poor and the poverty threshold. In order to make it comparable over time and space, this measure can be expressed as a percentage of the poverty threshold (this is the so-called poverty gap ratio (PG)).

$$PG = \frac{1}{p}\sum_{i=1}^{p}\frac{g_i}{z}, \qquad (2)$$

where g_i's are the poverty gaps and z is the poverty threshold (Hajdú 1997).

Besides the extent and the depth of poverty, measuring income inequalities is also necessary to get a profound view of poverty. Among other statistics, income inequalities can be measured with the Lorenz-curve or the Gini coefficient.

Sen (1976) postulated two desirable properties of poverty statistics: the monotonicity axiom requires an increase in the poverty level if the income of a poor person decreases while the transfer axiom requires a rise in the value of the poverty measure when a transfer is provided from a poor person to a person with higher income level. The poverty rate (H) meets neither of these axioms, while the poverty gap (PG) violates only the transfer axiom.

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Because of these problems, Sen (1976) elaborated an index of poverty that meets both requirements:

$$P_S = H \cdot [PG + (1 - PG) \cdot G_p], \quad (3)$$

where Gp is the Gini coefficient of the poor persons' income distribution.

The effect of economic growth on poverty

Economists and sociologists have long been debating the nature of the relationship between economic growth and poverty. There are ambiguities about how economic growth affects the conditions of the poor. If economic growth can significantly reduce poverty, strategies relying on economic growth to reduce poverty are probably justified (Bourguignon 2002).

In the 1970s, many economists argued that economic growth is not enough to reduce poverty. In 1974, Chenerey and his staff (1974) found that growth can make an improvement for only two-thirds of the population. Adelman and Morris (1973) had a similar opinion. They said that economic growth decreased the income level of the poor people in absolute and relative terms. Therefore, those who live in extreme poverty were rather hurt than supported by economic growth. Ravallion (2009) drew the same conclusion. He concluded that the growing advantage of beginning from a lower development level cannot be realised when poverty rate is high.

In the evaluation of the theories about the relationship between poverty and economic growth, Kuznets (1955) hypothesis played a significant role. It says that economic growth and poverty are related in an inverted U-shaped curve. It implies that in the early stages of economic growth, income distribution worsens and it only starts to improve when countries reach middle-income status. At the beginning of economic growth, income inequalities increase, this prevents the improvement of the poor's circumstances. Kuznets did not use any time series, just cross-sectional data and theory for his research. Later, economists started to use time series as well to describe the relationship between economic growth and poverty (similar research was carried out by Ravallion (2009), Deininger and Squire (1996), Brno, Ravallion and Squire (1998)). All of these studies tend to reject the Kuznets hypothesis. Empirical findings showed that economic development does not have any significant impact on income distribution (Adams 2003). Deininger and Squire (1996) found several countries where per capita GDP increased significantly while the value of Gini coefficients hardly changed at all.

Later many new findings appeared that supposed a significant relationship between economic growth and poverty. Dollar and Kray (2001) argued that the average income of the poorest part of society grew proportionately with average incomes. Their statement was based on empirical research using data from 92 countries throughout four decades. Kanbur (1987) claims that after a while – even without redistribution – poor people can cross the poverty line and get out of poverty. In the case of a developing country, however, it takes more than twenty years to be lifted out of poverty. Adams (2003) carried out research based on 50 countries and found that economic development reduced poverty significantly because it has little or no impact on income inequalities.

A research examining Northern Hungary between 2000 and 2007 concluded that economic growth can significantly decrease the poverty rate and poverty gap ratio where poverty was defined based on the existence minimum (Siposné Nándori 2009). This

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research, however, did not take into account the effect of the economic growth of the neighbouring regions, nor controlled for the differences in human development.

On the basis of this study and that of Adams (2003), this paper hypothesises that economic growth can reduce the headcount index, the depth of poverty and the Sen-index of poverty at the same time in Northern Hungary. Moreover, that spatial effects are significant in Northern Hungary, i.e. the economic growth of the surrounding areas can also decrease the headcount index, the poverty gap ratio and the Sen-index.

Applied methods

First, the study introduces spatial autocorrelation of the per person net income level in the settlements of the Northern Hungarian region. Spatial autocorrelation refers to the degree of dependency among observations in a geographic space. Calculating spatial autocorrelation will reveal whether the average income level of the neighbouring northern Hungarian settlements has an effect on each other or not. Moran's I is one of the spatial autocorrelation statistics. It requires measuring a spatial weight matrix that expresses the intensity of the spatial relationship between neighbouring observations (Kocziszky 2013). The formula for Local Moran's I is as follows:

$$I_i = \frac{(X_i - \overline{X})}{s_x^2} \cdot \sum_{j=1}^{n} [W_{ij} \cdot (X_j - \overline{X})] \qquad (4)$$

where I is the Local Moran's I statistics, $\overline{X}$ is the mean value of the examined variable, X_i is the value of the given variable in the i^{th} settlement, X_j is all the values of the given variable belonging to all the settlements except for i, s_x^2 is the variance of all the values of the examined variable, the summation over j indicates that only values of the neighbouring areas are included, and W_{ij} is the weights matrix (Tóth 2003). To make the interpretation easier, the weights W_{ij} are usually row standardized and $W_{ii} = 0$ (Anselin 1995).

Local Moran's I is a LISA (local indicator of spatial autocorrelation) statistic (Anselin 1995). Higher Local Moran's I value indicates higher similarity of the given region with its neighbouring regions regarding the examined variable.

Univariate Local Moran's I in Northern Hungary is calculated using GeoDa software (Anselin 2003) and the average per person income level from the database of the National Tax and Customs Administration of Hungary for the 610 settlements (towns and villages) of the region. The weight matrix is calculated by taking into account the five nearest neighbours as this way of creating a weight matrix is possible when the number of cases is more than 600. The number of permutations is 999 to ensure a robust solution. The Local Moran's I is calculated for 2007 and 2012. In this way, it is also possible to reveal if the economic crisis has resulted in any changes in the spatial effects.

The effect of economic growth on poverty can be described with regression analysis. Poverty at country i at time t can be expressed in the following way (Ravallion–Chen 1996):

$$P_{it} = \gamma + \beta \cdot \mu_{it} + \varepsilon_{it} - \beta v_{it} \qquad (5)$$

where P is a measure of poverty in country i at time t, μ_{it} is the measure of economic growth, β is the growth elasticity of poverty with respect to the given measure of economic growth, γ is a constant, ε_{it} is a white noise error term and v_{it} is a country-specific error term. This model ignores every other factor that can influence the relationship between economic

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growth and poverty. That is why the following extended form of this model is used in the further analysis:

$$lgP_{it} = \alpha + \beta_1 \cdot lg\mu_{it} + \beta_2 \cdot lgEDUC_{it} + \beta_3 \cdot lgREG_{it} + a_i + \varepsilon_{it} \qquad (6)$$

where *P* is the poverty measure (headcount index, poverty gap ratio or Sen-index) in county i at time t. The model contains three explanatory variables: μ_{it} as the measure of economic growth (per capita real GDP or per capita real net income), EDUC, the rate of secondary school students in the whole population and REG as the measure of spatial effects (the average level of the GDP of surrounding counties). α is the constant term, β_1 expresses the economic elasticity of poverty; β_2 provides information about the effect of human development on poverty and β_3 provides information about the effect of spatial autocorrelation on poverty. Including REG and EDUC variables in the model makes it possible to control for the different levels of human development and spatial autocorrelation among the counties.

Taking into account the availability of the data, the regression analysis can be carried out for the period 2000–2010 (data for the headcount index are available only from 2003). For this time period, data for the three counties of the Northern Hungarian region (Borsod-Abaúj-Zemplén, Heves and Nógrád) are available; therefore, a panel database is used for the analysis. The regression function is first determined using pooled OLS regression. Then the joint significance level of the different group means as a low p value counts against the null hypothesis that the pooled OLS model is adequate, in favour of the fixed effects alternative. Moreover, the Breusch-Pagan test statistics are examined, where a low p value counts against the null hypothesis that the pooled OLS model is adequate, in favour of the random effects alternative. Based on these significances, if necessary, random effect or fixed effect regression is carried out. All the regression analysis is carried out in the Getl program.

Data about income levels are derived from the personal income tax returns of the National Tax and Customs Administration of Hungary. Even if data can include biases (like hidden income or income from the black economy), the analysis is carried out using these data because of the lack of more reliable data sources. These data are used to calculate the poverty measures. Data about the rate of secondary school students are from the database of the Hungarian Central Statistical Office. Data about surrounding counties outside the country are derived from the database of Eurostat and the IMF.

In the analyses, three measures of poverty are used: the headcount index, the poverty gap ratio and the Sen-index. Measuring economic growth is also possible in several ways. Per capita GDP on purchasing power parity or per capita average income/average consumption are usually used to measure economic growth. In poverty analysis, per capita income or per capita consumption are used as a measure of economic growth by Kuznets (1955), Kanbur (1987), Kakwani (1993), Ravallion and Chen (1996), Bourguignon (2002); Per capita real GDP or GNI is used by Cashin (1995), Collier and Dollar (1999), and both measures are used by Adams (2003). These two kinds of measures do not often agree. Differences are the result of the different definitions of the two measures. Average income and average consumption values come from household surveys, so they are usually highly correlated with household expenses. However, per capita GDP and GNI values are derived from national accounts, where household expenses are residuals. So any errors or omitted items in national accounts result in the deviation of household expenses. Measuring

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average income or average consumption can also have different results. People are usually not very keen on talking about their income and they tend to reject answering questions related to their income level. According to a study made at the beginning of 1990s in Eastern Europe, average consumption level exceeds average income level in 82% of the cases (Milanovic 1998). Many economists believe that data derived from national accounts are more accurate than the results of a representative survey, but Daeton (2001) believes that this is without any basis.

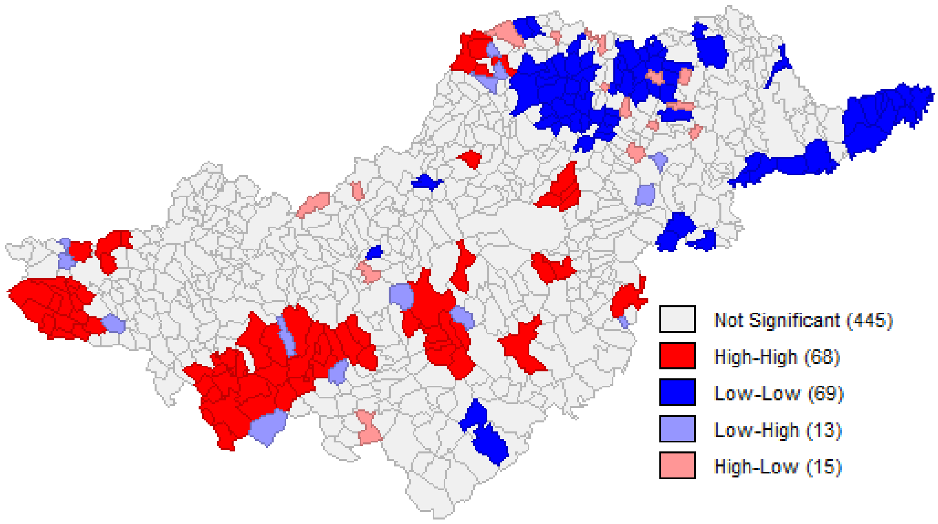
In the analysis, real GDP per capita derived from national accounts and per capita real net income levels are used (published by the Hungarian Central Statistical Office) to measure economic growth. The current GDP and income values are compensated for changes in the value of money using the inflation rate to get values that express the real change.

Spatial autocorrelation

In more than 70% of the settlements of Northern Hungary, autocorrelation was not significant in 2007. Every fifth settlement can be considered either a hot spot or cold spot (refer to Figures 1 and 2).

Figure 1

Local Moran I in the settlements of Northern Hungary, 2007



Source: Own compilation.

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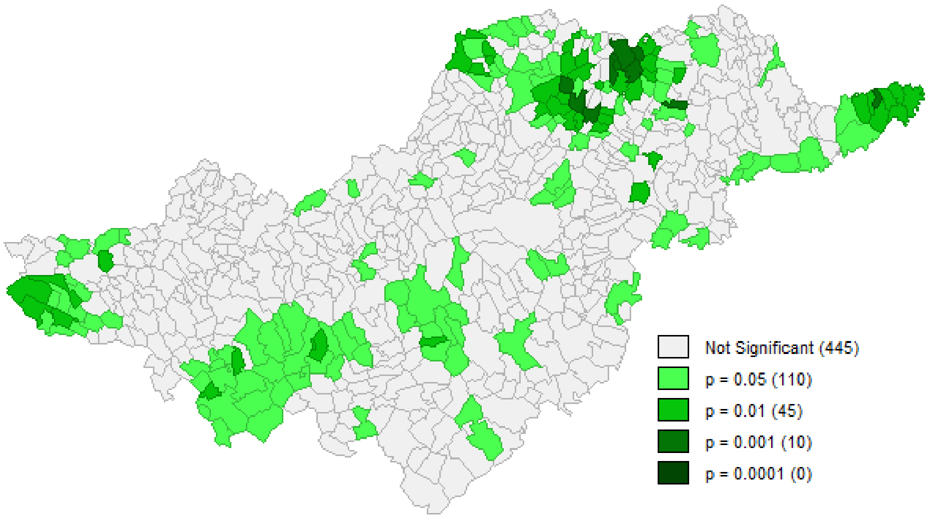
Figure 2

Significance level of the Local Moran I in the settlements of Northern Hungary, 2007



Source: Own compilation.

Hot spots (where settlements with a high-income level are neighboured by settlements with a high-income level) can be found in the Hatvani and Gyöngyösi sub-regions, in the bulk of the Egri (Heves county) and the western part of the Rétsági sub-regions (Nógrád county). Some further small hot spots can also be found in Borsod-Abaúj-Zemplén county (Tiszaújváros, Mezőkeresztes, Bükkaranyos, Nyékládháza, Bükkzsérc, Nagybarca or some settlements northward from Miskolc (Szirmabesenyő, Arnót, Sajópálfala, Sajóvámos) and some others close to the Slovakian border (Aggtelek, Jósvafő, Égerszög, Tornakápolna, Varbóc)).

Out of the 69 cold spots (where settlements with a low-income level are neighboured by settlements with a low-income level), 67 are situated in Borsod-Abaúj-Zemplén county. The majority of the cold spots are situated in the northern and eastern parts of Borsod-Abaúj-Zemplén county: in the bulk of the Bodrogközi, Edelényi, Szikszói and Encsi sub-regions and the southern part of the Sárospataki sub-region. Some further cold spots are isolated in the county: Csobaj, Prügy, Taktakenéz, Alsóregmec, Telkibánya, Abaújvár, Sáta. There are two settlements that belong to the cold spot category in Heves county: Sarud and Fedémes. In Nógrád, there are no cold spots at all.

In 2% of the settlements, mostly (75%) situated in the northern part of Borsod-Abaúj-Zemplén county, the average income level is high, while the neighbouring settlements have low-income levels. In another 2% of the settlements, income level is significantly lower than in the neighbouring settlements. These low-high settlements are distributed evenly in space: five can be found in Borsod-Abaúj-Zemplén, five in Heves and three in Nógrád counties.

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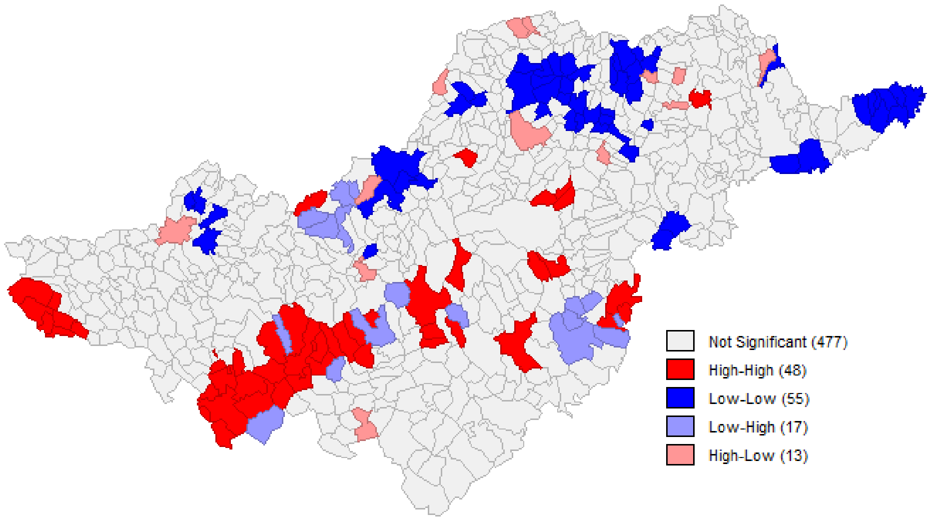
Figure 3

Local Moran I in the settlements of Northern Hungary, 2012



Source: Own compilation.

By 2012, autocorrelation had become not significant in more settlements (78% of the settlements) (see Figures 3 and 4). Eight percent of the settlements were hot spots, situated mainly in the western (in the Gyöngyösi and Hatvani sub-regions) and eastern (Egri sub-region) parts of Heves county, and in the western part of Nógrád county (in the Rétsági sub-region). Some smaller hot spots could also be found in Borsod-Abaúj-Zemplén county (Mezőkeresztes, Hejőkürt, Tiszapalkonya, Tiszaújváros, Bükkaranyos, Nyékládháza, Szirmabesenyő, Arnót, Sajópálfala, Bükkzsérc, Nagybarca and Mogyoróska).

The bulk of the hot spots remained the same from 2007 to 2012. The bulk of the Gyöngyösi, Hatvani, Rétsági, Egri sub-regions remained a hot spot in the examined period probably due to the closeness of the capital city. The smaller hot spots close to Miskolc (one including Bükkaranyos and Nyékládháza and the other one including Szirmabesenyő, Arnót, Sajópálfala) remained in this position probably due to the closeness of Miskolc. The hot spot of Tiszaújváros grew and included three settlements by 2012, probably due to the increasing influence of the town of Tiszaújváros.

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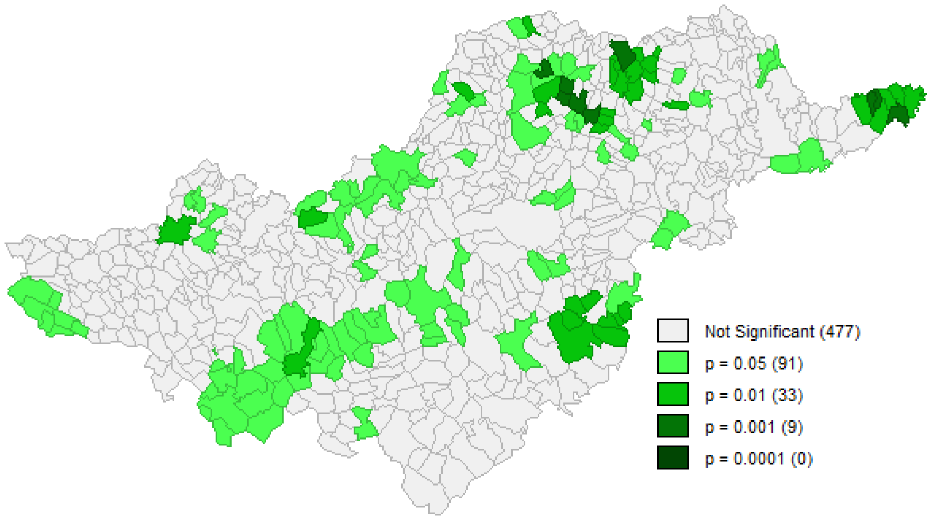
Figure 4

Significance level of the Local Moran I in the settlements of Northern Hungary, 2012



Source: Own compilation.

The number of settlements belonging to the cold spot category decreased to a lower extent than the number of hot spots by 2012. The bulk of the cold spots are situated in Borsod-Abaúj-Zemplén county (in the Bodrogközi, Edelényi, Szikszói, Sárospataki, Szerencsi, Ózdi and Encsi sub-regions). A new cold spot with a rather significant extension can be found in the Ózdi sub-region. Some new cold spots (Nógrádmegyer, Karancsság, Piliny and Szécsényfelfalu) can also be found in the northern part of Nógrád county. Fedémes is the only cold spot in Heves county.

Effect of economic growth on poverty

The parameters of the regression equation can be found in table 1 and 2. The increase of per capita gross domestic product cannot significantly influence any of the examined poverty measures (Table 1). The results of the regression analysis do not support the initial hypothesis. The economic growth of the neighbouring counties, however, can decrease the headcount index as well as the Sen-index. A one percent economic growth decreases the headcount index by 0.003 percent and the Sen-index by 0.0000246 percent.

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Table 1

The effect of economic growth on poverty statistics in the case of pooled OLS (economic growth is measured with per capita GDP) (t values are in brackets)

Explanatory variable	*Regression coefficient if*					
	Y = H	*p value*	*Y = PG*	*p value*	*Y = P_s*	*p value*
Constans	123.32 (9.112)	0.06195	45.777 (7.484)	$8.94*10^{-7***}$	0.407 (7.993)	$<0.00001^{***}$
GDP	–0,009 (–0.838)	0.420	0.0006 (0.048)	0.963	$-4.37*10^{-5}$ (–0.519)	0.614
EDUC	–123.098 (–0.509)	0.621	30.168 (0.113)	0.911	–1.165 (–0.611)	0.554
REG	–0.003 (–5.936)	$9.78*10^{-5***}$	0.0002 (0.448)	0.660	$-2.46*10^{-5}$ (–5.447)	0.0002^{***}
R^2	*0.81*		*0.02*		*0.77*	
Sample size	*24*		*33*		*33*	
Durbin-Watson	*2.13*		*2.41*		*2.48*	
F significance	*0.316*		*0.781*		*0.449*	
Breusch-Pagan test significance	*0.391*		*0.211*		*0.325*	
Fixed or random effects alternative model	–		–		–	

Source: Own computation based on the database of the National Tax and Customs Administration of Hungary.

By examining the F and the Breusch-Pagan test significances, it can be concluded that the pooled OLS models are adequate in all cases, so there is no need to carry out other regression analysis.

When economic growth is measured by per capita real income (Table 2), it has a significant effect on the poverty gap ratio. Surprisingly, this relationship is positive, i.e. a 10 percent increase in economic growth increases the poverty gap ratio by 0.002 percent. It does not support the initial hypothesis either, but the theories that argue that economic growth is useful only to a small part of the society and that the poor are rather hurt than helped by it. Per capita net income level does not have any significant effect on the headcount index and the Sen-index.

The economic growth of the neighbouring counties, however, has a significant effect on all examined poverty measures. A one percent economic growth decreases the headcount index and the poverty gap ratio by 0.003 percent and the Sen-index by 2.6 percent.

The F and the Breusch-Pagan test significances show that the pooled OLS is adequate in the case of regressions with per capita net income level.

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Table 2

The effect of economic growth on poverty statistics in the case of pooled OLS (economic growth is measured with per capita net income level) (t values are in brackets)

Explanatory variable	*Regression coefficient if*					
	Y = H	*p value*	*Y = PG*	*p value*	$Y = P_s$	*p value*
Constans	61.606 (10.721)	<0.00001***	54.635 (9.218)	<0.00001***	0.419 (9.319)	<0.00001***
INCOME	–5.771*10– 5	0.585	0.0002 (2.545)	0.021**	$8.661*10^{-8}$ (0.108)	0.916
EDUC	–278.47 (–2.865)	0.0154**	–171.35 (–1.549)	0.140	–2.177 (–2.857)	0.016**
REG	–0.003 (–2.900)	0.0145**	–0.003 (9.218)	0.0453**	–2.589 (–3.166)	0.009***
R^2	*0.81*		*0.30*		*0.77*	
Sample size	*24*		*33*		*33*	
Durbin–Watson	*2.19*		*2.80*		*2.38*	
F significance	*0.266*		*0.409*		*0.258*	
Breusch–Pagan test significance	*0.190*		*0.262*		*0.232*	
Fixed or random effects alternative model	–		–		–	

Source: Own computation based on the database of the National Tax and Customs Administration of Hungary.

Summary

In Northern Hungary, poverty is a big issue, not only in the country, but also in a European context. In the bulk of the northern Hungarian settlements, spatial effects are not significant in economic growth (measured by per person income level). Hot spots can mainly be found in the western part of Nógrád and Heves county while most of the cold spots are situated in Borsod-Abaúj-Zemplén county, mainly in its northern part.

The initial hypothesis about the relationship between economic growth and poverty has to be rejected as neither per capita GDP nor per capita net income level can decrease the examined measures of poverty. Instead, per capita net income level significantly increases the depth of poverty. The initial hypothesis about the relationship between the economic growth of the neighbouring regions and poverty is supported by the current research (the only exception is the effect of per capita GDP on the poverty gap ratio).

The fact that the economic growth of the surrounding areas can decrease the poverty rate and the Sen-index implies that the recent economic recession increases poverty along with many other unfavourable economic and social consequences. It means that the income of an increasing number of people falls below the poverty line, and they become poor. Significant economic growth of the neighbouring areas could play an important role in the poverty alleviation of the Northern Hungarian region. Another interesting result is that economic growth of a given county is currently not enough to reduce poverty. Other means are also necessary to improve the conditions of those living in poverty. This also raises the necessity of state help.

A possible extension of the study in the future is possible with the use of more poverty measures, like income inequalities statistics. This would further increase the reliability of the analysis.

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How the spatial distribution of the Hungarian TOP 500 companies affects regional development: an examination of income generation at subnational scale

Abstract

The research paper emphasizes the importance of export from the aspect of economic development. In the first part, the theoretical background of the regional development connected to export-led growth is introduced. As a bridge between the theoretical and empirical part, the territorial sense of export data and economic spaces is highlighted. In connection to the research, actual domestic research examining spatial differences and inequalities in Hungary is presented. The reviewed researches (Dusek–Lukács–Rácz 2014, Nemes Nagy–Tagai 2011, Obádovics 2013, Pénzes 2012) concur on the main territorial features in Hungary: territorial hegemony of the capital, increasing differences between the capital and rural areas, emergence of the 'West–East decline', and varied development patterns of micro-regions and settlements. Dusek–Lukács–Rácz (2014) describe the regional disparities in the country on NUTS-2 level, pointing out that Central Hungary is the most advanced region of Hungary, followed by Western Transdanubia and Central Transdanubia, and with significant lag, Southern Transdanubia, Southern Great Plain, Northern Great Plain and Northern Hungary trail the list. In the primary research, the aim is to explore the conditions of export-led growth in Hungary, and through an examination of the spatial distribution of the 500 companies with the best sales performance (TOP 500 list) an attempt is made to demonstrate the reasons for regional inequalities in Hungary. The other scope of the research is to demonstrate the concentration of different sectors in NUTS-3 level, as well as highlighting their export orientation. Furthermore research examines associations between different measures. The pool of data used for carrying out the research is derived from HVG (Heti Világgazdaság – a dominant economic weekly review in Hungary) about the first 500 companies with the best sales performance in 2012 (the TOP 500 companies) and from the Hungarian Central Statistical Office. Our research findings emphasize the importance of export for regional development (export-led growth), and resembles the secondary research outcomes about the development of NUTS-2 and NUTS-3 regions.

Keywords: Regional development, subnational scale, TOP 500 companies (on gross sales value basis) in Hungary, export-led growth.

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Introduction

Focuses of regional development

In today's globalized world, the existence of regional disparities (Dawkins 2003, Koczisszky 2009, Lengyel Rechnitzer 2004, Lengyel 2012 , Lengyel 2010, Magrini 1999), the different development path of countries or even the sub regions (Armstrong 1995, Bhagwati–Krueger 1973, Meyer 2005, North 1955, Simon 2001, Szentes 2011, Tomka 2011), the growing income inequalities within and amongst countries (Dusek–Lukács–Rácz 2014, Magrini 1999, Szentes 2011), the different effects of various economic policies (Bhagwati–Krueger 1973, Murphy–Shleifer–Vishny 1989, Szentes 2011) are the challenges that each decision maker must meet and confront. The different development path of regions, the effect of various economic policies (e.g. import substitution, export promotion, liberalization of markets) on development, persistent differences in social welfare across regions are all research areas of regional science with special attention to regional development (Armstrong 1995, Bhagwati–Krueger 1973, Dawkins 2003, Lengyel 2012, Lengyel–Rechnitzer 2004, Murphy–Shleifer–Vishny 1989, North 1955, Simon 2011, Szentes 2011, Tomka 2011) The conflict within regional development concerns the convergence or divergence of per capita income across regions and over time (1), the assumptions regarding the importance of internal and external economies of scale to regional economic growth (2), the role of space in shaping regional labour market outcomes(3) (Dawkins 2003, Murphy–Shleifer–Vishny 1989, Parikh–Shibata 2004, Szentes 2011) in a historical framework as the factors determining economic development may change over time (Meyer 2005, Szentes 2011).The importance of time on regional development can be readily understood when considering that:

- in the early stages, the abundance and diversity of natural resources are crucial for territorial development;
- later on, the existing production structure and agglomerative advantages derived from the concentration of economic players in the same area are significant (the portfolio of economic activity within the region), and their connectivity to each other;
- finally, as the competition has become global, the capability of income-generation and ability to influence the global demand trends (through innovation, research and development), thus the variety of information and spillovers exiting the given territorial unit are the determinants of regional development.

The reason for the growing attention to regions in the discussion of the persistent differences in levels of social welfare (increasing quantity of material goods, increasing level of incomes, more diversified consumption structure of inhabitants), or social well-being (social welfare adjusted with such problematically measurable or non-material dimensions as happiness or self-satisfaction and the quality of the natural environment) is due to that space has an impact on processes driving innovation and national economic growth (in reference to one of the main statements of regional economics / science, that "space matters"). The factors and conditions differ amongst regions (local natural resources, energy portfolio, local culture, the availability and quality of human resource other location-specific amenities), the economic activity and performance depends on

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location, and is strongly related to the shared attraction to the conditions of production, the region-specific so called endogenous technology level, the intra-regional and extra-regional cooperation intensity (enhancing technology-transfer and innovation, and access to exogenous technology) (Dawkins 2003, Lengyel–Rechnitzer 2004, Lengyel 2010, Szentes 2011).

Importance of internal and external scale economies to regional economic growth

Murphy, Shleifer and Vishny (1989) argue that in a closed economy, the rate of economic growth depends on the size of the domestic market; the condition of higher efficiency at large-scale production rather than artisanal production is a large part of the output. Where is it profitable to create large quantities of goods and services? The answer is evident: if the domestic demand is large enough and the income distribution of the population is favourable (the income inequality is moderate) (Major 2013, Murphy–Shleifer–Vishny 1989). As a consequence, economic growth in a closed economy (due to import-substitution economic policy) is the function of the domestic demand and the income distribution patterns, which may lack the effect of economies of scale referring to the diminishing level of per-unit costs due the increased output of a specific commodity (Dawkins 2003, Major 2013, Silberston 1972, Szentes 2011). Furthermore, if an economy is built on import-substitution, various consequences can occur: lack of market pressure on the industry to increase efficiency, accumulating government debt, barriers to benefit from comparative advantage (Major 2013). In contrast, the export-driven growth triggers demand for domestic commodities and supports more efficient manufacturing through economies of scale. The region's specialization based on its comparative advantages may assist stable growth supported by either further gains in efficiency from international competition or the acquisition of 'Learning by doing' knowledge through participation in international production, trade and R&D networks (Dawkins 2003, Major 2013).

Therefore, for regions (agglomeration of enterprises of a specific geographical space), the 'reasons of trade' are benefits from economies of scale, knowledge from international economic relations (Dawkins 2003, Major 2013, Murphy–Shleifer–Vishny 1989). According to Bhagwati and Krueger (1973) if a government intervenes in the market to facilitate economic growth export promotion is more preferable than import-substitution since export promotion leads to higher efficiency due to the higher level of competition. Import substitution applies quantitative and direct intervention measures, while export-oriented strategies entails market-conforming and indirect means of intervention; consequently, the costs of export promotion are more visible to policy-makers than the costs of import substitution (Bhagwati–Krueger 1973, Major 2003). Parallel to the 'reason of trade,' export growth is one of the key determinants of economic growth (export-led growth hypotheses) (Dawkins, 2003, Kimbugwe–Banerjee–Gyawali 2010, Lengyel 2012, Major 2013, Medina-Smith 2001, Murphy–Shleifer–Vishny 1989, North 1955, Silberston 1972, Szentes 2011).

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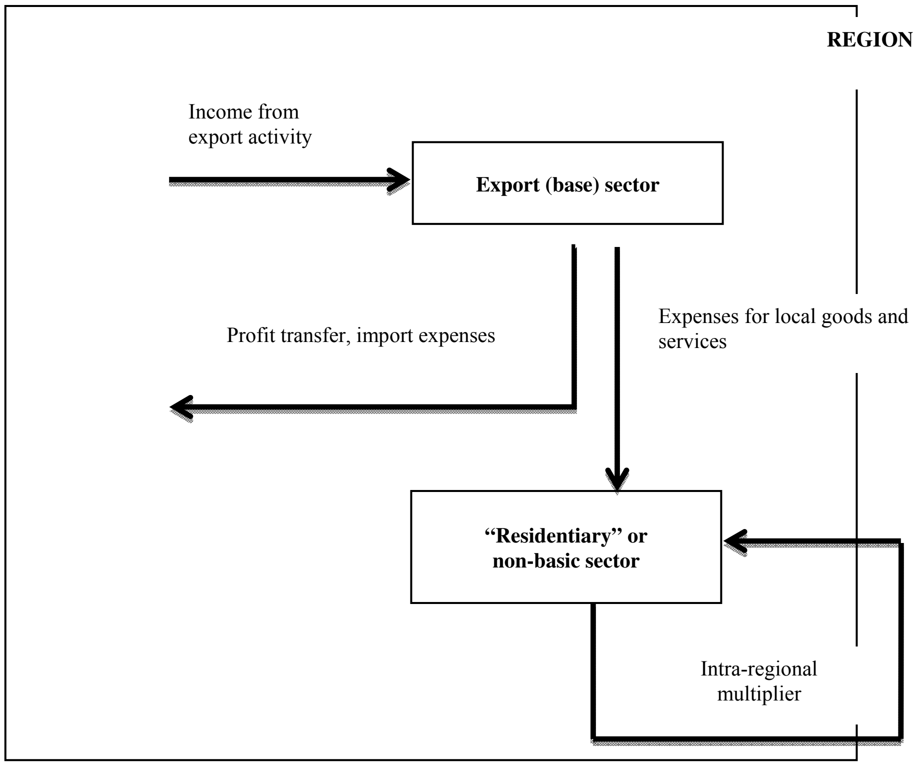
Export Base Theory

D. C. North's Export Base Theory (1955) is a widely accepted economic theory describing economic development through export activity (Dawkins 2003 Kimbugwe–Banerjee–Gyawali 2010).

Figure 1

The Export Base Theory



Source: Self-editing based on Koczisky 2008, Lengyel 2010.

In North's Export Base Theory (1955), two different types of sectors are distinguished:

1. the first is the export (base) sector to which is given prior role in regional growth,
2. the second one, the "residentiary", or non-basic, sector (the term derives from P. Sargent Florence, who used it in National Resources Planning Board mimeographed releases); the term designates such economic activity – production or providing services – which is maintained to satisfy the local demand at that territory where the consuming population resides (North 1955) and its only reason for existence is to serve the basic sector.

As the figure shows, the economic performance of export base is a defining factor to both absolute and per capita income of the region through the connections to

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"residentiary" sector. The number of participants of the basic sector impacts the number and diversity of players of the non-basic sector, which refers to how many organizations are in the industrial branch, or service sector. Economic development depends on how regions are able to respond to exogenous global demand, and how the local political, economic, and social institutional structure may cope with the challenges in serving international markets (Dawkins 2003, Lengyel 2010, Lengyel–Rechnitzer 2004, Kimbugwe–Banerjee–Gyawali 2010, North 1955, Pike–Rodriguez-Pose–Tomaney 2006).

According to North's view, growth did not only results from the industrialization; since the export basket of a specific territory may also consist of either semi-finished and finished agricultural- and manufactured goods or services (Dawkins 2003). According to the model, North points out the factors of regional development as follows:

- the more a region is capable of satisfying "non- residential" markets, the more likely it is to grow;
- the more sectors are capable of satisfying the demand from international markets through the expansion of their economic space, the more regional development is triggered;
- the more favourable the economic atmosphere, the more the concentration of organizations can be expected, which can result in the growth of local per capita incomes and emergence of new industries (North 1955).

The Export Base Theory has been criticized for various aspects; C. J. Dawkins (2003) mentions Charles M. Tiebout (1956) 'Exports and regional economic growth' in which Tiebout argues that North's model ignores the importance of various supply-side factors, which affect a region's power to support an emerging export base; Kimbugwe–Banerjee–Gyawali (2010) cites W. Cris Lewis (1976) 'Export base theory and multiplier estimation: A critique', highlighting the model's theoretical flaws; Lengyel (2010) references Pike–Rodrígues-Pose–Tomaney (2006) 'Local and regional development' describing that the export-ability of a region depends on the technological changes and innovations. In less developed regions, the qualification of labour and the preparedness of entrepreneurs can be a barrier to technology adaptation. In addition, they point out that not the supply of the exporting region, but rather, the demand of the importing region is the determining factor for economic development (Dawkins 2003, Kimbugwe–Banerjee–Gyawali 2010, Lengyel 2010).

Besides this, the great contribution of the Export Base Theory to the field of regional development is that it draws attention to the importance of specialization and the impact of external demand for a region's growth (Pike–Rodriguez-Pose–Tomaney 2006). The model emphasizes furthermore that development depends on the cooperative links between enterprises: the external demand is not only beneficial for the exporting enterprise, but also to its business/cooperative partners (Dawkins 2003, North 1955, Silberston 1972). The cyclical flow of income creates a multiplier effect in the region. According to Domanski and Gwosdz (2010) the multiplier effect refers to:

"An increase (or decrease) of one type of economic activity in a given city or region prompts an increase (or decrease) in demand for goods and services, which then triggers the development of other types of economic activity in the same region or city. An increase (or decrease) in income or employment in a local or regional economy triggered by the emergence of a new type of economic activity is called a multiplier effect"

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(Domanski–Gwosdz 2010, p. 1). In the Export Base Theory, the multiplier effect is the function of the proportion of locally available/locally produced resources and imported resources (Kocziszky 2009).

The territorial sense of export data and economic spaces

In those studies that concentrate not on a supranational territorial scale, the empirical data collection and analysis can be a sufficient alternative when assessing the differences of export capability amongst smaller territorial units than a national economy. Besides this, we have to be aware that the economic space of actors has more layers; according to François Perroux (1950):

1. the first one "economic space as a field of forces" means the banal space of organizations from which they use resources for their production;
2. the second can be defined by the intra- and extra-sectoral connections and linkages, which the actors utilise in their production and distribution system for value creation and dispatching various goods;
3. finally, the third one is the "economic space as homogeneous aggregate", which refers to relations of homogeneity in specific measures such as products or services, or price-levels (Perroux 1950).

It is important to highlight that simplification is necessary to the examination considering territorial differences of export activities in our case, thus we order an aggregate measure of economic performance (the sales value and the export value in Hungarian Forint, hereinafter HUF) to specific sub-national territory; the value refers to the SUM of those organizations which centre is located at the given territorial unit, although the organization may have further sites within the national economy.

The research

In recent years, a number of papers and publications have examined spatial differences and inequalities in Hungary. Pénzes (2012) summarizes the basic trends of Hungarian spatial development (Cséfalvay–Nikodémus 1991, Rechnitzer 1993, Enyedi 1996, Kozma 1998, Nemes Nagy 1998, Beluszky–Győri 1999, Faluvégi 2000 in Pénzes, 2012): territorial hegemony of the capital ('dominant development' in Pénzes, 2012; 'monocentric character of Hungary' in Nemes Nagy–Tagai 2011); increasing difference between the capital and rural territories (Pénzes 2012, 'divergence between territorial levels' in Nemes Nagy–Tagai 2011); emergence of the 'West-East declination' (Pénzes 2012; 'a distinct regional dimension (west–east)' in Nemes Nagy – Tagai, 2011); variant development patterns of micro-regions and settlements (Pénzes 2012, Obádovics 2013). The status of increasing regional inequalities appears in various research contexts. Dusek–Lukács–Rácz (2014) cites Nemes, Nagy J. (2009 p. 38 in Dusek–Lukács–Rácz, 2014 p. 275): 'in the last two decades, the indigenous territorial development was determined by the growth of inequalities', in connection with their research results on population change (based on a dynamic analysis carried out for the period 1990–2010, the population has decreased in each region of Hungary, except for Central Hungary), labour market conditions (in the examined period, the number of employees was the

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highest in Central Hungary due to the largest population size and lowest unemployment rate) (Dusek–Lukács–Rácz 2014). The research highlights that income inequalities in Hungary (measured by the average gross monthly earnings of employees); or more precisely, differences between Central Hungary and other regions has increased (Dusek–Lukács–Rácz 2014). Dusek–Lukács–Rácz (2014) argue that based on the results (1990–2010), Central Hungary is the most advanced region of Hungary, followed by Western Transdanubia and Central Transdanubia, and with significant lag from Southern Transdanubia, Southern Great Plain and Northern Great Plain, with Northern Hungary trailing the list. Obádovics (2013) used population analysis to confirm the increasing regional disparities due to the migration towards large cities and the increasing labour flow from underdeveloped areas to more developed ones. Pénzes (2012) explains the changes in the spatial income with the ability of attracting foreign capital after the regime's change (the main drivers of receiving foreign capital is favourable geographical and market position, the proximity of significant markets with good purchasing power), as a consequence, the increasing regional inequalities are due to the different capability of regions for attracting capital. Nemes Nagy–Tagai (2011) focusing on regional inequalities and regional development evaluates the performance of counties (NUTS-3 level) from GDP per capita changes point of view for the period of 1994 to 2008. By the calculation of GDP per capita in relation to the national average, they assess the period of maximum development levels in Hungarian counties between 1994 and 2008.

Table 1

Period of GDP per capita maximum (1994–2008)

Period	Name of county/NUTS-3 level (NUTS-2 region) in alphabetical order
2006	1: Budapest (Central Hungary)
2002–2005	1: Pest (Central Hungary); 2: Komárom-Esztergom (Central Transdanubia); 3: Zala (Western Transdanubia)
1998–2001	1: Fejér (Central Transdanubia); 2: Győr-Moson-Sopron (Western Transdanubia); 3: Vas (Western Transdanubia)
1994–1997	1: Bács-Kiskun (Southern Great Plain); 2: Baranya (Southern Transdanubia); 3: Békés (Southern Great Plain); 4: Borsod-Abaúj – Zemplén (Northern Hungary); 5: Csongrád (Southern Great Plain); 6: Hajdú-Bihar (Northern Great Plain); 7: Heves (Northern Hungary); 8: Jász-Nagykun-Szolnok (Northern Great Plain); 9: Nógrád (Northern Hungary); 10: Somogy (Southern Transdanubia); 11: Szabolcs-Szatmár-Bereg (Northern Great Plain); 12: Tolna (Southern Transdanubia); 13: Veszprém (Central Transdanubia)

Source: Self-editing based on Nemes Nagy–Tagai (2011).

If we assess the result of Nemes Nagy–Tagai (2011) and Dusek–Lukács–Rácz (2014) we can observe cohesion in the results: Budapest and consequently Central Hungary is the most advanced region, Western Transdanubia, Central Transdanubia are in better position than Southern Transdanubia, Southern Great Plain, Northern Great Plain and Northern Hungary.

Due to the nature and scope of the introduced research,the basis of investigating regional development, regional inequalities were results indicators. Demographic changes, GDP per capita values and income are such indicators which demonstrate the change of welfare from the output side. They are a consequence of various territorial

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economic conditions. The research proposes a different approach in investigating regional differences. The aim is to explore the conditions of export-led growth in Hungary, and through the examination of the spatial distribution of the 500 companies with the best sales performance (TOP 500 list) the paper attempts to demonstrate the reasons for regional inequalities in Hungary. It should be noted that economic concentrations are not the product of coincidence their increase is related to historical aspects, abundance of raw materials, infrastructural developments, connectivity to important markets, agglomeration advantages, innovative industrial branches, etc. (Dawkins 2003, Lengyel–Rechnitzer 2004, Meyer 2005). The other scope of the research is to demonstrate the concentration of different sectors in NUTS-3 level, as well as highlighting their export orientation. The last part of the research deals with examining associations between different measures.

The research seeks to find answers to the following questions related to regional development: is there a relationship between the volume of sales achieved by companies and their export performance? What is the distribution of companies in the TOP 500 list with respect to their location, examined on a county level? How do companies export in different sectors? Are there any inequalities (disparities) between the counties and the capital Budapest from an export performance point of view? Can we find a relationship between the spatial distribution of TOP 500 companies, unemployment and nominal income level?

The data used for the study's elaboration comes from a Hungarian weekly – HVG – which annually issues the list of those companies that have achieved the greatest sales value during the previous business year. This list contains the first 500 companies with the best sales performance; consequently the list is called the TOP 500 list. In this list, we can find the names of companies with their total sales value (gross), their sales value from export activities, and the sector they operate in. The weekly provides information about the distribution of companies amongst the 19 Hungarian counties (NUTS-3 level) and the capital of the county. In this research, the same scaling will be used for examination, namely that the capital is separated because of its territorial and economic hegemony in the country (Pénzes 2012, Nemes Nagy–Tagai 2011).

In order to carry out the research based on the printed weekly (published in November, 2013 based on the companies' result in 2012), a database was developed in MS Excel. During its preparation, the reliability of the presented information was regularly verified; with the help of the HVG weekly's analysis, it was possible to compare the territorial total values, furthermore, the total values with respect to economic sectors, confirming the accuracy of the data used for the research. With the help of MS Excel, it was possible to query the spatial distribution of TOP 500 companies and sectors through filtering, and making the necessary calculations for the research. The other data pool used is the database of the Hungarian Central Statistical Office (unemployment rate and nominal income level of the counties and the capital).

Distribution of the participants of TOP 500 list on subnational scale

Examining the regional development connected to the income generation of firms – the sales value – it makes sense to highlight the differences of sub-national units concerning

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the number of participants from the TOP 500 list ranked on the basis of sales value. The table below shows the rank of the capital and the counties based on the TOP 500 companies' distribution.

Table 2

Distribution of participants of the TOP 500 companies according to their location, 2012

Territorial level /Capital, NUTS-3/ and code of NUTS-2		Number of participants from "TOP 500" enterprises	Share from the number of participants, %
1.	Budapest (HU10)	216	43.20
2.	Pest (HU10)	76	15.20
3.	Fejér (HU21)	26	5.20
4.	Komárom-Esztergom (HU21)	26	5.20
5.	Borsod-Abaúj–Zemplén (HU31)	22	4.40
6.	Győr-Moson-Sopron (HU22)	21	4.20
7.	Hajdú-Bihar (HU32)	17	3.40
8.	Bács-Kiskun (HU33)	14	2.80
9.	Csongrád (HU33)	14	2.80
10.	Jász-Nagykun-Szolnok (HU32)	13	2.60
11.	Vas (HU22)	12	2.40
12.	Veszprém (HU21)	9	1.80
13.	Szabolcs-Szatmár-Bereg (HU32)	7	1.40
14.	Heves (HU31)	6	1.20
15.	Somogy (HU23)	6	1.20
16.	Baranya (HU23)	5	1.00
17.	Békés (HU33)	3	0.60
18.	Tolna (HU23)	3	0.60
19.	Nógrád (HU31)	2	0.40
20.	Zala (HU22)	2	0.40
	Total	*500*	*100,00*

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

Code of units NUT-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

It can be seen that the differences are quite high between the territorial units in the number of participants of the list, the territorial hegemony of the capital is obvious. The inequalities according to the number of TOP 500 companies are high, more than the half of the companies can be found in the advanced Central Hungary NUTS-2 region.

Total sales value, sales value from export activities by sectors of subnational territorial units

The following section interprets the data used for the analysis both on a territorial level and according to 15 sectors that are represented in the TOP 500 ranking.

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Table 3

Distribution of the total sales value and sales vale from export activities by sectors (Electronics industry, Food and tobacco industry, agriculture; Energetics; Construction and materials industries) of subnational territorial units

Territorial level /Capital, NUTS-3/ and code of NUTS-2	Electronics industry		Food and tobacco industry, agriculture		Energetics		Construction and materials industries	
	A	B	A	B	A	B	A	B
Budapest (HU10)	84 092	55 610	596 797	297 568	11 247 833	4 724 833	391 020	818
Bács-Kiskun (HU33)	0	0	170 127	115 375	0	0	69 131	10 970
Baranya (HU23)	0	0	17 369	789	60 905	0	0	0
Békés (HU33)	0	0	32 415	9 618	0	0	20 541	15 321
Borsod-Abaúj-Zemplén (HU31)	432 377	429 667	56 693	6 563	228 060	111	0	0
Csongrád (HU33)	0	0	169 994	51 889	391 092	6	40 664	19 262
Fejér (HU21)	288 661	222 531	133 865	45 675	80 261	2 379	24 828	18 376
Győr-Moson-Sopron (HU22)	0	0	46 730	1 286	92 437	0	50 049	46 352
Hajdú-Bihar (HU32)	130 028	129 271	98 653	22 899	349 280	0	0	0
Heves (HU31)	0	0	0	0	94 083	2	0	0
Jász-Nagykun-Szolnok (HU32)	713 517	621 684	0	0	0	0	20 828	0
Komárom-Esztergom (HU21)	999 761	949 046	63 536	8 371	69 371	12 684	0	0
Nógrád (HU31)	0	0	0	0	0	0	0	0
Pest (HU10)	304 328	193 830	426 301	175 162	112 247	43 591	57 981	4 613
Somogy (HU23)	528 642	480 191	17 656	4 258	136 627	23 419	0	0
Szabolcs-Szatmár-Bereg (HU32)	0	0	27 232	11 542	0	0	0	0
Tolna (HU23)	0	0	23 443	976	184 243	18	0	0
Vas (HU22)	85 361	80 372	22 428	9 011	0	0	49 144	10 476
Veszprém (HU21)	0	0	19 672	2 966	0	0	0	0
Zala (HU22)	0	0	0	0	21 665	7 963	0	0
Total	*3 566 767*	*3 162 202*	*1 922 911*	*763 948*	*13 068 104*	*4 815 006*	*724 186*	*126 188*

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

Note: A: Total sales value (gross) in million HUF; B: Sales value (gross) from export activities in million HUF.

Code of NUTS-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

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Table 4

Distribution of the total sales value and sales vale from export activities by sectors (Metal working, Machine engineering; Pharmaceutical industry; Automotive industry; Retail; Light industry) of subnational territorial units

Territorial level /Capital, NUTS-3/ and code of NUTS-2	Metal working		Machine engineering		Pharmaceutical industry		Automotive industry		Retail		Light industry	
	A	B	A	B	A	B	A	B	A	B	A	B
Budapest (HU10)	0	0	1 570 435	1 526 044	859 094	730 182	89 087	47 103	748 240	3 003	34 199	4 298
Bács-Kiskun (HU33)	0	0	0	0	0	0	307 374	305 356	0	0	0	0
Baranya (HU23)	0	0	30 952	30 716	0	0	0	0	0	0	0	0
Békés (HU33)	0	0	0	0	0	0	40 486	30 279	0	0	0	0
Borsod-Abaúj-Zemplén (HU31)	0	0	68 758	26 862	0	0	193 787	191 468	24 875	0	0	0
Csongrád (HU33)	0	0	20 403	16 906	0	0	0	0	0	0	0	0
Fejér (HU21)	565 046	448 331	19 266	19 039	0	0	492 476	464 637	356 614	347	89 103	71 988
Győr-Moson-Sopron (HU22)	57 674	47 501	0	0	0	0	1 854 356	1 790 860	0	0	0	0
Hajdú-Bihar (HU32)	0	0	31 043	29 630	188 438	173 525	0	0	0	0	0	0
Heves (HU31)	0	0	0	0	0	0	466 727	449 390	0	0	0	0
Jász-Nagykun-Szolnok (HU32)	0	0	433 447	318 340	0	0	52 163	48 975	46 266	0	0	0
Komárom-Esztergom (HU21)	22 807	12 261	181 587	175 602	0	0	578 599	506 085	0	0	0	0
Nógrád (HU31)	0	0	0	0	0	0	33 741	33 464	0	0	0	0
Pest (HU10)	0	0	113 823	105 584	310 732	194 962	264 728	247 920	1 068 900	25 904	66 809	28 750
Somogy (HU23)	0	0	0	0	0	0	0	0	0	0	0	0
Szabolcs-Szatmár-Bereg (HU32)	0	0	0	0	0	0	0	0	40 903	0	16 916	16 628
Tolna (HU23)	0	0	0	0	0	0	0	0	0	0	0	0
Vas (HU22)	0	0	0	0	0	0	369 489	336 478	0	0	0	0
Veszprém (HU21)	32 001	29 868	24 098	21 184	0	0	295 330	292 571	49 397	2 331	0	0
Zala (HU22)	0	0	0	0	0	0	0	0	0	0	0	0
Total	*677 528*	*537 961*	*2 493 812*	*2 269 907*	*1 358 264*	*1 098 669*	*5 038 343*	*4 744 586*	*2 335 195*	*31 585*	*207 027*	*121 664*

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

Note: A: Total sales value (gross) in million HUF; B: Sales value (gross) from export activities in million HUF.

Code of NUTS-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

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Table 5

Distribution of the total sales value and sales vale from export activities by sectors (Transport; Wholesale; Service industry; Telecommunications and postal services; Chemical, rubber and plastic industries) of subnational territorial units

Territorial level /Capital, NUTS-3/ and code of NUTS-2	Transport		Wholesale		Service industry		Telecommunications and postal services		Chemical, rubber and plastic industries	
	A	B	A	B	A	B	A	B	A	B
Budapest (HU10)	1 256 626	403 679	3 602 686	1 490 207	1 671 418	655 995	1 039 545	114 294	177 125	122 916
Bács-Kiskun (HU33)	0	0	138 110	15 058	27 039	1 714	0	0	38 736	36 619
Baranya (HU23)	0	0	27 519	0	0	0	0	0	0	0
Békés (HU33)	0	0	0	0	0	0	0	0	0	0
Borsod-Abaúj–Zemplén (HU31)	0	0	23 126	3	20 918	0	0	0	813 544	474 639
Csongrád (HU33)	0	0	55 897	25	0	0	0	0	80 501	73 701
Fejér (HU21)	0	0	78 112	16 812	0	0	0	0	162 449	143 293
Győr-Moson-Sopron (HU22)	29 295	14 997	42 259	0	141 773	91 399	0	0	19 307	18 915
Hajdú-Bihar (HU32)	0	0	280 396	23 919	44 433	3 143	0	0	0	0
Heves (HU31)	0	0	21 801	0	0	0	0	0	0	0
Jász-Nagykun-Szolnok (HU32)	0	0	52 314	823	0	0	0	0	0	0
Komárom-Esztergom (HU21)	0	0	54 433	2 123	0	0	0	0	135 434	124 884
Nógrád (HU31)	0	0	25 880	3	0	0	0	0	0	0
Pest (HU10)	69 583	43 541	2 091 863	925 860	402 892	373 068	209 011	2 499	22 542	20 732
Somogy (HU23)	0	0	27 179	0	17 622	0	0	0	0	0
Szabolcs-Szatmár-Bereg (HU32)	0	0	100 099	76 270	26 709	0	0	0	185 670	164 598
Tolna (HU23)	0	0	36 881	4 683	0	0	0	0	0	0
Vas (HU22)	0	0	0	0	17 139	17 139	0	0	48 834	5 305
Veszprém (HU21)	0	0	0	0	0	0	0	0	80 809	0
Zala (HU22)	32 636	28 241	0	0	0	0	0	0	0	0
Total	*1 388 140*	*490 458*	*6 658 555*	*2 555 786*	*2 369 943*	*1 142 458*	*1 248 556*	*116 793*	*1 764 951*	*1 185 602*

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

Note: A: Total sales value (gross) in million HUF; B: Sales value (gross) from export activities in million HUF.

Code of NUTS-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

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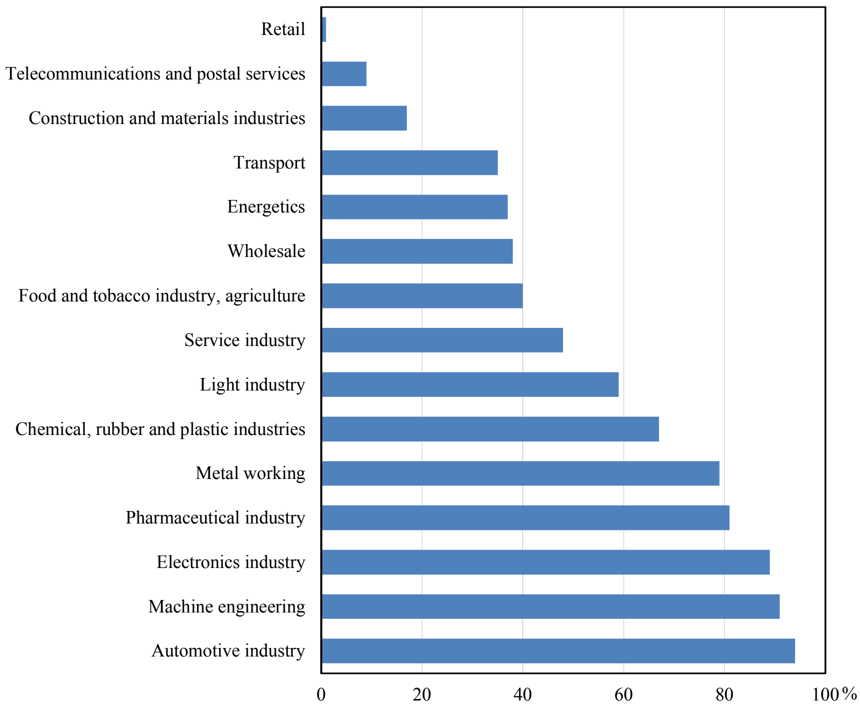
Export orientation of sectors

Using the data from Tables 3, 4 and 5, it is possible to calculate how the different sectors are export oriented simply dividing the sales values (gross) from export activities (denoted by variable "B" in the tables) by the total sales value (gross) (denoted by variable "A" in the tables). The following figure shows the rank of sectors from an export-orientation point of view for 2012.

Figure 2

Rank of sectors from export orientation point of view



Source: Self-editing based on the HVG TOP 500 list.

It can be seen that the companies of the TOP 500 list are highly export-oriented, but there are some sectors which are naturally less export-oriented, such as retail or telecommunications. The figure seems to validate the hypothesis that those companies are able to generate high-level income and exceptional performance, whose export-capability is high. The well-known phenomenon, the so called "Red queen hypothesis", which explains that those organizations that have been familiarized with a high level of competition (being the most defining factor of international markets) are more competitive and consequently capable of high income generation seems to be validated (Koós 2008).

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Generation of sales value from export activities amongst territorial units, sectors

The next section will examine the territorial differences and sector-oriented differences of export value generation.

Table 6

Distribution of sales value from export activities amongst the subnational regions, share from total sales value from export activity and the cumulative share value

Territorial level /Capital, NUTS-3/ and code of NUTS-2		Sales value (gross) from export activities, million HUF	Share from total sales value (gross) from export activities, %	Cumulative share, %
1.	Budapest (HU10)	10 176 550	43.93	43.93
2.	Pest (HU10)	2 386 016	10.30	54.24
3.	Győr-Moson-Sopron (HU22)	2 011 310	8.68	62.92
4.	Komárom-Esztergom (HU21)	1 791 056	7.73	70.65
5.	Fejér (HU21)	1 453 408	6.27	76.93
6.	Borsod-Abaúj-Zemplén (HU31)	1 129 313	4.88	81.80
7.	Jász-Nagykun-Szolnok (HU32)	989 822	4.27	86.08
8.	Somogy (HU23)	507 868	2.19	88.27
9.	Bács-Kiskun (HU33)	485 092	2.09	90.36
10.	Vas (HU22)	458 781	1.98	92.34
11.	Heves (HU31)	449 392	1.94	94.28
12.	Hajdú-Bihar (HU32)	382 387	1.65	95.93
13.	Veszprém (HU21)	348 920	1.51	97.44
14.	Szabolcs-Szatmár-Bereg (HU32)	269 038	1.16	98.60
15.	Csongrád (HU33)	161 789	0.70	99.30
16.	Békés (HU33)	55 218	0.24	99.54
17.	Zala (HU22)	36 204	0.16	99.69
18.	Nógrád (HU31)	33 467	0.14	99.84
19.	Baranya (HU23)	31 505	0.14	99.98
20.	Tolna (HU23)	5 677	0.02	100.00
	Total	*23 162 813*	*100,00*	–

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

Code of NUTS-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

The above table shows the ranking of the capital and the counties in relation to their sales value (gross) from export activities. The share shows the distribution of the sales value (gross) from export activities amongst the territorial units. The hegemony of the capital can again be seen.. What is further interesting is that the biggest difference of the share value is between the first two rated territorial units. By the cumulative share value, the inequality of the sales value from export activities' distribution can be analysed: nearly 80% of the value is generated by the first six territorial units, therefore, 80% of the sales value (gross) from export activities derive from 30% of the number of territorial units in the research, which indicates significant disparity of sales value from export activities' generation amongst the sub-national units. The counties which represents 80% of the share of the export values from the TOP-500 base are Central Hungary, Western

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Transdanubia, Central Transdanubia and Northern Great Plains. The result resembles the results of Dusek–Lukács–Rácz (2014), the most advanced region Central Hungary is the largest exporter followed by Eastern Transdanubia and Central Transdanubia.

Table 7

Distribution of sales value from export activities amongst the sectors, share from total sales value from export activity and the cumulative share value

Sectors		Sales value (gross) from export activities, million HUF	Share from total sales value (gross) from export activities, %	Cumulative share, %
1.	Energetics	4 815 006	20.79	20.79
2.	Automotive industry	4 744 586	20.48	41.27
3.	Electronics industry	3 162 202	13.65	54.92
4.	Wholesale	2 555 786	11.03	65.96
5.	Machine engineering	2 269 907	9.80	75.76
6.	Chemical, rubber and plastic industries	1 185 602	5.12	80.88
7.	Service industry	1 142 458	4.93	85.81
8.	Pharmaceutical industry	1 098 669	4.74	90.55
9.	Food and tobacco industry, agriculture	763 948	3.30	93.85
10.	Metal working	537 961	2.32	96.17
11.	Transport	490 458	2.12	98.29
12.	Construction and materials industries	126 188	0.54	98.83
13.	Light industry	121 664	0.53	99.36
14.	Telecommunications and postal services	116 793	0.50	99.86
15.	Retail	31 585	0.14	100.00
	Total	*23 162 813*	*100.00*	–

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

The table above shows the different sectors contribution to the sales value (gross) from export activities: the energetic sector leads the list with the nearly 21% share from the sales value (gross) from export activities, the second one is the automotive industry. The difference is less between the first and second rated sector than in the territorial ranking. Concerning the inequalities, close to 80% of the sales value (gross) from export activities is generated by the 40% of the sector; the inequality is also less than in the case of the capital and counties ranking regarding the sales value (gross) from export activities.

Furthermore, it is worth comparing the results of the second figure regarding the sectors export-orientation and the sales value rankings. From an export orientation perspective, one which is calculated by the ratio of sales value (gross) from export activities and total sales value (gross) in million HUF, the first in the ranking is the automotive industry, which stands at second place in the actual ranking when we consider the amount of sales value from export activities. Based on this result, it can be stated that this sector creates value mainly for outer-regional (the region in this case

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refers to Hungary) demand satisfying purposes. While the sector, which created the largest sales value from export activities in 2012, namely Energetics, its export orientation based on the ratio is less significant. Resembling the sales value from export activity and the ranking from export orientation it can be stated that this sector satisfy both inner and outer-regional demands. This situation, from the regional development point of view, is more preferable since if the outer regional demand patterns alter, it does not means that the sector vitality is questionable. Long term, those sectors presence are preferable for regional development which both satisfies demand in the country where they operates and in international markets, thus maintaining stability.

Correlation analysis

In this part of the study several circumstances on how the performance of companies of the TOP 500 list affects regional development will be tested. At first the correlation between the total sales value and sales value from export activities will be tested, answering the question that from an income generation point of view, how important the export activity is.

The correlation in this case is elaborated on a company level (for better accuracy), using the correlation function of MS Excel, which estimates the correlation coefficient. The correlation coefficient is used to analyse the linear association between two variables – in this case between the total sales value and sales value from export activities. The value set of correlation coefficient is between –1 and +1, where value "1" indicates strong linear relation and "0" indicates no linear relationship, and the plus/minus quality refers to the direction of change.

Table 8

Correlation between the total sales value and sales value from export activities

First variable	Second variable	Correlation coefficient
Total sales value	Sales value from export activities	0.9519

Source: Self-editing based on the HVG TOP 500 list (reference year: 2012).

The correlation of the two variables are considered as strong, positive, linear one, indicating that the success of the income generation of the TOP 500 in Hungary, in 2012 are the function of export activity. The outcome fits the theory of export-led growth, higher efficiency can be reached by increased outputs (economies of scale), and international competition triggers development (Dawkins 2003, Kimbugwe–Banerjee–Gyawali 2010, Lengyel 2012, Major 2013, Medina-Smith 2001, Murphy–Shleifer–Vishny 1989, North 1955, Silberston 1972, Szentes 2011).

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Relationship between the sales value (gross) from export activities and unemployment

Table 9

Sales value from export activities of TOP 500 of subnational regions and the unemployment rate

Territorial level /Capital, NUTS-3/ and code of NUTS-2		Sales value (gross) from export activities of TOP 500, million HUF	Unemployment rate, 2012, %
1.	Budapest (HU10)	10 176 550	9.3
2.	Bács-Kiskun (HU33)	485 092	9.5
3.	Baranya (HU23)	31 505	14.7
4.	Békés (HU33)	55 218	12.0
5.	Borsod-Abaúj–Zemplén (HU31)	1 129 313	17.3
6.	Csongrád (HU33)	161 789	10.6
7.	Fejér (HU21)	1 453 408	10.3
8.	Győr-Moson-Sopron (HU22)	2 011 310	5.3
9.	Hajdú-Bihar (HU32)	382 387	13.5
10.	Heves (HU31)	449 392	14.4
11.	Jász-Nagykun-Szolnok (HU32)	989 822	11.3
12.	Komárom-Esztergom (HU21)	1 791 056	7.8
13.	Nógrád (HU31)	33 467	17.5
14.	Pest (HU10)	2 386 016	9.1
15.	Somogy (HU23)	507 868	10.3
16.	Szabolcs-Szatmár-Bereg (HU32)	269 038	16.2
17.	Tolna (HU23)	5 677	9.6
18.	Vas (HU22)	458 781	6.1
19.	Veszprém (HU21)	348 920	10.9
20.	Zala (HU22)	36 204	11.8

Source: Self-editing based on the HVG TOP 500 list and Hungarian Central Statistical Office's data (reference year: 2012).

Code of NUTS-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

Next, the relationship between the capital and counties' export activity based on the TOP 500 list enterprises and the unemployment rate is examined (the data comes from the Hungarian Central Statistical Office Regional Statistics). If the differences amongst the territorial units' performance concerning the export activity have impact on the unemployment rate, the association is expected to reach the value "1" and the quality of the relation is expected to be reversed.

Table 10

Correlation between the sales value from export activities and unemployment rate

First variable	Second variable	Correlation coefficient
Sales value from export activities	Unemployment rate (territorial)	–0.2814

Source: Self-editing based on the HVG TOP 500 list and Hungarian Central Statistical Office's data (reference year: 2012).

It can be seen that the relationship between the two variables are reversed: the higher level of sales value from export activities results in lower unemployment rate, but the value of the correlation coefficient indicates weak association between the variables.

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Based on the data from the TOP 500 ranking, unfortunately, we cannot state that the export activity is a guarantee for reducing unemployment in Hungary.

Relationship between the sales value (gross) from export activities and nominal income level

Table 11

Sales value from export activities of TOP 500 of subnational regions and the nominal income level

Territorial level /Capital, NUTS-3/ and code of NUTS-2		Sales value (gross) from export activities of TOP 500, million HUF	Nominal income level (net, 2012)
1.	Budapest (HU10)	10 176 550	182 622
2.	Bács-Kiskun (HU33)	485 092	116 078
3.	Baranya (HU23)	31 505	119 803
4.	Békés (HU33)	55 218	105 515
5.	Borsod-Abaúj–Zemplén (HU31)	1 129 313	114 587
6.	Csongrád (HU33)	161 789	119 966
7.	Fejér (HU21)	1 453 408	137 794
8.	Győr-Moson-Sopron (HU22)	2 011 310	145 310
9.	Hajdú-Bihar (HU32)	382 387	119 860
10.	Heves (HU31)	449 392	131 168
11.	Jász-Nagykun-Szolnok (HU32)	989 822	113 239
12.	Komárom-Esztergom (HU21)	1 791 056	139 441
13.	Nógrád (HU31)	33 467	110 457
14.	Pest (HU10)	2 386 016	132 517
15.	Somogy (HU23)	507 868	115 075
16.	Szabolcs-Szatmár-Bereg (HU32)	269 038	105 738
17.	Tolna (HU23)	5 677	129 022
18.	Vas (HU22)	458 781	123 777
19.	Veszprém (HU21)	348 920	120 838
20.	Zala (HU22)	36 204	112 505

Source: Self-editing based on the HVG TOP 500 list and Hungarian Central Statistical Office's data (reference year: 2012).

Code of NUTS-2 regions: Central Hungary (HU10); Central Transdanubia (HU21); Western Transdanubia (HU22); Southern Transdanubia (HU23); Northern Hungary (HU31); Northern Great Plain (HU32); Southern Great Plain (HU33).

One measure of regional development is the income level of the inhabitants from which they can consume goods and services and manage savings. It was for this reason that this dimension was included in the research about the Export Base Theory. The Hungarian Central Statistical Office Regional Statistics provided data for the calculation investigating the relationship of the two variables. We expect that on those sub-national territorial levels where the sales value is at higher level, the nominal income level will be higher amongst the sample.

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Table 12

Correlation between the sales value from export activities and nominal income level

First variable	Second variable	Correlation coefficient
Sales value from export activities	Nominal income level (territorial)	0.8740

Source: Self-editing based on the HVG TOP 500 list and Hungarian Central Statistical Office's data.

The correlation coefficient indicates a positive and strong relationship between the two variables: the increase in the sales value from export activities means the increase in nominal income level. The strength of correlation coefficient implies that export activity influence the income level of sub-national regional levels. As a consequence we can acknowledge that export activity is important indeed for economic development, regional welfare (since income level is an important measure of welfare).

Conclusion

Reducing the regional disparities amongst regions with respect to their long-term sustainable growth is nowadays one of the greatest challenges of each national economy. The regions – due to differences in the abundance of natural resources, capital, technology level, human capital and the capability to compete at international markets – reach different levels of social welfare, with the level of it also varying within the region's population. The wide range of regional development theories points out those conditions which enable the economic decision-makers to decrease the territorial disparities. In the European Union, to which economic area Hungary belongs, regional policy aims to simultaneously (1) decrease the disparities by enhancing the economic convergence and cohesion, and (2) support those sectors which enable the EU to participate in transnational competition derived from globalization.

By having answered the research questions, it can be concluded that the sales value achieved by the companies and the export value have a strong a relationship. By analysing the spatial distribution and added value generation capability of the TOP 500 companies, it is possible to observe the territorial hegemony of the capital (Central Hungary), the importance of the Western and Central Transdanubian regions, and the lagging regions in the Eastern part of the country except Borsod-Abaúj-Zemplén county (Northern Hungary), where the number of TOP 500 companies and the added value are significant.

The outcomes of the research indicated that export activity has a large impact on the Hungarian economy. The regional inequalities exist in the country are parallel to the distribution of the largest firms' location and export activity. The analysis has demonstrated that the TOP 500 companies are export oriented to a higher extent, and they are concentrated in the developed regions of the country.

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Method of the Geographically Weighted Regression and an Example for its Application

Abstract

This research is concerned with a statistical method that has recently become widespread in the international literature; although, it is still limited in Hungarian research. The method is geographically weighted regression (GWR), which is demonstrated through an example of its application. GWR is a local model that is founded on the basis of regression, prominently taking into consideration the geographical distance. Since it does not calculate the global relations of the whole data, but concentrates on the relationship of the dependent and independent variables locally within a determined search area, it allows consideration of the spatially varying processes. Simply, GWR is a developed version of the global regression model, since, through its use, it is possible to take into account the local features that are hidden by the global approach.

Keywords: GWR model, local regression.

Introduction

The research is concerned with a statistical method, the geographically weighted regression (GWR) that has recently become widespread in the international literature; although, it is still limited in Hungarian research. The GWR is a local model that is founded on the basis of regression, prominently taking into consideration the geographical distance. In the first part of the study, the methodology is presented; then, the use of the method is demonstrated through an example of its application: an analysis of the local features of economic development with the help of territorial data series of GDP per capita.

Geographically weighted regression

Regression is one of the most widespread mathematical-statistical tools of social scientific researches. Its popularity is based on its essence, since this is a method which is suitable to explore the relationships between the phenomena being the key objective of research. Regression analysis means finding and describing the function that describes the stochastic relationship between two or more variables. It differs from correlation (which also examines the probability relationship between variables) insofar that correlation only indicates the existence of the relationship and does not give detailed information on it. For

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further exploration of the relationship, another method must be used, which is in most cases regression analysis.

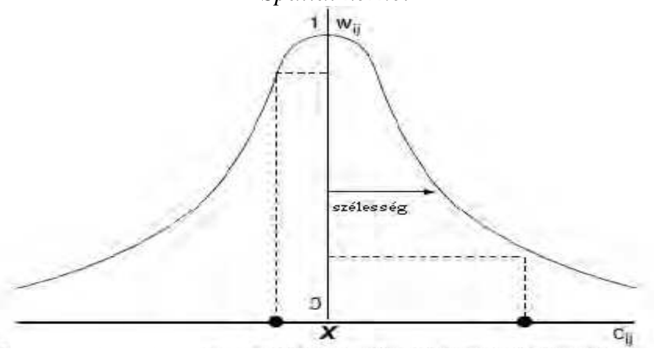
However, if this is applied for territorial data, it may result in a significant problem since regression examines phenomena as if they were constant over space. On the contrary, geographically weighted regression (GWA) is suitable, due to its methodology, to model spatial processes as variables, i.e. as opposed to simple regression; GWA can solve the problem of how continuous territorial processes can be examined with the help of discrete weighting (Figure 1).

The logic of GWR is most similar to that of the moving window regression. With the help of the moving window regression, the problem that processes do not end at the borders of territorial units can be solved. Its methodology is as follows: the first step is to stretch the grid of regression points for the study area. As a result, a region/window can be determined around each regression point, which is generally a square or a circle, although theoretically it could be any shape that is suitable to cover the space, i.e. to include all points examined. Depending on the problem examined, it is possible to determine what the certain region is (e.g. squares around a regression point). The regression model is based on the different data points in the regions created around the regression points, and the process is repeated in case of each regression point. By mapping the received local parameter estimates, the non-stationary assumption can be examined (Fotheringham–Brunsdon–Charlton 2002).

The main problem of this method is that spatial processes, which can be considered continuous, are not handled as continuous. Namely, it gives a weight of 1 for data points within the region/window and a weight of 0 for those outside the region/window, which may seem arbitrary in case of continuous phenomena. The result largely depends on the size of the region/window, and, due to the fewer regression points at the edges and in the lack of measures eliminating this problem, it is also biased. In the case of GWR, each data point within a defined distance has to be weighted with its distance from the regression point. Thus, data points nearer to the regression point will have a larger weight in the model than those which are farther away (Fotheringham–Brunsdon–Charlton 2002).

Figure 1

Spatial kernel



x Regression point — w_{ij} The weight of j data point in i regression point

• Data point — d_{ij} The distance between I regression point and j data point

Source: Fotheringham–Brunsdon–Charlton 2002, p. 44.

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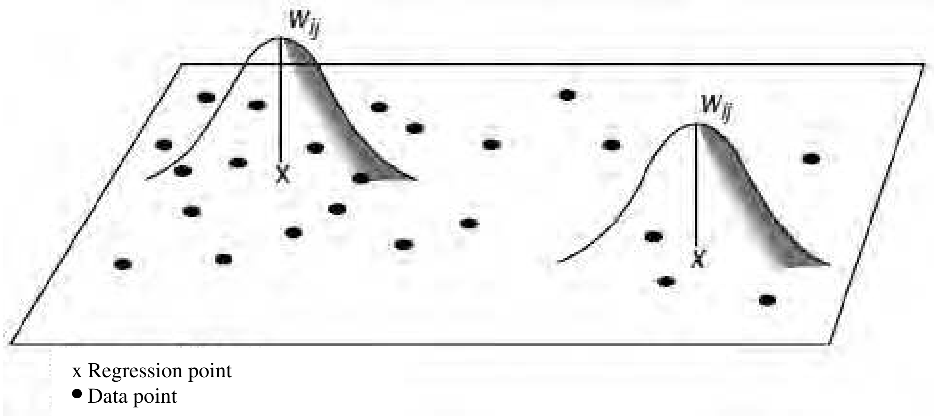
It is possible to apply a fixed spatial kernel (Figure 2). In this case, regarding one regression point, the data point coinciding with the regression point will have the largest weight. This maximum weight is continuously decreasing by the increase in the distance between the two points (regression point and data point). With this method, the regression model will be local in a way such that the regression point is moving in the study area. Since the weight of the data point is different in each area, local calculations are completely different. Mapping these local calculations will provide the surface including parameter estimates. In most cases, the result of GWR is not sensitive to weighting, but is sensitive to the bandwidth/diameter used for weighting. Therefore, its optimal definition is especially important in case of each examination. When comparing this with the moving window regression, it can be said that, due to the difference in the kernels, GWR gives a less even picture and shows more local differences, thus, in case of continuous phenomena its application is more realistic (Fotheringham–Brunsdon–Charlton 2002).

Figure 2

GWR with fixed spatial kernel



Source: Fotheringham–Brunsdon–Charlton 2002, p. 45.

This means in practice that points within a circle of a certain radius from the point examined are taken into account with a weight continuously decreasing the further they are from the starting point. The radius of the circle is determined by the scale of the examination, but more than one possibility is usually tested.

Also, in case of GWR with a fixed spatial kernel, the problem arises that there are some parts of the area where data points are much more sparsely located, and so, the local models estimated from them also have a greater random error. In extreme cases, the estimation of some parameters is impossible due to the low number of data. This problem can be solved by applying an adaptive kernel (Figure 3). Its distinctive feature is that its bandwidth can adapt to the number and density of data points, i.e. it will be narrower where the data are denser and wider where the data is sparse. In respect of the settlement network of Hungary, the difference between the settlement density of the Great Plain and Transdanubia is a good example for the necessity of applying the adaptive kernel. Comparing a map with a fixed kernel with that prepared with an adaptive kernel, the picture is very similar, with the difference that the map with an adaptive kernel is more even. The reason for this is that, in

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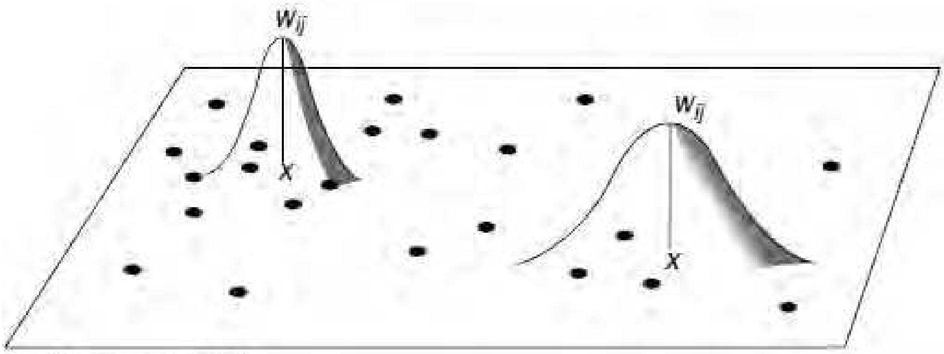
case of local models calibrated from fewer points, greater variability is expected (Fotheringham–Brunsdon–Charlton 2002).

The simplest way of performing an examination with an adaptive kernel in practice is to setup the regression models on the basis of a certain number of nearest neighbours to the points.

Figure 3

GWR with adaptive kernel



x Regression point
● Data point

Source: Fotheringham–Brunsdon–Charlton 2002, p. 47.

This method can be imagined so that so many different regression equations/estimates are available as the number of territorial units. Namely, the regression model is set up for territorial units together with its nearest neighbours selected in a defined way, i.e. we do quasi-local calculations. GWR is a complex statistical process; some elements of autocorrelation, regression and spatial moving average calculations can be found in its application. The logic of the method is the same as that of spatial moving average: GWR with a fixed spatial kernel is similar to moving average with a constant radius, while GWR with an adaptive kernel to that with a varying radius (Dusek 2004).

Although this method was described for point-like units of observation, it can be applied for larger territorial units, which can be marked as a point; this has been shown by numerous examples in the scientific literature (e.g. Chasco–García–Vicéns 2007, Eckey–Kosfeld–Türck 2007, Yu 2005).

The equation of the geographically weighted regression (Fotheringham–Brunsdon–Charlton 2002) is:

$$y_i = \beta_0(u_i,v_i)+\sum_k \beta_k(u_i,v_i)\, x_{ik}+\varepsilon_i$$

where (u_i,v_i) is the geographical coordinates of point i and $\beta_k(u_i,v_i)$ is the calculated value of the continuous function $\beta_k(u,v)$ in point *i*.

The essence of GWR is that it handles the regression coefficient as a function of location and not as a fixed constant value (Yu 2005). GWR expands the framework of global regression so that it allows the local estimation of parameters (Bálint 2010).

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Weighting options

The weighting options of fixed kernels: the shape and the extension of the kernel is unchanged during the examination.

$$w_{ij} = 1 \text{ each } i,j$$

where *j* is a point in the space where the observation was made and *i* is a point in the space whose parameter was estimated (Fotheringham–Brunsdon–Charlton 1996).

This approach is used in the global model, as the weight of every element is the same.

A possible shift towards taking into account locality is if, outside a certain distance from the regression point, some elements are not taken into account. This is equivalent with the case if these have a weight of 0. This approach is used in case of moving window regression:

$$w_{ij} = 1 \text{ if } d_{ij} < d$$
$$w_{ij} = 0 \text{ otherwise}$$

This weighting method makes the calculation simpler, since at the single regression points, the further calculation should be made only with the subset of the data points. The problem of this kind of weighting is that spatial processes, which can be considered continuous, are not handled as continuous ones. As the regression point changes, the coefficient may drastically change according to whether the data point moved into or out from the "window" (Charlton–Fotheringham–Brunsdon 1997).

A possible solution to this problem, i.e. that the weights are not continuous, is to determine a w_{ij} matrix which derives from the function of the continuous distance d_{ij} (between *i* point and *j* point):

$$w_{ij} = \exp\,[-½(d_{ij}/b)^2]$$

where *b* is the bandwidth. If the *i* point and *j* point coincide, since the *i* point may also be a point of observation, the data will have a per unit weight at this point and the weight of the other data points will decrease according to the Gaussian Curve as the distance between *i* and *j* points is increasing (Fotheringham–Brunsdon–Charlton 1998).

Another possibility is that a kernel uses the function b^2:

$$w_{ij} = \exp\,[1 - (d_{ij}/b)^2]^2 \text{ if } d_{ij} < b$$
$$w_{ij} = 0 \text{ otherwise.}$$

This is useful since it is a continuous, near Gaussian weight function to distance *b* from the regression point and has 0 weight at data points beyond *b* (Fotheringham–Brunsdon–Charlton 1998).

Turning to the presentation of adaptive kernels, there are further reasons for their use. First, where data points are densely located, it is possible to examine the changes of the relation within a relatively small distance, which would otherwise remain ignored in case of using a fixed kernel. In an area where data points are sparsely located, the value of estimated standard errors may be high when using fixed kernels since the number of used data points is low.

There are at least three types of adaptive kernels that can be applied for calculating GWR. According to the first one, the data points should be arranged in series depending on their distance from each *i* point:

$$w_{ij} = \exp - (R_{ij}/b),$$

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where R_{ij} is the rank number of point *j* from point *i*, i.e. the distance of *j* from *i*. The weight of the data point nearest to i is 1, and the weights are decreasing by the increase in the rank number. This will automatically reduce the bandwidth of the kernel in areas where there are many data, since, by taking the 10 nearest data points, the distance will be smaller than in the case of a regression point in a region comprising only a few data points (Fotheringham–Brunsdon–Charlton 2002).

Another, more complicated way to create an adaptive kernel is to define that the sum of weights is constant, *C* at any *i* point. In areas where data points are densely located, the kernel has to be shrunk so that the sum of the weights is the defined *C*, while the kernel will be wider where there are fewer points.

$$\Sigma_j w_{ij} = C \text{ for each i}$$

With this method, to define optimal *C* may cause difficulty. Defining *C* can be done as follows: first an optional value has to be defined; the weight function has to be created with this value and a *goodness-of-fit* test has to be run for the model. Then, another *C* value has to be chosen, the weight function has to be created, the *goodness-of-fit* test has to be run again and these two steps must be repeated until the optimally fitting *C* values are found (Fotheringham–Brunsdon–Charlton 2002).

As a third possibility, taking into account the *N* number of nearest neighbours can be considered.

$$w_{ij} = 1 \text{ if j is one of the N nearest neighbours of i}$$
$$w_{ij} = 0 \text{ otherwise}$$
or
$$w_{ij} = [1 - (d_{ij}/b)^2]^2 \text{ if } j \text{ is one of the } N \text{ nearest neighbours of i, and b is the distance of the } n \text{ nearest neighbour}$$
$$w_{ij} = 0 \text{ otherwise.}$$

In this case, the calibration of the model also involves the definition of *N*. Namely, *N* means the number of those data points which are included in the calibration of the local model, and the weight function determines the weight of each point to *N*. The weights converge to 0 (Fotheringham–Brunsdon–Charlton 2002).

To define the optimal diameter of the kernel

One option is to minimize the value of z as follows:

$$z = \sum [y_i - \hat{y}_i (b)]^2$$

where $\hat{y}_i$ is the estimated value of the dependent variable, by using *b* diameter. In order to get this estimated value, the estimation of the $\beta_k(u_i,v_i)$ values at each data point and the *x* values are needed. In a general case, the problem may arise that, if the value of *b* is too small, the value of the other points except for *i* will become negligible by the weighting. As a result, the estimated value will be very similar to the original one at the selected points, and so the equation will equal 0 as well. Therefore, the parameters of such a model cannot be determined in some cases, and the estimation will change in space so that there will be locally appropriate estimated values at each regression point (Fotheringham–Brunsdon–Charlton 2002).

In order to eliminate this, the extension of the above correlation is needed. The cross-validation applied also in case of local regressions is necessary:

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$$CV = \sum [y_i - \hat{y}_{\neq i}(b)]^2$$

where $\hat{y}_{\neq i}$ is the estimated value of the dependent variable if *i* point is left out of the calibration. This is a good solution since, if the value of b is small, the model will be based on points close to point *i* and not on point *i* itself (Fotheringham–Brunsdon–Charlton 2002).

Another possibility to define the optimal diameter of the kernel is the application of the Akaike information criterion (AIC) and the Schwarz criterion (SC). The indicators combine the error of fitting with the complexity of the model. The more complex the model and the more explanatory variables it contains, the more it will be penalized. The smaller the value of indicators, the more the model will fit. Consequently, that kernel diameter is the optimal with the help of which the AIC and SC values calculated for the model are minimal (Bálint 2010, Fotheringham–Brunsdon–Charlton 2002).

GWR can be widely applied, as it is utilised in economic and geographical researches alike. This is illustrated in the following examples. In the study of Yu (2005), the regional development of the wider area of Beijing was examined with GWR in terms of spatial heterogeneity. Lin, Cromely and Yang (2011) used the method for solving interpolation problems. Fotheringham, Brunsdon and Charlton (2002) set up a GWR model for London house prices in order to explore local features. Eckey, Kosfeld and Türck (2007) analysed the regional convergence of the German labour market with the help of this method. Ridefelt, Etzelmüller, Boelhouwers and Jonasson (2011), when modelling mountain permafrost, studied the existence of stationarity with the help of geographically weighted regression.

According to some opinions, the GWR method is one of the most often used local regressions, and is considered an excellent visualisation tool to present spatially varying effects (Bálint 2010). Several criticisms were expressed in connection with the method, suggesting that it cannot be considered a model, since it has rather an illustrative role, and the emphasis is not on the estimations but on the regional pattern of parameter estimates. Another disadvantage of the method is that it is sensitive to outliers, additionally, the probability of problems coming from multicollinearity is also higher than in a global regression model (Lloyd 2007, Wheeler–Páez 2010).

Local analysis of the fragmentation of regional development in Europe

With the help of an example for the application, the paper presents in which aspects the use of the GWR method is better than the use of global regression.

Beginning with defining the regional framework: the calculations refer first of all to the EU member states including Macedonia from the candidate countries. In the interest of as complete an analysis as possible, Switzerland and Norway are also included. Due to their large distance from the continent, Cyprus, Malta, as well as the overseas regions of France, Portugal and Spain are left out.

Initially, the calculations were for the NUTS-2 regions, but, when interpreting the results, it became obvious that this approach is not detailed enough, since selecting the neighbours was often difficult due to the shape of Europe. Therefore, the decision made to carry out the examinations for regional units of lower level. In respect of the European regional structure, this would unambiguously mean the use of the NUTS-3 level. However,

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because of the heterogeneity of the NUTS structure, the mixed use of the NUTS-2 and NUTS-3 levels was decided on. In the case of Belgium, the United Kingdom, the Netherlands, Germany and Switzerland, the NUTS-2 level, while in the case of the other countries, the NUTS-3 level (793 regions) was used. Thus, more homogeneous data series were available and the dispersion deriving from the differences in size was also reduced.

Most of the data come from the *Regio* database of Eurostat. Some of the data missing from the data series were supplemented from the websites of the national statistical offices while others were estimated with the help of regression on the basis of longer data series.

Some words about the calculations: The model for GDP data measured in purchasing power parity per capita was set up in 2009. The computation was made with the Matlab program on the basis of the methodological study of Fotheringham–Brunsdon–Charlton titled *Geographically Weighted Regression, the analysis of spatially varying relationships,* and the study of LeSage titled *The Theory and Practice of Spatial Econometrics* presenting the computation of some statistical methods with this program.

The dependent variable:

– GDP per capita.

The independent variables:

– rate of economically active people,

– unemployment rate,

– population density,

– rate of people employed in the tertiary sector.[1]

When interpreting the results, it is worth taking into consideration several opportunities. There is an opportunity to examine the standardised beta values of the different regression equations, utilising this, we get an answer as to which factors have a greater role in the evolution of the phenomenon at the different territorial units (Eckey–Kosfeld–Türck 2007).

By mapping the R^2 values, it can be seen how reliable the model is for the different territorial units and what the spatial relevance of the models is (Xiaomin–Shuo-sheng 2011).

It is possible to compare the original values with the ones estimated with the equations.

First, when examining the GDP per capita, the regions comprising the capitals or some large cities are in a more favourable situation (Figure 4). In addition, a central area with high GDP/capita values is outlined, which comprises first of all regions in Southern Germany, Switzerland and Northern Italy. Furthermore, due to her significant revenue from petroleum and low-population number, Norway also has outstandingly high values. The most backward regions in this respect are those in the new member states that acceded to the EU in 2004 and 2007.

1 As a starting point, an OLS model was set up in order to see which indicators have an influence on the GDP/capita. The computations carried out with the SPSS program, Regression/Stepwise method. This method was used, since, after defining the dependent and independent variables, the program creates the most optimal regression model.

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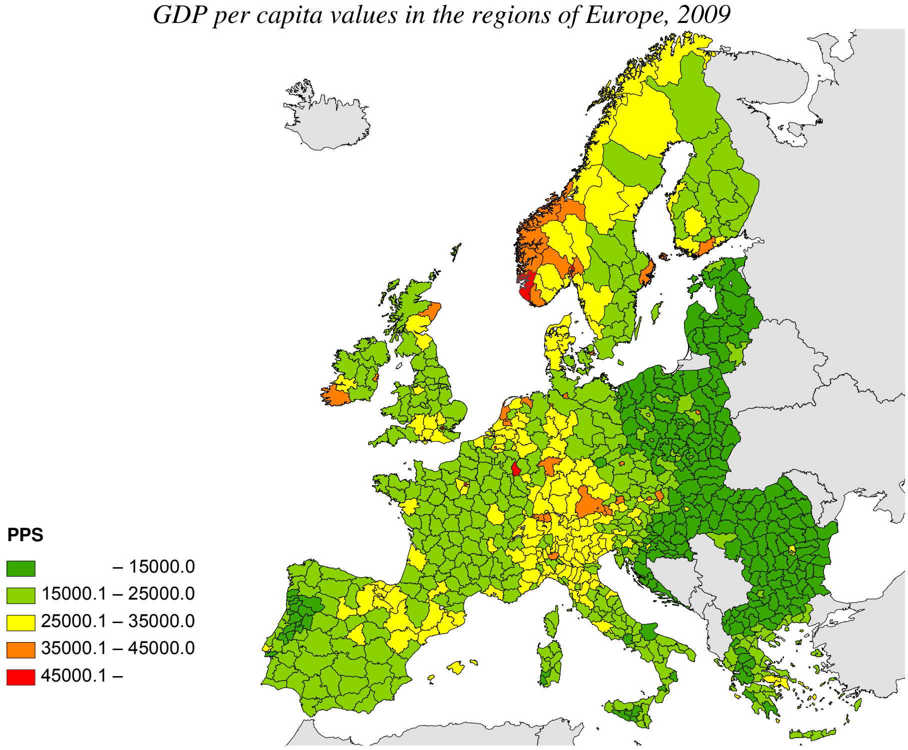
Figure 4

GDP per capita values in the regions of Europe, 2009



The estimates given by the GWR model for the dependent variable were then examined by using different bandwidths. In order to also compare the results calculated by different bandwidths, the optimal calculation was avoided. Both fixed and adaptive kernels were used, and a b^2 weight function chosen in case of fixed kernels and applied the N nearest neighbours method in case of adaptive kernels. In case of the fixed kernel, data points within a circle of a radius of 75 km, 100 km and 150 km were taken into account. In case of adaptive kernels, 10, 20, 50 and 75 nearest neighbours were examined. First, it was established that, due to the "irregular" shape of Europe and the uneven regional structure, the fixed kernel method is a less appropriate approach. Namely, when looking for neighbours, for example, within a distance of 100 km, many can be found in most regions of the continent, but none in the case of the farther, larger Northern Scandinavian and Scottish regions. Therefore, the fixed kernel method was not continued with.

By illustrating the results calculated with an adaptive kernel on a map (Figure 5), it can be seen that estimations of the GDP per capita made by the GWR model give good results. As expected, the more data points are involved in a local equation, i.e. the wider the bandwidth, the more homogenous the picture is. Namely, if more points are taken into account, the areas will become less unique. Later, the results of the calculation which takes into account 50 nearest neighbours will be analysed since this is the best in respect of multicollinearity, as well as the reliability (based on the significance value of the F test) and the fitting (coefficient of determination) of the model.

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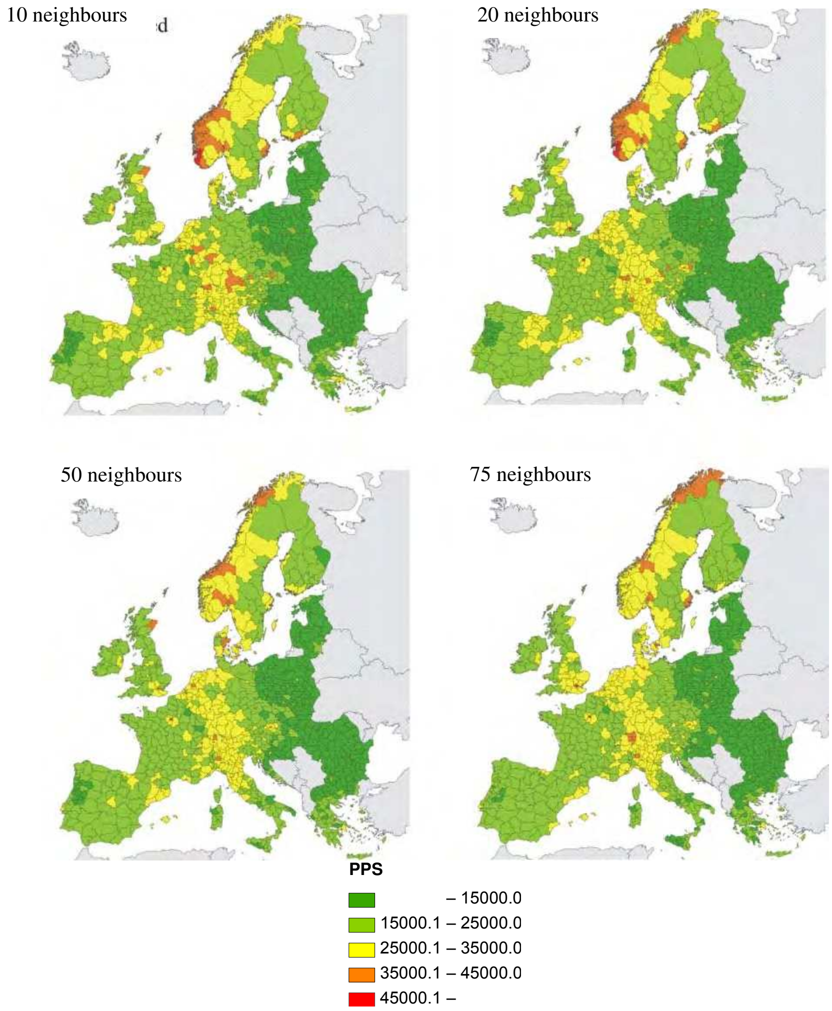
Multicollinearity was examined with the help of a Red indicator; the value of which can be between 0 and 1, and the closer it is to 0, the smaller the effect of multicollinearity is (Kovács 2008b). The Red indicator examines the considerable co-movement of the explanatory variables and the redundancy of data based on the dispersion of their eigenvalues. Its formula is:

$$\text{Red} = v\lambda / \sqrt{(m-1)}$$

where $v\lambda$ is the relative dispersion of eigenvalues, m is the number of elements. In the case of maximum redundancy, the value of the indicator is 1, while in case of complete absence of redundancy it is 0 (its value can be given in percentage as well).

Figure 5

GDP per capita estimated by an adaptive kernel taking into account a certain number of neighbours defined by GWR



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Following this, the R^2 values of the local equations were mapped in order to examine their geographical relevance (Figure 6). When analysing the maps, the first point to be established is that the explanatory power of the models decreased by the increase of the bandwidth. This is in line with the expected results since the more neighbours/elements are taken into account, the larger the number of those which are included in the model but have no actual effect on the GDP per capita of the initial region. The new elements quasi "ruin" the original model. Thus, the more territorial units are included, the more the local characteristics are neglected, and the global nature strengthens. On the other hand, the more neighbours the equations are based on, the more homogeneous the picture is. It can also be observed that, taking into account more and more neighbouring regions, correlations relating to territorial units in peripheral areas become less and less reliable. In respect of the R^2 values of the calculation taking into account only 50 neighbours, in the case of regions in Southern Norway, Denmark, Romania, Greece, Southern Italy and some regions in Northern Germany and Spain, the explanatory force of the models is lower than in the case of other regions. This may result first of all from the fact that these territorial units are peripherally located. Thus, the regression equations were not setup on the basis of neighbours actually associated with them. In respect of the R^2 values, it is important to mention that correlations between variables are not equally true for each region; in some of them, the correlation is closer to the trend throughout Europe, while in others, the fitting is more uncertain.

When setting up a global regression model, with the help of the standardised beta values, the strength of the effect of the different independent variables on the dependent variable is defined, i.e. which explanatory variable has the strongest impact on the result variable. This approach can also be applied in case of GWR models. However, in this case, since there are as many regression equations as the number of territorial units, we can say which variable has the greatest impact so that we select in each equation which indicator has the greatest role and combine them. This was examined in the present study (GWR taking into account 50 neighbours), and as opposed to the results expected on the basis of the global model (Table 1), in the local equations, not the rate of people employed in the tertiary sector but the unemployment rate influences the income per capita the most. The reason for the difference may be that the OLS estimation, in the absence of independence error structure, might have led to biased estimations (Moran I value is 0.380).

Seeing the results of the global regression (OLS) and the GWR, we can say that local relationships sometimes significantly differ from the global ones. Later, it will be obviously visible that, on a global level, the impact of an independent variable on the GDP per capita is only positive, while, on a local level, it can be positive or negative alike, i.e. the sign in the local model may differ from that in the global one (Shaoming–Huaqun 2010).

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Table 1

Results of the multivariable global regression (OLS)

	Unstandardised coefficients		Standardised coefficient	t	Sig.
	B	standard error	Beta		
Constant	–17838.8	1824.1		–9.8	0.0
Rate of people employed in the tertiary sector	383.3	16.7	0.536	23.0	0.0
Rate of economically actives	304.1	26.2	0.264	11.6	0.0
Unemployment rate	–408.5	40.2	–0.230	–10.2	0.0
Population density	2.0	0.2	0.237	10.1	0.0

By mapping the beta and standardised beta values, we can examine the impact of the different explanatory variables on the dependent variable (Figure 7, due to the considerable similarity, it was thought sufficient to present only the maps of the beta values). Thus, the GWR coefficients show the regional pattern of the impact of different explanatory variables on the GDP per capita, with the difference that beta values show the direction and strength of the relationship between the dependent and the independent variable in the original unit of measurement, while standardised beta values show them in a standardised, i.e. comparable way (Shaoming–Huaqun 2010). Examining the different beta values, in general, in respect of explanatory variables, the values of peripheral areas were negative, while those of central areas were rather positive. This is mainly the opposite in case of the unemployment rate. The reason for this is that the meaning of changes in the unemployment rate is just the opposite of that of the others (any increase has a negative effect in the case of unemployment rate).

When separately examining the different regression coefficients, a quite homogeneous picture can be seen in the case of population density. At most territorial units, the GDP/capita changes in the same direction as the change in the value of population density except for some regions in Spain, Poland, Estonia and Greece. The impact of population density on the state of development is the strongest in the regions in Southern France, Eastern Spain and some regions of Norway and Sweden. In respect of the beta values of the unemployment rate, the values of some regions in Portugal, Spain, Southern France and Southern Greece show the same direction, while the central regions show an opposite one. The strongest influencing effect can be seen in North-western Spain, Southern Norway, Central Sweden and Central Germany. In the case of regression coefficients of economic activity, a co-movement of opposite direction can be observed in the Eastern peripheral regions, in regions in Portugal-Spain and the territory of the Benelux countries, with a co-movement of the same direction in the central areas. The impact on the state of development is the strongest in the regions in Ireland, Northern England, Central Spain, Southern France, Benelux and Central Italy. Differently from the former ones, the beta values of the rate of people employed in the tertiary sector are quite various, since the effect of the opposite direction is only partly characteristic of the peripheral regions, and it can be observed in the regions of Southern France and Northern Spain. The impact on the state of development is the strongest in the regions of Northern Spain, Northern France, Ireland,

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Scotland, Benelux, the Czech Republic and Estonia. When examining the maps of the standardised beta values next to each other, it can be seen which of the four explanatory variables has a stronger impact on the state of development in a given region.

When comparing the values estimated by regression equations with the original ones, the models have rather underestimated than overestimated.

Figure 6

R^2 values of calculation with adaptive kernel taking into account a certain number of neighbours

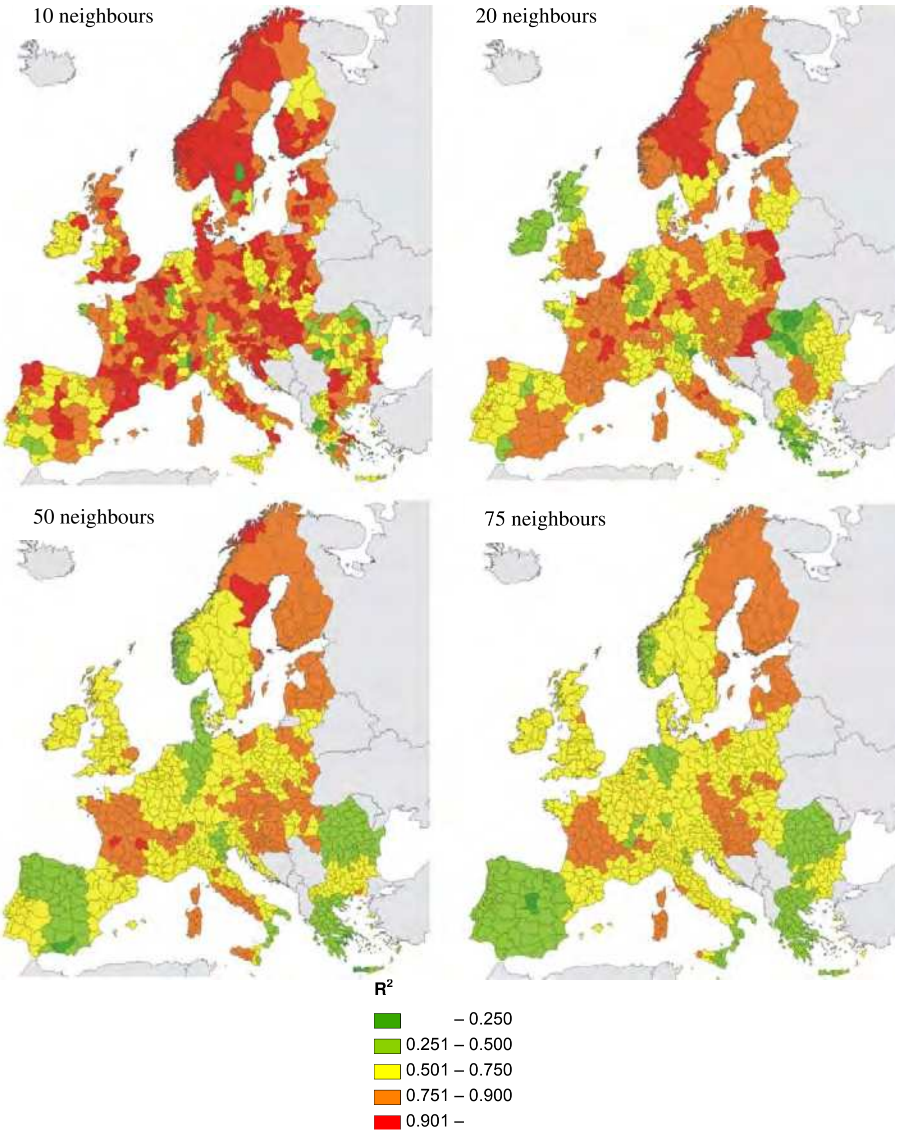

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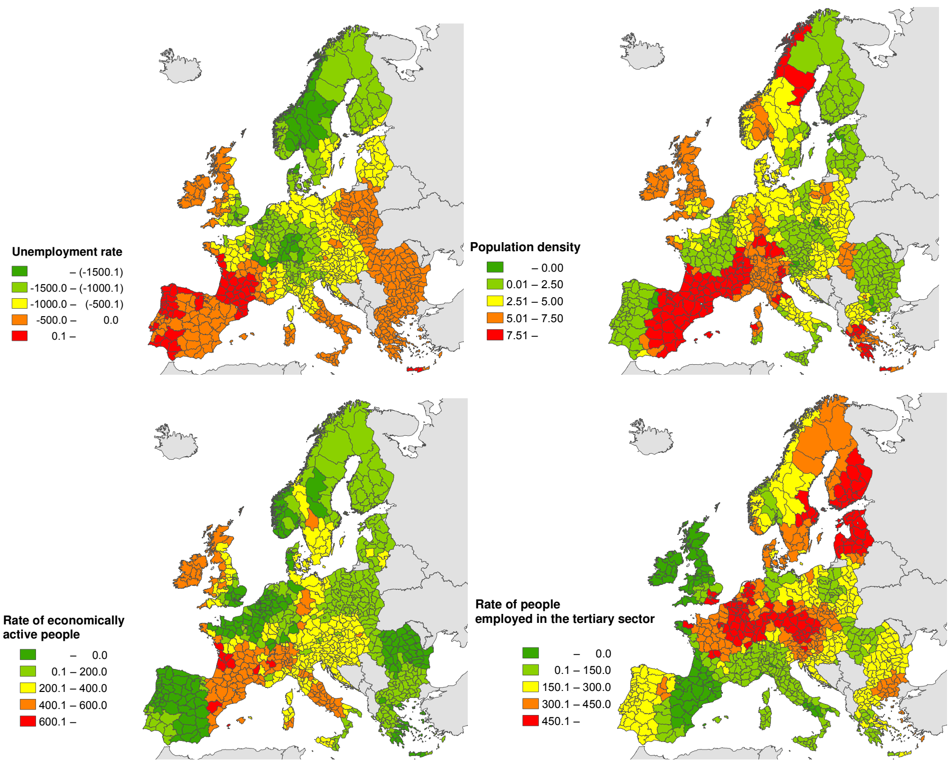
Figure 7

Beta values of GWR calculation with adaptive kernel taking into account 50 neighbours



Summary

GWR is a local model, since it does not calculate the global relations of the whole data, but concentrates on the relationship of the dependent and independent variables locally within a determined search area, and so is also suitable for the consideration of the spatially varying processes (Mitchell 2005). Fundamentally, the GWR is a developed version of the global regression model, since with the use of it, the local features remaining hidden by the global approach can be taken into account. In the author's opinion, the overriding result of its use is that the R^2 values of the different regions show that correlations between variables are not equally true for each region. In some of them, the correlation is closer to the trend throughout Europe, while in others, the fit is more uncertain. This also confirms that the global approach conceals or may conceal local features.

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Theoretical and Practical Possibilities of Lower-Medium-Level Spatial Division

Abstract

The paper is concerned with the theoretical and practical approaches to administrative regionalisation. The authors attempt to present a new methodology, which on one hand is theoretical and from the other, enables the design of an optimal spatial system in terms of the demands of the population. This is presented on through the example of Hungarian districts (the level between municipalities and counties in the administrative system).

Keywords: district, spatial division, methodology, accessibility.

Spatial division in scientific thinking

Theoretical issues of spatial division

The basis of the examination of spatial research engaged in spatial phenomena is made up in each case by a particular spatial division, which appears as a characteristic given from the beginning in the vast majority of cases. Many studies (Csanádi–Ladányi 1992, Dusek 2001, Forest 2005, Bömermann 2012) prove, however, that the results of research are closely related to spatial division, so they can highlight or disguise the different characteristics excessively. Spatial division, playing an important role in many fields of science, the characteristics of the formation of spatial structures applied in social scientific analyses and public administration is examined in connection with the subject of the paper.

A significant change in Anglo-Saxon social scientific research was brought about by scientific theoretical discussions following World War II, since the emphasis shifted from the principally descriptive analyses earlier on to modelling and the examination of structures and systems (Győri 2005). The questions of spatial division also came to the fore at the time: some researchers wrote entirely theoretical works (Gregory 1949, Haggett 1965, Grigg 1969), while others showed the importance of spatial divisions by highlighting certain aspects of space (Alampiyev 1961, Bunge 1966). There was another change in the approach from the 1970s, since the theoretical and methodological tools of former researchers could not answer the social problems in the world; therefore, widespread criticism was directed at the strongly quantitative approach. Thus, new intellectual trends emerged in scientific theoretical discussions that were rooted primarily in Marxist and

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humanistic ideas (Gregory et al. 2009). The need for and the necessity of amalgamating the different views are increasingly dominant at around the turn of the millennium, which is a task to be solved by the young generation (Barnes 2009).

Boundaries and territorial units

A task of spatial division is to delineate *boundaries* according to determined aspects, which thus separate *territorial units* from one another based on the analysis and classification of similar and different characteristics.

The examination of *boundaries* was the description and classification of the characteristics of (state) boundaries according to attributes of morphology, nature, origin and history from the end of the 19th century practically to the termination of World War II. The most dominant idea until the 1960s was that natural units are separated by natural boundaries, which, at the same time, means the embodiment of objective reality (Kristof 1959). However, as a result of increasingly intensive scientific theoretical discussions in the middle of the century, a growing number of people questioned from the 1960s and 1970s that boundaries were determined from the beginning, and considered them as social and political constructions as opposed to the earlier supposition. Interdisciplinary research became widespread from the 1980s, and as an effect of stronger post-modern intellectual currents, answering the questions "how?" and "why?" as opposed to hard analyses and the typification of functions came to the fore in examinations. This in turn pointed towards the deeper understanding of the themes of relations, co-operation or identity (Kitchin–Thrift 2009).

According to the present approach in social sciences, neither natural boundaries nor natural *territorial units* exist (Nemes Nagy 1998, Hajdú 2006), since they are established as a result of classifications by selected objective and subjective criteria. Spatial systems are used as political tools in most of the cases or are the consequences of power or ideological fights, so the structures established merely fix the state of a given moment of these "fights". The boundaries delimiting the many different territorial units are simultaneously the results of existing spatial disparities and in many cases are the cause of the further increase of the differences. For that very reason, epistemological criticism, which relies on the social history of the formation and use of boundaries/territorial units, is indispensable in scientific research (Bourdieu 1985).

Theoretical aspects of spatial division

As physical and social spaces are not homogeneous, designated points, or delimited territorial units are needed to ensure that as much and accurate information is available as possible for the performance of analysis, control and organisational tasks (Dusek 2004).

Relying on the Anglo-Saxon literature, Tamás Dusek highlights, in respect of spatial division, that each of the elements filling in the area to be divided should be part of the division on one hand, and that every element needs to be classified according to an unambiguous categorisation on the other. In addition, it is indispensable to apply identical criteria in case of multi-level classifications (Dusek 2006). József Nemes Nagy designates three aspects, in relation to the division of space, which have key importance in practice.

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The primary point of view of spatial division is that it should reflect the structures present in reality as accurately as possible. The second point is comparability, which means the necessity of the comparability of territorial data available at different points in time and the need for the stability of spatial systems in time. The third aspect concerns the subject of manageability, which comprises the options for size, cardinality and the aggregation of information (Nemes Nagy 2009).

The emphasis is laid on the possibilities and methods of the formation of administrative spatial division in the study, so the work of István Bibó should be highlighted among the theoretical references. Bibó elaborated an administrative spatial division system in the 1970s, which brought households needs to prominence. When forming the administrative breakdown in this way, top-down organisation operates to a lower and lower extent; the appropriate structure is determined much more importantly by every-day practices and possibilities, and is built from the bottom to the top (Bibó 1986 [1975]). Based on all these, Bibó highlighted that the centres of the different territorial units are ideally located at a distance that can be optimally approached according to households' needs, and the different territorial units should be proportionate to one another for the sake of a balanced administration. In addition, it is necessary to emphasise the unity of physical planning and the coherence of the different territorial levels, as well as to take into consideration the level-difference problematics of practical belonging to an area. In the modelling chapters, considerable emphasis is laid on the achievement of optimal accessibility from the five principles previously outlined.

Theories of public administration organisation in Hungary

The breakdown and organisation of the state area from an administrative aspect are basically power, political and organisational issues, where national characteristics and the imprints of historical processes also emerge. Public administration is a factor of dominant importance at the levels of both the state and the individual: it covers the life of the population, strongly affects the hierarchy and the development trend of the settlement network and the characteristics of socio-economic movements. This effect, however, is not one-way: the territorial distribution of the population and settlements, transport possibilities, natural conditions or the characteristics of the territorial division of labour, all form the approach and options of public administration organisation (Hajdú 1994).

The settlement network does not make up a homogeneous system, many settlements capable of performing central functions were formed in certain areas of the country, while, for example, areas with small villages having less than one thousand inhabitants fight the problems of a lack of towns. A settlement becoming a centre brings about many institutions and functions, so even if the new centre rises higher in hierarchical levels, it cannot develop primarily in the process of urbanisation (Beluszky 2005). Although proportionality among the many different territorial units is a basic need in forming an optimal breakdown, differences in the sizes (physical extension, population number) of settlements and functionally coherent areas raise questions that are difficult to eliminate.

In addition to the effects of the settlement network, transport and accessibility also play an important role in forming public administration. In the course of the 20th century, the importance of transport initially emerged in county-level planning (Prinz 1933, Vagács

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1952) and urban analyses (Erdősi 1985, Bajmócy–Kiss 1999). In this interpretation, there is a direct relationship between the attraction of towns and transport options, which emphatic emphasis should be laid in territorial planning. Even though info-communication and technological development since the turn of the millennium have rewritten territorial processes, the analysis of their impact on public administration is of limited significance in the literature.

In the following, three public administration organisation approaches that emerged in the 20th century will be presented. These had a significant effect not only on the practice of spatial division in Hungary but also reflect dominant ideologies and political efforts at the same time.

The elaboration of the *landscape administrative principle* is related to the name of Pál Teleki in Hungary. As according to the objective spatial approach of Teleki, "real" geography is landscape geography, which results from the inter-connection of natural geography and anthropogeography. His administrative analysis following the peace treaty of Trianon was prepared to take into consideration the nationality, natural, social, economic, transport and settlement-network characteristics in Greater Hungary. The division elaborated this way could not be of practical use owing to the reduction in the area of the country, but the followers of Teleki, adopting the approach, continued and applied the landscape-geographic approach. Following World War II, the landscape geographic and administrative approach was driven into the background in Hungary, and the economic factor came to the fore in the organisation of society as a consequence of political and ideological changes (Hajdú 2005).

Economic zoning was based on taking into account the characteristics of the conditions of production and the territorial division of labour (Beluszky 1987). Economic spatial structure forms a homogeneous system according to Marxist ideology: natural resources form the basis, and the different branches of production are established relying on this. The distribution of population is not homogeneous, consistent with these two factors, but is tightly associated with the characteristics of production; furthermore, the settlement network is closely related to the territorial distribution of population and the characteristics of production. Public administration does not form a single sphere in this approach but covers the components of economic structure, and thus enters into relation with the total natural, social and economic system (Krajkó 1989). The effort to highlight the economic sphere was present all through the period of socialism, which, interwoven with changes, shows up in today's administrative thinking after losing its exclusivity during the years of transition.

The theory of economic zoning considers the economic sphere as the basis of administrative breakdown, while the *theory of central places* designated the conditions of supply as the starting point of the organisation of society. The concept considers the settlement network's structural and functional relation system as the framework that delineates complex urban areas serving as grounds for public administration (Hajdú 2006). The approach came to the fore predominantly in the 1980s, which is apparent in that the breakdown by districts, abolished in 1983, changed urban neighbourhood administration at the lower-medium level of public administration in Hungary. This new form of administration aimed to create the unity of towns and villages so that the settlements

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belonging to one urban neighbourhood be designated by the types of relationships making up the daily space of population movement (Beluszky 1987).

Though in today's administrative-territorial organisation, the urban area approach is the most dominant one of these, all the three schools of thought form spatial thinking. It is also important to underline this because no optimal administrative territorial breakdown exists in itself. The judgement of territorial breakdown mainly consists of how much the established structure is suitable for reaching current political purposes (Hajdú 1987).

Classical social scientific methods of spatial division

The division of physical space can be established serving many different functions, and so needs to meet various requirements. Spatial structures applied in scientific research or statistical data collections have other characteristics than those in administrative structures, having a basic role in social management – therefore the methodologies of the divisions also offer different paths.

The simplest procedure is the *geometrical method*, according to which the centres of the area to be divided are pre-given, while the boundaries of districts are designated by perpendicular bisectors on the lines linking neighbouring points. In case the different centres have differing active force, perpendiculars need to be drawn on lines linking neighbours at points shifted depending on the magnitude of active force (Nemes Nagy 1998).

The geometrical method can be applied when the purpose is to project the information, measured in distinct points, to the whole space. Although this was used in certain practices and in setting up spatially statistical structures (Mezencev 2010), it is not suitable for delimiting optimal territorial breakdowns. Specifically, it does not take into consideration other spatial organisation processes since the primary determinant of setting up a breakdown is the spatial position of available centres and their relation to one another.

Another method is the determination of *urban areas*, where the possible centres are first selected, and then the areas belonging to them are delimited. The question of designating centres rarely emerges in the Hungarian literature (Bajmócy–Kiss 1999, Kiss–Bajmócy 2001); settlements having higher functions, including administrative breakdowns, gain the central role. The issue of the central role is relatively deeply discussed only in studies on administrative reforms (Beluszky 1987, Faluvégi 1994, Szalkai–Jakobi 2011, Szalkai 2012). Urban areas are determined with the aid of the gravity model, which calculates the boundaries of urban areas using weights assigned to centres and the distance between two centres. Although functional districts belonging to centres can be delimited with the aid of the gravity model, this method also does not meet certain criteria of spatial division (proportionality, comparability) in several respects; namely, it highlights disproportionalities and inequalities in the settlement network (Nagy 1996).

The third possibility for spatial division is offered by the method of *cluster analysis*. It is the elements of the area to be divided that are classified in cluster analysis, and this is completed by the spatial dimension. Thus, a cluster can include elements that show similar features not only in respect of socio-economic indicators, but also meet the neighbourhood criterion from the point of view of location (Kabai 1981). Despite expectations, this method is not optimal in practice, since often, many groups with low numbers of elements and a

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few with large numbers are created at a time, which raises the problem of spatial disproportionality (Nemes Nagy 2005).

It is important to highlight that, in addition to the presented three possibilities of spatial division, new methods have emerged; principally following the turn of the millennium, which are built mainly on the results of computer science (Fallah et al. 2009, Farahani–Hekmatfar 2009). With the development and availability of computer technology, as well as the opening of the different fields of science towards one another, the set of tools of social scientific research can be extended with methodological solutions that can lead to entirely novel results, opening the possibilities of examination in a wider spectrum. In the following chapters, this paper aims to present this. It is pointed out through theoretical and practical examples the new solutions that the application of a computer scientific set of tools can offer in the question of administrative spatial division besides the previously mentioned classical methods.

Models and algorithms

This chapter explores what applied mathematical, statistical and computation theoretical tools can be used to model spatial division, and within this, the problem of the delimitation of lower-medium-level administrative units through the re-establishment of the district system in Hungary.

In creating the model, the principles of Bibó (1986 [1975]), and the structural relationship system of the settlement network through accessibility by public roads were considered as the primary theoretical aspects of the administrative spatial organisation. Two models were established on the basis of these aspects. The paper shows possible ways of solving these, their actual implementations on computer, and, in possession of the results, examines their applicability to the original spatial division problem.

Applicability of facility location problems in spatial division

The purpose of problems known as *facility location* in the English literature is to determine the place of certain resources (facilities) so the costs of satisfaction of the demands for the resources should be minimal, while location meets certain conditions. Both the resources to be located and the criteria to be satisfied can be various, so the range of problems belonging to this category is also wide. As one will see, decisions on the siting of facilities often requires the simultaneous consideration of several aspects that might be conflicting. Thus, the problems to be solved – in both traditional and computation theoretical senses – set difficult tasks for decision makers. As a result, the issue has been the subject of countless studies from the second half of the 20th century to date (Farahani–Hekmatfar 2009).

The *location set covering problem* (LSCP) is a version of the *set covering problem* – a classical problem of computation theory – used in facility location, where the number of located resources and the costs of their location should be minimised so that all the demand for the resources should be satisfied. Its condition is that in no case should the resource fall farther from the demand to be served than a designated parameter of distance (Toregas–ReVelle 1972). To serve all emerging demand can be a purpose when, for instance, locating

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services that can be used in case of emergency, allocating aircrew, or in case of services provided by the public sector, those which should be accessible for all citizens (Toregas et al. 1971, Fallah et al. 2009).

Application of LSCP to establish districts

Based on the Bibó principles, the optimal accessibility of the centres of spatial units needs to be considered, with the fit of units to one another especially important from the theoretical aspects of administrative spatial division. In addition, it is an evident point of view that all should have access to the services provided by public administration. One version of LSCP is applied for these aspects in the first model. Optimal accessibility is modelled by the distance parameter.[1] A minimum sub-set of settlements (centres) is searched, with the selection of which, a centre can be found for every settlement within the particular area (generally a county, taking into account the fit to one another) from which it is not farther than the value of the distance parameter.

For the solution, the set covering problem is formulated as a "*binary integer programme*," in which the variables of the target function to be minimised can be one of the *{0, 1}* values:

$$\min \sum_{j=1}^{n} x_j,\ x_j = \begin{cases} 1, & \text{if j is otherwise a centre.} \\ 0, & \end{cases}$$

Thus, the purpose is the selection of a minimum number of centres out of the *n* settlements in the area, meeting the condition,

$$\sum_{j \in N_i} x_j \geq 1,\ i=1, 2, \ldots, n,\ N_i = \{j | d_{ij} \leq D\} n,$$

i.e. we need to find for every settlement *i* a centre *j*, for which the distance d_{ij} between these two is lower than the pre-defined distance parameter *D*.

"*NP*", the optimisation version of set covering, belongs to difficult problems. It is a class of computation theory problems, the solution of which – expressively – takes much time, and this time increases sharply along with the growth of the size of the problem.

Therefore, two groups of algorithms have been developed to solve such problems. One of the groups, although guaranteed to find the optimum, can require an unrealistically high running time in case of large problems, while "*approaching algorithms*" produce in less time a result on which it can be proved that it differs from the optimum only to a defined extent.

In the cases the paper seeks to solve, the size of the problem (typically some hundreds of settlements) was such that "*branch and bound*," one of the algorithms searching the optimum, produces a result in a reasonable time; using this provides the possibility to find the optimal solution.

The model was run on the tool specialised in binary integer problems (bintprog()) of the *Optimization Toolbox* of MATLAB software. This tool is suitable for solving min $f^T x$

1 The distance parameter is considered to be pre-given here, we are not concerned with its definition, but a recommendation concerning its actual value can be found in the work of Miklós Oláh and András Csite (2011).

$$A_x \leq b, \quad A_{eq}x = b_{eq}$$

form problems, where $(\ )^T$ indicates the operation of transposition, f, b and b_{eq} are vectors, A and A_{eq} are matrices, and the elements of x can equal 0 or 1.[2] Thus the condition on the distance parameter needed to be reformulated, so that it should comply with these criteria. A was simple to form having the $d \in R^{nxn}$ matrix, containing the distances between settlements on public roads, relevant to a particular area:

$$A_{ij} = \begin{cases} -1, & d_{ji} \leq D \\ 0, & d \rangle D. \end{cases}$$

(The negative sign is needed because of the direction of the relation during the inversion of indices because of transposition.) The other two parameters equalled $f_{1, 2,..., n} = 1$ and $b_{1, 2,..., n} = -1$ values. The problem in such form could be solved with the above-mentioned tool.

The elements of the produced result vector x correspond to the elements of X in the original formulation of the problem. Therefore, they indicate whether particular settlements are given a central role in the optimal solution.

In addition to the selection of centres, it was also important to delimit districts. Bearing in mind optimal accessibility every settlement was annexed to the centre closest to it, so forming for every centre j the set of settlements belonging to it:

$$S_j = \begin{cases} \{k | d_{kj} = \min(\{d_{kl} | X_l = 1\})\}, X_j = 1 \\ \qquad\qquad\qquad\qquad 0, X_j = 0. \end{cases}$$

This model can be completed in several ways. The following examines a case in which the need arises that on establishing districts, not only their minimum number should be taken into consideration, but also minimising the size of the population forced to commute to the district centre.

In case no other aspect occurs, the task can be solved with one version of the method described previously. The size of commuting population can be minimised most simply within a particular area (county) if the population of settlements designated as district seats is maximised or – as the algorithm used carries out the minimisation of the target function – the target function is weighted in inverse proportion to population numbers. Thus, the binary integer programme form of the task changes as follows:

$$\min \sum_{j=1} \frac{x_j}{p_j},$$

$$\sum_{j \in N_i} x_j \geq 1, \quad i = 1, 2, ..., n,$$

$$N_i = \{j | d_{ji} \leq D\}, \; x_j = \begin{cases} 1, & \text{if } j \text{ is otherwise a centre,} \\ 0, & \end{cases}$$

where p_j indicates the population resident in a particular settlement. Besides this, we continue to take into account the condition that for every settlement a district centre lying

2 Though we did not need the stipulations on the equation in this case, e.g. the situation, in which one wishes to select certain settlements by all means as district centres, could have been readily modelled by this.

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not farther than the distance parameter must be identified. One solution is with the optimisation toolbox $f_j = \frac{1}{p_j}$, and the conditions of inequality are unchanged.

However, the purpose cannot only be the minimisation of the population forced to commute – it may also arise as a more complex aspect that should take into consideration, in addition to the size of the population, the distances to cover while commuting. This means that the solutions are preferred in which – with a minimum number of districts and a maximum size of population in district centres – districts can be established so that their population should cover as small a distance as possible when commuting to the district centre. Nonetheless, this raises two opposite requirements: the minimisation of the distance from district centres would imply the reduction of the size of districts while the minimisation of the number of district centres would entail its growth.

Multi-objective optimisation model – minimising commuting population and distance of commuting

The first model and its modified form both originated in searching the optimum place of a single function. However, there are cases similar to the previously discussed one, when optimising more than one target functions at a time. This results in a "multi-objective optimisation task", in which the global optimum places of the target functions are not common, they contradict one another. This implies that instead of a single optimal solution there is only a *set* of solutions, out of which the actually suitable one can be selected based on some further aspect stemming from the original problem raised.

The group of genetic algorithms includes methods that – taking an idea from biological evolution – create a *population* of possible solutions in the course of all steps (*generations*), i.e. the "goodness" of more than one *entity*, that which means a possible solution at the time is examined with a *valuation function*. Afterwards, a new population is established by *selecting* the entities that proved to be good. This can be completed by mutation, i.e. a certain degree of randomised change of entities, the combination of two or more entities (*parents*), or the transfer of the best entities from the previous generation to the next one. Because of selection, the average goodness of the population increases from generation to generation, so it approaches the optimum.

However, the disadvantage of genetic algorithms is that it cannot be established from the result whether it is the actual global optimum of the target function. Although the size of the covered part of the solution space can be enlarged by increasing the size of the population and the number of generations, the optimality of the solution obtained cannot be proved, so decision on its suitability is only possible when one knows the original problem.

Many versions of genetic algorithms exist with which multi-objective optimisation problems can be solved (Binh–Korn 1996, Poloni et al. 1996, Kalyanmoy 2001, Robič–Filipič 2005). In the present work, one version of the *NSGA-II* algorithm is applied (Kalyanmoy et al. 2000) since this is available in MATLAB software's *Global Optimization Toolbox*, i.e. the toolbox usable for global optimum search problems.

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In solving the problem, the aim was to have a minimum number of districts at the same time so as to minimise both commuting population and the total distance covered by them while commuting. The optimum place was searched for in the following expressions:

$$\min \sum_{j=1}^{n} x_j,$$

$$\min -\sum_{j=1}^{n} p_j x_j,$$

$$\min \sum_{j=1}^{n} \sum_{k \in S_j} p_k d_{jk},$$

$$\sum_{j \in N_i} x_j \geq 1, \quad N_i = \{ j \mid d_{ji} \leq D, 1 \leq j \leq n \}, \quad x_j = \begin{cases} 1, & \text{if } j \text{ is otherwise a centre.} \\ 0, & \end{cases}$$

Thus, we minimise the number of districts (X_j), maximise the population of settlements having a central role (P_j), and minimise in every district the sum of the distances between the settlements belonging there (S_j) and the centre, weighted with their population. Set S_j is formed in every iteration according to what was described for the former model. The functions thus generated are used as valuation functions during the run of the genetic algorithm.[3] A simpler way of enforcing the stipulation on distance parameter D was not available as in the case of solving binary integer programming problems. Instead, the values of all the three target functions were considered $+\infty$ in the points of the solution space not meeting the stipulation.

It was found that the convergence of the algorithm was further speeded up if, before its run, the size of the problem was reduced. For this, the possible district centres are ordered by size, then – starting with the smallest – such a number of elements are removed from them with which the remaining ones can still "cover" all the settlements in the area within the particular distance parameter. The size of the parameter vector of the target function is thus identical to the number of the remaining settlements.

To further highlight the central role of larger settlements, it was also established in the following version of the model, in which the number of districts and the size of commuting population were dependent on the population of district centres (they were divided by this). The target functions, in this case, were modified as follows:

$$\min \sum_{j=1}^{n} \frac{x_j}{p_j x_j},$$

$$\min -\sum_{j=1}^{n} p_j x_j,$$

$$\min \sum_{j=1}^{n} \frac{\sum_{k \in S_j} p_k * d_{jk}}{p_j x_j}.$$

In the model thus generated, other aspects are damaged because of the big role of the population in the district centers: more and smaller districts are created.

3 Thus a centre belongs to its district, too, but this does not change the value of the target function, since the distance of a settlement from itself is zero in the matrix of accessibility on public roads.

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In the practical application of the genetic algorithm, many problems occurred. Due to the character of the algorithm, it cannot be proved that the results obtained are equivalent with the global optimum of the target functions. Because of the finite computing capacity available, a compromise concerning the accuracy of the algorithm was required in order to be able to keep run time within reasonable limits. Three tools (Table 1) were applied to adjust accuracy; the actual values of these parameters are as follows:

Table 1

Parameters of genetic algorithms and their values

Size of populations	500
Number of generations	500
Number of maximal "unchanged" generations	100

The role of the size of populations and number of generations is clear in enhancing accuracy, while the number of "unchanged" generations adjusts when reaching a deadlock: in case the algorithm cannot "move away" from the deadlock after a particular number of iterations, it stops running. By applying the algorithm to the same problem many times repeatedly, subjectively, good results applicable to the original problem were obtained; in case of the parameter values in Table 1, even within a runtime of a few minutes. Out of the Pareto-optimal results obtained, those with a minimum number of districts were selected. In addition, despite the stochasticity of the algorithm, the results of the repeated runs were the same or differed from one another only in the number of equivalent solutions with a minimum number of districts. Therefore, concluding the optimality of the results thus obtained.

Comparison and evaluation of models, further possibilities

Table 2 shows the disparities between the outcome and the run time of the different models, applying them to the settlements of Veszprém County and a distance parameter of 30 km.

The results in the table were obtained on a computer with Core i7 processor and 8GB of memory, run under Ubuntu Linux 12.04 operating system. The version of the MATLAB software used for the solution was 7.12.0.635 (R2011a). In case of the models solved by integer programming, the bintprog() tool was used.The run of the genetic algorithm was completed by gamultiobj() tool, ensured by the already mentioned *Global Optimization Toolbox*. In case of the latter, calculating the goodness of the entities of the current population can be readily paralleled; taking this into account, this parallel execution was permitted, which ran in 8 (the same number as the number of processor cores) parallel processes.

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Table 2

Results of applicable models and their characteristics

Model; algorithm	Number of districts	Population in district centres, persons	Commuting population, persons	Weight of commuting	Runtime, sec
Unweighted model; BIP, branch-and-bound	5	44 351	312 222	5 043 279.48	0.186
Maximisation of population in district centres; BIP, branch-and-bound	7	88 817	267 756	4 013 709.20	0.236
Minimisation of weight of commuting; NSGA-II	7	84 057	272 516	3 762 672.30	327.204
Minimisation of weight of commuting and emphasis on large settlements; NSGA-II	9	177 527	179 046	2 314 897.03	262.239

The table clearly reflects how the aspects arising during the different modifications of the problem are considered in the different algorithms. In most of the cases, it was found that the minimum number of districts could mostly be achieved by applying the unweighted model, since the structural aspects of settlement and public road networks are not damaged; this ensures the optimality of the location of centres. Furthermore, it can also be seen that in case of the multi-objective optimisation model run without emphasising large settlements, and by selecting out of the Pareto-optimal solutions, that with a minimum number of districts, the role and goodness of the other two target functions (populations in district centres and weights of commuting) are lower. Their values hardly differing from those of the model aiming at minimising population in district centres. The number of the commuting population and thus the weight of commuting could be best minimised by emphasising large settlements. However, this implies that many settlements in a better position from the aspect of accessibility on public roads could not have the role of a district centre, so a kind of fragmentation can be observed: more and smaller districts needed to be established in order to meet the distance parameter.

The lower medium administrative level of Hungary reflecting on the models

After reviewing considerations on spatial division and computation theoretical feasibility, the characteristics of lower-medium level were examined, the use of theories in practice and the applicability of models to Hungary.

Two possible methods of spatial division and centre choice were reviewed, which meant the implementation of the algorithms presented in the previous chapter. Choice between the models was made depending on the optimisation principles of spatial division. From a theoretical point of view, the "unweighted" model established by applying LSCP and the "weighted" model implemented with the aid of the genetic algorithm ideal was considered.

In case of the unweighted model, the establishment of spatial units that are optimised from the aspect that the average distance between settlements and their centres should be minimal within "districts" is required, while no settlement can be farther than that given in

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the distance parameter, which changed. This model is, therefore, unweighted, since it does not take into account the population number of either centres or the settlements to be categorised. At the same time, it leaves out of consideration the extent to which the infrastructural conditions necessary to establish district centres are available in a particular settlement. That is, it considers every settlement equal, and only makes a rule that the location of centres should be optimal from the point of view of the public road network and that counties could be covered with as few districts as possible along with the completion of the particular distance parameter. This is an ideal solution from a theoretical aspect, which selects centres based only on the access distance.

The model was run with the maximum permitted travel distances of between 20 km and 40 km, in line with the former considerations (Szalkai 2012). The map illustrates the centres of the 30 km model (Figure 1).

Figure 1

District centres for maximum travel distances of 30 km (unweighted model)

Resulting from the characteristics of the algorithm the idea that the model selects settlements other than those at the top of settlement hierarchy as centres was proven. Out of the total 122 seats, only 24 are of town rank, and merely three of the county seats (Kecskemét, Salgótarján and Debrecen) would become district centres if this theoretical solution was realized. The capital city would also be left out of the centres; Budapest would only be one settlement in the Budakalász district. Similar results are obtained by applying the other two distance parameters; the majority of settlements becoming centres are of village rank, they only emerge from the settlement network due to their location in space and the public road network.

After applying this unweighted model, which was first of all from a theoretical aspect important, there were - by using the genetic algorithm - spatial divisions established, which could be applied from a practical point of view as well. The purpose was to establish

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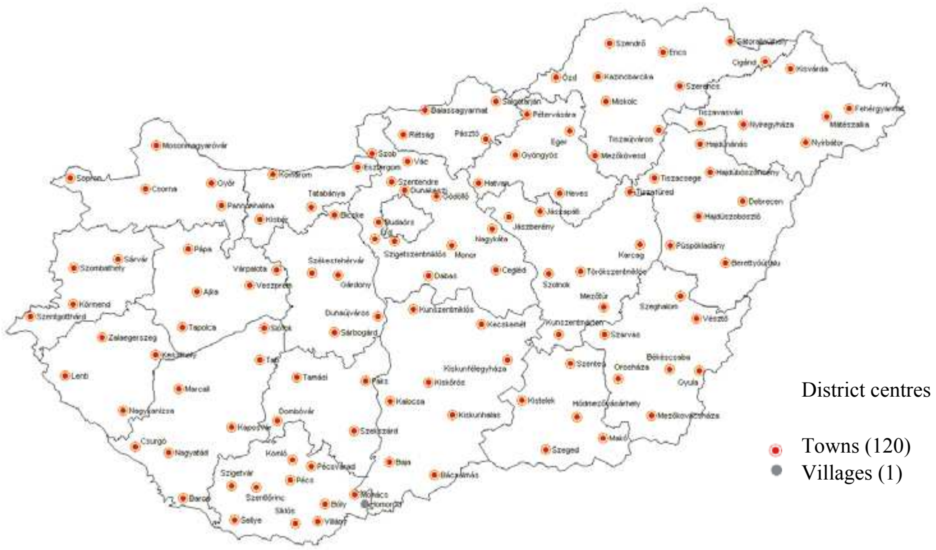
districts in which the travel distances weighted with the number of the population forced to travel to reach district centres are minimised. In an extreme case, it can be achieved if all settlements are made district centres, i.e. the value of travel distance is 0. Certainly, this is not a realistic solution, so – as already referred to – the minimisation of the number of districts also needs to be targeted. That is, two parameters with opposite effects should be optimised at a time, which is not possible. Thus, the algorithm applies an intermediary solution: taking into account both aspects at a time it tries to find Pareto-optimal solutions, knowing that the value of none of the parameters can be further improved without worsening that of the other. At last, the algorithm selects from the possible solutions those with a minimum number of districts. From the results, the model permitting maximum travel distances of 40 km is presented (Figure 2).

Figure 2

District centres for maximum travel distances of 40 km (weighted model)



The reason why this model was chosen is, that from the point of view of the number of the spatial units (districts) it can be best compared to the formerly presented unweighted 30 km model: 122 districts were established, compared with 121 here. The basic difference is that, owing to weighting with population, almost exclusively major elements of the town network become district centres in this case.

The 10 km difference between the two models, permitted for reaching district centres, is hardly reflected in the number of districts (elements). The reason for this is the better position of villages in space: to have almost the same number of elements, i.e. the same level of supply, smaller distances would be covered if district centres were villages. However, these settlements cannot ensure the required infrastructure, so the weighted model is closer to reality by all means.

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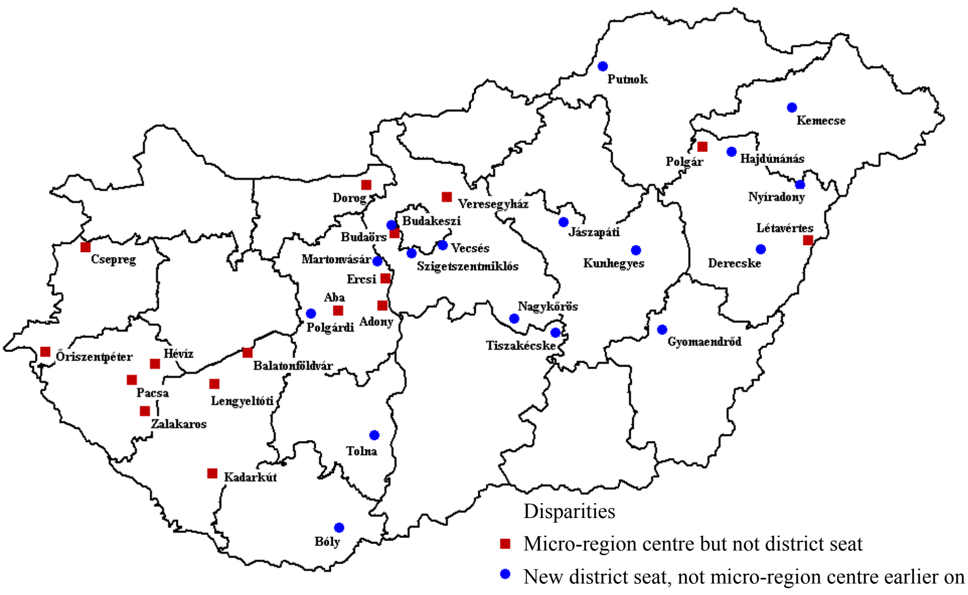
Differences in breakdowns by districts and micro-regions

Districts were re-established in Hungary on 1 January 2013, 30 years after their abolition. With the increasing timeliness of the topic, several studies were published in Regional Statistics, in the last three years, the authors summarise the history and the situation of lower-medium level and spatial administration, as well as the scientific theoretical approaches to the issue (Miklóssy 2011, 2012, Ivancsics–Tóth 2012, Faluvégi 2012). The methodology applied in establishing districts differed from the models presented here; it was replaced by complex indicators for district centres and then indicators of the level of supply with public administration services (Szalkai 2012), which are in relationship with the presented method through population numbers.

The centres determined in the new breakdown mainly came from among the most populous settlements; in respect of the number of units, the system of districts differs by only one from the system of micro-regions in effect at the time of planning the districts and comprising 175 areas.[4] Namely, Budapest, which is an undivided, single micro-region in the breakdown by micro-regions, and is not part of the present analysis. This way, the centres of the 174 micro-regions outside the capital and of the 175 districts largely coincide with each other, although the differences have marked spatial characteristics (Figure 3).

Figure 3

Differences between centres of micro-regions and districts



There are 17 settlements which newly obtained a central role. Consequently, 16 earlier micro-region seats did not become district centres at the same time. The two groups are

4 Act CCVII of 2012 effected (one) change compared to the former breakdown by micro-regions from 1 January 2013: enhancing correspondence with the system of districts, it changed the name of the Ercsi micro-region to Martonvásár micro-region, and extended its area with Kajászó.

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well separated in space; the majority of the settlements "left out" are located in Transdanubia, while the new district centres can be found principally in the eastern part of the country.

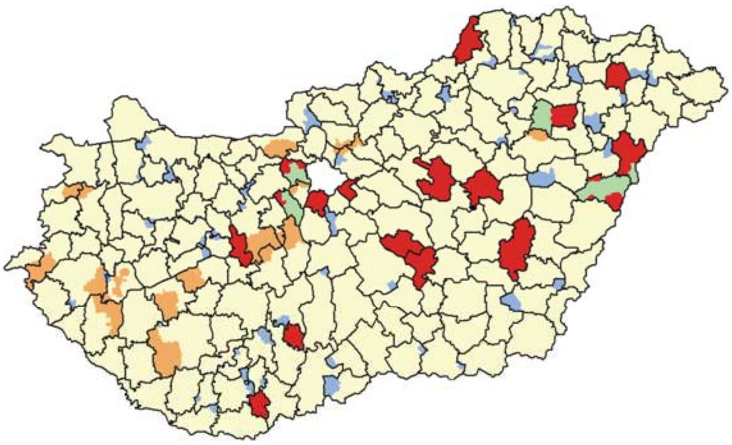
Ignoring the role played by national and local political interests in the changes of the settlements left out of the group of centres, Budaörs is the largest, with nearly 30 thousand inhabitants, while the population of the smallest district centre does not even reach 2,000. Based on the number of "settlement-level administrative functions," which was at last the only aspect of the professional designation of district centres, the elimination of Dorog can be explained to the lowest extent. (The settlement has 12 of the possible 15 functions.)

Leaving out of consideration these two conspicuous cases, the most suitable settlements became district centres, and based on the complex centre order indicator (Szalkai 2012) applied earlier, the next more than ten settlements, not qualified as district centres, are in Pest county. However, the majority of these partly sub-urban, partly commuter settlements will be properly served by the district offices to be established. Nevertheless, in case of smaller settlements having fewer functions, the exclusion of certain settlements from or their inclusion in district centres can be questioned.

In several cases, there is no spatial relationship between new district centres and non-district-centre micro-region seats, while new centres were established clearly with the intention of replacement in certain areas. The relocation of centres affected at the same time the group of attracted settlements, though not only splits of micro-regions but also transfers of other settlements between areas occur in such cases (Figure 4).

Figure 4

Change in classification of settlements by micro-region and district breakdowns



Situation of settlements

- Micro-region centre did not district centre, transferred to other, formerly also central settlement (175)
- Transferred to new district centre established to replace micro-region centre (28)
- Centre exchange (both old and new centres existed formerly) (110)
- Micro-region centre and district seat identical (2,712)
- Transferred to newly established district centre (128)

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The relocation of centres, i.e. the fact that although the former micro-region centre did not become a district centre, a new district centre close to it was designated to replace the micro-region centre, occurs in four cases among the differences between micro-region and district systems. That is how Martonvásár–Ercsi, Budaörs–Budakeszi, Polgár–Hajdúnánás, as well as the trio of Nyíradony, Derecske and Létavértes can be coupled. The settlements indicated in green were transferred to a new centre this way, while there were such settlements (indicatied in red) transfered to every similar districts, whose centres became a district center, but the legislator transfered this settlements to the neighbouring new districts.

Contrarily, because of the "drawing off" of their centres, certain settlements would be too far from new district centres, therefore, they were classified not to the new but to a neighbouring, old centre.

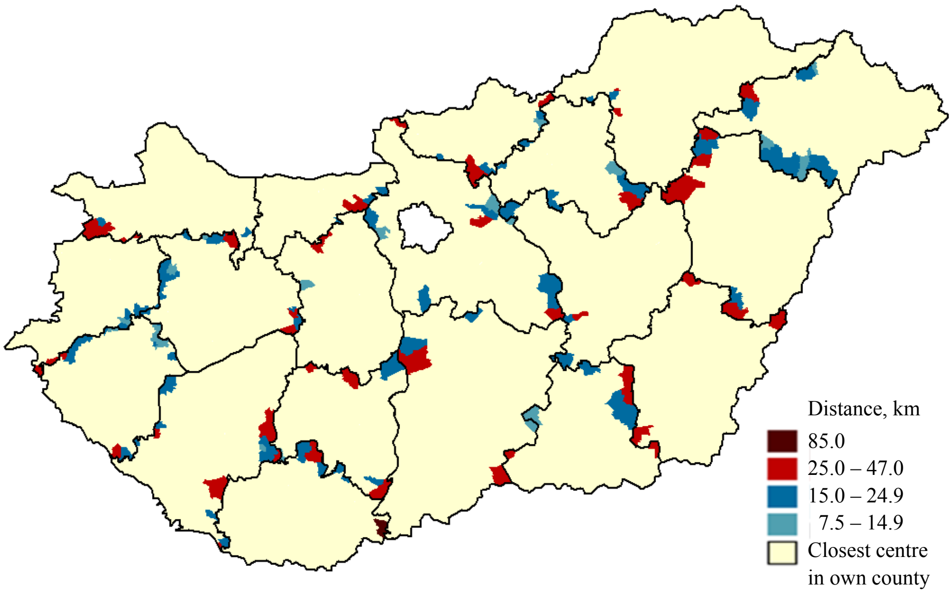
Several larger areas, mainly in Transdanubia, also belong to this same category (indicated in orange) since the most centre losses fall in this area. However, geographically and totally sporadically situated are the 110 settlements indicated in blue (with a population of 170 thousand people) whose micro-region will be a district centre at the same time, yet these villages were classified to another centre that had existed formerly.

Nonetheless, despite the changes, it is clear that the two lower-medium-level breakdowns are dominated much more by similarities than by differences; some 86% of our settlements belong to the same seat in the district as in the micro-region system earlier on.

The district breakdown established did not classify settlements to the closest centre in all cases. One of its cases is when settlements "could not be" annexed to the closest centre because of the location of county boundaries, so several settlements lie closer to a district centre that can be found not in its own county (Figure 5).

Figure 5

Distance of own district centre in case of settlements ideally attracted by another county



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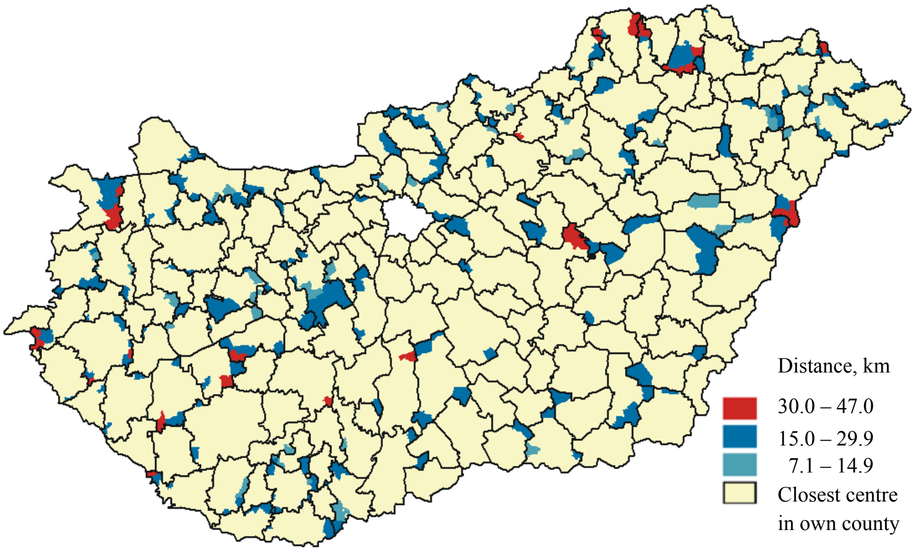
Out of the 219 such settlements comprising 300 thousand people in total, a settlement in a special situation in Southern Hungary is in the worst situation: if the ferry at Mohács is not in service, the district seat can only be reached with a detour of 85 km. Leaving this out of consideration, however, there are settlements that lie farther than 40 km from their district centre. Not considering county boundaries would affect the most luckily Egyek, belonging to Balmazújváros, since it lies only 13 km from Tiszafüred.

It deserves even more attention if the above train of thought is mapped at the level of districts, i.e. the group of the settlements is examined that do not lie closest to their own district centre, despite the fact that the closest centre is also within the county (Figure 6).

Figure 6

Distance of own district centre in case of settlements ideally attracted by another district centre in own county



This phenomenon already concerns 365 settlements with nearly half a million inhabitants, although the breakdown established is better for part of this population than as if the closest centre had been taken into consideration; commuting relations point towards the district centre. This can be seen both in the eastern part of the Sopron district and the southern part of the Székesfehérvár district. In contrast, the district breakdown is burdened by serious mistakes as in the case of border-side settlements near Debrecen, and especially in the Gönc district; here a settlement was classified to a centre of nearly the same size despite the fact that it lies 22 km closer to another, larger centre, and commuting is also observed in this direction. The Gönc district became the least favourable lower-medium-level unit of the country from this point of view, the average travel distance weighted with the population forced to travel to the district centre is the highest here, nearly 18 km. In contrast, the same value is below 1 km – considering district centres points – in the mostly concentrated Debrecen district.

Thus, the settlement network strongly determines the distribution of population within districts: the units having a large town as a centre show a favourable picture even if more

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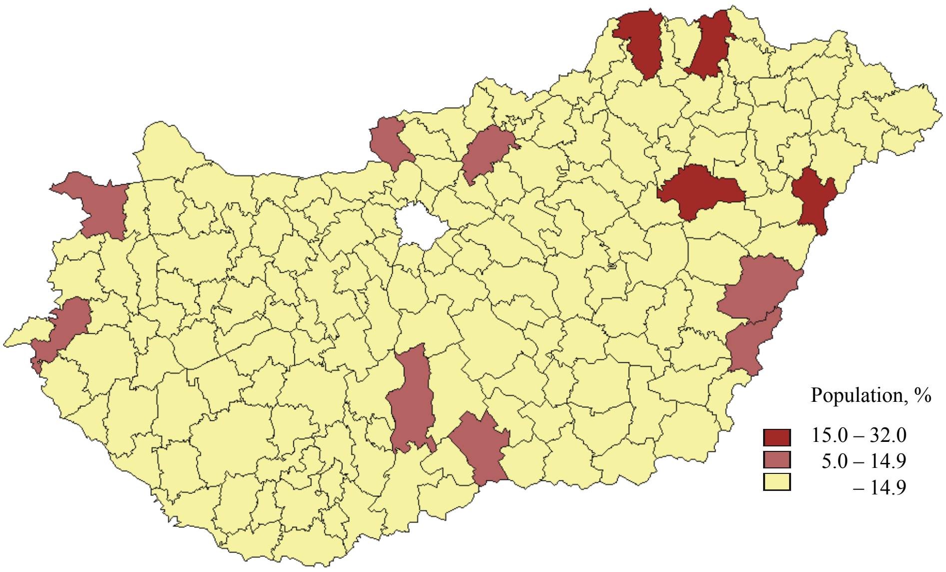
distant settlements also belong to the central town. Contrarily in areas with smaller centres and with a lack of towns, there is a high proportion of people living far from the centre (Figure 7).

This value is the highest in four eastern Hungarian districts (Balmazújváros, Gönc, Edelény, Nyíradony), and in the two former the micro-regions that were extended just along the boundaries farthest from the centre. In national terms, 122 settlements lie farther than 30 km from their centre, comprising a population of 86 thousand. Thus, the 30 km objective as laid down in a government decision of 2011 was mostly fulfilled in total, yet, if one wishes to be accurate, the district breakdown adopted can only be considered – even disregarding the problem at Homorúd – as a 47 km model. Namely, that is the distance between the settlement in the most disadvantageous situation and its district centre.

Figure 7

Proportion of population living farther than 30 km from the district centre



Comparison of model results and existing breakdowns

The analysis of spatial features, as well as the review of the statistical characteristics of the different versions, provides help for a deeper understanding of models and real spatial divisions. The characteristics of the two existing, micro-regional and district breakdowns, as well as six district models, are presented (Table 3).

The spatial division options in the table can be compared to one another in numerous ways. If the starting point is existing breakdowns, it can be stated that district and micro-regional breakdowns hardly differ from each other, the district system can be considered minimally better from the point of view of concentration: a higher proportion of the population live in the centre or within striking distance to it. From this point of view it deserves attention that the 30 km weighted model, which best approaching the real spatial division, has almost the same values (50% weight of central population), but it is achieved together with low distance value, but with an increase in the number of districts.

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Table 3

Statistical characteristics of different districts

District breakdowns	Proportion of population in centres	Proportion of population, 0–10 km	Proportion of population, 10–20 km	Proportion of population, 20–30 km	Proportion of population, over 30 km	Weighted average distance between centres and settlements, km	Unweighted average distance between centres and settlements, km	Maximum distance between centres and settlements, km	Average number of settlements	Number of districts
Districts, 175	50.9	66.3	25.2	7.5	1.0	6.9	14.6	85 (46)	18.0	175
Micro-regions, 175	49.7	64.2	25.1	9.3	1.5	7.4	14.4	88 (54)	18.1	174
Unweighted model, 40 km	8.1	19.1	27.7	37.7	15.6	19.8	21.6	40.0	43.2	73
Unweighted model, 30 km	10.5	26.8	47.3	25.8	0.0	14.4	16.4	30.0	25.8	122
Unweighted model, 25 km	11.5	34.1	54.5	11.4	0.0	12.1	13.5	25.0	18.7	169
Unweighted model, 20 km	20.5	52.9	47.1	0.0	0.0	8.9	10.8	20.0	13.0	243
Weighted model, 40 km	44.5	56.4	28.7	12.4	2.5	9.0	16.5.	39.7	25.2	121
Weighted model, 30 km	49.9	65.2	28.0	6.8	0.0	6.8	12.9	30.0	16.4	192

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All the other models move in the direction of deconcentration, and especially those unweighted. The low proportion of population in centres follows from the basic attribute of those since mostly villages with low population size are located in spatially optimum places. The proportion of population in centres decreases to 8% in case of the 40 km model while one can witness interesting realignment within the different distance zones. In the 20 km model with 243 elements, representing the most detailed breakdown in the analysis, the proportion of the population is still high in inner-most zones due to the high density of centres and to distance limits. i.e. large towns "cannot" fall far from villages lying in good positions from a spatial point of view. However, if the permitted travel distance is increased, zones concentrating population move farther from centres, and more than half the population would already live farther than 20 km from centres in the 40 km unweighted model. This refers to the fact that places optimal from the point of view of networks are specifically not located close to large towns in this breakdown.

As a result of this, but principally because of the lowest number of districts, average distance values are the highest in this model; at the same time, it deserves attention that nearly 50 fewer district centres would need to be delimited in case of this 40 km model than in the case of the weighted 40 km model. The same difference in case of the 30 km limit is even clearer.

As for average size, the fulfilment of the Bibó principles also needs to be touched on. As models ruled that optimal accessibility should be achieved, districts cannot meet the criterion of proportionality. So there are large differences in the system with respect both to the number of settlements in districts and to population number and area. The districts consisting of the fewest settlements were established in Hajdúság[5], each of the

Hajdúböszörmény and Debrecen districts consists of two settlements only while the Zalaegerszeg district comprises 84 settlements. From the point of view of population number, district sizes in the breakdown range from below ten thousand to a quarter of a million inhabitants.

Summary

In the urban area examinations, computerised implementation of theoretical and practical spatial delimitations that optimise the assignment of settlements to centres from different aspects was carried out. Taking into account Bibó's principle of optimal accessibility, the solved task was simpler in computation theoretical terms, determining centres by minimising travel distances, and also a more complex, multi-objective optimisation task.

The result of the first model calculation, with no practical relevance though interesting theoretically, is that the position of settlements in the settlement hierarchy does not follow from the position in the road network space. A good position in the road network does not mean a clear advantage, which means as well that the location of towns is not optimal from the point of view of settlements surrounding them.

In the case of the more complex model, the search was for the common optimum of travel distance, the number of the population forced to travel to centres and the number of territorial units. By shifting the result towards real feasibility – following from weighting

5 An area in the east of Hungary.

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with population – almost exclusively, the major elements of the town network became district centres in this case.

As a result, the values of average distance – between centres and the attracted settlements – in the two models largely depend on weighting. The distance weighted with the population forced to travel, and the unweighted distance are nearly the same in case of the first model, while the weighted average distance is only the half of the unweighted one for the second model (so in case of real spatial divisions, too). The difference between the two values clearly reveals that the division is favourable for the majority of the population, certainly for the urban population. However, in the peripheries, there remained several poorly supplied areas, which have also been the focuses of economic and social depression to date.

In the district system, set up on 1 January 2012, 122 settlements – comprising a population of 86 thousand inhabitants – lie in a distance exceeding 30 km, a recommended upper limit, from its centre. However, the unfavourable situation of these settlements is partly abated by the system of "government windows", the number of which is intended to be increased to about 300 by the end of 2013. That is, in addition to the 174 district centres (outside the capital) government windows will operate in a further 100 plus settlements on the basis of registration offices. This group will include Budaörs and Dorog, the two biggest losers of the district breakdown, while the district system left 86% of the settlements in an unchanged position compared to the micro-region system.

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Same or Different Development Paths? A Comparative Study of the Large Cities and Regions in Hungary*

Abstract

According to specialist literature, the current development of agglomerations is by large urban areas evolving by the expansion and structural transition of larger urban zones, where "the formerly hierarchic division of settlements with a different size and role is replaced by horizontal cooperation, linking into a network" (Enyedi 2012, p. 17). The aim of the present paper is to examine, how equal the domestic large cities and their agglomeration can be considered by their development and competitiveness, and if there is an economic basis for them to cooperate horizontally in a network in the present case. The authors use different methodological approaches to examine the development and competitiveness of cities and their agglomeration, and spatial autocorrelation circumstances to model the economic base of outlined cooperation.

Keywords: cities, catchment areas, accessibility, development, competitiveness, spatial autocorrelation.

Introduction

In national and international scientific literature, highly significant findings have been published in recent years on the socio-economic relations of cities and their catchment areas. The statement is particularly noticeable in regards to the current development of the catchment areas in the metropolitan regions, which were created by the extension and internal structural transformation of the major agglomerations; the previous hierarchical arrangement is being replaced by the horizontal cooperation and networking of settlements of different sizes and roles, but of the same rank (Enyedi 2012, p. 17). The purpose of this present study is to examine how cities and their city-regions in Hungary can be regarded as equal from the point of view of development and competitiveness as well as if there are economic grounds for their horizontal cooperation and networking. Prior to the actual analysis, it is important to refer to the most relevant connections to the questions in the scientific literature.

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Space is a term used for that which is connected to a settlement through a certain or a number of functions, as the catchment area of a given municipality. Function-based centre-periphery relations play a fundamental role in the spatial organisation of society (Benedek 2000). One of the first critical studies on catchment areas in Hungary was the two-part study of Pál Beluszky (1970) published in the periodical of Regional Statistics. He states in this study that central functions and services are delivered in the central settlement – in many cases a town – for the catchment area, this functional role is more significant than the sheer population size of the central settlement.

The importance of studying catchment areas and agglomerations as well as the outstanding role of relationships in cities, catchment areas and city regions is indicated by numerous researches and scientific analyses (inter alia OECD and ESPON studies). In addition, this topic is represented in many official documents, e.g. in the urban-oriented Leipzig Charter of the EU (2007):

"An equal partnership between cities and rural areas as well as between small-, medium-sized and large towns and cities within city-regions and metropolitan regions is the aim. We must stop looking at urban development policy issues and decisions at the level of each city in isolation. Our cities should be focal points of city-regional development and assume responsibility for territorial cohesion. It would, therefore, be helpful if our cities would network more closely with each other at European level."

As the scientific literature points out, successful economic areas are in the surroundings of major cities, but it does not mean that the success of the city region depends on the city (Dunford–Perrons 1994).

The catchment areas frequently overlap each other with the intensity of the effect of functions falling at different rates as the distance increases from the centre (Taylor 2004).

Concerning the relations between cities and their catchment areas, Coombes and Raybould (2004) pointed out that the smaller settlements of the commuter zones receive relocated jobs from central areas in more and more cases. In several states of Europe, the state bodies understood that city region oriented strategies are needed instead of focusing on the major cities assuming that coordinated developments promote development in the catchment areas (Adam 2003, Hoggart 2012); as proposed by the Leipzig Charter (2007).

Despite the close interrelatedness and mutual dependence between the city and its catchment area, unfortunately, the relationship is frequently subject to serious strains (Schuh–Sedlacek 2002).

There are several potential methods to delimit and analyse towns, cities and their catchment areas (Kovács 1987, Hajdú 1994, Mokos 1998, Győri 2000, Kovács 2002). Since the approach of this work is quite different from the previous ones, it only refers to those delimitation methods that are considered important based on the work of Norbert Bodor és János Pénzes (2012). Based on this, gravity models (Kiss–Bajmócy 2001, Pénzes 2005) and GIS devices can be distinguished among the deductive testing methods. There are empirical methods, such as the ankét method, the customer counting method, the evaluation of long-distance telephone calls.

A further option is to analyse how some stages of the agglomeration process take place in a major urban agglomeration instead of simply delimiting a catchment area. This is about analysing the real relationships between the main city and the attracted settlements to delimit major urban agglomerations (Kovács–Tóth 2003).

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Description of the methods and objectives

The purpose of the present study, for multiple reasons, is not to follow the previously described methods. On the one hand, no data is available for such delimitations as the data of the 2011 census (commuting, employment structure) were not available when the research was conducted. On the other, the authors did not wish to model real relationships while delimiting catchment areas, i.e. which settlement belongs to which central city based catchment area. In this regard, the authors believe that in certain areas of the country – as will be outlined in the study – some settlements are not only a hinterland of a great city, but may be related to more of them, fundamentally affecting the spatial structure of the country. It is possible to determine which centre attracts a given town in a stronger way, but it would be a very different approach for this analysis. The main purpose of the study is to show how similar or how different the major cities of Hungary are from their catchment areas in economic terms. A group of settlements was used that are in equal distance and time from the central city as a theoretical catchment area, i.e. an area from which the city attracts resources and on which the city exerts direct positive or negative economic influences. This approach is practically the same as the calculations determining the potential service area of a corporation.[1] The comparison between centres and catchment areas is by no means unique in Hungarian scientific literature. In a slightly different approach, János Pénzes conducted and published a similar research on the spatial structure of north-eastern and north-western Hungary (2013).

Concerning single cities, the authors are aware that the real catchment areas are not the same as the settlements subject to the analysis. In most cases, they form only one part of the actual catchment area or in case of several major cities, especially in case of the capital city, the real catchment area is somewhat larger.

The aspects of accessibility were considered during the determination of theoretical catchment areas (hereinafter catchment areas). Specifically, those settlements, whose geometric centre is located 30 or 45 minutes by road from the geometric centre of the given central settlement, were grouped into the respective catchment area. The data of the settlements in the catchment area were totalled to calculate the required indicators. It also follows from this calculation method that it only gives an average value for the catchment areas, which necessarily blurs or may blur the regional differences among the affected settlements. This must be taken into account when evaluating the results.

Accessibility-based delimitation of the theoretical catchment areas, as opposed to the traditional frameworks, was chosen as a technique because when making sub-regional or district level studies, the examination would be bounded by the county borders in any case, which are often overlapped by the catchment area relationships. (Szalkai 2010). The study might have been carried out by using “functional urban areas” (Sütő 2008), but their delimitation still reflects the conditions of 2001; so it was considered that the current accessibility relations based delimitation could also highlight important

1 The calculations were performed by running Service Area calculations in the Network Analyst of the ESRI ArcGIS 10 software.

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relationships. A similar problem arises if the method of agglomeration delimitation is used. The study of Hajnalka Lőcsei (2004) is a good example for this approach. The use of the accessibility analysis was only limited by the fact that only a nation-wide dataset was available, thus, it was not possible for to analyse cross-border catchment area relationships (see different approaches on this subject at Kovács 1990, Hardi 2008).

Although the results were also given for the group of settlements available within 45 minutes, the study focused on the group of settlements available within 30 minutes, as a closer relationship could be assumed in this case. When determining the minute-borders, it takes into account the findings of the international scientific literature according to which most travel to work journeys are shorter than 30 minutes even in such major metropolitan regions like Los Angeles (Giuliano–Small 1993). The study chose not to use the distance suggested by the results of the scientific literature, so calculations were carried out taking into account both 30 and 45 minute time frames. The need for such approaches is underlined by the fact that the size and growth potential of the urban markets are determined by the accessibility of their catchment areas (Muller 1977, p. 29).

Therefore, in this respect, the use of long-distance thresholds may be regarded as arbitrary; the study chose these as the boundaries, within which those settlements are situated, which are or can be in a meaningful relationship with the indicated central settlement. This is only a theoretical relationship, as it is possible that within the indicated distance thresholds or in some cases even beyond them there are such settlements, which can affect the central town and vice versa. With the different directional effects, it cannot be forgotten that next to the economic force of agglomeration (centripetal force), which facilitates city growth and the formation of spatial groupings, the repulsive force of the big city will appear as well. Thus, the advantages of this grouping are limited, because when transport costs increase, cheaper production costs can be suppressed (Haggett 2006). These tests were performed by using several methods.

Initially, the study tried to demonstrate the economic aspects of development by calculating per capita taxable incomes and unemployment rates. It is assumed that these two indicators clearly illustrate the spatial differences in development taking into account the current domestic relations. Although the use of other indices and indicators would be justifiable, these two indicators were used for the sake of simplicity. On the spatial structure of incomes, János Péter Kiss (2008) found that its size and changes are usually synchronized with the development of GDP. However, there are very significant differences in the spatial structure of GDP and that of incomes. Kiss also points out that the regional inequalities of incomes are smaller than that of GDP. Concerning the spatial pattern of unemployment, Hajnalka Lőcsei (2010a) has identified that it has been relatively stable since the second half of the 1990s and essentially reflects the spatial structure of development. As Lőcsei (2010b) also explains the area bounded by the capital city and its agglomeration, Lake Balaton, the region's motorways and the Austrian border area have the best unemployment figures. Inner periphery settlements situated east of an imaginary line connecting Balassagyarmat with Békéscsaba, outlying South Transdanubian and the north-eastern borders, as well as the Middle-Tisza area, are in the worst state.

This delimitation of the catchment areas results in the problem that the catchment areas overlap each other. This is certainly true in practice, although the paper does not try

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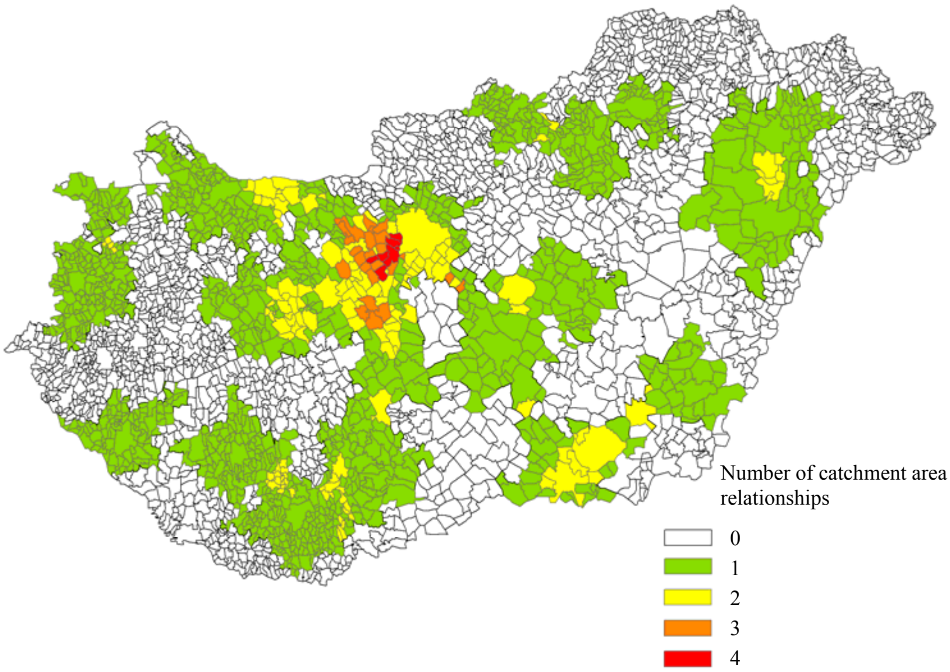
to delimit them in line with the effect intensity of the gravity method, i.e. the given settlement can even be in the catchment areas of several centres. There are even such cases (for example, Szeged, Hódmezővásárhely), when two centres are in the neighbourhood of each other. It is considered that the development of the given attracted settlement, may, on the one hand, be explained by its geographic location (i.e. which region of the country it lies in), the position of the centre(s) attracting it as well as, in particular, by how many attraction centres are available within 30 minutes. The latter, of course, represents only a potential opportunity, the effect of which is difficult to measure. Nevertheless it must be considered.

Figure 1

Grouping of settlements by 30-minute catchment areas of major cities, 2011



Source: Own compilation.

If we accept that the centre-catchment-area-relationship has a decisive importance in the spatial organisation of society, it is worth looking at what is the relationship between their economic strength. Put simply, how can the city and its surroundings mutually support each other or does the centre just drain the energy of the catchment area? The examination is about the economic basis of the potential links between the city and its environs. Of course, it is only one possible method to approach the relations between the city and its environs. The works of Viktória Szirmai (2007, 2009), taking into account the social factors, provide a good example for such assessments.

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The development of cities and their catchment areas

Based on 2011 data, in most cases – with the exception of three settlements – central cities always have a higher per capita income than their catchment areas. These exceptions are county towns, namely Érd, Tatabánya and Hódmezővásárhely; the other centre, which is significantly more developed than the local centre (at the former two it is Budapest, at the latter it is Szeged), is included in the catchment area because of the overlap between the catchment areas, causing the difference. Normally, the centres have an average value of about 20 percentage points higher than the average value of the settlements in the catchment area. Sopron slightly stands out from the income data of its catchment area while the largest difference can be seen in respect of Nyíregyháza. It is not surprising that Székesfehérvár and Budapest have the highest figures among central cities, nor the crucial role played by the Budapest agglomeration (It can be seen from the data of the catchment areas of Érd and Tatabánya).

Table 1

Per capita income in the studied settlements and their catchment areas as a percentage of the national average, 2011

(percent)

Capital city, county towns	Central settlement	30-minute	45-minute
		catchment areas	
Békéscsaba	96	81	78
Budapest	133	124	113
Debrecen	106	71	79
Dunaújváros	126	113	123
Eger	114	80	89
Érd	120	130	124
Győr	123	110	108
Hódmezővásárhely	84	97	87
Kaposvár	95	71	85
Kecskemét	107	81	117
Miskolc	100	88	83
Nagykanizsa	106	75	88
Nyíregyháza	104	67	81
Pécs	100	79	82
Salgótarján	93	72	83
Sopron	90	88	102
Szeged	102	76	85
Székesfehérvár	135	113	124
Szekszárd	121	89	90
Szolnok	115	81	85
Szombathely	117	102	99
Tatabánya	110	122	128
Veszprém	117	103	105
Zalaegerszeg	113	91	97
Mean	*120*	*109*	*110*

Source: Own compilation.

Looking at changes over time, it can be seen that from 2001 to 2011 – with the exception of Érd – there was a greater shift in case of each catchment area than in the

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case of its centre. Concerning the centre and its catchment area, the average displacement difference was nearly 40 percentage points over the period of ten years. Within this, the catchment area of Dunaújváros shows the most significant shift compared to the centre. That is, the lower initial base catchment areas show a slightly faster growth than their centres. Nevertheless, the basic conditions, i.e. the relative maturity of the centre compared to the surrounding areas, continues to exist.

Regarding unemployment rates, the situation is similar to that of per capita incomes, as with the exception of Dunaújváros, Hódmezővásárhely and Tatabánya, the unemployment in the catchment area is always higher than in the central settlement. On average, the difference is two-percentage points. In this regard, the biggest differences are in Nyíregyháza, Debrecen and Eger (7.0, 6.1 and 5.0% respectively).

Examining the temporal changes of the unemployment rate it can be generally stated, that in line with the national processes, there was a growth in all centres and catchment areas from 2001 to 2011. However, in the context of where unemployment increased further, in the centre or the catchment area, the picture is very mixed. There were 11 such centres (including Budapest), where the rise in unemployment was slower than in the centre during the analysed period, while 13 cases showed an opposite trend.

Table 2

Unemployment rate in the examined cities and catchment areas, 2011

(percent)

Capital city, county towns	Central settlement	30-minute	45-minute
		catchment areas	
Békéscsaba	9.0	9.7	10.0
Budapest	3.9	3.9	5.5
Debrecen	8.6	14.5	13.2
Dunaújváros	7.0	6.2	5.0
Eger	6.9	11.9	12.1
Érd	4.0	4.2	4.8
Győr	4.3	4.7	5.3
Hódmezővásárhely	6.5	6.3	7.8
Kaposvár	8.0	12.4	10.5
Kecskemét	7.5	8.2	5.3
Miskolc	10.3	13.1	13.9
Nagykanizsa	8.2	12.7	9.0
Nyíregyháza	8.5	15.5	13.6
Pécs	7.4	11.5	10.8
Salgótarján	15.3	15.7	12.4
Sopron	1.8	2.1	3.7
Szeged	5.8	7.6	8.3
Székesfehérvár	6.0	6.3	4.9
Szekszárd	6.3	8.5	9.1
Szolnok	7.5	9.9	9.5
Szombathely	3.8	4.7	5.5
Tatabánya	5.8	4.8	4.3
Veszprém	5.4	7.0	7.4
Zalaegerszeg	5.5	7.3	6.8
Mean	*5.6*	*6.6*	*6.7*

Source: Own compilation.

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The reasons may be quite complex in this matter. One explanation could come from the agglomeration processes; that is, among the highly educated population that moved into the catchment area (Forray–Hives 2009), the rise in unemployment is somewhat lower than in the centres, despite the rise in graduate unemployment that affects the highly educated population. This can be an explanation for the situation in Budapest although it is true that this study does not undertake the detailed exploration of the causes. The situation is completely different in a recessionary area such as in Békéscsaba and its surroundings. The biggest difference between the centre and the catchment area was recorded here in favour of the catchment area. In this case, the economic crisis exerted a stronger effect on the centre of the underdeveloped region than on the regionally and nationally less developed and more unemployment-stricken catchment area.

Examination of competitiveness

It is also worth considering the competitive position of a given town and catchment area. On the competitiveness of cities, several important studies were published in the scientific literature in Hungary (Lengyel 2003, Nemes Nagy 2004, Egedy 2012). In this study, the factorization method of Nemes Nagy (2004), who made calculations (formula 1) on domestic micro-regions and cities, is used:

$$\frac{\text{Income}}{\text{Population}} = \frac{\text{Income}}{\text{Employees}} * \frac{\text{Employees}}{\text{Activeagepeople}} * \frac{\text{Activeagepeople}}{\text{Population}} \qquad (1)$$

In the measurements, ‘earning’ means earnings generated in a given settlement and subject to personal income tax liability, the number of employees means the number of taxpayers in a given year, people aged 18–59 are regarded as active age people while the ‘population’ stands for the number of permanent residents.

The income per taxpayer essentially approximates the productivity of the economy of each accessibility group. The proportion of taxpayers in the working age population gives a reasonable estimate for the employment level. However, the proportion of active age people in the population, which is a specific age structural indicator, indicates a potential workforce reserve due to the high proportion of working age people (Nemes Nagy 2004).

After some mathematical transformation (the logarithm of the values should be calculated), the multiplication is transformed into a much more manageable amount, according to the following formula (Formula 2):

$$\log\left(\frac{\text{Income}}{\text{Population}}\right) = \log\left(\frac{\text{Income}}{\text{Employees}}\right) + \log\left(\frac{\text{Employees}}{\text{Activeagepeople}}\right) + \log\left(\frac{\text{Activeagepeople}}{\text{Population}}\right) \qquad (2)$$

The outlined defactorisation was used for region typing. The logarithm was to compare the size of the different factors with each other. Based on these calculations – in accordance with the results of Nemes Nagy – it was found that productivity differentials are mainly behind the income differentials while the effect of the structural factors is very low. The

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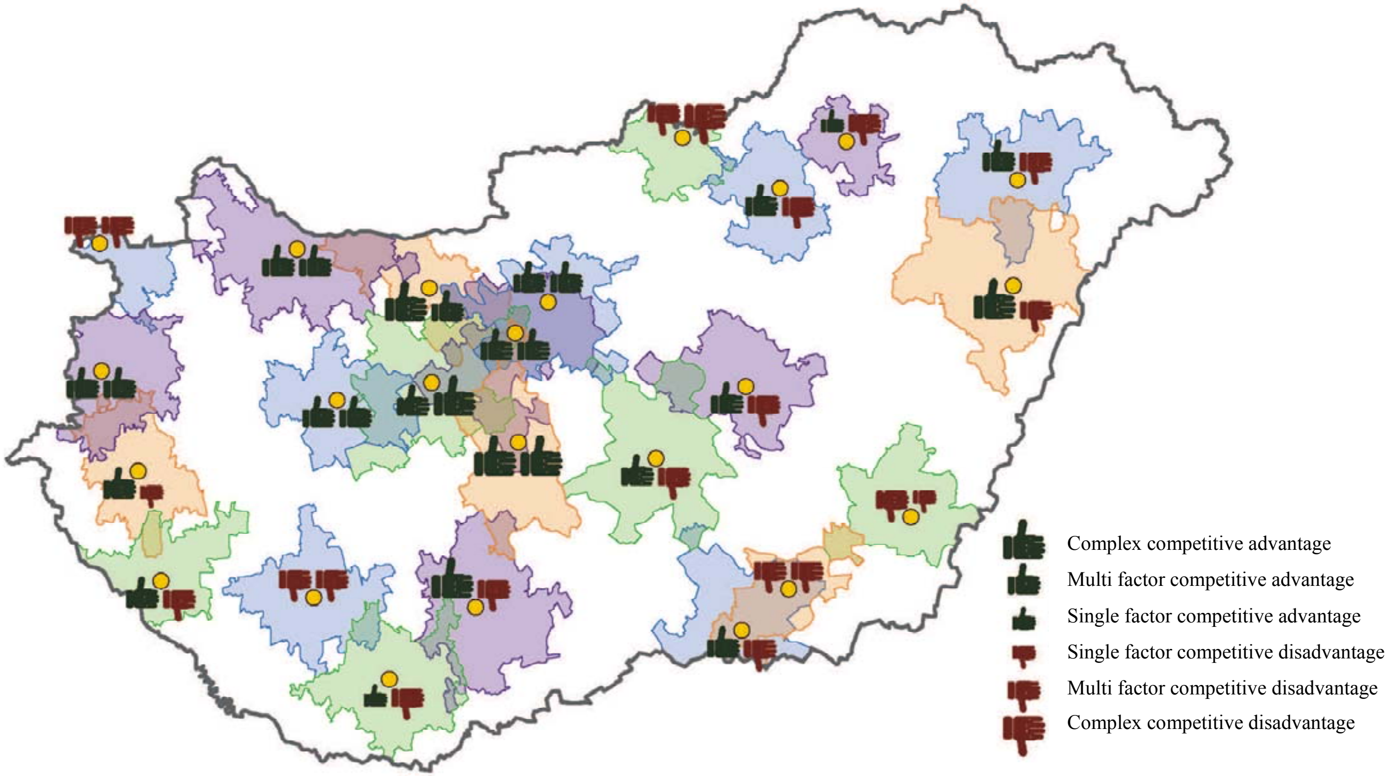
basis of the typing is the relationship of the values of each city and catchment area, with the national average in case of the household incomes, as well as their underlying three factors. Taking his technical solutions, in Annex 1 and 2, the factors above the national average were labelled 1 and those below the average 0 (the first number is always the symbol of household incomes, while the second is that of productivity, the third is employment and the fourth is the structural factor). Areas with above average household incomes are considered to be competitively advantaged areas and those with below average incomes are considered to be competitively disadvantaged areas. Within this, a complex competitive advantage is detected if the area has above average values in all three components of household incomes while there is a multi- or single-factor competitive advantage if that condition is fulfilled in the case of only one or two factor(s). The nature of the competitive disadvantage is interpreted in the analogy of this (Figure 2, 3). In the figures, the left signal always means the centres, while the right signal represents the 30-minute catchment area.

Based on the calculations performed on 2011 data, the differences were very significant in respect of the centre and its catchment area. Dunaújváros is in the best position since here the centre and the 30-kilometer catchment area have a complex competitive advantage. In the case of Budapest, Érd, Győr, Székesfehérvár, Szombathely, Tatabánya and Veszprém, both the centre and the catchment area are competitive on the basis of one of the underlying factors. In contrast to this, Debrecen, Eger, Kecskemét, Miskolc, Nagykanizsa, Nyíregyháza, Pécs, Szeged, Szekszárd, Szolnok and Zalaegerszeg show such examples, where the competitive centres are surrounded by competitively disadvantaged catchment areas. Békéscsaba, Hódmezővásárhely, Kaposvár, Salgótarján and Sopron are such cities where both the centre and the catchment area are competitively disadvantaged.

In respect of the change between 2001 and 2011, the situation is different since there is no such city where the change in both the centre and the catchment area would be competitive in a complex way compared to the national average. In the case of Miskolc, Nyíregyháza and Tatabanya, it can be seen that both the centre and the catchment area showed one of the types of competitiveness during the transformation. Érd is the only city where the centre is competitive, but the surrounding areas are competitively disadvantaged. Concerning the vast majority of cities, to be more precise in the case of 16 great cities, the combination of a competitively disadvantaged centre and a competitively advantaged catchment area is typical. As for Hódmezővásárhely, Sopron, Szombathely and Szekszárd, in the indicated period, the changes negatively affected the competitiveness of both the city and its catchment area.

Figure 2

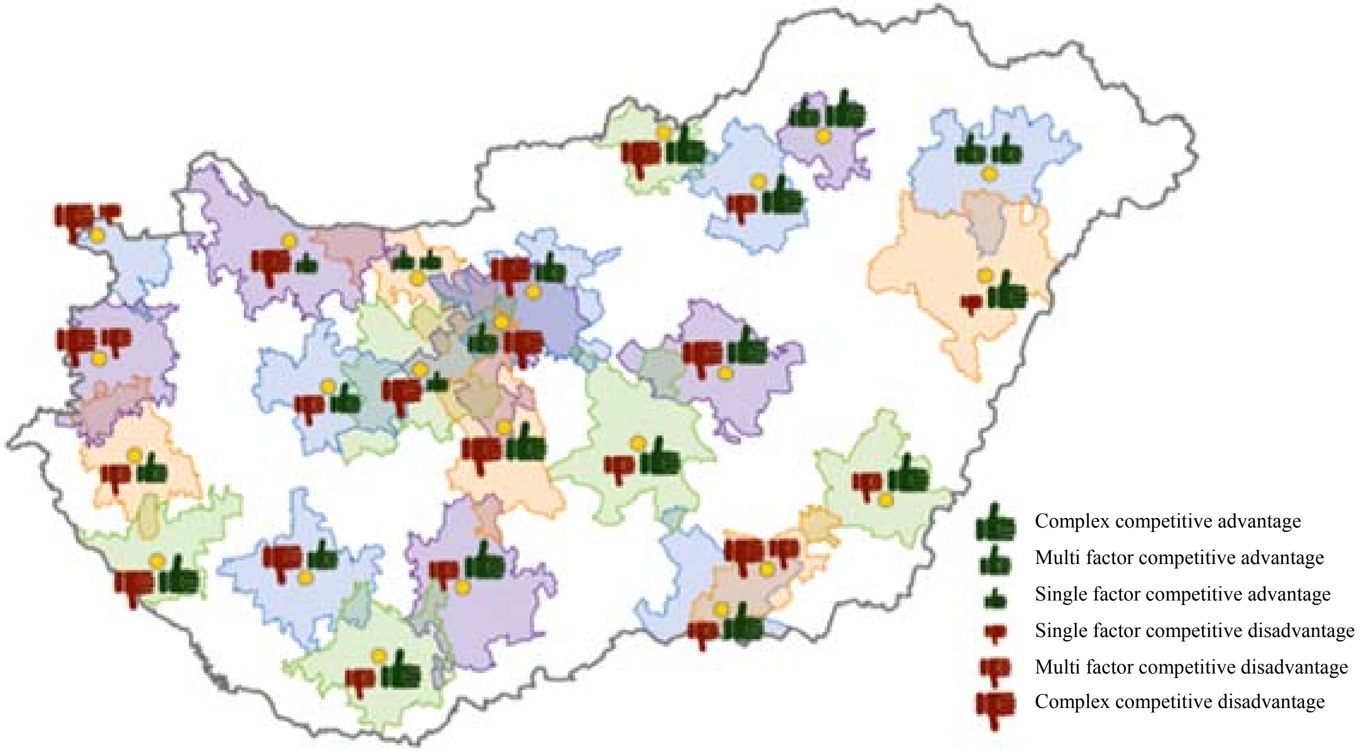
Competitiveness of the studied settlements and their catchment areas, 2011



Source: Own compilation.

Figure 3

Competitiveness of the studied settlements and their catchment areas, 2001–2011



Source: Own compilation.

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Spatial autocorrelation analysis

After presenting the process and competitiveness indicators, the spatial relationships are examined, which are partly due to the interplay of the above-mentioned factors, from the aspect of spatial autocorrelation. The research of spatial autocorrelation, which is often only called LISA (Local Indicators of Spatial Association) in the international scientific literature, started following the path breaking work of Luc Anselin (1995). Local autocorrelation indices have been already used by several studies in Hungary (Tóth 2003, Bálint 2011, Tóth–Kincses 2011). With the introduction of Moran's I, Luc Anselin (1995) developed the Local Moran's I statistic, which is one of the most commonly used methods to quantify and visualize spatial autocorrelation; in the paper, it is used to explore the spatial economic relations of large cities. Using the designation (1996) of Getis and Ord, I is defined as (Formula 3):

$$I_i = \frac{(Z_i - \overline{Z})}{S_z^2} * \sum_{j=1}^{N} \left[W_{ij} * (Z_i - \overline{Z}) \right], \qquad (3)$$

where Z is the average of all units, Z_i is the value of unit I, S_z^2 is the dispersion of variable z for all observed units and W_{ij} is the distance weighting factor between i and j units, which comes from the W_{ij} neighbourhood matrix (basically W_{ij} = 1 if i and j are neighbours and 0 if they are not).

Using the Local Moran's I value, the negative values mean a negative autocorrelation and the positive ones a positive autocorrelation. At the same time, the function has a wider range of values than the interval of –1; +1. The indicator also has a standardised version, but at this time it is not dealt with. The Local Moran statistics are suitable to show the areas that are similar to or different from their neighbours. The bigger the Local Moran I value, the closer the spatial similarity. However, in case of negative values, it can be concluded that the spatial distribution of the variables is close to a random distribution. Concerning the Local Moran I, the calculations were carried for the per capita income and the unemployment rate at municipal level for 2001 and 2011. During the work, the results of the Local Moran statistic were compared with the initial data in order to be able to examine whether the high degree of similarity is caused by the concentration of the high or low values of the variable (Moran Scatterplots). As a first step, on the horizontal axis of the graph the standardised values of the observation units were plotted, while on the y-axis the corresponding standardised Local Moran's I values (average neighbour values) were plotted. The scatterplot puts the municipalities into four groups according to their location in the particular quarters of the plane:

1. High–high: area units with high value, where the neighbourhood also has a high value.
2. High–low: area units with high value, where the neighbourhood has a low value.
3. Low–low: area units with low value, where the neighbourhood also has a low value.
4. Low–high: area units with low value in which the neighbourhood has a high value.

The odd-numbered groups show a positive autocorrelation, while the even-numbered groups a negative one.

Of the local spatial autocorrelation indices, it is highly appropriate to choose a Local Moran I to search for spatially outlying values. Specifically, it shows where the high–low

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values are grouped in the space (HH–LL), and where those territorial units are, which are significantly different from their neighbours (HL–LH). In this case, the isolation and analysis of these four groups is important to ascertain how similar or different these large cities are if compared to their catchment areas. The use of four different clusters also provides an opportunity to examine the issue of whether or not a separate cluster can be isolated around the given city or is it the part of a larger structural unit? If the catchment area essentially forms a separate cluster, a theoretical situation can be assumed in which the cluster emerges like an island from the relatively undeveloped group of settlements. Of course, it will only very rarely be the case, for example, because of the intertwining of the catchment areas.

This latter case may be one reason behind the development of larger spatial units, which are essentially about the merger of hot, as well as cold spots, (hot and cold spots mean the spatial concentration of high or low values).

The calculations were performed on per capita incomes and unemployment rates for 2001 and 2011. It can be said for both indicators that there was no fundamental change in the spatial picture of the clusters, so this study only deals with 2011.

A large area in Northwestern Hungary and the Budapest agglomeration are essentially closely related hot spots (Figure 4), where the group of those municipalities, which are more advanced than the average, is closely linked. In the corridors of motorways M6 and M3, several southern and eastern Hungarian settlements are also connected to this. There are also county seats in this block: Szombathely, Veszprém, Tatabánya; the catchment areas of these settlements are not separate from the broader environment, but essentially melt into it. A somewhat different situation can be observed in the case of Miskolc, Pécs and Zalaegerszeg. Smaller hot spots are also clearly outlined here; that is, the centre and its narrow catchment area are more advanced than the average, and they are similar to each other. Nyíregyháza and Debrecen should be distinguished among the county seats, as both of them can be regarded as spatial outliers (i.e. a settlement of spatially outstanding value) that is, such a central municipality, which is more advanced than the national average, but very sharply different from the developmental situation of its environment. Concerning the other county seats, a significant relationship cannot be established between the centre and its catchment area. It means that the changes in the degree of proximity (measured by road accessibility between municipalities) and the per capita income of neighbouring municipalities are not significantly correlated with each other.

As for the unemployment rate, only minor differences can be seen compared to the preceding ones (Figure 5). The group of the best areas, that is, the cold spot, which has low values and is different from its environment, also covers roughly similar areas, but it is true that in this case the range of these regions is separated into two groups, one of them covers Budapest and its wider agglomeration, and the other a significant part of Győr-Moson-Sopron and Vas counties.

Szeged, Pécs and Szombathely together with their catchment areas are also considered to be cold spots. The other towns of county rank do not show any significant relationship with their neighbours and their catchment areas in respect of the unemployment rate.

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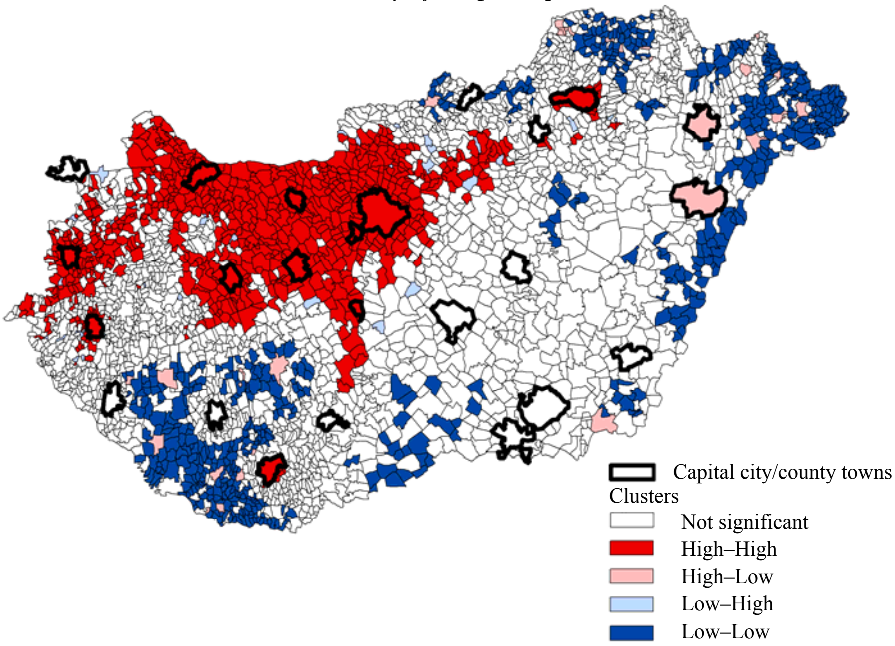
Figure 4

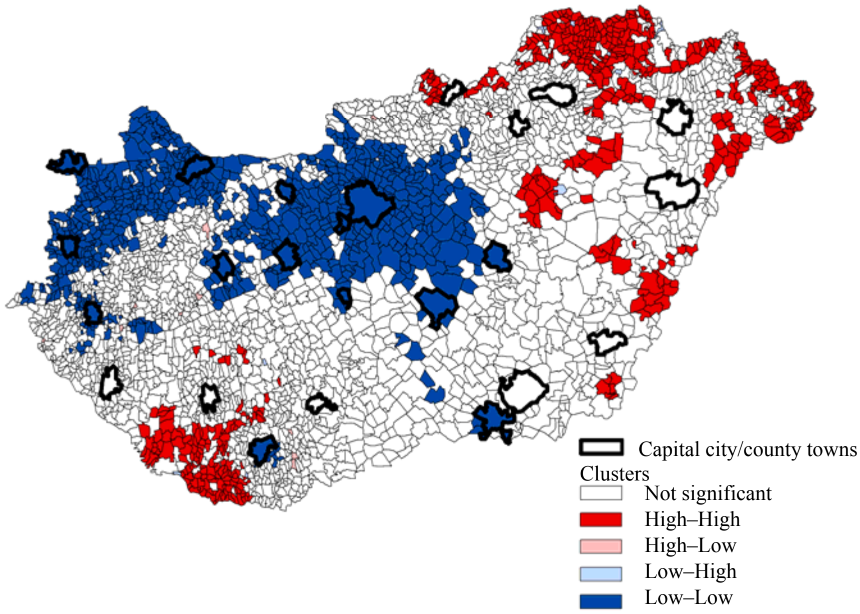
The local similarity of the per capita income, 2011



Source: Own compilation.

Figure 5

The local similarity of the unemployment rate, 2011



Source: Own compilation.

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Figures 4 and 5, showing the data of Northwest Hungary and the Budapest agglomeration, are suitable to evoke the thoughts of Enyedi (2012), who said that nowadays traditional urban agglomerations, which are made up by a central city as well as adjoining small towns and villages, are replaced by wide areas of metropolitan regions, where the big city remains the core, but it also has several sub-centres which are closely related due to the functional division of labour. "Such a metropolitan region is emerging around Budapest through the expansion of the Budapest agglomeration" (this region's peripheral towns are Tatabánya, Székesfehérvár, Kecskemét, Szolnok and Gyöngyös) (Enyedi 2012, p. 17).

The scientific literature does not recommend comparing Local Moran's I indices with each other (Dusek 2013), unless the concerned indicators were calculated primarily using the same territorial matrix. At present, this is the case as between 2001 and 2011 only the secession of a few settlements modified the settlement matrix. Therefore, during the following analysis, the unstandardised Local Moran I indices will be compared with each other disregarding those significance levels, which were taken into account while determining the clusters.

Table 3

Unstandardised Local Moran I indices, 2001–2011

Capital city, county towns	Per capita income		Unemployment rate	
	2001	2011	2001	2011
Békéscsaba	–0.023	–0.108	0.2006	–0.165
Budapest	8.254	4.792	1.2058	4.564
Debrecen	–0.640	–0.276	0.0407	–0.434
Dunaújváros	4.249	1.819	0.5083	1.272
Eger	1.094	0.393	0.1925	0.231
Érd	3.788	2.955	0.9607	2.691
Győr	5.052	3.136	0.8086	2.969
Hódmezővásárhely	0.303	0.047	0.3227	0.027
Kaposvár	0.236	0.094	0.2476	0.019
Kecskemét	0.002	0.082	0.4095	–0.002
Miskolc	0.438	0.545	0.0021	0.446
Nagykanizsa	–0.053	0.218	0.2140	0.135
Nyíregyháza	–0.775	–0.364	0.0192	–0.480
Pécs	0.208	0.492	0.4505	0.427
Salgótarján	–0.442	–0.246	0.0818	–0.339
Sopron	1.844	0.236	1.1863	0.283
Szeged	0.040	–0.062	0.4248	–0.202
Székesfehérvár	4.312	3.382	0.6490	3.239
Szekszárd	0.694	0.131	0.1030	0.021
Szolnok	0.000	0.241	0.3695	0.135
Szombathely	4.357	1.949	0.7647	1.841
Tatabánya	1.764	1.856	0.5324	1.757
Veszprém	4.389	2.145	0.6047	1.994
Zalaegerszeg	1.852	1.218	0.6126	1.177

Source: Own compilation.

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Concerning per capita income, in 2011, in the case of 19 of the 24 cities, the index was positive, in that, to some extent, the development of the centre was similar to that of the catchment area. In 2011, compared to 2001, the value of this indicator fell in 13 settlements, that is, to some extent, there was a fall in the similarity between the centre and its environs. This indicates the weakening of the agglomeration processes. It can be seen that the sharpest declines were mainly detected at those Local Moran's I indices, which were in the positive range; despite the fact that the positive autocorrelation persists, its strength is considerably weakened. In 2011, among the examined settlements, Budapest was the most similar to its environment, while Nyíregyháza was the most different.

In respect of the unemployment rate, in 2011, a positive Local Moran I index was seen in 18 of the 24 cities, but by 2011, compared to 2001, there were also 13 such cases, where the value of the indicator fell. Also in this case, those centres were affected by the positive changes, which were similar to their environment, i.e. in the relationship of the centre and its catchment area, the unemployment situation became more similar than ever before. In 2011 – similarly to per capita incomes – Budapest and Nyíregyháza represented the two extreme values.

Summary

Our calculations revealed that although in recent times the catchment areas of major cities overtook their centres in terms of the growth of per capita income, fundamentally they remained less developed than their centres. Looking at the unemployment rate, the situation is already different in so far that the centres are usually in a better position than the surrounding areas, but in recent times they were often characterised by more unfavourable processes than their hinterlands.

Compared to the national average, the state of the competitiveness reflects the basic territorial development conditions as those cities and their catchment areas proved to be competitive which were in relatively well-developed counties, while in the underdeveloped counties the competitive centre and the less-competitive catchment area was the most frequent matching. In particularly unfavourable cases, both units are competitively disadvantaged. Recent changes showed only a few examples where both the centre and its catchment area were characterised by advantageous competitive processes. Most frequently, the catchment area is in a competitively advantaged position, while its centre is competitively disadvantaged.

The papers autocorrelation analysis shows that large cities and their catchment areas, in many cases, are part of a large structural unit – in this case it is also an area of northwest Hungary involving the Budapest agglomeration – and there are only a few cases where they are clearly separated as a stand-alone unit from the surrounding settlements.

Thus, the results of the study clearly indicate that the economic potential of the metropolitan areas in Hungary (in various cities and their catchment areas) is quite different. There are such areas where the economic fundamentals of a mutual benefit based development are clearly detectable, but in most cases this is not typical. The

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economic status of either one party or the other or even both of them hinders the unfolding of a healthy development.

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Annex

Competitiveness of the studied settlements and their catchment areas, 2011

Capital city, county towns	Central settlement	30-minute	45-minute
		catchment areas	
Békéscsaba	0010	0011	0011
Budapest	1110	1110	1110
Debrecen	1111	0001	0001
Dunaújváros	1111	1111	1110
Eger	1110	0001	0001
Érd	1101	1110	1110
Győr	1110	1011	1011
Hódmezővásárhely	0010	0010	0000
Kaposvár	0010	0001	0001
Kecskemét	1110	0001	1100
Miskolc	1100	0001	0001
Nagykanizsa	1011	0001	0011
Nyíregyháza	1011	0001	0001
Pécs	1100	0001	0001
Salgótarján	0001	0000	0001
Sopron	0010	0010	1011
Szeged	1110	0001	0001
Székesfehérvár	1110	1111	1110
Szekszárd	1111	0001	0001
Szolnok	1110	0001	0001
Szombathely	1110	1011	0011
Tatabánya	1111	1110	1110
Veszprém	1110	1011	1011
Zalaegerszeg	1110	0011	0011

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Competitiveness of the studied settlements and their catchment areas, 2001/2011

Capital city, county towns	Central settlement	30-minute	45-minute
		catchment areas	
Békéscsaba	0100	1111	1111
Budapest	0000	1110	1110
Debrecen	0110	1111	1011
Dunaújváros	0000	1111	0000
Eger	0100	1111	1111
Érd	1110	0000	0000
Győr	0000	1100	1101
Hódmezővásárhely	0000	0100	1100
Kaposvár	0000	1011	1001
Kecskemét	0100	1111	0000
Miskolc	1110	1111	1011
Nagykanizsa	0000	1111	1011
Nyíregyháza	1110	1011	1011
Pécs	0100	1111	1111
Salgótarján	0000	1111	0011
Sopron	0000	0001	0000
Szeged	0100	1111	1111
Székesfehérvár	0000	1100	0000
Szekszárd	0100	0101	1101
Szolnok	0000	1111	1111
Szombathely	0000	0001	0001
Tatabánya	1100	1100	0000
Veszprém	0100	1101	0101
Zalaegerszeg	0100	1101	0001