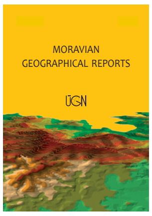

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The efficiency of areal units in spatial analysis: Assessing the performance of functional and administrative regions

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Abstract

An attempt to provide a procedure for the assessment of the efficiency of various regional systems for the purposes of spatial analysis is presented in this paper. Functional regions as well as approximated functional regions and the existing administrative regions in the Czech Republic are evaluated, as examples of regional systems to be compared and assessed. Functional regions and approximated functional regions are defined according to the adjusted third variant of the CURDS regionalisation algorithm, using the latest knowledge on the operation of the constraint function. The comparisons of individual regional systems are based on LISA maps and particularly on the assessment of regional variability, including the measures of internal homogeneity and external variability in the regional systems.

Keywords: *spatial analysis, functional regions, administrative regions, regional variability, LISA, Czech Republic*

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1. Introduction

This paper attempts to provide a procedure which uses the concept of functional region to assess the efficiency of agglomerated areal units for the purposes of spatial analysis, particularly for the assessment of regional variability. Each grouping of arbitrary basic spatial units into larger regions is part of the so-called modifiable areal unit problem (MAUP – Openshaw, 1984; Fortheringham and Wong, 1991; Unwin, 1996; Grasland et al., 2006). As there is an extensive number of ways to organise basic spatial units into regions, the question of identification of an optimal or near-optimal solution is raised. If an inappropriate solution is chosen, important characteristics of the spatial distribution of geographical phenomena may remain concealed, and the application of such regions for spatial analysis of phenomena such as regional inequalities would be compromised in such a case.

Spatial analysis is a set of techniques and models that explicitly use various scales of reference and data related to phenomena and objects/cases in a spatially arrayed manner. The 'correct' grouping of these objects into more "manageable" cases can be seen as a necessary precondition for sensitive spatial analyses that explain or predict the spatial distribution of geographical phenomena. One of the objectives of spatial analysis can be the identification and characterisation of areal units (as regions, for example) that manifest either a higher degree of internal homogeneity and external separation (formal regions), or a large degree of internal cohesion and external self-containment in relation to other areal units or regions (functional regions).

This paper examines two types of regions: functional regions and administrative regions. Correctly-defined functional regions (i.e. those based on informed choices) can serve better as a geographical tool for administrative use than unsuitably- and arbitrarily-delineated administrative regions, which has been acknowledged long ago by Haggett (1965) and Dziewoński (1967). It can be assumed that suitable administrative regions, particularly at a micro-regional level, should be based on functional spatial relations. In addition, it can be generally assumed that functional regions better capture the geographical variability of spatial information for spatial analyses. If similar measurements of geographical variability are obtained for administrative regions, then it would indicate that such administrative regions are defined according to spatial functionality and suitable for spatial analyses. The hypothesis of this paper is that a regional system of functional regions (or approximated functional regions) should manifest at least the same value

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(or higher) for a measure of internal homogeneity and external variability. A procedure that enables one to assess the suitability of administrative units for spatial analyses is expected to be the main methodological outcome of the work. Several sets of functional regions, based on the 2011 census data for the Czech Republic are expected to be the applied outcome of the paper. If functional regions have higher values for internal homogeneity and external variability, the administrative division would have certain insufficiencies regarding the principles of spatial efficiency and equity. If these values were comparable, administrative regions could be considered as being defined according to spatial functionality and as suitable for spatial analyses.

Given these introductory remarks, the main objective of the paper is to evaluate the efficiencies and suitability of administrative regions for spatial analysis. In order to fulfil this objective, two steps have to be carried out. First, as a tool for further analyses and the introductory objectives, functional regions based on daily travel-to-work flows have to be defined. Several sets of optimised functional regional systems and approximated functional regional systems are produced to serve as bases for comparison. Second, the analyses of regional variability of a set of selected variables for each regional system will be carried out. This paper will use the territory of the Czech Republic as the study area, and will analyse selected socio-economic characteristics in terms of their regional variability, in two administrative systems ('districts', and 'Areas of Municipalities with Extended Powers': AMEP) and five functional regional systems (three of them consisting of optimised ["natural"] functional regions, and two of which consist of approximated functional regions, with the latter approximation taking into consideration the number of districts and AMEPs).

The remainder of the paper is organised in the following way. Section 2 presents some necessary theoretical background regarding the issue of functional regions, administrative regions and regional variability. Section 3 describes the methods that are applied in the paper regarding the delineation of functional regions and the measurement of regional variability. Section 4 presents the results and necessary comments. In the conclusion the paper returns to the objectives and hypothesis.

2. Theoretical background

The paper theoretically builds on three presuppositions that are interlinked, the common denominator being that some units for spatial analysis are needed and are sought, and this has its practical purposes (such as the reporting of statistical data in general (e.g. the Census) and for planning purposes – the two most general). Statistical data in geography have mostly an aggregated character; they are composed of attributes referring to an individual, who has a position in geographic space. The first presupposition is that there are two options with regard to the units of spatial analysis: either the existing administrative regions can be used, or regions based on particular criteria have to be defined. With reference to the latter, this paper has opted to use functional regions based on daily travel-to-work flows, and to compare them to the existing administrative units. The second presupposition is based on the general fact that all geographical regions which consist of some arbitrary basic spatial units face the general problem of how many regions there should be optimally, and how these regions should be composed from basic spatial units (MAUP; see section 2.2). Finally, the third presupposition is based on the belief or the requirement that the spatial uncertainty stemming from the MAUP be reduced as much as possible. Thus, there are two types of regional systems (administrative and functional) and the need to decide on their suitability for other purposes is paramount: in order to achieve such suitability, the analysis of regional variability within both systems appears to be a convenient procedure.

2.1 Functional and administrative regions

A functional region is regarded in this paper as it is in our preceding research (e.g. Klapka et al., 2013a, 2014; Halás et al., 2015). It is a general concept that has to meet only the condition of the self-containment of region-organising horizontal interactions or flows. This means that these horizontal functional relations should be maximised within a region and minimised across its boundaries, so that the principles of internal cohesiveness and external separation regarding spatial interactions are met (see for instance, Smart 1974; Karlsson and Olsson, 2006; Farmer and Fotheringham, 2011). Sometimes functional regions can be seen as nodal regions, i.e. regions defined and identified by the core-periphery dichotomy. Such nodal regions, however, also very often fulfil the condition of self-containment and they can be regarded as a more specific concept, a subset for a functional region (see Klapka et al., 2013a). As the interactions come from human activities, functional regions can be seen as representative spatial images or imprints for relevant aspects of the (aggregated) spatial behaviour of individuals (Halás et al., 2015). The delineation of functional regions is mostly based on the analysis of statistical data, particularly daily travel-to-work flows (e.g. Goodman, 1970; Casado-Díaz and Coombes, 2011). These flows represent a residence-workplace daily rhythm of spatial behaviour and as such are the most frequent regular movements for a large part of the population (Hanson and Pratt, 1992; Heldt Cassel et al., 2013; Halás et al., 2015).

Administrative regions are usually strictly defined on the basis of rigorous rules and criteria and are used for normative purposes. One can assume that it should be of the utmost importance that they reflect an existing geographical reality (spatial behaviour of individuals, spatial patterns of their movements). If this is done, the inhabitants of respective areas will find their administrative region, particularly its centre with all the necessary offices and public services, localised in a space which they frequently use in their daily rhythms. Their ties to such regions exist objectively and are considerably strong. All this can also result in the strengthening of their emotional ties to a space. If such a spatial pattern and design is achieved, other geographical factors and characteristics can reflect and follow this arrangement, such as transport infrastructure, the distribution of public transport lines in space and time, etc.

Apart from the above-mentioned functional relationships, the construction of administrative regions also takes into account other auxiliary criteria, such as historical precedents, the existence of natural borders and barriers, and the spatial distribution of national and other population groups, inter alia. This is not always the case, however, and in some cases administrative systems are not well designed for political reasons or just because the rules or norms are unsuitable or they are designed on purpose (as is the case of Slovakia: see for example Buček, 2002, 2005; or Romania: Suciu, 2002). The delineation of administrative regions can be negatively affected by several risks, which have potentially opposite effects to the delineation of administrative regions compared to definitions using a functional approach. For example, such risks are political influence, nationalistic motives, economic motives, etc. In this respect the risk of gerrymandering is among the first to arise (see for example, Bunge, 1966; Johnston, 2002; Moore, 2002; Suciu, 2002; Apollonio et al., 2009). As administrative regions also frequently serve as statistical areas, their unsuitable delineation can distort statistical spatial analyses in many cases – and in statistically unknowable ways.

In theory, the definition of administrative regions should respect three basic principles with regard to a space: spatial efficiency, spatial equity, and spatial stability (Bezák, 1997, who builds upon the concepts put forward by Goodall, 1987; Michniak, 2003; Halás and Klapka, 2012; Klapka, et al., 2014). The principle of spatial efficiency states that the administrative geography of a territory should reflect the population distribution and its spatial behaviours (particularly spatial movements) to the greatest possible extent. Here is a clear connection to the concept of a functional region. The principle of spatial equity is based on the assumption that administrative centres should be equally accessible from the most peripheral parts of each administrative region. Finally, the principle of spatial stability requires that the administrative geography (e.g. boundaries of administrative units) of a territory should be stable over time.

The principle of spatial efficiency can sometimes be in contrast to the principle of spatial equity, because large regional centres usually tend to form much larger hinterlands than smaller regional centres. In this case, it is necessary to balance the opposite demands of the two principles. If functional regions are to be used as administrative regions, the principle of spatial equity should prevail. This requirement can be secured in concrete functional regionalisation tasks by relativising the interaction data, for instance by the use of Smart's interaction measure (Smart, 1974; Casado-Díaz, 2000; Klapka, et al., 2014). Similarly the principle of spatial stability can be in contrast to the two above-mentioned principles. This is the case when a biased administrative division does not respect natural patterns of settlement and regional systems and the interactions occurring in them. It is also appropriate to note that regions defined according to daily travel-to-work flows can change over time (Ozkul, 2014). Therefore, a compromise between the principle of spatial stability on the one hand and the principles of spatial efficiency and equity on the other should be reached in legitimate cases, and revisions to administrative divisions should be made only in the most necessary cases.

2.2 Considerations on the assessment of relations between spatial distribution patterns and regional variability

A geographic space is non-homogeneous, both in vertical and horizontal directions. This inherent quality of space forms the basis for the study of spatial distribution patterns and regional variability. There is also an inherent temporal dimension. The assessment and analysis of such variability, however, relies to a considerable extent on the character and availability of relevant statistical information. Geographers often work with data that are spatially referenced and aggregated. The reason is twofold. First, secondary data are reported for some kind of arbitrary spatial units (e.g. census tracts, municipalities etc.) and they do not have the character of unique objects (statistical individuals). Second, it is useful to report primary or individual statistical data for certain kinds of spatial units, otherwise the analyses of their spatial distribution would be impossible or methodologically incorrect. In both cases, however, there is a possibility of spatial bias, which can compromise the spatial analyses and the interpretation of the results, because there is an almost infinite number of ways to aggregate individual pieces of statistical information into spatial units, zones and regions, and it has to be decided or estimated which spatial design better follows the spatial functionality principle and is thus more suitable.

This is referred to as a modifiable areal unit problem (MAUP); it has been identified by Gehlke and Biehl (1934), extended by Yule and Kendall (1950) and discussed thoroughly by Openshaw (1984), Fotheringham and Wong (1991), Unwin (1996) and Grasland, et al. (2006). MAUP consists of two issues demanding attention: the first concerns the number of spatial units and is referred to as a scale effect (Openshaw, 1984); and second concerns the issue of alternative aggregations at the same or similar scales and is referred to as a zoning or aggregation effect (Openshaw, 1984).

There are ways to tackle the MAUP, or, more precisely, how to choose from various solutions to spatial designs, in terms of which one is more suitable for a given purpose and which one is less suitable (see for example, suggestions made already by Openshaw, 1977, 1984; Fotheringham and Wong, 1991). This paper does not tackle the problem fully in the first place, because the objective is not to define functional regions using quantitative methods so that their internal homogeneity and external variability is maximised. Consideration of MAUP cannot be avoided, however, because the paper compares the internal homogeneity and external variability of the existing normative administrative regions to the optimised and approximated functional regions, defined on the basis of daily movements of the population. Three types of regional variability measures can be generally applied in this respect: inter-regional variability, intra-regional variability (internal homogeneity), and relative regional variability inequality (for methods, see section 3).

Another inherent quality of space, the horizontal distance (either absolute or relative) between geographical locations, raises the question of whether neighbourhood matters or not, when assessing the spatial distribution of geographical phenomena. It is generally agreed that it does (Goodchild, 1986: 3), which means that the values for a certain characteristic in one location, in one spatial unit, are affected by the values of this characteristic in neighbouring locations and neighbouring spatial units (see for instance Cliff and Ord, 1973; Goodchild, 1986; Anselin, 1995; Getis, 2008). This spatial dependency is considered to be an inherent feature of spatial data and reflects such basics as Tobler's 'first law of geography' (Tobler, 1970: 236; 2004) and the role of distance in the probability of contacts between geographical locations (distance-decay functions). Spatial dependency can be measured by spatial autocorrelation statistics, which can be expressed both by global and local indices (see for instance, Anselin, 1995; Spurná, 2008; Netrdová and Nosek, 2009 in the Czech literature). While the global indices enable us to quantify the extent of spatial clustering of similar values in a space with one value, the results of local indices can be depicted on a map and used to identify spatial clusters and outliers. In the context of this paper, the global statistic of spatial autocorrelation, Moran's I (Cliff and Ord, 1973; Anselin, 1988), is important for the selection of studied characteristics according to their different level of spatial concentration. LISA analysis, the local statistic of spatial autocorrelation, is interesting for its comparisons of how defined regional systems conform to the actual spatial patterns of selected geographical characteristics.

3. Methods and data

3.1 Functional regions

A detailed overview of methods for the definition of functional regions is beyond the scope of this paper. Relevant discussions can be found for example in Coombes (2000), van der Laan and Schalke (2001), Flórez-Revuelta, et al. (2008); Casado-Díaz and Coombes (2011), Farmer and Fotheringham (2011), and in our own earlier papers (Klapka et al., 2013b, 2014; Halás et al., 2014, 2015). This paper favours the use of the so-called rule-based, or multistage approach to functional regionalisation that was introduced to this field of study by Smart (1974) and later extended at the Centre for Urban and Regional Development Studies (CURDS) in Newcastle, UK (Coombes, et al., 1982, 1986). In this paper, the third variant of the CURDS regionalisation algorithm (Coombes and Bond, 2008; Coombes, 2010) is applied using the constraint function proposed and used by Halás et al. (2015), and which has already been tested practically (Halás et al. 2014; Klapka et al., 2014), but only on the 2001 census data and using the second variant of the CURDS algorithm (Coombes et al., 1986). This is the first time the third variant of the CURDS regionalisation algorithm has been applied to the territory of the Czech Republic. The method identifies as many functional regions as possible, according to the criteria set by the regionalisation algorithm.

The identification of functional regions is based on the analysis of spatial patterns of daily travel-to-work flows using the 2011 population census. These data have been stored in a large and sparse 6,251 × 6,251 non-symmetrised (flows: $t_{ij} \neq t_{ji}$) matrix, for the municipalities of the Czech Republic that served as basic spatial units for all analyses presented in this paper. It is very important to note that the diagonal of the matrix included intra-unit flows (t_{ii} – in fact it is the number of employed residents working locally).

A crucial role in the regionalisation algorithm is played by the constraint function. It sets the minimal size and self-containment criteria for the resulting functional regions and it also comprises the trade-off between the two parameters. The trade-off means that smaller regions have to reach a higher level of self-containment, while, in contrast, larger regions are allowed to manifest a lower level of self-containment. The constraint function is in the form of a continuous curve and its shape is determined by five parameters (see below), four of which can be easily estimated. The notation of the constraint function is:

$$\frac{T_{jj}}{\left(\sum_k T_{jk} + \sum_k T_{kj}\right) - T_{jj}} - \frac{\alpha(\beta_4 - \beta_3)(\beta_2 - \beta_1)}{\left|\max\left(\beta_3 + 1; \sum_k T_{jk}\right) - \beta_3\right|} \geq \beta_1 \qquad (1)$$

where β_1, β_2, β_3, β_4 are limits of the trade-off between the size and self-containment of a region (β_1, β_2 are lower and upper limits of the self-containment; β_3, β_4 are lower and upper limits of the size), and α determines the measure of the deflection of the trade-off part of the function ($\alpha = 0.09$ in this paper). For remaining expressions see the notation of the Smart's measure (2) below.

As proposed by Halás et al. (2015), the constraint function can be used for the identification of the relatively optimal number of resulting functional regions through the estimation of four beta parameters. The analysis starts with loose values for these parameters, which produce a larger number of functional regions, and which provide the initial spatial pattern (in this paper $\beta_1 = 0.5$, $\beta_2 = 0.55$, $\beta_3 = 2{,}000$, $\beta_4 = 10{,}000$). These regions can be plotted on a graph according to the self-containment and size variables. The graph also contains the constraint function and the regions appear in its upper right sector. If there is a considerable gap in the field of points, a new constraint function can be inserted and the values for the new beta parameters can be estimated. This step can be repeated several times and thus it can provide several variants of the optimised regional system (3 in the case of this paper). Of course, this operation can be used for the identification of a given number of regions, i.e. approximated regional systems can be defined in this way (2 in the case of this paper). The parameters for all regional systems, including their total self-containment[1], are presented in Table 2. Detailed theoretical and methodological discussion of the constraint function and its use is provided in Halás et al. (2015), and operations with the constraint function were applied by Halás et al. (2014) and Klapka et al. (2014).

The interaction measure used for the expression of the strength of the relationship between two basic spatial units (or a basic spatial unit and a "proto" region) was recommended, but not used, by Smart (1974). This measure is currently the most frequently used for the type of research tasks presented in this paper (see for example, Casado-Díaz and Coombes, 2011). It is mathematically the most correct way for the relativisation and symmetrisation of two-dimensional interaction data. This measure levels the size differences between the regions and thus it is the most suitable compromise between the principles of spatial efficiency and equity.

The notation of the Smart's measure is

$$\frac{T_{ij}^2}{\sum_k T_{ik} \sum_k T_{kj}} + \frac{T_{ji}^2}{\sum_k T_{jk} \sum_k T_{ki}} \qquad (2)$$

where T_{ij} is a value for a flow from the municipality i to the municipality j, T_{ji} is a value for a flow from the municipality j to the municipality i, and k is the total number of basic spatial units (municipalities) in the system.

Finally, the procedure for the identification of functional regions of the Czech Republic consists of the following steps:

1. all basic spatial units are ranked in descending order according to the values of the constraint function and are considered to be so-called "proto" functional regions;
2. if all regions equal or exceed the value of the β_1 parameter in the constraint function, the procedure stops, otherwise it proceeds to the next step;
3. the "proto" functional region with the lowest rank according to the value of the constraint function is dissolved into its constituent basic spatial units (municipalities) and these are ranked in descending order according to the constraint function;

[1] The total self-containment of the regional system is calculated as $\frac{\sum_j T_{jj}}{\sum_j \sum_k T_{jk}}$.

4. the constituent basic spatial unit with the highest rank is amalgamated with the "proto" functional region that it is most strongly related to according to the interaction measure (see further); and
5. after each amalgamation the values for the constraint function are recalculated and the procedure returns to the first step.

3.2 Spatial distribution patterns and regional variability

There are different types of geographical characteristics in a spatial and regional context, which have different spatial patterns and are influenced by different spatial and regional processes. The basic typology of the possible nature of characteristics based on spatial and regional concentration is shown in Table 1. Three of four types of characteristics can be found in reality, the characteristic with high regional concentration and low spatial concentration does not exist because a high regional concentration always implies a level of spatial concentration. We have analysed 17 characteristics from the 2011 census at the municipal level through both global and local spatial autocorrelation statistics and the regional decomposition of variability.

According to this typology, 4 geographical characteristics have been selected for analysis in this paper, in terms of their distinctive spatial distribution patterns and relative regional variability. Two characteristics with high spatial concentration are closely connected to the data used for the definition of functional regions, i.e. with the economic activity of the population: unemployment rate, and employment rate in agriculture. While the unemployment rate exhibits a relatively high regional concentration at all hierarchical regional levels, employment in agriculture is a specific characteristic influenced more by physical conditions than a regional structure based on socioeconomic relations. The two remaining characteristics with low regional concentration differ in their spatial concentration and do not manifest such a close connection for methodological reasons: average years in education, and the age preference index. The basic typology of the data used including their definitions is presented in Table 1. All the data for municipalities were obtained from the 2011 census.

For the purposes of comparison between the sets of the existing normative administrative regions and the optimised and approximated functional regions, a minor adjustment had to be made. As the four largest cities of the Czech Republic (Prague, Brno, Ostrava, and Plzeň) have their own normative administrative units, these cities are treated separately from their functional regions in all five sets of optimised and approximated regional systems in the parts of the paper dealing with the assessment of the regional variability of the four above-mentioned geographical characteristics.

The basic spatial patterns of the characteristics studied are introduced using local spatial autocorrelation, specifically LISA cluster maps (local indicators of spatial association) (Anselin, 1995). Based on the LISA methodology, we can categorize the municipalities with significant local spatial clustering into four categories. If a municipality, as well as its surrounding (geographically close) municipalities, has an above-mean value and the relationship is statistically significant, a cluster (hot spot or high-high type in this case) is formed. Besides hot spots, there are cold spots (low-low clusters), high-low (high values surrounded by low values), and low-high (low values surrounded by high values) outliers. If the relationship between the close municipalities is not significant according to tests based on the comparison between observed and expected values for the local Moran's I statistics and the computation of z-scores, then no clusters or outliers are identified.

In spatial autocorrelation analysis it is important to operationalize geographical proximity using the matrix of spatial weights. In this paper, the distance-based spatial weight matrices are not chosen arbitrarily, but with respect to analyses of global spatial autocorrelation. Firstly, for each variable, Moran's I (Cliff and Ord, 1973; Anselin, 1988) is calculated for a series of distances. Then the LISA cluster maps are constructed using the spatial weight matrix with the maximum z-score. With regard to the definition of regions, the highest values of z-score identify the level (geographical distance) at which the process operates most significantly. Thus, selected geographical characteristics can be attributed to specific regional levels. By using a z-score which reflects

	Regional Concentration HIGH	Regional Concentration LOW
Spatial Concentration HIGH	SPATIALLY dependent and bounded in REGIONS Concentrations in regions *– Unemployment rate – based on a labour market delimitation, which highly corresponds with regional levels in the Czech Republic*	SPATIALLY dependent with no relation to REGIONS Concentrations across regional borders *– Employment in agriculture – determined to a large extent by physical geography* *– Average years in education – concentrated in larger settlements*
Spatial Concentration LOW		Both SPATIALLY and REGIONALLY independent No concentrations *– Age preference index – as a demographic characteristic relatively regularly distributed in space*

Tab. 1: General "spatial and regional" typology of characteristics used in the analysis
Source: Nosek and Netrdová (2014) – modified
Notes: (1) The unemployment rate is computed as the ratio of unemployed to the economically active population; (2) Employment in agriculture as a ratio of employed in agriculture to the total number of the employed population; (3) The average years in education as a weighted mean of the ratio of educated people at different stages in their education and the number of years needed to achieve this level of education; (4) The age preference index as a ratio of the population older than 64 years to the population younger than 15 years.

the intensity of spatial clustering for the identification of the optimal spatial weight matrix, the final LISA cluster map with the highest significance shows the largest clusters for each characteristic.

Sets of normative and functional regional systems are compared through:

1. a measure of regional variability (differences between regional means);
2. a measure of relative regional variability (importance of the regional level compared with the overall inter-municipal variability); and
3. a measure of the internal homogeneity of regions (variability within regions).

For further description of different concepts of regional variability, see Nosek and Netrdová (2014).

Regional variability is measured using standard variability measures such as the coefficient of variation, and the Theil index. All these measures are analysed both in unweighted and weighted forms. The unweighted measures treat all regions the same, no matter how large they are in terms of their size. The weighted measures take some measure of size into account (see note below Table 3). Similarly, homogeneity (intra-regional variability) is measured by both weighted and unweighted coefficients of variation.

Relative regional variability is measured by the Theil index decomposition. Of the standard variability measures, the Theil index is scale independent and decomposable, similar to the variance (Cowell and Jenkins, 1995; Shorrocks and Wan, 2005). The main purpose of the Theil index decomposition is to calculate both inter-regional (between regional) variability (T_B) and intra-regional (within regional) variability (T_W). By comparing inter-regional variability (T_B) with the overall variability ($T_B + T_W$), the importance of respective regional levels can be quantified. These results are skewed to some extent, however, by stochastic variability, which appears irrespective of the design of regional patterns. Thus, a geographical standardization is introduced, which can filter out the stochastic component and isolate the contextual component (for details including formulas, see Novotný and Nosek, 2012). This filtering and isolation is used also in this paper.

4. Results

Basic statistical characteristics for five regional schemes are presented in Table 2: for three variants of optimised functional regions (functional regions according to daily travel-to-work flows – FRD); and for two variants of approximated functional regions (AFRD). Regional system AFRD 1 approximates the number of AMEPs, and regional system AFRD 2 approximates the number of districts in the Czech Republic. Delimitation of regions for regional systems is presented in Figures 1–5. For a comparison with the results from the 2001 census, see Klapka et al. (2014).

The overall spatial distribution of four selected characteristics regarding various manifestations of the neighbourhood effect is presented in Figure 6. Types of spatial autocorrelations are laid over the mean variant of the optimised functional regional system (FRD 2). The unemployment rate shows clusters of low unemployment in a belt stretching from south-western Bohemia through central Bohemia to north-eastern Bohemia. Clusters of high unemployment are particularly concentrated in problematic regions of north-western Bohemia and peripheral areas of Moravia and Silesia. Employment in agriculture presents a high degree of clustering, but without relation to the borders

Attribute for regional system		FRD 1	FRD 2	FRD 3	AFRD 1	AFRD 2
β_1 value		0.60	0.60	0.65	0.56	0.65
β_2 value		0.65	0.65	0.70	0.70	0.80
β_3 value		7,500	6,000	11,500	2,500	7,500
β_4 value		15,000	100,000	30,000	25,000	120,000
Self-containment of regional system		0.908	0.916	0.926	0.896	0.930
No. of regions		142	125	95	201	80
Self-containment	Mean	0.802	0.820	0.841	0.776	0.857
	Median	0.809	0.824	0.857	0.778	0.861
	Coeff. of variation	0.097	0.080	0.076	0.094	0.060
Economically active population	Mean	28,434	32,217	42,501	20,087	50,585
	Median	16,843	19,149	27,217	10,029	34,973
	Coeff. of variation	2.016	1.955	1.715	2.420	1.541
Population	Mean	74,381	84,497	111,181	52,548	132,027
	Median	46,989	54,368	76,305	29,290	95,159
	Coeff. of variation	2.037	1.761	1.547	2.185	1.386
Area km^2	Mean	555.39	630.93	830.17	392.37	985.83
	Median	463.81	504.63	734.01	343.17	849.91
	Coeff. of variation	0.585	0.579	0.568	0.600	0.471

Tab. 2: Attributes for variants of regional system
Source: authors´ computations

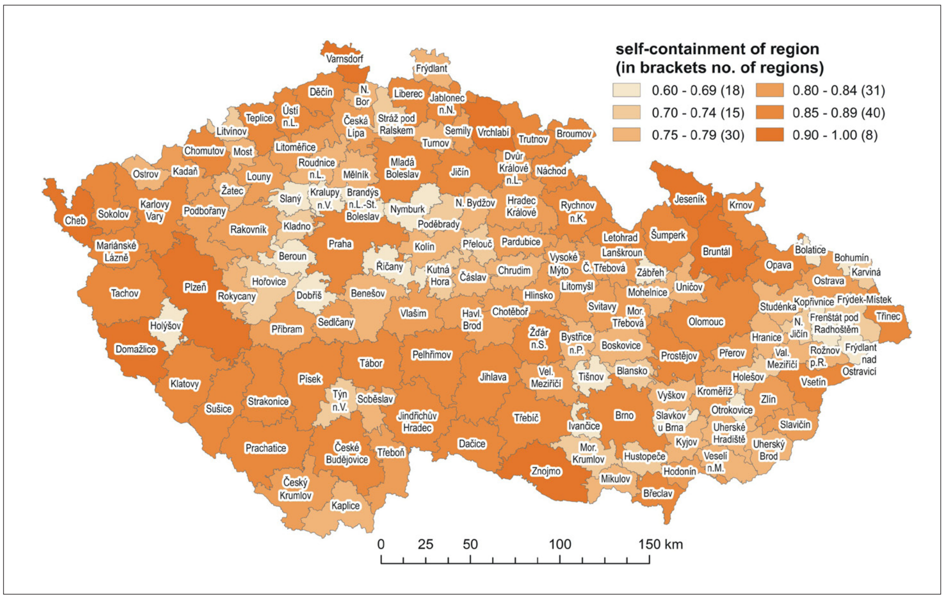

Fig. 1: Regional system FRD 1. Source: authors' elaboration

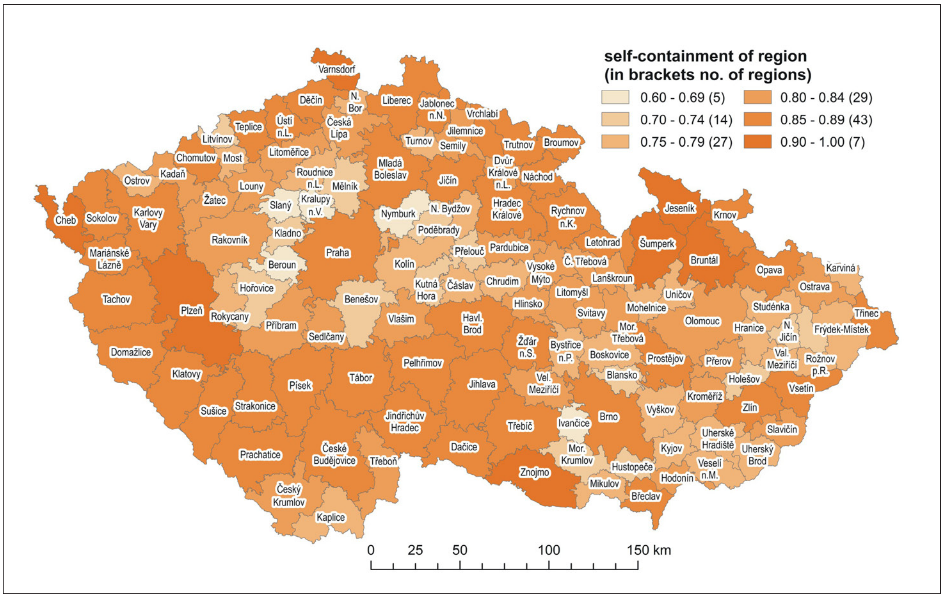

Fig. 2: Regional system FRD 2. Source: authors' elaboration

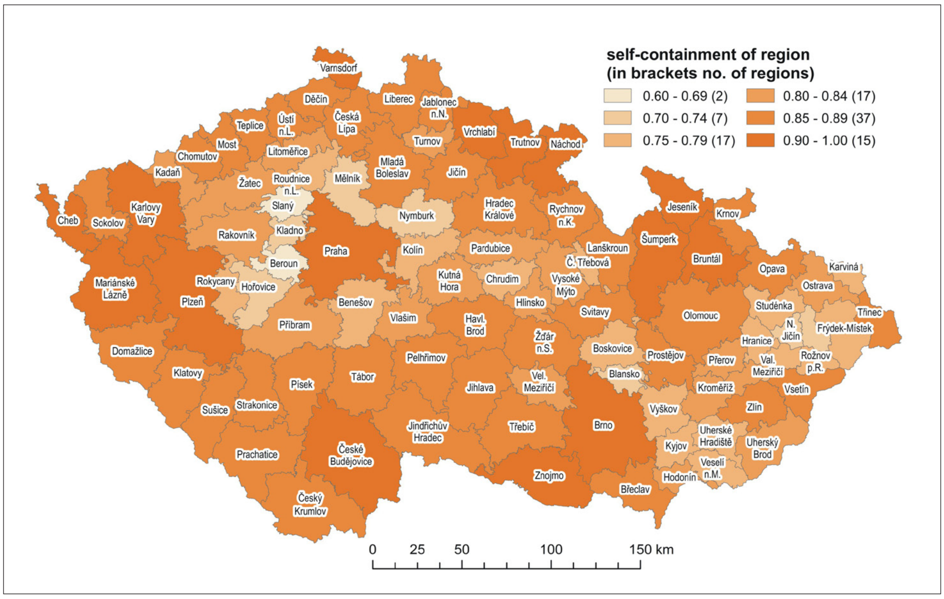

Fig. 3: Regional system FRD 3. Source: authors' elaboration

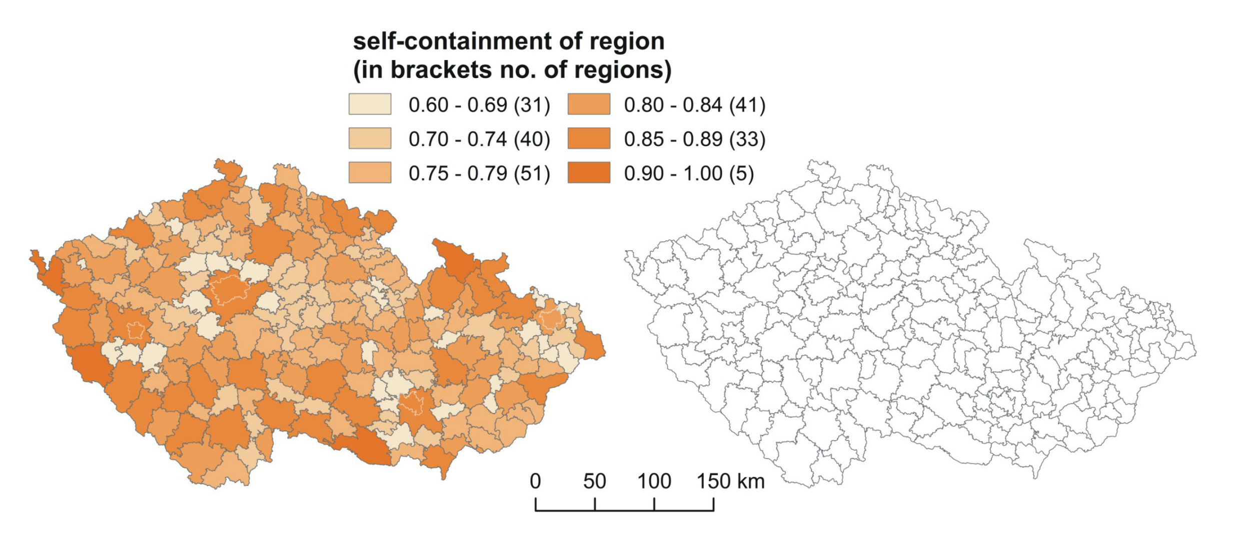

Fig. 4: Approximated regional system AFRD 1 (left) and AMEPs (right)
Source: authors' elaboration

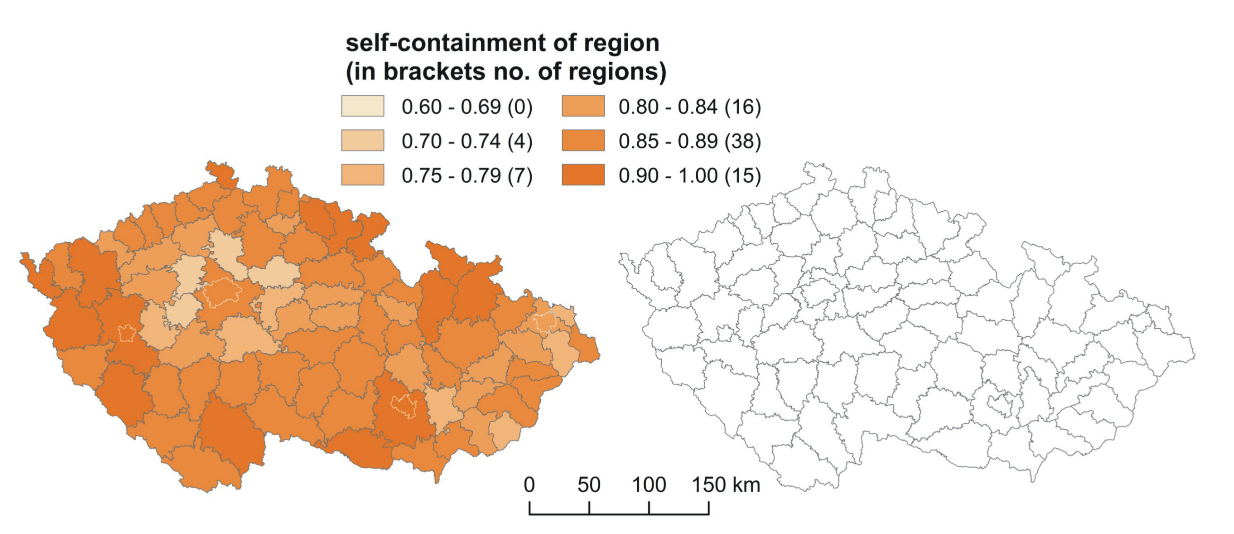

Fig. 5: Approximated regional system AFRD 2 (left) and districts (right)
Source: authors' elaboration

of micro regions and even those of meso regions. The average years in education cluster positively in the hinterland of large university cities. Finally the age preference index, as the least complex characteristic, clusters the least in spatial terms. The most relevant regions for this characteristic should have their centres approximately 40 km apart. Out of the four selected characteristics, the unemployment patterns in LISA cluster maps best approximate the borders of functional regions. Relatively cohesive clusters within functional regions result from the fact that unemployment is a characteristic directly related to the interaction data used for the construction of functional regions – i.e. daily travel-to-work flows.

Tables 3, 4, and 5 show different statistics measuring homogeneity, the importance of respective regional levels for overall variability, the regional variability for different regional systems (two administrative systems, two approximated regional systems, and three optimised regional systems), and the four selected socio-geographical characteristics. In accordance with the main objective of the paper, special attention is paid to the differences (and similarities) between administrative systems and functional regional systems. Intra-regional variability (homogeneity) is measured by the coefficient of variation, separately for each regional unit. This statistic was calculated in both unweighted and weighted form in order to eliminate the effect of different population sizes of units. The minimum, maximum, and mean values of the coefficient of variation presented in Table 3 show the level of differences between municipalities in each regional unit for a particular regional system.

Employment in agriculture has the highest values for intra-regional variability of all regional systems. In contrast, the average number of years in education has the lowest values. These results fully correspond with the spatial patterns of the characteristics studied and presented in Figure 6, particularly in regards to the homogeneity of spatial clusters of high or low values (i.e. the presence of spatial outliers), and the spatial relationship between clusters and regional boundaries. For example, agriculture is primarily not affected by the socio-economic regions, but by differences between rural and urban areas and by physical geographical conditions. In general, the values of inter-regional variability indicate no differences between administrative and functional regional systems. The only

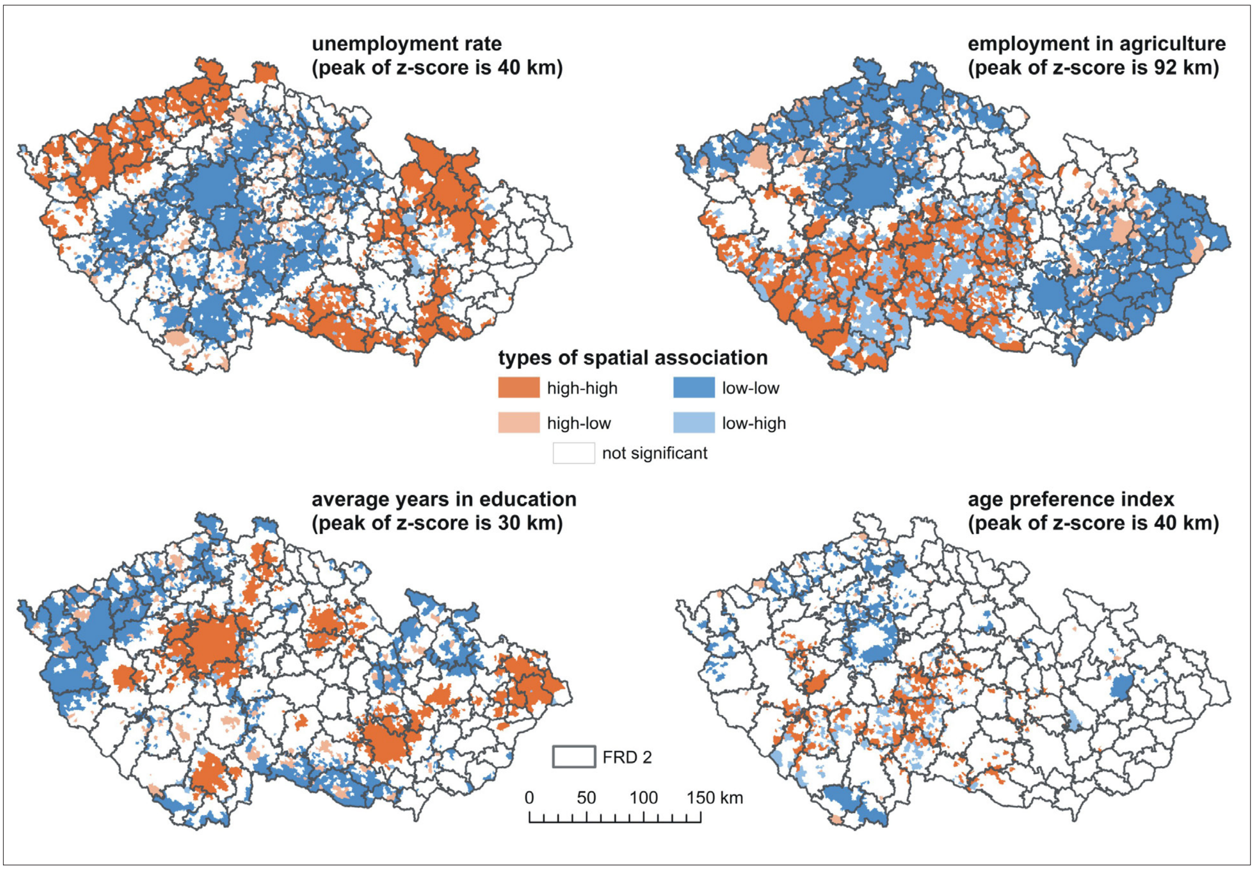

Fig. 6: LISA cluster maps for studied characteristics. Source: authors' elaboration
Notes: LISA cluster maps are constructed using a distance-based spatial weight matrix with the cut-off equal to the maximum z-score for respective characteristics. The significance level is 5%.

logical dependence is on the number of units in each regional system: the more units there are, the lower the measure of intra-regional variability.

Table 4 presents values for inter-regional variability using the coefficient of variation. The same results were reached using the Theil index as another measure of interregional variability. The values show that not only the intraregional, but also the interregional variability reaches maximum values for the employment in agriculture and minimum values for the average number of years in education. The comparison of different regional systems again shows neither significant differences between administrative and functional systems, nor the influence of the number of units.

Table 5 presents the share the interregional component of the Theil index has of the total variability, when its intraregional component can be easily derived as an algebraic complement to 100%. Unlike previous results, these calculations bring new and unexpected information about the structure of interregional variability. The unemployment rate and the average years in education have the highest interregional component of the overall variability. In the case of the unemployment rate, it documents the effect of local labour markets (i.e. the functional regions used in this paper) on the spatial pattern of this characteristic. However, even this characteristic with its close relationship with functional regions does not show any major differences when compared with administrative regions.

All measures of intra-regional, relative regional and inter-regional variability for selected socio-geographical characteristics show very similar results for all seven sets of regional systems; only the number of regions, i.e. the scale effect of MAUP, plays some role in this respect. All of the measures of variability are primarily affected by the number of regions; the zoning effect of MAUP has a marginal role with minimum effects as documented by the comparison of administrative and functional regional systems with similar numbers of units. One reason for this is that all characteristics studied are influenced by and operate on a micro-regional level, as demonstrated by the spatial autocorrelation analysis. It can be expected that more distinct regional variability should occur at higher or lower hierarchical levels. In this work, however, only the structure as a whole was analysed, without regard to local differences. It could be interesting to compare the regional delimitation and regional variability of some particular administrative and functional regions for a broader set of characteristics.

5. Conclusion

The third variant of the CURDS regionalization algorithm, using the original constraint function proposed by Halás et al. (2015), has proved to be a suitable method for the definition of functional regions, and has produced relevant results. This variant uses the latest knowledge of operations using the constraint function and the regions are delineated without the unnecessary effects of further constraints, such as normative identification of regional cores and normative determination of size and self-containment of the resulting regions. The paper analysed seven regional systems in the Czech Republic at the micro-regional level. Two of them were represented by existing administrative divisions: districts and areas of municipalities with extended powers

	Area type		Coefficient of variation unweighted				Coefficient of variation weighted			
			UNEMP	AGRI	EDU	AGE	UNEMP	AGRI	EDU	AGE
Czech Republic			0.47	0.86	0.04	0.74	0.33	1.36	0.06	0.27
Administrative regions	AMEP (206 units)	Minimum	0.09	0.32	0.00	0.04	0.05	0.30	0.00	0.02
		Maximum	0.72	1.67	0.12	1.57	0.42	1.87	0.07	0.79
		mean	0.34	0.69	0.03	0.42	0.20	0.85	0.03	0.24
	districts (77 units)	Minimum	0.20	0.46	0.02	0.10	0.07	0.64	0.01	0.04
		Maximum	0.62	1.57	0.07	1.34	0.39	1.83	0.05	0.57
		mean	0.37	0.77	0.04	0.52	0.22	0.99	0.03	0.26
Functional regions	AFRD 1 (205 units)	Minimum	0.09	0.35	0.01	0.03	0.06	0.33	0.01	0.02
		Maximum	0.64	1.48	0.11	1.67	0.44	2.01	0.07	0.83
		mean	0.35	0.69	0.03	0.44	0.21	0.88	0.03	0.25
	AFRD 2 (84 units)	Minimum	0.19	0.44	0.02	0.10	0.10	0.65	0.02	0.13
		Maximum	0.62	1.37	0.07	1.50	0.39	1.85	0.05	0.62
		mean	0.37	0.75	0.04	0.50	0.23	0.99	0.03	0.26
	FRD 1 (146 units)	Minimum	0.09	0.34	0.01	0.03	0.07	0.43	0.01	0.02
		Maximum	0.62	1.51	0.07	1.62	0.44	1.85	0.05	0.81
		mean	0.35	0.71	0.03	0.47	0.21	0.92	0.03	0.25
	FRD 2 (129 units)	Minimum	0.14	0.34	0.02	0.10	0.07	0.44	0.01	0.10
		Maximum	0.62	1.44	0.07	1.61	0.44	1.99	0.05	0.70
		mean	0.35	0.72	0.04	0.47	0.22	0.93	0.03	0.25
	FRD 3 (99 units)	Minimum	0.14	0.44	0.02	0.10	0.10	0.51	0.01	0.11
		Maximum	0.61	1.44	0.07	1.50	0.38	1.85	0.05	0.62
		mean	0.36	0.74	0.04	0.49	0.22	0.96	0.03	0.25
difference between AMEP and AFRD 1 means			0.01	0.00	0.00	0.03	0.01	0.02	0.00	0.01
difference between districts and AFRD 2 means			0.00	– 0.02	0.00	– 0.02	0.00	0.00	0.00	– 0.01

Tab. 3: Intra-regional variability for administrative and functional regional systems. Source: authors' computations Notes: (1) in this and all following tables: UNEMP = unemployment rate; AGRI = employment in agriculture; EDU = average years in education; AGE = age preference index; (2) the weights used are (a) economically active population for UNEMP, (b) population for AGRI, EDU, and AGE.

Area type	Coefficient of variation unweighted				Coefficient of variation weighted			
	UNEMP	AGRI	EDU	AGE	UNEMP	AGRI	EDU	AGE
AMEP (206 units)	0.26	0.59	0.03	0.14	0.28	0.80	0.05	0.14
districts (77 units)	0.25	0.55	0.03	0.12	0.26	0.72	0.05	0.13
AFRD 1 (205 units)	0.25	0.59	0.03	0.13	0.28	0.81	0.05	0.14
AFRD 2 (84 units)	0.24	0.56	0.03	0.11	0.26	0.72	0.05	0.13
FRD 1 (146 units)	0.24	0.55	0.03	0.12	0.27	0.76	0.05	0.14
FRD 2 (129 units)	0.24	0.54	0.03	0.12	0.26	0.76	0.05	0.14
FRD 3 (99 units)	0.24	0.55	0.03	0.11	0.26	0.73	0.05	0.13
difference between AMEP and AFRD 1 means	0.01	0.00	0.00	0.00	0.00	– 0.01	0.00	0.00
difference between district and AFRD 2 means	0.01	– 0.01	0.00	0.01	0.00	0.00	0.00	0.00

Tab. 4: Inter-regional variability of the coefficient of variation for administrative and functional regional systems Source: authors' computations

Area type	Inter-regional component (%)			
	UNEMP	AGRI	EDU	AGE
	Theil	Theil	Theil	Theil
AMEP (206 units)	70.42	50.73	75.83	32.07
districts (77 units)	62.12	43.38	68.18	23.58
AFRD 1 (205 units)	69.74	51.15	75.70	32.33
AFRD 2 (84 units)	61.74	44.17	68.43	25.09
FRD 1 (146 units)	65.97	47.98	72.62	28.42
FRD 2 (129 units)	65.15	47.19	71.71	28.00
FRD 3 (99 units)	62.95	45.29	69.06	25.91
difference between AMEP and AFRD 1 means	0.68	− 0.43	0.14	− 0.26
difference between district and AFRD 2 means	0.38	− 0.78	− 0.26	− 1.51

Tab. 5: Inter-regional component for administrative and functional regional systems
Source: authors' computations

(AMEPs). Five spatial schemes were based on the concept of a functional region, which particularly favours the self-containment of regions. Three of these spatial patterns were considered to consist of optimised functional regions, while two consisted of approximated functional regions, where the approximation took into account the number of administrative units, i.e. districts and AMEPs. The regional variability of four selected socio-geographical characteristics for the seven regional systems was analysed in order to fulfil the main objective of the paper, which was the evaluation of the efficiency and suitability of agglomerated areal units for the purpose of spatial and regional analysis.

The results of the spatial analyses indicated that there are no significant differences between administrative and functional regional systems with respect to the measurement of regional variability in the Czech Republic, at least for the chosen characteristics. Regarding the modifiable areal unit problem (MAUP), the agglomeration of basic spatial units (municipalities) into administrative or functional regions does not manifest any significant deviations within the set of seven regional systems. It has been shown that the number of regions is significant (the issue of scale) and that the statistical information presented in the tables changes gradually with a decreasing number of regions, without any shift in the direction of this change (with a decreasing number of regions the inter-regional variability and internal homogeneity increases). When the issue of aggregation (zoning) is taken into account, for the two pairs of regional systems with approximately the same number of regions, the results of all three kinds of analyses also did not show any significant differences within each pair.

The three variants of optimised functional regional systems, however, have the advantage of capturing the natural distribution of daily movements of a considerable part of the population, and thus for purely scientific and local view purposes they should be preferred to administrative regions. Moreover, these sets of functional regions are not manually adjusted, for instance with regard to the contiguity of regions. Thus, these regional systems offer further possibilities for spatial analyses between the level of AMEPs and the level of districts, such as a local view of the differences in the delineation of individual regions.

Finally, it can be generally concluded that the two analysed administrative systems of the Czech Republic (districts and AMEPS) do not differ significantly from regional systems which consist of functional regions with similar numbers of units, according to the measurement of regional variability. Therefore, administrative regional systems can be regarded as efficient enough and suitable for geographic, regional and spatial analysis. On the other hand, however, there are local differences between administrative and functional regional systems, particularly in the hinterlands of large cities. The outcomes of this project offer general conclusions not only for the Czech Republic, but also for other countries and regions. This generalisation is that functional regions are very suitable areal units for spatial analysis, regarding the labour market in particular. Given that the results of this analysis, however, do not differ to a great extent from the analysis carried out for administrative regions (at the same hierarchical level), there is no crucial reason to modify the administrative division in a more significant way. In this case it is more suitable to follow the principle of spatial stability, i.e. to support the stability of the current administrative divisions, including the operation of its institutions, over time.

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References:

ANSELIN, L. (1988): Spatial Econometrics: Methods and Models. Dordrecht, Kluwer Academic Publishers.

ANSELIN, L. (1995): Local Indicators of Spatial Association – LISA. Geographical Analysis, 27(2): 93–115.

APOLLONIO, N., BECKER, R. I., LARI, I., RICCA, F., SIMEONE, B. (2009): Bicolored graph partitioning, or: gerrymandering at its worst. Discrete Applied Mathematics, 157(17): 3601–3614.

BEZÁK, A. (1997): Priestorová organizácia spoločnosti a územno-správne členenie štátu. Acta Universitatis Matthiae Belii, Geografické štúdie, 3: 6–13.

BUČEK, J. (2002): Regionalization in the Slovak Republic – from administrative to political regions. In: Regionalization for development and accession to the European Union: A comparative perspective. Budapest (pp. 141–178). Local Government and Public Service Reform Initiative.

BUČEK, J. (2005): The role of local government in local economic development – Slovakia. In: Local government and economic development. Budapest, Local Government and Public Service Reform Initiative (pp. 461–542). Open Society Institute.

BUNGE, W. (1966): Gerrymandering, geography, and grouping. Geographical Review, 56(2): 256–263.

CASADO-DÍAZ, J. M. (2000): Local labour market areas in Spain: a case study. Regional Studies, 34(9): 843–856.

CASADO-DÍAZ, J. M., COOMBES, M. (2011): The delineation of 21st century local labour markets areas: a critical review and a research agenda. Boletín de la Asociación de Geógrafos Espańoles, 57: 7–32.

CLIFF, A. D., ORD, J. K. (1973): Spatial Autocorrelation. London, Pion.

COOMBES, M. (2010): Defining labour market areas by analysing commuting data: innovative methods in the 2007 review of Travel-to-Work Areas. In: Stillwell, J., et al. [eds.]: Technologies for migration and commuting analysis: spatial interaction data applications (pp. 227– 241). Hershey, IGI Global.

COOMBES, M. G. (2000): Defining locality boundaries with synthetic data. Environment and Planning A, 32(8): 1499–1518.

COOMBES, M. G., BOND, S. (2008): Travel-to-Work Areas: the 2007 review. London, Office for National Statistics.

COOMBES, M. G., DIXON, J. S., GODDARD, J. B., OPENSHAW, S., TAYLOR, P. J. (1982): Functional regions for the population census of Great Britain. In: Herbert, D. T., Johnston, R. J. [eds.]: Geography and the Urban Environment. Progress in Research and Applications 5 (63–112). Chichester, John Wiley and Sons Ltd.

COOMBES, M. G., GREEN, A. E., OPENSHAW, S. (1986): An Efficient Algorithm to Generate Official Statistical Reporting Areas: The Case of the 1984 Travel-to-Work Areas Revision in Britain. The Journal of the Operational Research Society, 37(10): 943–953.

COWELL, F. A., JENKINS, S. P. (1995): How Much Inequality Can We Explain? A Methodology and an Application to the United States. Economic Journal, 105(429): 421–430.

DZIEWOŃSKI, K. (1967): Concepts and terms in the field of economic regionalization. In: Macka, M. [ed.]: Economic regionalization (pp. 25–36). Praha, Academia.

FARMER, C. J. Q., FOTHERINGHAM, A. S. (2011): Network-based functional regions. Environment and Planning A, 43(11): 2723–2741.

FLÓREZ-REVUELTA, F., CASADO-DÍAZ, J. M., MARTÍNEZ-BERNABEU, L. (2008): An evolutionary approach to the delineation of functional areas based on travel-to-work flows. International Journal of Automation and Computing, 5(1): 10–21.

FOTHERINGHAM, A. S., WONG, D. W. S. (1991): The modifiable areal unit problem in multivariate statistical analysis. Environment and Planning A 23(7): 1025–1044.

GEHLKE, C. E., BIEHL, K. (1934): Certain effects of grouping upon the size of the correlation coefficient in census tract material. Journal of the American Statistical Association, 29(185): 169–170.

GETIS, A. (2008): A History of the Concept of Spatial Autocorrelation: A Geographer's Perspective. Geographical Analysis, 40(3): 297–309.

GOODALL, B. (1987): The Penguin dictionary of human geography. Harmondsworth, Penguin.

GOODCHILD, M. F. (1986): Spatial Autocorrelation. CATMOG 47. Norwich, GeoBooks.

GOODMAN, J. F. B. (1970): The definition and analysis of local labour markets: some empirical problems. British Journal of Industrial Relations, 8(2): 179–196.

GRASLAND, C. et al. (2006): ESPON 3.4.3 The Modifiable Areas Unit Problem: Final Report [online]. [cit.14.04.2016]. Available at: https://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/StudiesScientificSupportProjects/MAUP/espon343_maup_final_version2_nov_2006.pdf

HAGGETT, P. (1965): Locational Analysis in Human Geography. London, Arnold.

HALÁS, M., KLAPKA, P. (2012): Contribution to regional division of Slovakia based on the application of the Reilly's model. Hungarian geographical bulletin, 61(3): 237–255.

HALÁS, M., KLAPKA, P., BEDNÁŘ, M., TONEV, P. (2015): An alternative definition and use for the constraint function for rule-based methods of functional regionalisation. Environment and Planning A, 47(5): 1175–1191.

HALÁS, M., KLAPKA, P., BLEHA, B., BEDNÁŘ, M. (2014): Funkčné regióny na Slovensku podľa denných tokov do zamestnania. Geografický časopis, 66(2): 89–114.

HANSON, S., PRATT, G. (1992): Dynamic dependencies: a geographic investigation of local labor markets. Economic Geography, 68(4): 373–405.

HELDT CASSEL, S., MACUCHOVA, Z., RUDHOLM, N., RYDELL, A. (2013): Willingness to commute long distance among job seekers in Dalarna, Sweden. Journal of transport geography, 28: 49–55.

JOHNSTON, R. (2002): Manipulating maps and winning elections: measuring the impact of malapportionment and gerrymandering. Political Geography 21(1): 1–31.

KARLSSON, C., OLSSON, M. (2006): The identification of functional regions: theory, methods, and applications. The Annals of Regional Science, 40(1): 1–18.

KLAPKA, P., HALÁS, M., ERLEBACH, M., TONEV, P., BEDNÁŘ, M. (2014): A multistage agglomerative approach for defining functional regions of the Czech Republic: the use of 2001 commuting data. Moravian Geographical Reports, 22(4): 2–13.

KLAPKA, P., HALÁS, M., TONEV, P. (2013a): Functional regions: concept and types. In 16th International Colloquium on Regional Sciences, Conference Proceedings (pp. 94–101). Brno, Masaryk University.

KLAPKA, P., HALÁS, M., TONEV, P., BEDNÁŘ, M. (2013b): Functional regions of the Czech Republic: comparison of simple and advanced methods of regional taxonomy. Acta Universitatis Palackianae Olomucensis, Facultas Rerum Naturalium, Geographica, 44(1): 45–57.

MICHNIAK, D. (2003): Dostupnosť okresných miest na Slovensku. Geografický časopis, 55(1): 21–39.

MOORE, T. (2002): Comments on Ron Johnston's "Manipulating maps and winning elections: measuring the impact of malapportionment and gerrymandering". Political Geography, 21(1): 33–38.

NETRDOVÁ, P., NOSEK, V. (2009): Přístupy k měření významu geografického rozměru společenských nerovností. Geografie, 114(1): 52–65.

NOSEK, V., NETRDOVÁ, P. (2014): Measuring Spatial Aspects of Variability. Comparing Spatial Autocorrelation with Regional Decomposition in International Unemployment Research. Historical Social Research, 39(2): 292–314.

NOVOTNÝ, J., NOSEK, V. (2012): Comparison of regional inequality in unemployment among four Central European countries: an inferential approach. Letters in Spatial and Resource Sciences, 5(2): 95–101.

OPENSHAW, S. (1977): A Geographical Solution to Scale and Aggregation Problems in Region-Building, Partitioning and Spatial Modelling. Transactions of the Institute of British Geographers, New Series, 2(4): 459–472.

OPENSHAW, S. (1984): The Modifiable Areal Unit Problem. CATMOG 38. Norwich, GeoBooks.

OZKUL, B. D. (2014): Changing home-to-work travel in England and Wales. Regional Studies, Regional Science, 1(1): 32–39.

SHORROCKS, A. F., WAN, G. (2005): Spatial Decomposition of Inequality. Journal of Economic Geography, 5(2): 59–81.

SMART, M. W. (1974): Labour market areas: uses and definition. Progress in Planning, 2(4): 239–353.

SPURNÁ, P. (2008): Prostorová autokorelace – všudypřítomný jev při analýze prostorových dat? Sociologický časopis/ Czech Sociological Review, 44(4): 767–787.

SUCIU, M. (2002): Local government and decentralisation in Eastern Europe. Case study on Romania. Revista Romana de Geografie Politica, 4(1–2): 33–55.

TOBLER, W. (1970): A computer movie simulating urban growth in the Detroit region. Economic Geography, 46, Supplement: Proceedings. International Geographical Union, Commission on quantitative methods: 234–240.

TOBLER, W. (2004): On the first law of geography: a reply. Annals of the Association of American Geographers, 94(2): 304–310.

UNWIN, D. J. (1996): GIS, spatial analysis and spatial statistics. Progress in Human Geography, 20(4): 540–551.

VAN DER LAAN, L., SCHALKE, R. (2001): Reality versus policy: the delineation and testing of local Labour Market and Spatial Policy Areas. European Planning Studies, 9(2): 201–221.

YULE, G. U., KENDALL, M. G. (1950): An introduction to the theory of statistics. London, Griffin.

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