DE G DE GRUYTER OPEN
DOI: 10.1515/mgr-2014-0019

A MULTISTAGE AGGLOMERATIVE APPROACH FOR DEFINING FUNCTIONAL REGIONS OF THE CZECH REPUBLIC: THE USE OF 2001 COMMUTING DATA

Pavel KLAPKA, Marián HALÁS, Martin ERLEBACH, Petr TONEV, Marek BEDNÁŘ

Abstract

The issue of defining functional regions in the Czech Republic is presented in this paper, which contributes to both theoretical discussions (e.g. the modifiable areal unit problem) and practical applications (e.g. spatial administration, regional planning). A multistage agglomerative approach to functional regional taxonomy is applied, which has been used in Czech geographical research for the first time only recently. The regionalisation algorithm provided four optional solutions for this issue, based on the analysis of daily travel-to-work flows from the 2001 census. The resulting regions correspond to the micro-regional level and two additional tiers were identified at this level. The basic statistics for all variants are presented.

Shrnutí

Vícestupňový aglomerační přístup k vymezení funkčních regionů České republiky: využití údajů o dojížďce z roku 2001

Článek se zabývá problémem vymezení funkčních regionů na území České republiky a přispívá jak k teoretické diskusi (např. problém modifikovatelné územní jednotky) tak k praktickým aplikacím (např. prostorová správa, regionální plánování). Je aplikován vícestupňový aglomerační přístup k funkční regionální taxonomii, jenž byl v české geografii použit poprvé zcela nedávno. Regionalizační algoritmus poskytl čtyři variantní řešení založené na analýze denních toků do zaměstnání z censu z roku 2001. Výsledné regiony odpovídají mikroregionální úrovni a v rámci této úrovně byly identifikovány další dva stupně. Ke všem variantám jsou rovněž uvedeny základní statistiky.

Key words: *functional region, daily urban system, local labour market area, regional taxonomy, multistage agglomerative method, labour commuting, Czech Republic*

---

1. Introduction

The recognition of functional regions has a wide potential for development of both geographical theory and practice. One primary and underlying consideration rests in a belief that administrative or political divisions of territories often tend to ignore basic functional geographical logic, asking for some kind of organisational unity and functional similarity of a region, expressed for instance by labour commuting flows. As Baumann et al. (1996), Cörvers et al. (2009) and Mitchell and Watts (2010) point out, delineation of functional regions is a part of the modifiable areal unit problem – MAUP (as addressed for example by Openshaw, 1984, or Unwin, 1996). MAUP is an inseparable part of almost any spatial analysis in cases when arbitrary and modifiable objects (spatial units) are grouped into larger areas. There is the question of the aggregation or zoning problem (i.e. which way of aggregation is used in order to amalgamate functional regions out of basic spatial units), and the question of the scale problem (i.e. how many functional regions there should be).

Theoretical considerations are closely related to a practical point of view. Administrative or political divisions do not reflect the rapid changes in geographical reality; thus, they can manifest a considerable degree of inefficiency. Correctly-defined functional regions (i.e. those based on informed choice) can serve better as a geographical tool for normative use (a virtue acknowledged by Haggett, 1965, and by Dziewoński, 1967) than administrative regions. Correctly-defined functional regions can contribute not only to statistical and regional geography, but also to spatial planning, regional economics, or administration (most recently acknowledged by Coombes, 2010; Casado-Díaz, Coombes, 2011; and Farmer, Fotheringham, 2011). Based on travel-to-work flows, functional regions can be used for the assessment of regional disparities, labour market policy, allocation of investments, planning of transport infrastructure, etc. – actually everywhere where there is a need for some kind of spatial units with an internal geographical logic, in order to reduce possible spatial bias caused for instance by political decisions or by the modifiable areal unit problem.

This paper contributes to the issue of the definition of the regional system of the Czech Republic by the application of a sophisticated regionalisation algorithm using daily travel-to-work flow data. Thus, it touches upon both aspects briefly presented above. This report has the following objectives: first, it attempts to produce four variants of the regional system of the Czech Republic, based on the size of regions and on a predominant principle for their delineation (i.e. self-containment – see below); and, second, to provide basic information on the regions and their spatial differentiation for each variant, using the same dataset as for their delineation. The variants can serve several purposes – such as a framework for spatial analyses of various human geographical phenomena, or as a correction for the existing administrative divisions. A third objective is to apply an acknowledged method for defining functional regions, which was applied in Czech geographical research for the first time only recently (see Klapka et al., 2013b and Tonev, 2013), and presents several methodological refinements. Thus, it contributes to a wider discussion on the behaviour of applied regionalisation methods under different geographical conditions. As an outcome fourth aim, this paper offers an alternative to the existing regional divisions of the Czech Republic based on the same dataset. As these objectives are defined, it should be admitted that the paper concentrates intentionally on the presentation of results, rather than on the procedure itself although it will be detailed sufficiently.

The paper is organised as follows. The following section addresses the issue of a functional region and approaches used for its delineation. It also briefly comments upon recent developments in the Czech Republic in this field of research. The subsequent section describes methodological procedure to a necessary and sufficient extent. The next section presents results for all four variants of the Czech regional system. The concluding section discusses findings of the paper and highlights its contributions.

2. Functional regions

The concept of functional regions was introduced into human geography by Philbrick (1957); Nystuen and Dacey (1961); Haggett (1965); Dziewoński (1967); and Berry (1968). A functional region (Klapka et al., 2013a) is conceived as a general concept that has to prove only the condition of self-containment, which is considered its crucial defining and identifying characteristic. Its inner structure, inner spatial flows and interactions, need not necessarily show any regular patterns – on the contrary, they can be random in some cases. Nodal regions, functional urban regions, daily urban systems, local labour market areas or travel-to-work areas, are considered special instances of a general functional region, that need to meet some specific conditions regarding the character of the region-organising interaction, the presence of urban cores, etc. (for more information, including the schemes, see Klapka et al., 2013a). Functional regions are usually understood to be the areas organised by the horizontal functional relations (flows, interactions) that are maximised within a region and minimised across its boundaries, so that the principles of internal cohesiveness and external separation regarding spatial interactions are met (for example, see Smart, 1974; Karlsson, Olsson, 2006; Farmer, Fotheringham, 2011; Klapka et al., 2013a).

Travel-to-work flows, particularly those on a daily basis, are the interactions that are commonly used in order to delineate functional regions (e.g. Goodmanm, 1970; Smart, 1974; Coombes et al., 1979; Ball, 1980). Labour commuting is the most frequent and stable regular movement of the population with a daily periodicity, and the changes in employment patterns remain modest in scale, so the use of these flows remains relevant. Functional regions based on the daily travel-to-work flows are referred to as local labour market areas (LLMA) or travel-to-work areas (TTWA). Both concepts are virtually identical (Klapka et al., 2013a) and were introduced into geography during the 1970s and early 1980s (Goodman, 1970; Smart, 1974; Coombes et al., 1979; Ball, 1980; Coombes, Openshaw, 1982). In the case that the region-organising interactions (i.e. travel-to-work flows) are oriented at an urban core, the functional regions can be denoted as daily urban systems (DUS). Daily urban systems were discussed, for instance, by Berry (1973), Hall (1974), and Coombes et al. (1978).

Functional regions are identified by a set of approaches, procedures and methods that are subsumed under the concept of functional regional taxonomy (see, for instance, the pioneering works by Spence, Taylor, 1970; Masser, Brown, 1975). According to Coombes (2000), regional taxonomy is the part of spatial analysis that attempts to set boundaries for clusters of interrelated spatial zones and to distinguish them from other clusters using the analysis of travel-to-work flows. Laan and Schalke (2001) propose that there is no sole correct method for the delineation of functional regions and that different analyses of the same data can provide considerably different results.[1]

Based on the literature, methods of defining functional regions can generally be sorted into two groups: clustering methods and multistage methods (also rule-based methods). For each group further distinct cases can be identified. Functional regions can be defined by divisive or agglomerative approaches, then by hierarchical or non-hierarchical procedures, and finally by numerical or graph theory procedures. This classification of approaches to regional taxonomy is only one of several possibilities. Alternatives are provided for instance by Coombes (2000), Laan, Schalke (2001), Casado-Díaz and Coombes (2011) or Farmer, Fotheringham (2011).

From all possible combinations, the literature tends to favour three approaches to functional regional taxonomy: clustering methods, using either (i) numerical or (ii) graph theory procedures, and (iii) multistage procedures. A review of these methods of functional regional taxonomy is presented by Casado-Díaz and Coombes (2011). The clustering methods based on numerical taxonomy were used by Brown and Holmes (1971), Smart (1974), Masser and Brown (1975), Masser and Scheurwater (1978, 1980), and Baumann et al. (1983). They mostly used the general principles of cluster analysis. Clustering methods based on graph theory approaches were proposed by Nystuen and Dacey (1961), Slater (1976), Holmes and Haggett (1977), and recently addressed by Karlsson and Olsson (2006).

These clustering methods were criticised for being too heuristic (Ball, 1980; Coombes, Openshaw, 1982), although some of their principles appear again in the latest variant of the measures produced at the Centre for Urban and Regional Development Studies (CURDS), in Newcastle, U.K. (Coombes, Bond, 2008; Coombes, 2010), as a result of the simplification of the regionalisation algorithm. On the other hand, the clustering methods were favoured against the rule-based methods relatively recently by Cörvers et al. (2009), Krygsman et al. (2009), Drobne et al. (2010), and by Mitchell and Watts (2010). Landré and Håkansson (2013) compared the results of both approaches for the territory of Sweden.

The third, multistage or rule-based approach, which is used in this paper, was proposed by the research group at CURDS (Coombes et al., 1982; 1986; Coombes, Bond, 2008; Coombes, 2010), and became probably the most successful and acknowledged approach to the functional regional taxonomy

[1] This is acknowledged by this paper as well: therefore its proposals are presented as alternatives to the existing regional divisions, and it was corroborated using the case of the Czech Republic earlier by Klapka et al. (2013b).

of several territories. Apart from the above-mentioned works that concerned the U.K., this approach was applied in Italy (Sforzi [ed.], 1997), Slovakia (Bezák, 2000; Halás et al., 2014), Spain (Casado-Díaz, 2000; Flórez- Revuelta et al., 2008), New Zealand (Papps, Newell, 2002; Newell, Perry, 2005), Belgium (Persyn, Torfs, 2011), Poland (Gruchociak, 2012), and in the Czech Republic (Klapka et al., 2013b; Tonev, 2013). The principle used in these methods lies in the definition of a set of rules that are applied in several stages and determine the results of the analyses. The rules are often used iteratively in order to reach or approximate an optimal solution, i.e. to define as many regional classes as possible according to the rules.

As for the situation in the Czech Republic and using the 2001 census commuting data, the clustering methods using graph theory approaches have been predominantly applied to date. For example, the Czech Statistical Office (ČSÚ, 2004), Hampl (2005) and Sýkora and Mulíček (2009), identified potential regional cores using their size and function, and then assigned remaining spatial zones to the cores based on the so-called first flow. Halás et al. (2010) applied similar methods that differed in the choice of potential cores. In all cases, the results had to be refined manually in order to secure the contiguity and the size of resulting regions. Multistage methods have been applied in the Czech Republic by Klapka et al. (2013b) and Tonev (2013), though only as a testing of the second variant of the CURDS algorithm in the former case, and as a tool for the assessment of the development of commuting patterns in the latter case. This paper presents the results of the first deliberate attempt to define functional regions of the Czech Republic using the multistage agglomerative approach.

All the above-mentioned methods, regardless of type and class, use various interaction measures to express the relation between spatial zones based on the travel-to-work flows, and to define functional regions based on travel-to-work flows. The interaction measures are discussed by Casado-Izquierdo and Propín-Frejomil (2008). In this paper, two interaction measures are applied ([1] and [2], below). The first one was proposed but not used by Smart (1974), and until the present remains the most-used measure as it is the mathematically most correct way of relativisation and symmetrisation of statistical interaction data. It was used also by the second and third variant of the CURDS algorithm (Coombes et al., 1986; Coombes, Bond, 2008); its notation is as follows:

Smart's measure $$\left[\frac{T_{ij}^2}{\left(\sum_k T_{ik} * \sum_k T_{kj}\right)} + \frac{T_{ji}^2}{\left(\sum_k T_{jk} * \sum_k T_{ki}\right)}\right] \quad [1],$$

where T_{ij} denotes the flow from spatial zone i to spatial zone j, and T_{ji} from j to i, $\sum_k T_{ik}$ denotes all outgoing flows from i, $\sum_k T_{kj}$ denotes all ingoing flows to j, $\sum_k T_{jk}$ denotes all outgoing flows from j, and finally $\sum_k T_{ki}$ denotes all ingoing flows to i.

The second interaction measure was proposed by Coombes et al. (1982) in the first variant of the CURDS algorithm and its notation is as follows:

CURDS measure $$\left[\frac{T_{ij}}{\sum_k T_{ik}} + \frac{T_{ij}}{\sum_k T_{kj}} + \frac{T_{ji}}{\sum_k T_{jk}} + \frac{T_{ji}}{\sum_k T_{ki}}\right] \quad [2]$$

This expression will be referred to in this paper as the CURDS measure. The notation for both measures [1] and [2] is consistent.

Preliminary analyses of the interaction data and experimentation with the algorithm showed differences in the behaviour of the two interaction measures. Generally, Smart's measure tends to mitigate the regional influence of large centres and emphasises the regional influence of smaller centres. This measure slightly equalises the size of resulting regions and allows the formation of smaller regions in the hinterlands of large centres, which conforms to the principle of spatial equity (see Bezák, 1997 or Michniak, 2003) favouring the equal accessibility of the most distant parts of regions to their regional centres.

Coombes (2010) also claims that it conforms best to the rule that any procedure should identify as many regions as possible. On the contrary, the CURDS measure emphasises the influence of large centres at the expense of the centres in their hinterlands, which frequently are not able to form their own region. As a result, the principle of spatial efficiency (Bezák, 1997; Michniak, 2003) is acknowledged favouring the conformity between regional boundaries and intra-regional interactions, in fact the self-containment of a region, when the inter-regional interactions are minimised.

3. Procedure

The adjusted and simplified second variant of the CURDS algorithm (Coombes et al., 1986) is applied in this paper. It is a multistage, agglomerative, non-hierarchical and numerical procedure of functional regional taxonomy. This version of the second variant of the algorithm is favoured over the more recent one for several purposes. First, it allows some international comparability of the procedure and the results. Second, it might be found useful to identify a set of potential regional cores, a possibility that the newest variant does not provide. Knowing the cores is important for further analyses of the inner structure of the resulting regions. Third, parameters for the second variant can be set so that the variant actually behaves in the same way as the newest variant. The procedure is described in detail by Coombes et al. (1986: 948–952). Alterations in the value of the parameters and simplifications that were made in this paper are described in the following paragraphs.

The algorithm uses the commuting data, i.e. the daily travel-to-work flows of employed persons, from the 2001 census. The data are stored in the square matrix having 6,258 rows and columns, which is the number of municipalities (basic spatial zones) as of the 2001 census. The matrix is sparse (with a great portion of zero flows) and features inner flows along its diagonal. The original data had to be refined in some cases when there were errors caused by incorrect encoding and interpretation (this problem is discussed in detail by Tonev, 2013).

The algorithm is divided into three stages, which include four steps and several operations (see below):

a. identification of proto-regions:

1) identification of potential cores; and

2) identification of multiple cores by critical values of the interaction measure;

b. assignment of remaining spatial zones:

3) assignment of spatial zones to the proto-regions by interaction measure maximisation; and

c. assessment of the validity of the solution:

4) application of the constraint function and iterative dissolution of regions that do not meet the criteria set by the constraint function.

A basic spatial zone has to meet two conditions in order to qualify as a potential regional core, i.e. a job ratio function:

$$\frac{\sum_j T_{ji}}{\sum_j T_{ij}} > 0.8 \quad [3]$$

and supply-side (or residence-based) self-containment:

$$\frac{T_{ii}}{\sum_j T_{ij}} > 0.5 \quad [4]$$

In the case that the potential core j does not meet the condition of a sufficient self-containment, i.e.

$$\frac{T_{jj}}{\left(\sum_k T_{jk} + \sum_k T_{kj}\right) - T_{jj}} > 0.5 \quad [5]$$

potential groupings of the cores j are identified on the basis of mutual relations between them and the value of the interaction measure. The criterion of the value for the interaction measure was altered in comparison with the original algorithm to 0.01 in the case of Smart's measure, and to 0.2 in the case of the CURDS measure. Both values were estimated on the basis of extensive experimentation and reflect the character of the Czech settlement system. The resulting set of cores and multiple cores is considered as a set of the proto-regions.

In the next step, the remaining basic spatial zones i are sorted in descending order by the number of employed persons and assigned to the proto-region that is most strongly linked to each of them, according to the interaction measure. Once a basic spatial zone i is assigned to a proto-region j, all incident flows have to be recalculated and a new interaction matrix is formed. This step is repeated until there is no basic spatial zone i left.

The next step applies the constraint function that sets a minimum size and self-containment criteria for the resulting regions. The regions are sorted in descending order by the value of constraint function, and the lowest-ranked region that does not meet the condition of the constraint function is dissolved, its constituent basic spatial zones being assigned to another region according to Step 3. This operation is iteratively repeated until all regions meet the condition of the constraint function.

As demonstrated in the above paragraphs, the role of the constraint function is crucial for the resulting regional pattern The constraint function controls two parameters of the resulting regions and the so-called trade-off between them. Basically, it means that smaller regions have to reach a higher level of self-containment, and larger regions are allowed to manifest a lower level of self-containment. The size of regions is given by the number of employed persons. The constraint function employed in this paper has the form of a continuous curve (Fig. 1), and its shape is determined by four parameters that can be easily set by the user: the upper and lower size limits and the upper and lower self-containment limits.

The constraint function still has one important implication for this paper. It is used to estimate the parameters for the size and the self-containment of the regions. The analyses were commenced by setting the lower limits of self-containment and size to $\beta_1 = 0.6$ and $\beta_3 = 2{,}500$ in order to acquire an initial regional pattern. As the experiments showed, these limits, together with $\beta_2 = 0.65$ and $\beta_4 = 15{,}000$ as the upper limits, were sufficient enough to identify virtually all possible and basic functional regions in the Czech Republic. Two initial regional patterns were gained, one based on the application of Smart's measure, and the other based on the application of the CURDS measure.

The position of each region can be plotted on an x-y graph as a point according to the values of its size and self-containment. The regions appear in the upper right sector of the graph from the curve of the constraint function (see Fig. 1). A graphical assessment of the results can help to identify the course and position of the constraint function on the graph. If there is a considerable gap in the field of points, this is the area of the discontinuity of size and self-containment parameters, or more precisely, the trade-off of these parameters and the insertion of the constraint function into the gap is able to provide new estimates for the values of the four size and self-containment parameters.[2]

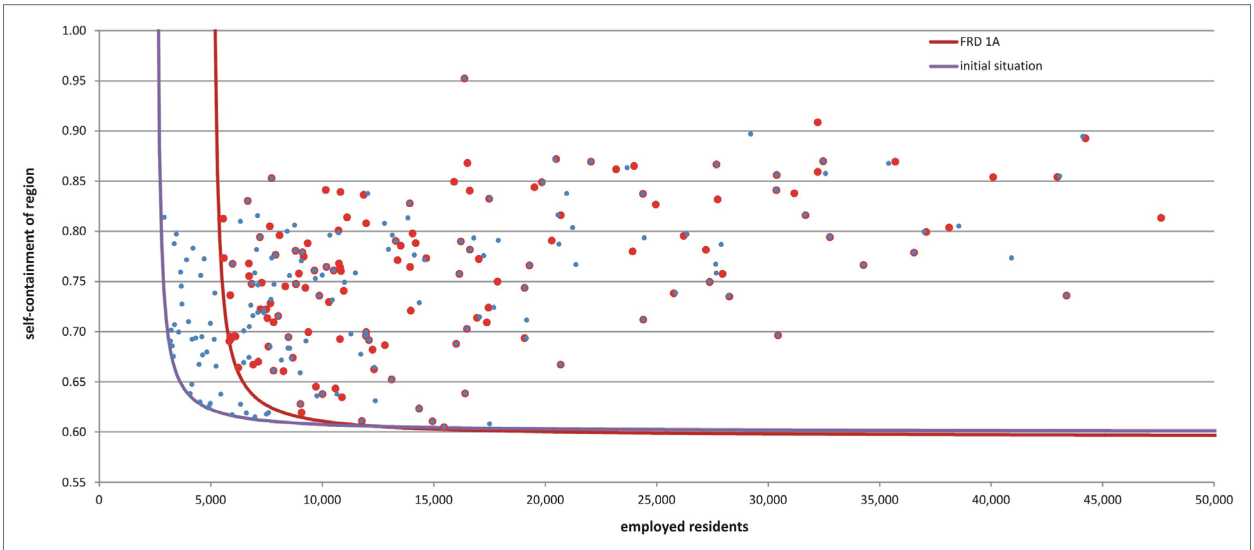

Fig. 1: An example of the use for the constraint function. Source: authors´ elaboration

[2] It should be noted that an infinite number of curves could in fact be inserted into the gap and that the presented solution is therefore not strictly objective.

The principle of the estimate is documented in Fig. 1 that presents a case of gap identification in the initial situation based on the CURDS measure, the insertion of a new constraint function with new parameters, and the plotting of new results on the graph. This operation was repeated four times in the following manner: (1) curve shift for the initial situation based on the CURDS measure (see Fig. 1 again), (2) curve shift for Variant 1, (3) curve shift for the initial situation based on Smart's measure, and (4) curve shift for Variant 3. This gradual identification of gaps in the respective point patterns produced four variants of the regional system of the Czech Republic (see the next section: where appropriate, they are denoted as "FRD" standing for functional regions based on daily interactions).

4. Results and discussion

This procedure has provided four variants of the Czech regional system at two tiers, determined by the number and size of the regions. These two tiers, however, still represent a micro-regional hierarchical level as far as population size, area and number of regions is concerned. Each tier comprises two variant solutions depending on the interaction measure employed in the algorithm, either the CURDS measure or Smart's measure. Thus there is a regional system FRD 1A (the first tier, CURDS measure), a regional system FRD 1B (the first tier, Smart's measure), a regional system FRD 2A (the second tier, CURDS measure), and a regional system FRD 2B (the second tier, Smart's measure). Basic statistics for all four variants of the Czech regional system are presented in Table 1. Beta values for all four regional systems were estimated by the procedures with the constraint function mentioned above. The total self-containment of the regional system was calculated by using the formula:

$$\frac{\sum_j T_{jj}}{\sum_j \sum_k T_{jk}} \quad [6]$$

Figures 2, 3, 4 and 5 provide spatial patterns for all four regional systems respectively and the levels of the self-containment for the resulting regions. First, a note on the contiguity of regions should be made. The algorithm provides contiguous regions without the need for further adjustments with several insignificant exceptions. Only in one case is there a naturally (i.e. by the spatial pattern of interaction data) conditioned exclave: Jesenice, that belongs to the Rakovník region in the western part of central Bohemia. This discontinuity occurs in regional systems FRD 1A, FRD 1B and FRD 2A. Any remaining discontinuities that were identified are caused by the existence of geographically disjunct basic spatial units (municipalities) and as such were not taken into account.

The FRD 1A regional system consists of 160 regions (Fig. 2) and provides the most fragmented regional pattern out of all proposed variants. This can be particularly witnessed in the belt extending from northwest Bohemia to northwest Moravia, i.e. in the traditionally industrial half of present-day Czech Republic. The variations in size (total population, economically active population) and area are the greatest. As for the self-containment of the regions, the highest values are scored either for the regions of the largest centres (Prague, Brno, Pilsen), then for the border regions (Znojmo, Jeseník, Cheb, Aš), and finally for some regions in agglomerations or conurbations (Liberec, Jablonec nad Nisou, Ústí nad Labem, Děčín). Contrariwise, lower values of self-containment are scored for regions in the wider hinterland of the largest centres (e.g. Kralupy nad

Attribute for regional system	FRD 1A	FRD 1B	FRD 2A	FRD 2B
β_1 value	0.595	0.64	0.60	0.63
β_2 value	0.65	0.72	0.70	0.75
β_3 value	5,000	4,500	10,000	6,000
β_4 value	21,000	10,000	50,000	70,000
Self-containment of regional system	0.900	0.901	0.917	0.915
Number of regions	160	149	104	98
Self-containment (mean)	0.766	0.781	0.816	0.828
Self-containment (median)	0.767	0.779	0.820	0.835
Self-containment (variation coefficient)	0.097	0.082	0.081	0.064
Economically active population (mean)	32,833.75	35,257.72	50,513.46	53,606.12
Economically active population (median)	16,528.50	20,046.00	30,865.50	37,351.00
Economically active population (variation coefficient)	2.112	1.895	1.722	1.450
Population (mean)	63,937.88	68,658.12	98,365.96	104,388.40
Population (median)	32,452.50	39,407.00	61,303.00	75,130.50
Population (variation coefficient)	2.037	1.821	1.659	1.391
Area km^2 (mean)	493.22	529.62	758.79	805.24
Area km^2 (median)	393.78	466.48	633.45	736.86
Area km^2 (variation coefficient)	0.759	0.539	0.695	0.468

Tab. 1: Attributes for variants of the Czech regional system. Source: authors´ computation
Note: The value of the β_1 parameter for FRD 1A (0.595) is lower than the value of the β_1 parameter for the initial situation (0.6). It is caused by the operations related with the insertion of the constraint function curve, and it does not affect the results in any way since no region in the regional system FRD 1A has lower self-containment than 0.6.

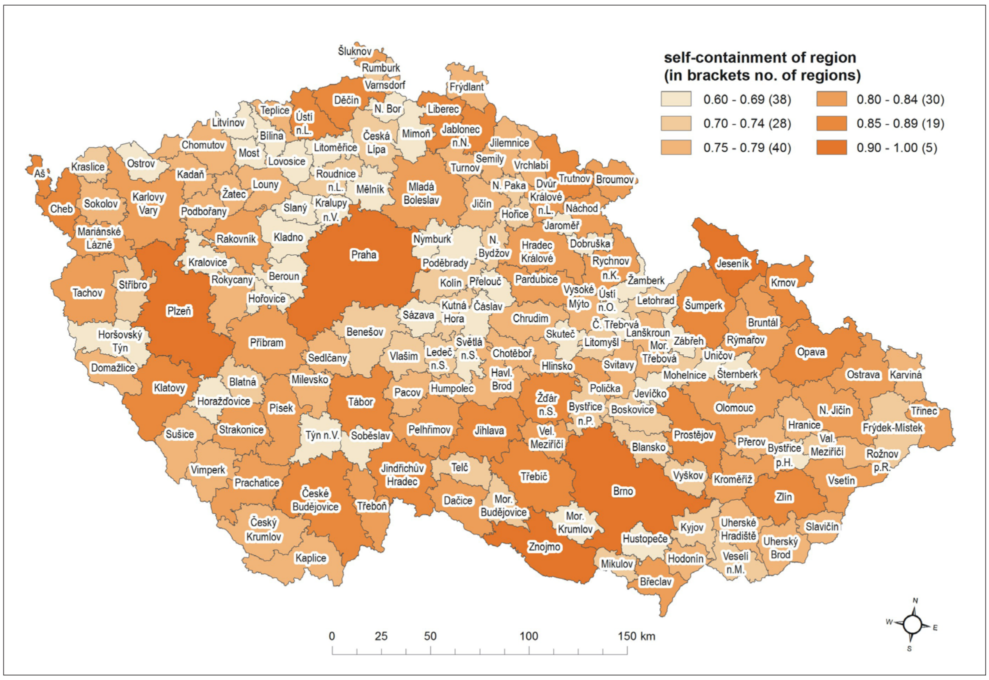

Fig. 2: FRD 1A Regional system. Source: authors' elaboration

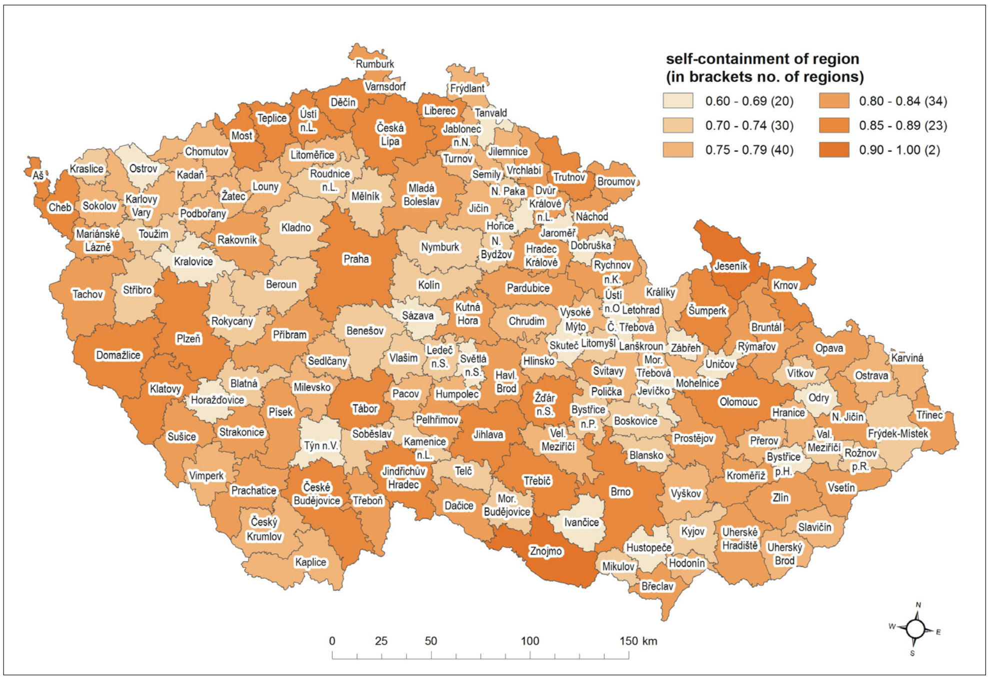

Fig. 3: FRD 1B Regional system. Source: authors' elaboration

Vltavou, Slaný, Kralovice, Moravský Krumlov, Hustopeče), for regions of smaller centres in conurbations (e.g. Litvínov, Bílina) or in the vicinity of meso-regional centres (e.g. Týn nad Vltavou, Přelouč, Šternberk), and for regions in areas with a relatively even distribution of similar smaller centres (typically eastern Bohemia and north western Moravia).

The FRD 1B regional system presents the same tier as FRD 1A and consists of 149 regions (Fig. 3). The regional pattern is more consolidated in the hinterlands of the largest centres and in agglomerations and conurbations. The spatial influence of the largest centres is mitigated as well. Fragmented patterns remain in eastern Bohemia and north-western Moravia, however. The variations in size and area become smaller in comparison to the statistics for FRD 1A. The same holds true for the self-containment of the regions. It remains highest in the border regions (again Jeseník, Aš, Cheb, Znojmo, newly for instance in Trutnov, Domažlice, Klatovy), and it has become higher in some agglomerations and conurbations due to the consolidation of regional patterns (e.g. in the belt reaching from Most to Liberec in northern Bohemia). On the contrary, the self-containment was lowered for the regions of the largest centres (Prague, Brno, Pilsen) and remains low for regions in the wider hinterland of the largest centres (Ivančice, Hustopeče, Sázava, Kralovice, Horažďovice).

The FRD 2A regional system at the second tier consists of 104 regions (Fig. 4). Its most notable feature is that the spatial influence of the largest centres is very extensive (Prague, Brno, Pilsen). The lower number of regions provides a more consolidated regional pattern even for north-eastern

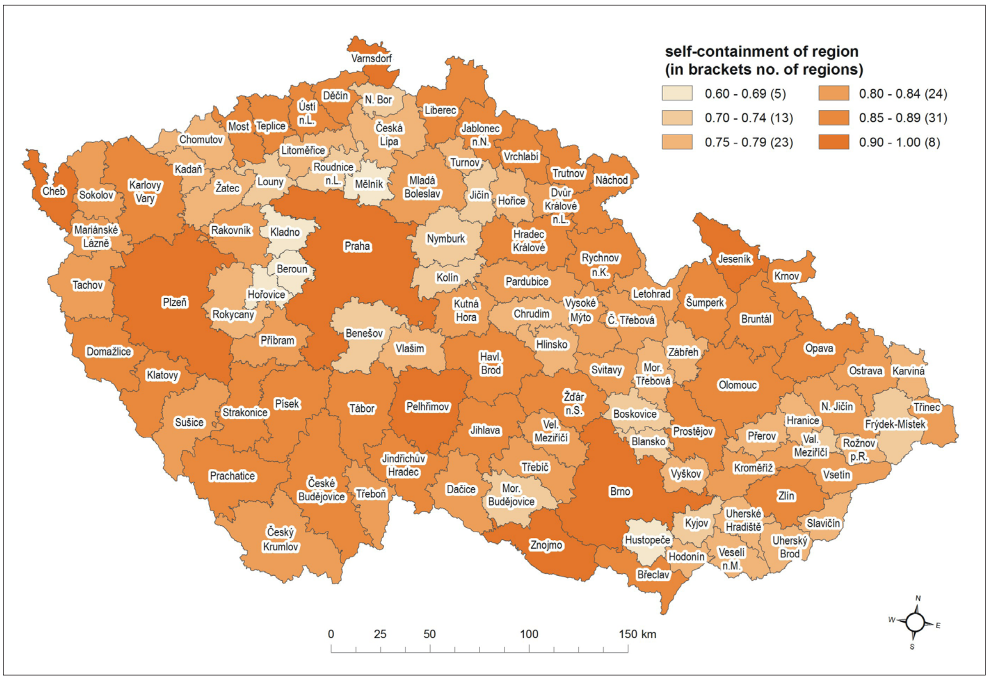

Fig. 4: FRD 2A Regional system. Source: authors' elaboration

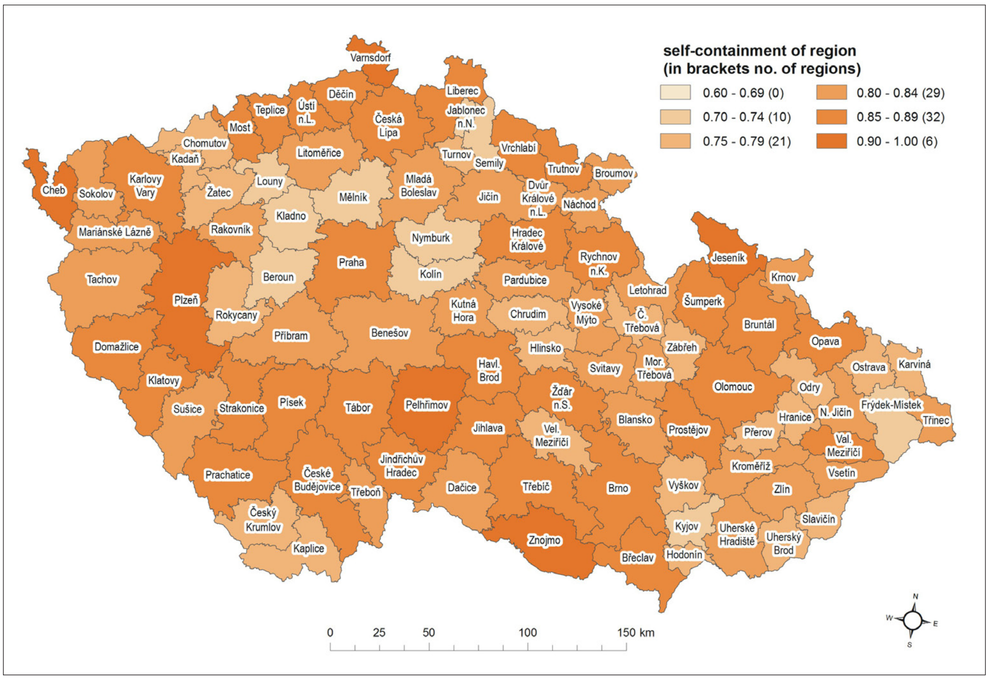

Fig. 5: FRD 2B Regional system. Source: authors' elaboration

and eastern Bohemia in this solution. Variations in size are relatively high but the variation coefficient for area is higher than for FRD 1B. The highest values for the self-containment of regions are reached in the regions of the largest centres (Prague, Brno, Pilsen), in the border regions (Jeseník, Znojmo, Cheb, Varnsdorf), in some agglomerations and conurbations (northern Bohemia), and for the first time in consolidated areas (the belt extending from Liberec to Rychnov nad Kněžnou, northwest Moravia, or the region of Pelhřimov). Lower values of self-containment are concentrated in the vicinity of the largest centres.

The FRD 2B regional system presents the same tier as FRD 2A and consists of 98 regions (Fig. 5). The regional pattern is most consolidated out of all four variants, as is shown by the variation coefficients for size and area. The pattern regarding self-containment values remained virtually the same as for FRD 2A, with minor differences in cases when the regional boundaries were reconfigured in comparison to FRD 2A (e.g. Jablonec nad Nisou and Semily).

Since the definition of regions is based on the daily-travel-to-work flows, the same data can be used for further characteristics of the regions by calculations of three indexes. The first index is expressed by the formula:

$$\frac{\sum_k T_{kj}}{\sum_k T_{jk}} \qquad [7]$$

and is called the job ratio. It is a ratio of jobs and employed persons. If the index value is higher than 1 it denotes that the region offers more jobs than is the number of its employed population. The results for all four variants of the regional system of the Czech Republic are shown in Fig. 6. The beige-red shades denote the in-commuting regions, basically organised around economic centres of the Czech Republic at both micro- and meso-regional levels. The blue shades denote the out-commuting regions that lack the job opportunities to various degrees. The influence of modifiable boundaries can be seen quite clearly, but the general pattern is easily identifiable.

The second index is expressed by the formula:

$$\frac{T_{jj}}{\sum_k T_{jk}} \qquad [8]$$

and it is a measure of the supply-side (or residence-based) self-containment expressing the proportion of employed persons working locally. The results for all four variants of the regional system of the Czech Republic are shown in Fig. 7. This index correlates significantly with the self-containment of the regions as presented in Figures 2, 3, 4 and 5, and regional patterns have the same underlying logic and interpretation as stated above.

The third index is expressed by the formula:

$$\frac{T_{jj}}{\sum_k T_{kj}} \qquad [9]$$

and it is a measure of the demand-side (or workplace-based) self-containment expressing the proportion of jobs filled by the residents. The results for all four variants of the regional system of the Czech Republic are shown in Fig. 8. Darker shades denote regions where most jobs are filled by local residents. These are basically located along the state border or in the promontories of the state territory, then in the areas that are economically less developed and the settlement system has a lower number of micro-regional centres (generally the southern part of the Czech Republic), and also in the spatially large regions of important economic centres (especially in FRD 2A).

5. Conclusions

The application of advanced methods for functional regional taxonomy as presented in this paper warrants several conclusions. First, regional patterns provided by four runs of the regionalisation algorithm do not require any significant and extensive manual and often subjective refinements and amendments, in comparison to simpler regionalisation methods. The regions are contiguous and their self-containment is ensured in order to qualify them as functional regions according to the definition stated in Section 2.

Second, the application of these methods is able to produce numerous viable and objectively unbiased solutions to the regionalisation problem, that reflect the purpose, objectives and demands for various research tasks. Moreover, only one dataset (daily travel-to-work flows) is used for all computations and under the defined rules for the regionalisation process. The only purely subjective input lies virtually in the estimation of beta parameters. Thus, the method shows a great degree of flexibility. For instance, the procedure used in this paper has provided four variants of the regional system of the Czech Republic at a micro-regional level, and two tiers of regional patterns have been identified at this level, which means there is an option of choice inherent in the method and its results.

Third, two interaction measures have been used in the regionalisation algorithm (the CURDS measure and Smart's measure) and they have provided variant solutions for each tier of the regional patterns. The solutions provided by the

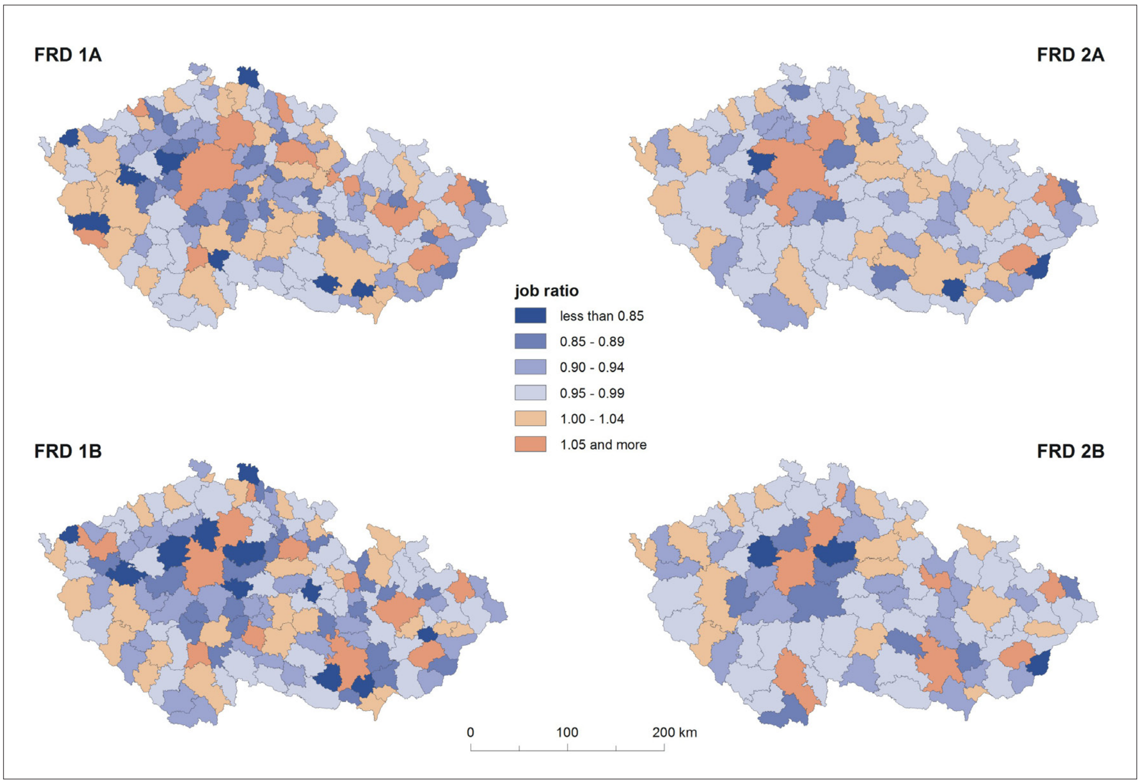

Fig. 6: Job ratio for variants of the regional system. Source: authors' elaboration
Note: For identification of regions, see Figs. 2, 3, 4 and 5

application of the CURDS measure show a greater degree of variation within the regional system and "natural" spatial relationships are recognised, for instance in the extent of hinterlands of the largest centres (Praha, Brno, Plzeň), and the principle of spatial efficiency is favoured. These regional patterns can be preferably denoted as daily urban systems or functional urban regions (based on daily interactions).

On the contrary, the solutions provided by the application of Smart's measure show a lower degree of variation within the regional system, and thus supports what can be referred to as a spatial equity principle. This principle is more advantageous also for administrative, statistical and planning purposes, and Smart's measure remains actually the sole measure usually used in this research issue. The

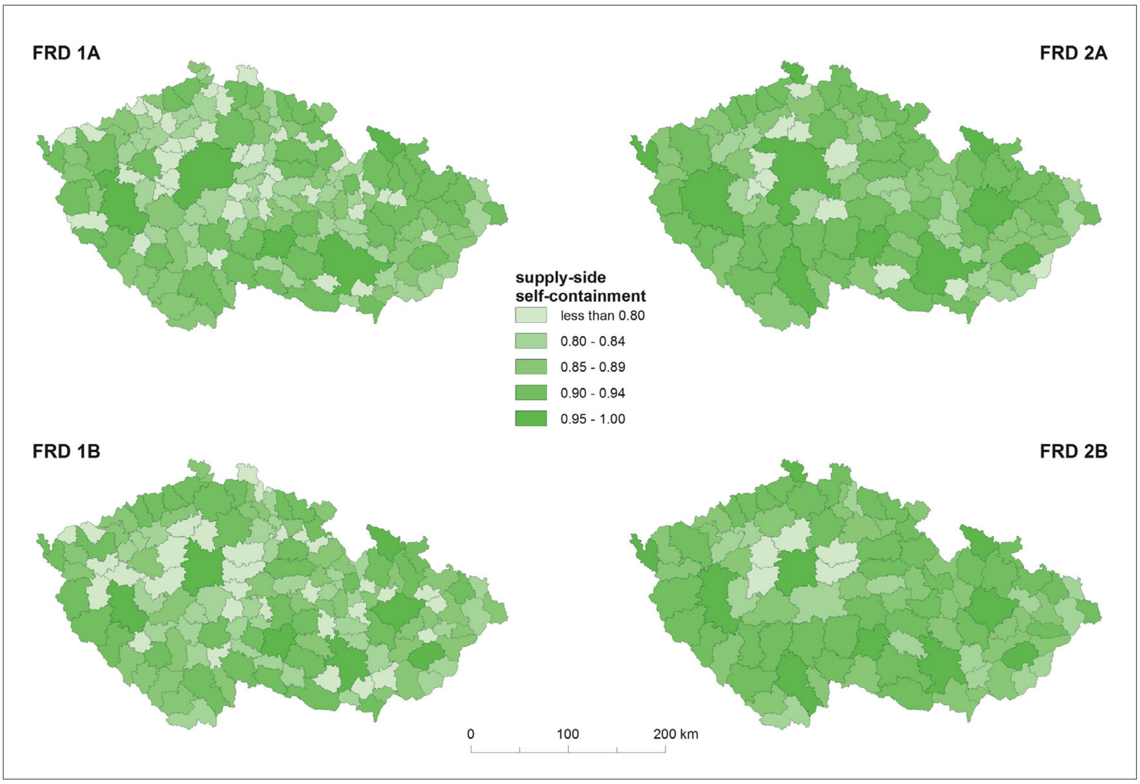

Fig. 7: Supply-side self-containment for variants of the regional system. Source: authors' elaboration
Note: For identification of regions, see Figs. 2, 3, 4 and 5

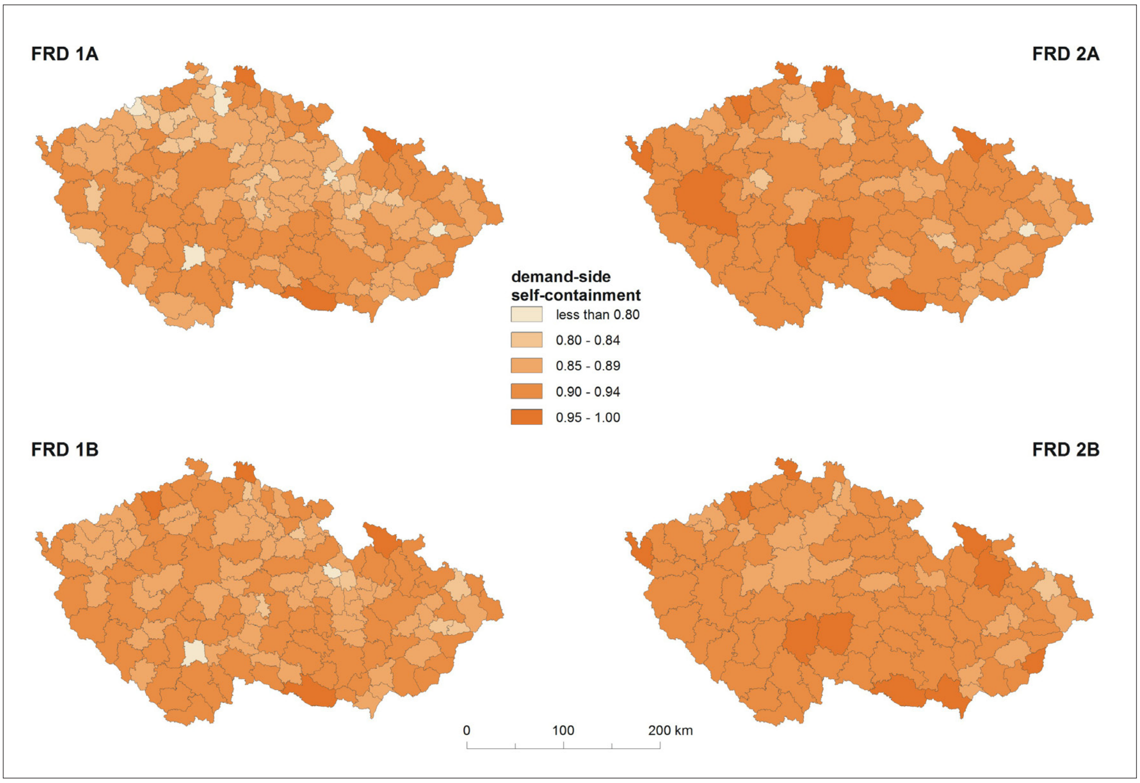

Fig. 8: Demand-side self-containment for variants of the regional system. Source: authors' elaboration
Note: For identification of regions, see Figs. 2, 3, 4 and 5

solutions for regional patterns provided by its application can be denoted as local (or regional) labour market areas or travel-to-work areas, and they are referred to as such in the literature.

As a consequence of the effective mathematical relativisation of the interaction flows, Smart's measure produces smaller regions for large centres and larger regions for small centres. This result, however, is responsible for the possibility of reaching lower total self-containment counts for the regional system. Clearly, this is evidenced in comparing the regional systems FRD 2A and FRD 2B, when the former consists of more regions, which should generally imply a lower total self-containment, but the configuration of regions actually provides a higher total self-containment. This finding lies in the fact that Smart's measure can assign basic spatial units having strong absolute links to a large centre (e.g. Praha) to another region, and this means there are more flows across regional boundaries.

Acknowledgement

This paper has been supported by the project of the Internal Grant Agency of Palacký University, Olomouc: "Human behaviour and activities in geographical environment: analysis and modelling of the organisation of space" (IGA_PrF_2014012). The authors are grateful for this support.

References:

BALL, R. M. (1980): The use and definition of travel-to-work areas in Great Britain: some problems. Regional Studies Vol. 14, No. 2, p. 125–139.

BAUMANN, J. H., FISCHER, M. M., SCHUBERT, U. (1983): A multiregional labour supply model for Austria: the effects of different regionalisations in multiregional labour market modelling. Papers in Regional Science, Vol. 52, No. 1, p. 53–83.

BERRY, B. J. L. (1968): A synthesis of formal and functional regions using a general field theory of spatial behaviour. In: Berry, B. J. L, Marble, D. F. [eds.]: Spatial Analysis. Prentice-Hall, Englewood Cliffs, p. 419–428.

BERRY, B. J. L. (1973): Growth Centers in the American Urban System: Community development and regional growth in the sixties and seventies. Balinger Publishing Company, Cambridge (Mass.), 197 pp.

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

BEZÁK, A. (2000): Funkčné mestské regióny na Slovensku. Geographia Slovaca, Vol. 15, Geografický ústav SAV, Bratislava, 89 pp.

BROWN, L. A., HOLMES, J. (1971): The delimitation of functional regions, nodal regions, and hierarchies by functional distance approaches. Journal of Regional Science, Vol. 11, No. 1, p. 57–72.

CASADO-DÍAZ, J. M. (2000): Local labour market areas in Spain: a case study. Regional Studies, Vol. 34, No. 9, p. 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 Españoles, Vol. 57, p. 7–32.

CASADO-IZQUIERDO, J. M., PROPIN-FREJOMIL, E. (2008): Praxis internacional en el estudio de mercados laborales locales. Investigaciones Geográficas, Boletín del Instituto de Geografía, Vol. 65, p. 118–137.

COOMBES, M. (2000): Defining locality boundaries with synthetic data. Environment and Planning A, Vol. 32, No. 8, p. 1499–1518.

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., Duke-Williams, O., Dennett, A. [eds.]: Technologies for migration and commuting analysis: spatial interaction data applications. IGI Global, Hershey, p. 227–241.

COOMBES, M. G., BOND, S. (2008): Travel-to-Work Areas: the 2007 review. Office for National Statistics, London. 57 pp.

COOMBES, M. G., DIXON, J. S., GODDARD, J. B., OPENSHAW, S., TAYLOR, P. J. (1979): Daily urban systems in Britain: from theory to practice. Environment and Planning A, Vol. 11, No. 5, p. 565–574.

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, John Wiley and Sons Ltd., Chichester, p. 63– 112.

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, Vol. 37, No. 10, p. 943–953.

COOMBES, M. G., OPENSHAW, S. (1982): The use and definition of travel-to-work areas in Great Britain: some comments. Regional Studies, Vol. 16, No. 2, p. 141–149.

COOMBES, M. G., DIXON, J. S., GODDARD, J. B., OPENSHAW, S., TAYLOR, P. J. (1978): Towards a more rational consideration of census areal units: daily urban systems in Britain. Environment and Planning A, Vol. 10, No. 10, p. 1179–1185.

CÖRVERS, F., HENSEN, M., BONGAERTS, D. (2009): Delimitation and coherence of functional and administrative regions. Regional Studies, Vol. 43, No. 1, p. 19–31.

ČSÚ (2004): Dojížďka za prací a do škol v Jihomoravském kraji (na základě výsledků Sčítání lidu, domů a bytů 2001). Český statistický úřad, Krajská reprezentace Brno, Brno. 220 pp.

DROBNE, S., KONJAR, M., LISEC, A. (2010): Razmejitev funkcionalnih regij Slovenije na podlagi analize trga dela. Geodetski vestnik, Vol. 54, No. 3, p. 481–500.

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

FARMER, C. J. Q., FOTHERINGHAM, A. S. (2011): Network-based functional regions. Environment and Planning A, Vol. 43, No. 11, p. 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,Vol. 5, No. 1, p. 10–21.

GOODMAN, J. F. B. (1970): The definition and analysis of local labour markets: some empirici problems. British Journal of Industrial Relations, Vol. 8, No. 2, p. 179–196.

GRUCHOCIAK, H. (2012): Delimitacja lokalnych rynków pracy v Polsce. Przegląd statystyczny. Numer specjalny, No. 2, p. 277–297.

HAGGETT, P. (1965): Locational Analysis in Human Geography. Arnold, London, 337 pp.

HALÁS, M., KLADIVO, P., ŠIMÁČEK, P., MINTÁLOVÁ, T. (2010): Delimitation of micro-regions in the Czech Republic by nodal relations. Moravian Geographical Reports Vol. 18, No. 2, p. 16–22.

HALÁS, M., KLAPKA, P., BLEHA, B., BEDNÁŘ, M. (2014): Funkčné regióny na Slovensku podľa denných tokov do zamestnania. Geografický časopis, Vol. 66, No. 2, p. 89–114.

HALL, P. (1974): The containment of urban England. Geographical Journal, Vol. 140, No. 3, p. 386–408.

HAMPL, M. (2005): Geografická organizace společnosti v České republice: transformační procesy a jejich obecný kontext. Univerzita Karlova, Praha, 147 pp.

HOLMES, J. H., HAGGETT, P. (1977): Graph theory interpretation of flow matrices: a note on maximization procedures for identifying significant links. Geographical Analysis, Vol. 9, No. 4, p. 388–399.

KARLSSON, C., OLSSON, M. (2006): The identification of functional regions: theory, methods, and applications. The Annals of Regional Science, Vol. 40, No. 1, p. 1–18.

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

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, Vol. 44, No. 1, p. 45–57.

KRYGSMAN, S., DE JONG, T., NEL, J. (2009): Functional transport regions in South Africa: an examination of national commuter data. In Proceedings of the 28th Southern African Tranport Conference, p. 144–154.

LAAN, L. VAN DER, SCHALKE, R. (2001): Reality versus Policy: The Delineation and Testing of Local Labour Market and Spatial Policy Areas. European Planning Studies Vol. 9, No. 2, p. 201–221.

LANDRÉ, M., HÅKANSSON, J. (2013): Rule versus interaction function: evaluating regional aggregations of commuting flows in Sweden. European Journal of Transport and Infrastructure Research, Vol. 13, No. 1, p. 1–19.

MASSER, I., BROWN, P. J. B. (1975): Hierarchical aggregation procedures for interaction data. Environment and Planning A, Vol. 7, No. 5, p. 509–523.

MASSER, I., SCHEURWATER J. (1978): The specification of multi-level systems for spatial analysis. In: Masser, I., Brown, P. J. B. [eds.]: Spatial representation and spatial interaction. Studies in Applied Regional Science, Vol. 10, p. 151–172.

MASSER, I., SCHEURWATER J. (1980): Functional regionalisation of spatial interaction data: an evaluation of some suggested strategies. Environment and Planning A, Vol. 12, No. 12, p. 1357–1382.

MICHNIAK, D. (2003): Dostupnosť okresných miest na Slovensku. Geografický časopis, Vol. 55, No. 1, p. 21–39.

MITCHELL, W. F., WATTS, M. J. (2010). Identifying functional regions in Australia using hierarchical aggregate techniques. Geographical Research, Vol. 48, No. 1, p. 24–41.

NEWELL, J. O., PERRY, M. (2005): Explaining continuity in New Zealand's local labour market areas 1991 to 2001. Australasian Journal of Regional Studies Vol. 11, No. 2, p. 155–174.

NYSTUEN, J. D., DACEY, M. F. (1961): A graph theory interpretation of nodal regions. Regional Science Association, Papers and Proceedings, Vol. 7, No. 1, p. 29–42.

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

PAPPS, K. L., NEWELL, J. O. (2002): Identifying functional labour market areas in New Zealand: a reconnaissance study using travel-to-work data. Discussion Paper 443. Institute for the Study of Labor, Bonn, 34 pp.

PERSYN, D., TORFS, W. (2011): Functional labour markets in Belgium: evolution over time and intersectoral comparison. In: Discussion Paper 17. Vlaams Instituut voor Economie en Samenleving. Leuven, Katholieke Universiteit, p. 1–17.

PHILBRICK, A. K. (1957): Principles of areal functional organization in regional human geography. Economic Geography, Vol. 33, No. 4, p. 299–336.

SFORZI, F. [ed.] (1997): I sistemi locali del lavoro. 1991. Istat, Roma, 393 pp.

SLATER, P. B. (1976): A hierarchical regionalization of Japanese prefectures using 1972 interprefectural migration flows. Regional Studies, Vol. 10, No. 1, p. 123–32.

SMART, M. W. (1974): Labour market areas: uses and definition. Progress in Planning, Vol. 2, No. 4, p. 239–353.

SPENCE, N. A., TAYLOR, P. J. (1970): Quantitative methods in regional taxonomy. Progress in Geography, Vol. 2, p. 1–64.

SÝKORA, L., MULÍČEK, O. (2009): The micro-regional nature of functional urban areas (FUAs): lessons from the analysis of Czech urban and regional system. Urban Research and Practice, Vol. 2, No. 3, p. 287–307.

TONEV, P. (2013): Změny v dojížďce za prací v období transformace: komparace lokálních trhů práce. Ms. (dissertation thesis, Department of Geography, Masaryk University), 122 pp.

UNWIN, D. J. (1996): GIS, spatial analysis and spatial statistics. Progress in Human Geography, Vol. 20, No. 4, p. 540–551.

Authors´ addresses:

Mgr. Pavel KLAPKA, Ph.D., e-mail: *pavel.klapka@upol.cz*
Assoc. Prof. RNDr. Marián HALÁS, Ph.D., e-mail: *marian.halas@upol.cz*
Department of Geography, Faculty of Science, Palacký University Olomouc
17. listopadu 12, 771 46 Olomouc, Czech Republic

Mgr. Martin ERLEBACH
Department of Geography, Faculty of Science, Masaryk University
Kotlářská 2, 611 37 Brno, Czech Republic
e-mail: *martin.erlebach@seznam.cz*

Mgr. Petr TONEV, Ph.D.
Dept. of Regional Economics and Administration, Faculty of Economics and Administration, Masaryk University
Lipová 41a, 602 00 Brno, Czech Republic
e-mail: *tonev@econ.muni.cz*

Ing. Marek BEDNÁŘ
Department of Ecology and Environmental Sciences, Faculty of Science, Palacký University Olomouc
Třída Svobody 26, 771 46 Olomouc, Czech Republic
e-mail: *marek.bednar@upol.cz*

Initial submission 15 April 2014, **final acceptance** 20 October 2014

Please cite this article as:

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, Vol. 22, No. 4, p. 2–13. DOI: 10.1515/mgr-2014-0019.