EVALUATING FUNCTIONAL REGIONS

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Abstract

In the paper, we suggest an approach to evaluate the number and composition of functional regions. Suggested approach is based on basic characteristics of functional regions, that are (1) more intensive intra-regional than the inter-regional interactions and (2) internal social and economic heterogeneity. Those characteristics are measured by factors estimated in spatial interaction model. The approach to evaluate functional regions was applied to Slovenia for three time periods.

Key words: *region, functional region, spatial interaction model, number of functional regions, decision-making*

1. INTRODUCTION

Traditionally regions have been described and differentiated with respect to broad classes of variables (Noronha and Goodchild, 1992). The structural taxonomy of regions differentiates between formal, functional, nodal, and equitable regions. The *formal* region has been defined as the largest area over which a generalization remains valid. In their concept, formal regions are internally homogeneous. Formal regionalization is achieved by clustering spatial units at lower level (e.g. communities, municipalities, postal zones) so as to minimize between group variance on one or more variables. In contrast, *functional regions* (FRs) are internally social and economic heterogeneous that causes mutual complementarity and independence. In the quantitative literature, *the functional region has often been defined as that aggregation of elementary spatial units (ESU) at lower level which maximizes the ratio of intra-regional (within-region) to inter-regional (between-region) interaction*. The third structural class, the *nodal* region, is defined by cores and regional dominance in networks. And, the *equitable* regions are the regions that contain approximately equal populations and number of administrative spatial units at lower levels, like census tracts and/or electoral districts.

The basic presumption of this paper is that the functional regions can be evaluated by propensity to travel between the regions and by measure of heterogeneity of significant social and economic factors in the region. We suggest an approach to evaluate FRs by basic concepts of modelling spatial interactions. For modelling FRs, we chose the Intramax method (Masser and Brown, 1975, 1977; Masser and Scheurwater, 1980) that calculated FRs by hierarchical clustering, and, for analysing the interactions, we chose the Spatial Interaction Model (SIM) approach (Cesario, 1973, 1974). The remainder of this paper is organised as follows: the concepts of functional regions and functional regionalisation procedures are presented in section 2, followed by the short presentation of the concepts of spatial interaction models in section 3. In section 4, the approach to evaluate FRs is presented. Section 5 focuses on empirical results by applying the approach to the study in Slovenia. The final conclusions are in the section 6.

2. FUNCTIONAL REGIONS

A functional region is a territorial area characterised by high frequency of intra-regional economic interaction, such as intra-regional trade in goods and services, labour commuting, and household shopping (Karlsson and Olsson, 2006). In the literature, a number of regionalisation procedures have been suggested (e.g., Masser and Brown, 1975, 1977; Slater, 1976, 1981; Coombes et al., 1986; Florez-Revuelta et al., 2008; Farmer and Fotheringham, 2011). Farmer and Fotheringham (2011) have identified three general classes of functional regionalisation procedures: (a) hierarchical clustering (in e.g. (Brown and Holmes, 1971; Masser and Brown, 1975, 1977; Masser and Schuerwater , 1980; Slater, 1976, 1981)), (b) multistage aggregation (in e.g. (Coombes et all, 1986; Laan and Schalke, 2001; Konjar et al, 2010)), and (c) central place aggregation (in e.g. (Drobne et al, 2010)). The aim of these regionalisation procedures is to determine as many FRs as possible, subject to certain statistical constraints which ensure that the regions remain statistically and operationally valid (Farmer, 2009).

A problem with many functional regionalisation procedures is that they cannot be used directly for selecting the number of functional regions, k. Farmer (2009) made a review of approaches to determine the number of FRs: (a) some procedures require the value of k to be specified a priori (e.g. Brown and Holmes, 1971; Masser and Scheurwater, 1980; Cörvers et al., 2009), (b) others determine k through the use of ad hoc assessments of the data, where the subjective assessments of the configuration of FRs are often based on authors' perceptions of local environments and specific application contexts to determine the optimal number of FRs, and (c) the network based methods that are designed to find the community structure of a network (e.g. Farmer, 2009; Farmer and Fotheringham, 2011). But, we believe that k is locally optimal where marginal costs of organizing central activities in additional region are lower than the difference in the aggregate benefits to commuters, measured by coefficients in the gravity model.

3. SPATIAL INTERACTION MODEL

The concepts of the Spatial Interaction Model (SIM) have been introduced by Cesario in 1973 by the "generalized trip distribution model" (Cesario, 1973). However, SIM has been provoked by the criticism of many applications of the gravity model in the social science. Gravity Model (GM) (Zipf, 1946) is a direct analogy of Newton's law of gravitation. It states that interaction between two points i and j is proportional to the product of their populations and a function of the distance between them:

$$I_{ij} = K\, P_i\, P_j\, d_{ij}^{-b} \tag{1}$$

where I_{ij} is the interaction between i and j, K is a constant of proportionality, P_i is the population of i, P_j is the population of j, d_{ij} is the distance between i and j, and b is the constant friction of distance. In 1950s and 1960s, there were lot applications of GM in quantitative geography and other disciplines to derive universal calibration constant b in (1). It was concluded that gravity model was "no more than a physical analogy based on questionable empirical fit in the absence of a valid null hypothesis" (Noronha and Goodchild, 1992, 90). Cesario (1973, 1974) answered to the criticism for use of the GM outside of the physics with the generalized SIM:

$$I_{ij} = E_i\, A_j\, f(d_{ij})\,, \tag{2}$$

where Newtonian mass terms have been specified as emissivity of the origin, E_i, and attraction of the destination, A_j. Emissivity is assumed to measure the propensity of the origin i to generate interaction. Similarly attraction measures the propensity of the destination to attract a flow. In many applications, emissivity is strongly dependent on population, but it may depend also on other factors such as income, level of employment, price of real estate etc. Similarly attraction may depend, besides population in destination, on socio and economic factors. Model (2) expresses interaction as the product of all influences specific to the origin and the destination and a function of the intervening distance (Noronha and Goodchild, 1992). Haynes and Fortheringham (1984) and Fortheringham and O'Kelly (1989) have reviewed different works on spatial interaction models.

4. METHODOLOGY

The Intramax method has been chosen to model functional regions. When functional regions were modelled, they were evaluated in SIM by (a) propensity to travel between functional regions – considering the same definitions for emissivity and attraction as Intramax method; and by (b) factors that significantly influence analysed interactions.

The Intramax method belongs to the methods of hierarchical clustering. Such methods include Markov chain analysis techniques of Brown and Holmes (1971), as well as the strategy of Masser and Brown (1975, 1977) and Masser and Schuerwater (1980), which is based on refinements to Ward's (1963) hierarchical aggregation procedures (Farmer, 2011).

The Intramax method, which was introduced by Masser and Brown (1975) and improved in (Masser and Brown, 1977; Masser and Schuerwater, 1980), carries out a regionalization of an interaction matrix. The objective of the Intramax procedure is to maximise the proportion within the group interaction at each stage of the grouping process, while taking account of the variations in the row and column totals of the matrix. In the grouping process, two ESUs, in our case municipalities, are grouped together for which the objective function I is maximised (Masser and Brown, 1975):

$$\max I, \quad I = \frac{I_{ij}}{O_i \cdot D_j} + \frac{I_{ji}}{O_j \cdot D_i}, \tag{3}$$

where I_{ij} is the interaction between i and j, I_{ji} is the interaction between j and i, $O_i = \sum_j I_{ij}$ is the total of interactions originating from origin i, $D_j = \sum_i I_{ij}$ is the total of interactions coming to destination j, $O_j = \sum_i I_{ji}$ is the total of interactions originating from origin j, $D_i = \sum_j I_{ji}$ is the total of interactions coming to destination i, and $O_i, O_j, D_i, D_j > 0$.

The Intramax analysis is a stepwise analysis. In each step two spatial units (SU) are grouped together and the interaction between them becomes the internal interaction for the new resulting SU. This new SU takes the place of the two parent SU at the next step of the analyses. So with N ESUs after $N-1$ steps all ESUs are grouped together into one SU (region) and all interactions become internal.

In our application, the Flowmap software (Breukelman et al., 2009), with implemented Intramax method, was used to delineate FRs of the analysed territory. Analysed territory were divided into $k_{\max}$

sets of FRs, where $k_{\max}$ is maximal number of FRs, in each analysed time interval Y. The sets of FRs were analysed in each analysed time interval and between them to discover stable sets of FRs.

Following two basic characteristics of functional regions, (C1) more intensive intra-regional than the inter-regional interactions, and (C2) internal (social and economic) heterogeneity, we evaluated sets of pre-modelled FRs. Evaluation of the sets of functional regions was based on the results of modelling interactions in SIM.

The first characteristic of functional regions (C1) was analysed by the *propensity to travel between functional regions*. Following the concept of the Intramax method which delineate FRs by relative interactions $\frac{I_{ij}}{O_i\ D_j}$, then SIM model (2) can be modified to (4). In (4) we limit interactions I_{ij} to only inter-regional interactions:

$$\frac{I_{ij}}{O_i\ D_j} = a\ d(\mathrm{t})_{ij}^{\beta} \quad \text{for } i \in FR_g,\ j \in FR_h \text{ and } FR_g \cap FR_h = \varnothing, \tag{4}$$

where FR_g is the set of municipalities in the FR of origin g, FR_h denotes the set of municipalities in the FR of destination h. In (4), $d(t)_{ij}$ is time-spending distance between municipality of origin i and municipality of destination j, a is a constant of proportionality, and β is (direct) measure of *propensity to travel between functional regions*. Parameters a and β were estimated in the regression analysis. Taylor (1975) called model (4) as “bivariate gravity model”. The bivariate gravity model has the advantage of being easily presented graphically by plotting the relative interaction $\frac{I_{ij}}{O_i\ D_j}$ against distance on double-log graph and with the model illustrated by means of a straight line through the data points. With the model in this form (4) the distance decay (or propensity to travel) is directly represented as the gradient or slope of the line. Thus comparisons can be easily illustrated for different types of interaction or for different time interval (as it was the case in our application).

The second characteristic (C2), that is *internal social and economic heterogeneity in the functional regions*, was analysed by factors s that significantly influenced analysed interactions in the analysed time interval Y. To discover those factors general SIM (2) was modified to

$$I_{ij} = a^{*} P_i^{\alpha_1} P_j^{\alpha_2} d(t)_{ij}^{\beta^{*}} \prod_{s \in S'} C_{s,i}^{\kappa_s} C_{s,j}^{\lambda_s}. \tag{5}$$

In model (5), I_{ij} denotes analysed interactions in each analysed time interval Y, a^* is a constant of proportionality, P_i is the population of origin i, P_j is the population of destination j, C denotes the ratio of analysed factors s (ratio between the factor in the municipality and factor for the state), so s denotes the set of analysed socio and economic factors in the elementary spatial units respectively for the state. α_1 and κ_s are measures of *emissivity* (in some applications also called measures of *stickiness*), while α_2 and λ_s are measures of *attractiveness*, β^* is a measure of *propensity to travel* (in some applications also called measure of *accessibility*). Note, that β^* is biased by the other analysed parameters in multiple-SIM (5) and it is estimated for the whole set of interactions, i.e. inter- and intra-regional interactions, but in (4), we estimated unbiased propensity to travel between FRs β. Parameters $a^*, \alpha_1, \alpha_2, \beta^*, \kappa_s, \lambda_s$ were estimated in the regression analysis. Statistically significant estimates κ_s, λ_s of analysed factors were included as combined weights into the evaluation procedure evaluating the heterogeneity in FRs.

Weights for s were calculated as average of absolute values of significant estimates κ_s, λ_s; if estimate wasn't significant, the estimated value was replaced by 0:

$$w_s = \frac{1}{2}(|\kappa_s| + |\lambda_s|) . \tag{6}$$

The heterogeneity in FRs was analysed separately for each set of FRs by sum of weighted average variances of factors s in FRs that significantly influenced interactions I_{ij}

$$\sum_s w_s \bar{\sigma}_s^2 , \tag{7}$$

where $\bar{\sigma}_s^2$ was average variance of factor s of municipalities in FR, and w_s was weight of factor s calculated by (6).

The sets of FRs were evaluated (separately for each analysed time interval Y) by two indicators of functional regions (IFR): the propensity to travel between functional regions (C1) was analysed by

$$IFR_1 = |\beta| , \tag{8}$$

that is the absolute value of the regression coefficient β in (4), and the average heterogeneity in FR (C2) was analysed by

$$IFR_2 = \sum_s w_s \bar{\sigma}_s^2 , \tag{9}$$

that is the sum of weighted average variances of factors s in FR (6). IFR_1 and IFR_2 were normalized for the whole continuous interval of the analysed sets of FRs in the analysed year Y to the interval $0,1$.

$IFR_1^{(n)}$ and $IFR_2^{(n)}$ can be combined by simple weighting the influence of both indicators:

$$f = u \cdot IFR_1^{(n)} + (u-1) \cdot IFR_2^{(n)} \text{ for } k = 2,3,...,k_{\max} . \tag{10}$$

In (10) we are searching for local maximums; but, in the global optimisation the value f should be compared with the costs of establishing additional regional unit: from k to $k+1$.

5. APPLICATION FOR SLOVENIA

The proposed approach to evaluate functional regions was applied to the whole territory of the Republic of Slovenia. For that reason FRs were modelled for each analysed time interval of one year $Y:(2000, 2005, 2010)$ by using the Intramax algorithm implemented in the FlowMap software. Sets of 2 to 30 and 50 to 70 FRs in the country were chosen arbitrarily: on the interval of 2 to 30 FRs 2 cohesion regions at NUTS 2 level and to 12 statistical regions at NUTS 3 level in Slovenia could be optimised, but on the interval between 50 and 70 FRs 58 administrative units in Slovenia could be better regionalised. And, we chose three years arbitrarily: $Y = 2010$ as a reference year for the economic crisis, $Y = 2005$ as a reference year for the economic conjuncture, and $Y = 2000$ as a control year.

FRs were modelled and analysed by data on labour commuting between municipalities in Slovenia (SORS, 2011a). Using data on state roads (SRA, 2011), we developed network models in geographical information system, which were the basis for calculation of optimal (the shortest) time-spending distances travelling by car between the municipal centres of Slovenia. Three origin-destination matrices for three time intervals were calculated considering conditions on state roads (construction of new highways per year, toll stations on highways). The emissivity and the attractiveness of municipalities and the propensity to travel for labour commuters were analysed in SIM. Parameters had been already evaluated in ESPON-ATTREG (The Attractiveness of European regions and cities for residents and visitors) project’s case study of Slovenia (Drobne and Bogataj, 2011). They were population in the municipality, travel time by car between municipalities’ centres, employment rate in the municipality, average gross earnings per capita in the municipality, and average price per m^2 of flats in the municipality (SORS, 2012b; TAO, 2008; SMAS, 2011). Economic coefficients that were applied in model (5) had been calculated as follows:

$$C_{EMP,i} = \frac{EMP_i / WFP_i}{EMP_{SI} / WFP_{SI}} \quad \text{for } i = 1, 2, ..., n, \tag{11}$$

$$C_{GEAR,i} = \frac{GEAR_i}{GEAR_{SI}} \quad \text{for } i = 1, 2, ..., n, \tag{12}$$

$$C_{APF,i} = \frac{APF_i}{APF_{SI}} \quad \text{for } i = 1, 2, ..., n, \tag{13}$$

where EMP_i was the number of employed persons in the *i*-th municipality, EMP_{SI} was the number of employed persons in Slovenia, WFP_i was the number of workforce population in the *i*-th municipality, WFP_{SI} was the number of workforce population in Slovenia, $GEAR_i$ was the average gross earnings in the *i*-th municipality, $GEAR_{SI}$ was the average gross earning in Slovenia, APF_i was the average price per m^2 of flat in the *i*-th municipality, and APF_{SI} was the average price per m^2 of flat in Slovenia.

When FRs were modelled, the interactions were marked as inter- or intra-regional. The propensity to travel between FRs, $IFR_1 = |\beta|$, for 50 sets of FRs in each analysed year were analysed in SIM model (4). The average inter-regional propensity to travel has increased from -1.35 in 2000 to -1.32 in 2005, and it has decreased again to -1.34 in 2010.

Emissivity ($\alpha_1, \kappa_{EMP}, \kappa_{GEAR}, \kappa_{APF}$), attraction ($\alpha_2, \lambda_{EMP}, \lambda_{GEAR}, \lambda_{APF}$) and biased propensity to travel (β^*) have been estimated in the regression analysis of the model (5). Table 1 shows the results of the analysis; note that insignificant estimates are in parentheses.

For each set of FRs, the average variance of the analysed economic factor s in the region was calculated. Those average variances were multiplied by weights derived from SIM model (5) to calculate second indicators of functional regions, $IFR_2 = \sum_s w_s \bar{\sigma}_s^2$. Weights for each factor s were calculated as average of absolute values of significant estimates of κ_s, λ_s (insignificant estimate was replaced by 0) and normalized to be included in the evaluation procedure of FRs; results of normalized weights of economic factors are in Table 2.

Table 1: Results of the regression analysis of the inter-municipal SIM (5) for Slovenia in 2000, 2005 and 2010 (insignificant estimates are in parentheses)

Parameter	Symbol of reg. coeff. in (5)	2000			2005			2010		
		Coeff.	St. Err.	P-value	Coeff.	St. Err.	P-value	Coeff.	St. Err.	P-value
constant	a	0,147	0,209	0,000	0,150	0,188	0,000	0,102	0,355	0,000
P_i	α_1	0,471	0,015	0,000	0,498	0,014	0,000	0,465	0,026	0,000
P_j	α_2	0,613	0,015	0,000	0,610	0,013	0,000	0,676	0,023	0,000
$d(t)_{ij}$	β^*	-1,675	0,017	0,000	-1,693	0,016	0,000	-1,703	0,028	0,000
$C_{EMP,i}$	κ_{EMP}	-0,484	0,061	0,000	-0,437	0,058	0,000	-0,329	0,127	0,010
$C_{EMP,j}$	λ_{EMP}	1,076	0,077	0,000	1,311	0,076	0,000	1,143	0,145	0,000
$C_{GEAR,i}$	κ_{GEAR}	(-0,006)	0,087	0,947	(0,047)	0,100	0,640	-0,391	0,182	0,031
$C_{GEAR,j}$	λ_{GEAR}	0,711	0,088	0,000	1,200	0,099	0,000	0,639	0,182	0,000
$C_{APF,i}$	κ_{APF}	-0,254	0,044	0,000	-0,427	0,035	0,000	-0,318	0,050	0,000
$C_{APF,j}$	λ_{APF}	0,270	0,043	0,000	0,173	0,033	0,000	0,134	0,053	0,012

Table 2: Normalized weights of economic factors

Parameter	Normalized weight of economic factor			Change of	
	2000	2005	2010	2005-2000	2010-2005
C_{EMP}	0.5580	0.4930	0.4982	-7%	1%
C_{GEAR}	0.2540	0.3380	0.3486	8%	1%
C_{APF}	0.1880	0.1690	0.1532	-1%	-2%

From Table 2, it follows that the most important economic factor influencing the labour commuting flows was the coefficient of employment. But, its relative importance was declined for 6% in ten years. The average gross earnings gained the most in the analysed period: it increased for 9%. The relative importance of the average price per m^2 of flat was the lowest all the time, and it decreased for 3% in the analysed period. However, comparing the years before and after crisis (2010-2005), we can realized that the relative importance of the employment and of the average gross earnings were increased a bit, but the prices of the real estate become less important in the last five years.

Both indicators of FRs were studied individually and in combined. Because of the shortage of the space in this paper, only the results for the equally weighted combination is presented for 2-30 FRs in 2010; see Figure 1. In the case that u=0.5 in (10), there were two very stable sets of FRs for 2010, namely regionalization into four and nine functional regions. Regionalization into four FRs is much more stable than regionalization into three or five regions, and regionalization into nine FRs is much more stable than regionalization into eight or ten regions in the country. On the other side, if we consider only the propensity to travel, it is evident that regionalization into eight FRs is the least stable, if we evaluate regionalization into seven to nine regions; and, if we consider 13 to 15 regions, regionalization into 14 FR is more stable. Figure 2 shows the sets of nine and four FRs in Slovenia in

2010 that have been calculated as ones of the most stable sets of FRs determined by equally weighted basic characteristics of functional region.

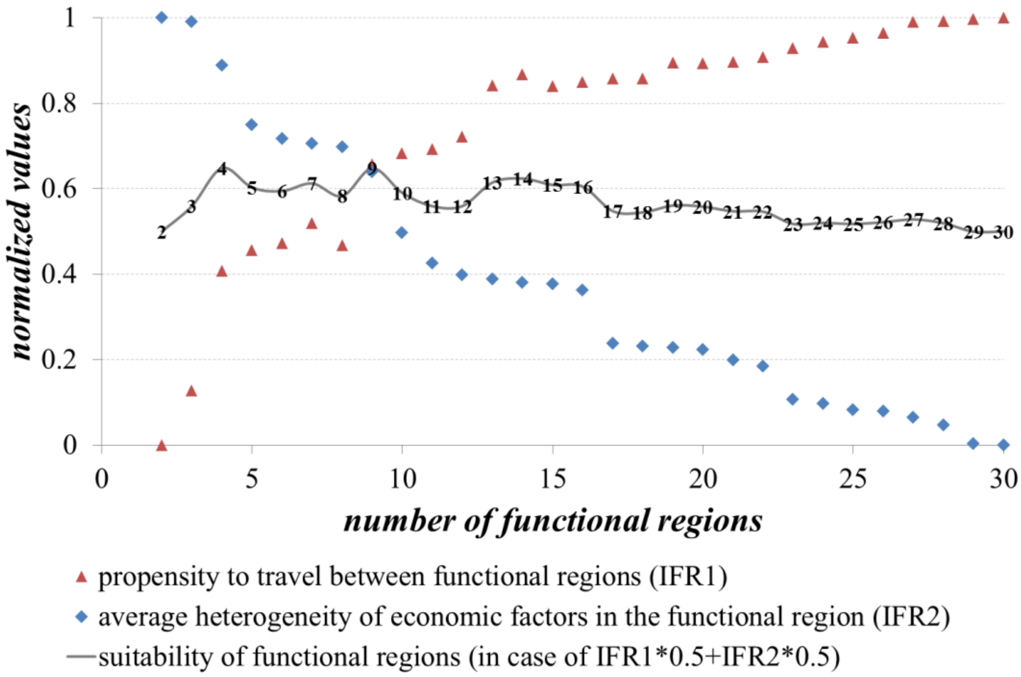

Figure 1: Suitability of functional regions (more stable regions are in local maximums) modelled by Intramax method and equally weighted criteria in Slovenia in 2010.

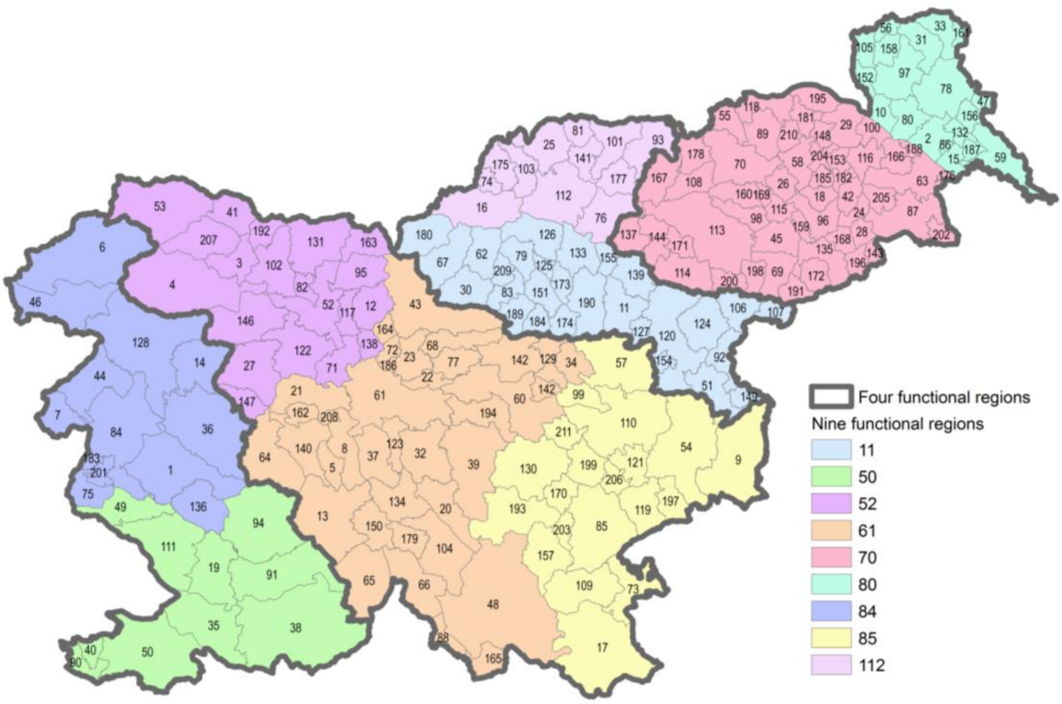

Figure 2: Four and nine functional regions in Slovenia in 2010 calculated by Intramax method.

6. CONCLUSIONS

In many countries, it is the case that the standard administrative regions used by governments for policy making, resource allocation, and research do not provide meaningful information on actual connectivity of a particular place or region (Ball, 1980; Casado-Diaz, 2000; Laan and Schalke, 2001; Andersen, 2002; Karlsson and Olsson, 2006). As such, there has been a move towards the identification and delineation of functional regions. Consequently, the identification and delineation of functional regions are commonly based on the conditions of the local labour markets, LLMs, (Smart, 1974; Coombes et al., 1986; Casado-Diaz, 2000; OECD, 2002; Karlsson and Olsson, 2006; Cörvers et al., 2009; Farmer, 2009). But, the local labour markets can be changed by economic perturbations like the nowadays' economic crises is.

In this paper, we suggest an approach to evaluate the number and composition of stable sets of functional regions. Suggested approach is based on basic characteristics of functional regions (more intensive within than between regional interactions and internal social and economic heterogeneity).

Discovering the stable sets of functional regions enable us not only to control better their dynamics but also to analyse the investments needed for support required changes in spatial interactions. Evaluation of functional regions can be applied also to administrative regions to check their "functionality" or suitability to fit the real spatial interactions (Drobne et al., 2009).

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