APPLICATION OF SELECTED WEIGHTING METHODS AND TOPSIS METHOD IN REGIONAL DISPARITIES ANALYSIS

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Abstract

The paper deals with a multicriteria analysis of regional disparities in the context of European cohesion. The elimination of the economic, social and territorial disparities among European regions is the primary objective of the European Union (EU). Thanks to EU Cohesion Policy, the regional disparities decreased over the past decade, however a wide gap has still remained between the less developed and the highly developed regions. In terms of the evaluation of regional disparities there is no uniform methodological approach to determination of weights of regional indicators and regional disparities assessment. The multicriteria decision making (MCDM) methods can be considered as a suitable and useful tool. The main aim of the paper is to outline the different weighting methods within MCMD method and compare the effects of their application in the regional disparities analysis namely on case study. The selected weighting methods are used to derive the weights of the regional indicators. The TOPSIS method is employed to rank the NUTS 2 regions in the selected EU countries according to their socio-economic development in the context of EU cohesion. An empirical study demonstrated a feasibility of the weighting and MCDM methods in quantitative evaluation of the regional disparities.

Key words: CRITIC, entropy, evaluation, TOPSIS, regional disparities

JEL Code: C02, O18, R11

Introduction

The paper aims to outline the different weighting methods within MCMD method and compare the effects of their application in the regional disparities analysis namely on a case study. The evaluation of regional disparities in Visegrad Four countries (V4; the Czech Republic, Hungary, Poland and Slovakia) in the context of EU cohesion in the year 2012 has been selected for the case study. The evaluation of disparities in the regional development in countries of the EU is actual and important topic of many discussions and regional research studies at the European and national level. However, the attitude of researchers towards the quantitative evaluation of regional disparities is not uniformed. Several disparities indicators are processed by different mathematical and statistical methods, e.g. Campo, Monteiro and Soares (2008), Ginevičius, Podvezko and Mikelis (2004), Melecký and Staníčková (2011), Minarčíková (2015). The assessment of regional development includes not only a problem of selection of evaluation criteria and method of their processing but also a big question of criteria weights. The regional indicators can have different representativeness during regional trends development. There is no uniform methodological approach to determination of weights of the regional indicators. Some researchers favour equal weights of regional indicators, others use the various approaches to weight determination, see e.g. Ginevičius and Podvezko (2005), Melecký (2015).

An alternative approach with wide potential of using in regional analysis represents the MCDM methods. The MCDM methods have been successfully applied to the areas of business and management, transportation, product design, water management, see e.g. Tzeng and Huang (2011), Kashi and Franek (2014). High flexibility of this concept enables its further extension such as into regional economic research. The MCDM methods enable an expert to rank the regions according to their level of economic, social and territorial development, compare the results in given time period and describe changes and trends in regional differences. Decision making process involves a series of step: identifying the problems, constructing the weights of criteria, evaluating the alternatives and determining the best alternatives (Tzeng and Huang, 2011). The determination of weights of evaluation criteria by suitable weighting method is one important step in most of MCDM models (e.g. TOPSIS, VIKOR). The weighting methods can be classified as subjective, objective and combination methods, see e.g. Ginevičius and Podvezko (2005), Zou, Yun and Sun (2006), Zardari, Ahmed, Shirazi and Yusob (2015), Zmeškal and Dluhošová (2015). In objective weighting methods, weights are obtained by mathematical methods and decision makers have no role in determining the relative importance of criteria. Common objective methods are e.g. Entropy, CRITIC, literature review, standard deviation or statistical variance procedure (Zardari, Ahmed, Shirazi and Yusob, p. 23-24; Ginevičius and Podvezko, 2005). In the use of subjective weighting methods, the process of assigning importance to criteria depends on the preferences of decision-makers, to these methods belong e.g. direct rating, ranking method, point allocation, pairwise comparison (used within method of AHP), swing method, Delphi method (Zardari, Ahmed, Shirazi and Yusob, p. 23-25).

1 Methodology and data description

This section discusses the theoretical background of the weighting and MCDM methods and describes data base. In this paper, Entropy and CRITIC is used to derive the objective weights of the regional indicators. Subsequently, TOPSIS method ranks the NUTS 2 regions according to their socio-economic development in the year 2012.

1.1 Entropy method

In information theory, entropy is a general measure of the uncertainty. It is represented by a discreet probability distribution, in which broad distribution represents more uncertainty. When the difference of the value among the evaluating objects on the same indicator is high, while the entropy is small, it illustrates that this indicators provides more useful information, and the relative weight of this indicator would be higher and vice versa (Zou, Yun and Sun, 2006). The procedure of entropy includes the following steps. *The first step* of entropy is to get the normalized decision matrix $R = (r_{ij})_{m \times n}$, where r_{ij} is the data of the i-th evaluating object on the indicator, and $r_{ij} \in [0,1]$. If there are benefit indicators then r_{ij} is calculated as (Zou, Yun and Sun, 2006):

$$r_{ij} = \frac{x_{ij} - \min_i \{x_{ij}\}}{\max_i \{x_{ij}\} - \min_i \{x_{ij}\}}, \text{ if there are cost indicators then } r_{ij} = \frac{\max_i \{x_{ij}\} - x_{ij}}{\max_i \{x_{ij}\} - \min_i \{x_{ij}\}}, \qquad (1), (2)$$

The second step is to calculate entropy value H_j. In the n indicators, m evaluating objects evaluation problem, the entropy of j-th indicator is defined as:

$$H_j = -k \sum_{i=1}^{m} f_{ij} \ln f_{ij}, \; j = 1,2,\ldots,n, \qquad (3)$$

in which $f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}, \; k = \frac{1}{\ln m}$, and suppose when $f_{ij} = 0, \; f_{ij} \ln f_{ij} = 0,$ (4)

The third step is to determine the weight of entropy of j-th indicator as:

$$w_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j}, \qquad 0 \le w_j \le 1, \sum_{j=1}^{n} w_j = 1. \qquad (5)$$

1.2 CRITIC method

CRITIC (The Criteria Importance Through Intercriteria Correlation) has been proposed by Diakoulaki, Mavrotas and Papayannakis (1995) and uses correlation analysis to detect contrasts between criteria. First vector x_j of the normalized matrix is generated where x_j denotes the scores of all n alternatives. Each vector x_j is characterized by the standard deviation σ_j, which quantifies the contrast intensity of the corresponding criterion. The standard deviation of x_j is a measure of the value of that criterion to be considered in the decision-making process. Next, a symmetric matrix is constructed, with dimensions $m \times m$ and a generic element r_{jk}, which is the linear correlation coefficient between the vectors x_j and x_k. The more discordant the scores of the alternatives in criteria j and k are, the lower is the value r_{jk}. In this sense, the sum shown in formula (6) represents a measure of the conflict created by criterion j with respect to the decision situation defined by the rest of criteria (Diakoulaki, Mavrotas and Papayannakis, 1995, p. 765):

$$\sum_{k=1}^{m}\left(1-r_{jk}\right), \tag{6}$$

the amount of information *Cj*, emitted by the *j-th* criterion can be determined by composing the measures which quantify the two notions through the following multiplicative aggregation formula:

$$C_j = \sigma_j \sum_{k=1}^{m}\left(1-r_{jk}\right), \tag{7}$$

The higher the value *Cj*, the larger the amount of information transmitted by the corresponding criterion and the higher its relative importance for the decision making process. Objective weights result by normalizing these values to unity according to the following equation (Diakoulaki, Mavrotas and Papayannakis, 1995, p. 765):

$$w_j = \frac{C_j}{\sum_{k=1}^{m} C_k}. \tag{8}$$

1.3 TOPSIS method

TOPSIS (the Technique for Order Preferences by Similarity to an Ideal Solution) is based on the determination of the best alternative that comes from the concept of the compromise solution. The compromise solution can be regarded as choosing the best alternative nearest to the ideal solution (with the shortest Euclidean distance) and farthest from the negative ideal solution (Tzeng and Huang, 2011). The procedure of TOPSIS method includes the following steps. *The first step* is to construct the decision matrix. Given a set of alternatives A= {A_i| i= 1.….n}, and a set of criteria (attributes), C= {C_j| j= 1.…. m}, where Y= {y_{ij}| i= 1.…. n; j=

1….. m} denotes the set of performance ratings and w= {w_j| j= 1….. m} is the set of weights for criteria. *The second step* is to calculate the normalized decision matrix according to formula:

$$r_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{n} y_{ij}^2}},\ i = 1...n;\ j = 1...m, \tag{9}$$

The third step is to calculate the weighted normalized decision matrix expressed as $v_{ij} = w_j \cdot r_{ij}$. *The fourth step* includes the determination of the positive ideal solution $H_j = \max(v_{ij})$ and the negative ideal solution $D_j = \min(v_{ij})$. *The fifth step* is to calculate the separation from the ideal d_i^+ and the negative ideal solutions d_i^- between alternatives. The separation values can be measured using the Euclidean distance which is given as:

$$d_i^+ = \sqrt{\sum_{j=1}^{k} \left(v_{ij} - H_j\right)^2},\qquad d_i^- = \sqrt{\sum_{j=1}^{k} \left(v_{ij} - D_j\right)^2}, \tag{10), (11}$$

The last step includes the calculation of the relative closeness from the ideal solution and ranking the alternatives in descending order. The relative closeness of the *i*-th alternative A_i is expressed as:

$$c_i = \frac{d_i^-}{d_i^- + d_i^+}. \tag{12}$$

1.4 Data description

Visegrad Four countries are divided into 35 NUTS 2 regions. These NUTS 2 regions (alternatives) are evaluated by 16 selected indicators (criteria) of economic, social and territorial disparities shown in table 1. These indicators are most frequently used indicators of regional disparities monitored within Cohesion reports, see e.g. European Commission (2010). These indicators are available in the Eurostat database, the last available regional data are for the year 2012.

Tab. 1: Selected regional indicators (criteria) of disparities in V4

Type of disparity	Indicator	Abbreviation
Economic disparity	Gross domestic product per inhabitant (PPS/inhabitant)	GDP
	Gross fixed capital formation (mil. EUR)	GFCF
	Total intramural R&D expenditure (% GDP)	GERD
	Patent applications to the European Patent Office (number/mil. inhabitant)	EPO
	Employment in technology and knowledge-intensive sectors (%)	ETKS
Social disparity	Employment rate from 15 to 64 years (%)	ER15-64
	Employment rate of older workers from 55 to 64 years (%)	ER55-64
	Unemployment rate from 15 and more (%)	UR15+
	Persons aged 30-34 with tertiary education attainment (%)	TE30-34
	Early leavers from education and training, persons aged 18–24 (%)	EL
Territorial disparity	Density of railway (km/1000 km^2)	DR
	Density of motorway (km/1000 km^2)	DM
	Life expectancy at age less than 1 year (mean number of years)	LE
	Infant mortality rate (%)	IMR
	Hospital beds (number/100000 inhabitant)	HB
	Victims in road accidents (number/mil. inhabitant)	VRA

Source: Eurostat, 2016; Minarčíková, 2015; author's processing, 2016

2 Application of MCDM methods and empirical results

The final values of indicators' weights (criteria) calculated by the Entropy (w_E) and CRITIC methods (w_C) in the year 2012 are shown in Table 2.

Tab. 2: Final weights of regional indicators in the year 2012

Criterion\ weight	w_E	w_C
GDP	0.098	0.046
GFCF	0.083	0.064
GERD	0.064	0.051
EPO	0.067	0.057
ETKS	0.074	0.064
ER15-64	0.053	0.051
ER55-64	0.067	0.045
UR15+	0.039	0.053
TE30-34	0.041	0.099
EL	0.018	0.077
DR	0.081	0.044
DM	0.152	0.062
LE	0.018	0.058
IMR	0.035	0.064
HB	0.056	0.077
VRA	0.054	0.089

Source: author's calculation, 2016

Based on Entropy, indicators density of motorway, GDP per inhabitant and Gross fixed capital formation had the biggest importance in the evaluation. On contrary, CRITIC method determined the highest importance of the indicators persons aged 30-34 with tertiary education attainment, victims in road accidents and early leavers from education and training and hospital beds.

Table 3 provides the final ranking of regions according to their level of development based on TOPSIS method using different weights w_E and w_C. Table 3 presents and compares the scores of relative closeness to ideal solution (c_i) and the ranking over different weights of regional indicator. The highest ranked region is the closest to ideal solution.

Tab. 3: Comparison of regions' ranking by TOPSIS in the year 2012 based on different regional indicators weights

	type of weight	w_E		w_C	
code	region	c_i	rank	c_i	rank
CZ01	Praha	0.6282	2	0.7552	1
CZ02	Střední Čechy	0.3332	5	0.4206	5
CZ03	Jihozápad	0.2137	17	0.3240	14
CZ04	Severozápad	0.2044	19	0.2999	21
CZ05	Severovýchod	0.2396	12	0.3673	11
CZ06	Jihovýchod	0.3539	4	0.4772	4
CZ07	Střední Morava	0.2296	13	0.3914	7
CZ08	Moravskoslezsko	0.2399	11	0.3700	10
HU10	Közép-Magyarország	0.6011	3	0.6286	2
HU21	Közép-Dunántúl	0.3281	6	0.3204	15
HU22	Nyugat-Dunántúl	0.2497	10	0.2879	24
HU23	Dél-Dunántúl	0.2793	9	0.3020	20
HU31	Észak-Magyarország	0.2185	16	0.2803	29
HU32	Észak-Alföld	0.1806	23	0.2896	22
HU33	Dél-Alföld	0.2034	20	0.3164	17
PL11	Łódzkie	0.1950	21	0.2880	23
PL12	Mazowieckie	0.2969	7	0.4163	6
PL21	Małopolskie	0.2224	15	0.3777	9
PL22	Śląskie	0.2920	8	0.3892	8
PL31	Lubelskie	0.1532	28	0.2727	31
PL32	Podkarpackie	0.1612	26	0.2840	26
PL33	Świętokrzyskie	0.1734	24	0.2824	27
PL34	Podlaskie	0.1228	34	0.2748	30
PL41	Wielkopolskie	0.1844	22	0.3081	18
PL42	Zachodniopomorskie	0.1290	33	0.2874	25
PL43	Lubuskie	0.1423	30	0.2455	34
PL51	Dolnośląskie	0.2278	14	0.3285	12
PL52	Opolskie	0.1519	29	0.2590	32
PL61	Kujawsko-Pomorskie	0.1341	32	0.2549	33
PL62	Warmińsko-Mazurskie	0.0823	35	0.2015	35
PL63	Pomorskie	0.1690	25	0.3180	16
SK01	Bratislavský kraj	0.6556	1	0.6273	3
SK02	Západné Slovensko	0.2126	18	0.3256	13
SK03	Stredné Slovensko	0.1355	31	0.2818	28
SK04	Východné Slovensko	0.1593	27	0.3032	19

Source: author's calculation, 2016

Taking into account the results of TOPSIS method using weights of criteria based on Entropy (w_E), the shortest relative closeness to ideal solution was achieved by NUTS 2 regions with capital cities Bratislavský kraj, Praha and Közép-Magyarország. These regions were ranked at the top three positions and they are considered as the most developed regions in V4. Also two Czech regions Jihovýchod and Střední Čechy had very short relative closeness to ideal solution and they followed the regions with capital cities. Polish region with capital city Mazowieckie was ranked at 7th position. On the other hand, the farthest distance to ideal solution was indicated by Polish regions Warmińsko-Mazurskie, Podlaskie, Zachodniopomorskie, Kujawsko-Pomorskie, Lubuskie and Slovak region Stredné Slovensko. These regions occupied the last five positions and are considered as less developed. As can be seen from table 3, the weights of indicators determined by CRITIC (w_c) have diverse influence on regions' ranking. The regions with capital cities are again considered as five most developed regions, however their positions changed. Region Praha was ranked at first position and Bratislavský kraj was ranked at the third position. Bratislavský kraj was the regions with the highest value of GDP per inhabitant in V4 in the year 2012 but the preferences of the indicator GDP per inhabitant (w_c) according to CRITIC is lower. At the last five positions were ranked again regions Polish regions Warmińsko-Mazurskie, Kujawsko-Pomorskie, Lubuskie, Podlaskie and newly Lubelskie and Opolskie. Generally, the analysis shows that Czech NUTS 2 regions had better position in the level of regional development in comparison with the other V4 countries, the best region Praha was ranked at 1st or 2nd position, and the worst region Severozápad was placed at 19th or 21st position. On the contrary, Polish regions achieved worse ranking among V4 regions, since regions were placed at the second half of ranking. The regions' ranking implied visible differences among regions with capital cities and the rest of V4 regions.

Conclusion

The integration of the indicators' weights into regional analysis is appropriate and enables to better differentiate the results. I recommend use the objective weighting methods in case of requirements of independent evaluation or in case where expert's preferences of regional indicators are not possible to obtain. Advantage of this method is the calculation of stable weight for given year in time period which enables to observe and analyse the changing trends in importance of regional indicators. The case study showed that different weights calculated by objective methods of Entropy and CRITIC have small impact on the ranking of the most developed regions (Bratislavský kraj, Praha, Közép-Magyarország, Mazowieckie, Střední Čechy, Jihovýchod, Śląskie) and the less developed regions (Warmińsko-Mazurskie, Kujawsko-Pomorskie, Lubuskie, Podlaskie). Bigger differences in ranking can be found by rest of regions. The highest influence of the different weights w_E and w_c on regions' ranking is visible in Hungary, where the difference is even fourteen positions. As it was shown, that used weighting methods have some advantages and disadvantages. Entropy method can compute unbiased relative criteria weights in a rather simple and straightforward manner. This method considers adequately the information of values all the monitoring sections provided to balance the relationship among numerous evaluating objects. It weakens the bad effect from some abnormal values and makes the result of evaluation more accurate and reasonable. On the other hand, it takes no account of the mutual relationships among criteria. On contrary, CRITIC incorporates to the weights both contrast intensity and conflict which are contained in the structure of the decision problem. The weights are found to embody the information which is transmitted from all the criteria. CRITIC enables the incorporation of interdependent criteria.

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