WEIGHTING METHODS FOR CONSTRUCTING COMPOSITE INDICES IN REGIONAL DEVELOPMENT

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Abstract

The paper deals with an issue of weighted composite indices construction for evaluation of regional development in the European Union. There is no uniform methodological approach to the evaluation of regional development and composites indices are one of the suitable techniques that allow to aggregate and summarise the multidimensional characteristics. However, the constructing of the composite indices includes not only a problem of the selection of indicators and quantitative method of their processing but also a question of indicators or sub-indices weights. The regional indicators can have different representativeness during regional trends development. The main aim of the paper is to explore the various types of weighting methods and analyse their possibilities for the constructing of composite indices in a field of regional development. The empirical case of a weighted composite index of regional disparities is discussed.

Key words: Composite index, indicators, region, sub-index, weighting methods

JEL Code: C80, O18, R11

Introduction

In the European Union, the regional disparities decreased over the past decade, however, a wide gap has still remained between the less developed and highly developed regions. The assessment of regional disparities and the identification of key development factors that may contribute to increasing the dynamics and development potential are crucial to adopt the measures supporting the long-term growth of regional economies. There are no uniform methods for evaluation of disparities, cohesion and development potential of the European regions. Several regional indicators are processed by different mathematical and statistical methods (Poledníková, 2014). Composites indices are one of the other approach that enables to aggregate a set of regional indicators moreover with different importance (weights). The *main aim* of the paper is to explore the various types of weighting methods and on the empirical example analyse their possibilities for the constructing of composite indices in a field of regional development. The paper is based on a method of literature review and quantitative

methods of Entropy and CRITIC deriving the objective weights of particular sub-indices creating the weighted composite index of regional disparities.

1 Methodology of composite indices

Composites indices are one of the suitable techniques that allow to aggregate a set of indicators and summarises and simplifies the multidimensional characteristics into easily understood formats for a general public. Composites indices are composed in various areas as economic well-being (Sharpe, Andrews, 2012), economic, social and territorial disparities (Melecký, 2015), knowledge economy (Saisana, Tarantola, 2002), country economic performance and policy (Freudenberg, 2003; Saltelli, Nardo, 2006), development potential of regions (Viturka, 2014) and etc. Many international organisations such as the EU, the Organisation for Economic Co-Operation and Development or the World Economic Forum compute various composite indices with a general objective to rank the countries (regions, subjects) according to some aggregated dimensions (Munda, Nardo, 2005). Generally, a *composite index CI* can be understood as weighted linear aggregation of a set of variables, see e.g. Munda, Nardo (2005), Freudenberg (2003):

$$CI = \sum_{i=1}^{N} w_i X_i \tag{1}$$

where X_i is normalized variable, w_i is weight of variable X_i where $\sum_{i=1}^{N} w_i = 1$ and $0 \leq w_i \leq 1,\ i = 1, 2, ..., N.$ Number of crucial steps for the constructing of composite indices can be found (OECD, 2008; Freudenberg, 2003): development a theoretical framework for the composite; identification of relevant variables and their standardization; selection of the weighting methods of (groups) variables; selection of aggregation techniques; execution of sensitivity tests on the robustness of aggregated variables. Composite indices can be easier to interpret than trying to find a trend in many separate indicators. They also could help to reduce the size of a list of indicators or to include more information within the existing size limit (Saisana, Tarantola, 2002). Composite indices have also some methodological difficulties regarding their accuracy and reliability (e.g. the sensitivity of the results to different weighting and aggregation techniques). The composite index is not "the unique solution" when representing complex systems that real socioeconomic issues are but only "a solution", i.e. a limited exercise to take into account non-equivalent observers and observations. The major limitation of the composite index is its subjective nature (Saltelli, Munda, Nardo, 2006). On the

other hand, subjectivity cannot be avoided when representing the complex systems (Saltelli, Nardo, 2006). Therefore, composite indices should be accompanied by explanations of their components, construction, weaknesses and interpretation (Freudenberg, 2003). The issue of weights as one of the controversial step of composite index's computation will be described in the following section. For the detailed summary of pros and cons on composite indices and description of particular steps of the construction see, OECD (2008), Saltelli, Nardo (2006), Freudenberg (2003), Saisana, Tarantola (2002).

2 Weighting methods

After identification of relevant variables, the weights have to be given to variables or sub-indices before they are aggregated in one composite index. Weights represent the relative importance of each indicator or group of indicators (sub-indices) and their manipulation can involve linear or geometric combination, the use of an outscoring matrix in a multicriteria setting or other forms. The question of weights computation is always crucial because the weights given to different indicators heavily influence the final outcomes of the composite index. For this reason, weighting method should be chosen in compliance with a theoretical framework or conceptual rationale for the composite index and should be explained transparently (Freudenberg, 2003). Based on literature review we can generally define three main approaches to the weights determination: equal weighting, explicit/subjective weighting and statistical/objective weighting, see e.g., Freudenberg (2003), Saisana, Tarantola (2002).

2.1 Equal weighting

Equal weights imply that all indicators or sub-indices in the composite index have equal importance on the performance being measured. In many composite indices, equal weights are used for reasons of simplicity. With the equal weighting approach, there is the risk that certain performance aspects will be double weighted (Freudenberg, 2003). Moreover, the results of an equally weighted index are still conditioned by the choice of the normalisation method. The most prominent substantive justification for equal weighting goes back to Occam's razor. Since it is probably impossible to obtain agreement on weights, the simplest arrangement is the best choice. As far as composite indices are concerned, taking the simplest weighting scheme, in fact, does not imply choosing the simplest model from a set of otherwise equivalent models of a given phenomenon. As a rule, the problem in this context is rather that there are at best partially conflicting opinions about underlying models available. Stated differently, equal

weighting may sometimes not even be an adequate description of the debate in composite indices construction (Saisana, Tarantola, Schulze, Laurens, Moesen, Puyenbroeck, 2005, p. 30). Sharpe, Andrews (2012, p. 5) also stated that the use of equal weighting is justified when surveys of the weights people place on the components of an index are not available. In practice, these weights will rarely be available, as most indices contain a unique set of components (otherwise an index would be irrelevant).

2.2 Explicit/subjective weighting

Explicit or subjective weighting includes mostly three main methods: *experts' opinion*, *survey weighting (public opinion)* and *Analytic Hierarchic Process (AHP),* see e.g. Sharpe, Andrews (2012), OECD (2008), Freudenberg (2003), Saisana, Tarantola (2002). *Experts' opinion* is based on subjective personal judgement. The OECD (2008) describes expert weighting as a *Budget Allocation Process* (BAP). Within BAP experts on a given theme are asked to allocate a "budget" of one hundred points to the indicator set, based on their experience and subjective judgment. It is essential to bring together experts representing a wide spectrum of knowledge and experience to ensure that a proper weighting system is established (OECD, 2008, p. 96). In *survey weighting*, people are asked to express their concern about certain problems measured by the indicators. The simplest way to replicate valuations of society relatively accurately is to collect a representative sample of the population. However, in many cases, there are no resources to conduct such a survey. Therefore, survey weighting remains the optimal solution to the weighting issue, but it is rarely achievable (Sharpe, Andrews, 2012, p. 5). *AHP* is one of the most popular analytical techniques for complex decision-making problems. AHP enables to handle decision situations involving subjective judgments, multiple decision makers and to provide measures of consistency of preference. The AHP creates a hierarchical structure of the criteria. The weights of indicators within AHP can be determined by the pairwise comparison (Saaty's method).

2.3 Statistical/objective weighting

Although explicit weights have the favourable quality of being transparent, the options available often do not satisfy all necessary conditions. Given that the weights are chosen based on patterns in the data, the researchers cannot be criticised for a particular bias in their assignment of weights (Sharpe, Andrews, 2012, p. 5). Thus, statistical methods represent an objective approach as the *method of efficiency frontier, method of distance to targets, conjoint analysis, factor analysis, regression analysis, Data envelopment analysis (DEA)*, see e.g.

Sharpe, Andrews (2012), OECD (2008). In the method of *efficiency frontier*, the weights depend on where the subject is located in relation to the frontier. The method of *distance to targets* assigns the weights according to the distance to target, i.e. the nearer the defined target is, the smaller the equivalent weight is. *Conjoint analysis* asks for an evaluation of a set of alternative scenarios. A scenario might be a given set of values for the individual indicators. The preference is then decomposed by relating the single components to the evaluation. Although this methodology uses statistical analysis to treat the data, it relies on the opinion and preferences of people (e.g. experts, citizens) (OECD, 2008). *Factor analysis* endogenously determines the weights to be used in the summation of a composite index. This methodology aims to describe the data with a set of orthogonal factors which are considerably large (Sharpe, Andrews, 2012, p. 5). *Regression analysis* is a natural weighting method. Multiple linear regression is used to estimate a set of weights which best fit the data by the criteria of least squares. Regression can be used to estimate the weights of variables when there is a dependent variable. It is often difficult to find a suitable dependent variable. The higher the correlation, the more important the indicator could be in the composite index (Sharpe, Andrews, 2012, p. 5). *DEA* uses the best performing observations in each indicator to create a "boundary" of feasible performance which is then used to measure the score of each observation (Staníčková, 2014). For example, the top-ranking country in each measured component is given the score 1 and the data point is incorporated into the boundary. The weighting of each component will be determined uniquely for each observation in the data.

2.4 Weighting methods of multicriteria decision-making process

Besides the approaches mentioned above, an appropriate alternative for the weighting of indicators might be discovered and applied for the composite indices construction in the regional development. Zardari, Ahmed, Shirazi, Yusop (2015) or Ginevičius, Podvezko (2005) define the weighting methods in the multicriteria decision-making process. In the use of *subjective weighting methods*, the process of assigning importance to criteria depends on the preferences of decision-makers. Popular weighting methods are e.g. direct rating, point allocation, AHP, ratio method, swing method, graphical weighting, Delphi method, etc., see e.g. Poledníková (2014). The *objective methods* determine criteria weights by solving mathematical models automatically without any consideration of the decision. As common methods are considered e.g. Entropy method, CRITIC (The Criteria Importance through Intercriteria Correlation), literature review, mean weight, standard deviation, statistical variance procedure, see e.g. Minarčíková (2016).

3 Empirical case of weighted composite indices of regional disparities

Within the aim and scope of the paper, an example of using the selected objective weighting methods - Entropy and CRITIC for the construction of weighted composite indices of regional disparities is presented. The composite weighted aggregate index of regional disparities (CWAID) has been proposed by Melecký (2015) to analyse the economic, social and territorial disparities among 35 NUTS 2 regions in Visegrad Four countries in the years 2000-2011. Construction of CWAID is based on a combination of selected multivariate mathematical and statistical methods (using 24 selected indicators) that lead to unique *three-layer model* includes *three sub-indices* of economic, social and territorial disparities. For more details of used database, the CWAID construction, Entropy and CRITIC methodology see Staníčková, Melecký (2015), Melecký (2015), Minarčíková (2015).

Table 1 shows the final weights (w_j) of particular sub-indices calculated by methods of Entropy, CRITIC and Equal weighting in the years 2000 and 2011. In the year 2000, the sub-index of social disparities showed the highest weight based on the Entropy and CRITIC methods. On contrary, sub-index of territorial disparities had the lowest weight in the construction of CWAID. In the year 2001, the different results are observed. The Entropy assigned the highest weight to the sub-index of social disparities while the CRITIC method determined the highest importance of the sub-index of territorial disparities.

Tab. 1: Weights of particular sub-indices based on different weighting methods

Year	2000			2011		
Weighting method	wj Entropy	wj CRITIC	wj Equal weight	wj Entropy	wj CRITIC	wj Equal weight
Sub-index of economic disparities	15%	33%	33%	22%	30%	33%
Sub-index of social disparities	81%	40%	33%	68%	25%	33%
Sub-index of territorial disparities	4%	28%	33%	9%	45%	33%

Source: authors' calculation, 2017

Table 2 provides the final values of CWAID using different weights of particular sub-indices' and shows the final ranking of regions according to the CWAID value. The lower value of CWAID then higher ranking of the region and lower level of disparities. As it can be seen, different weighting of sub-indices has diverse influence on the value of CWAID and regions' ranking. The case study showed that different weights have the smaller impact on the CWAID of the three most developed NUTS 2 regions with capital cities (Praha, Bratislavský kraj and Közép-Magyarország) and two least developed regions (Warmińsko-Mazurskie, Východné Slovensko). Higher differences in the CWAID values can be found by rest of regions using the Entropy weighting on the one hand and CRITIC and Equal weighting on the other hand. In the

year 2011, the value of the CWAID and regions' ranking changed that indicates the decrease in regional disparities (e.g. Střední Čechy, Západné Slovensko, Slaskie) or increase in disparities (e.g. Észak-Magyarország, Észak-Alföld, Podlaskie). In the case of the most and least developed regions, the higher differences are again between the results using Entropy weighting on the one hand and CRITIC and Equal weighting on the other hand.

Tab. 2: CWAID and regions' ranking based on different sub-indices' weights

Year		2000						2011					
Weighting method		Entropy		CRITIC		Equal weight		Entropy		CRITIC		Equal weight	
Code	Region	CWAID	Rank	CWAID	Rank	CWAID	Rank	CWAID	Rank	CWAID	Rank	CWAID	Rank
CZ01	Praha	0.8854	1	3.2446	1	3.6497	1	0.4974	1	3.1310	1	3.2273	1
CZ02	Střední Čechy	3.8569	6	9.4353	7	10.2970	7	3.0750	4	15.2130	5	16.7305	5
CZ03	Jihozápad	3.8610	7	10.0015	9	10.9582	10	3.6504	8	19.1456	9	23.7479	9
CZ04	Severozápad	6.2467	13	10.8896	13	11.5179	12	5.1373	13	31.9094	11	34.4319	13
CZ05	Severovýchod	3.6524	3	9.0658	6	9.9018	6	3.6360	7	19.8864	7	19.4102	6
CZ06	Jihovýchod	3.6712	4	8.3639	4	9.0628	4	3.1437	5	15.7626	4	14.1622	4
CZ07	Střední Morava	5.0485	10	9.8893	8	10.5908	8	4.4457	9	27.8471	13	32.4188	12
CZ08	Moravskoslezsko	7.0776	16	11.0177	14	11.5781	13	4.5619	10	30.3920	8	27.8470	10
HU10	Közép-Magyarország	3.8549	5	6.7686	2	7.2870	2	3.0295	3	10.7214	3	10.9136	3
HU21	Közép-Dunántúl	6.3363	14	10.6345	11	11.1895	11	5.4180	16	33.2108	12	38.7190	15
HU22	Nyugat-Dunántúl	4.8915	9	10.0005	10	10.7168	9	5.1099	12	31.1704	14	36.6899	14
HU23	Dél-Dunántúl	8.1219	21	12.4659	18	13.0300	19	8.0525	31	51.2255	19	59.5893	24
HU31	Észak-Magyarország	9.9363	26	13.2869	27	13.6555	27	9.8706	35	64.5066	27	75.7182	32
HU32	Észak-Alföld	10.0794	27	13.2983	28	13.6739	28	9.1473	33	64.5290	33	77.8685	33
HU33	Dél-Alföld	7.2710	17	12.0144	16	12.6316	16	7.2857	27	49.1987	24	59.6813	25
PL11	Lódzkie	8.2429	22	12.8249	23	13.4710	25	5.2895	15	50.1370	21	45.7316	18
PL12	Mazowieckie	4.5667	8	8.9418	5	9.7132	5	3.1692	6	27.2245	15	23.7111	8
PL21	Malopolskie	5.7322	11	10.8732	12	11.5773	14	5.1058	11	43.4094	16	40.9011	16
PL22	Śląskie	11.2364	31	12.5442	19	12.6219	15	5.4877	17	47.3290	6	23.5912	7
PL31	Lubelskie	5.8131	12	11.9379	15	12.7485	17	6.5802	24	55.6038	32	67.2805	28
PL32	Podkarpackie	7.4878	19	12.6832	20	13.3288	22	6.9863	26	60.5051	28	64.0668	27
PL33	Świętokrzyskie	9.3148	25	13.3892	29	13.8027	29	7.3052	28	68.7716	29	70.3797	30
PL34	Podlaskie	6.9215	15	12.6833	21	13.4468	24	6.4706	22	58.8906	34	72.6463	31
PL41	Wielkopolskie	7.3863	18	12.1335	17	12.8066	18	5.5245	18	48.1262	17	43.6575	17
PL42	Zachodniopomorskie	11.5110	32	14.1431	31	14.4666	31	7.7779	29	70.5870	26	63.9869	26
PL43	Lubuskie	11.7404	33	14.5988	33	14.8793	33	6.4744	21	61.0203	25	56.5706	23
PL51	Dolnośląskie	10.8125	30	13.0131	25	13.2406	20	5.2782	14	50.7373	10	30.0849	11
PL52	Opolskie	7.8842	20	12.9071	24	13.5471	26	6.5092	23	58.8245	22	54.4038	22
PL61	Kujawsko-Pomorskie	10.6200	28	13.0794	26	13.2671	21	6.9249	25	60.7431	18	52.1973	21
PL62	Warmińsko-Mazurskie	12.7673	34	15.5924	35	15.8782	35	8.0839	32	80.7289	35	82.2917	35
PL63	Pomorskie	8.7832	23	12.7609	22	13.3517	23	5.6494	20	55.3946	23	49.9379	20
SK01	Bratislavský kraj	2.2227	2	7.2957	3	8.1922	3	1.7930	2	8.0331	2	8.3746	2
SK02	Západné Slovensko	9.2343	24	13.6262	30	14.2454	30	5.6274	19	42.2504	20	47.8097	19
SK03	Stredné Slovensko	10.7837	29	14.1777	32	14.6218	32	7.8387	30	66.9101	30	71.3562	29
SK04	Východné Slovensko	13.1296	35	15.1796	34	15.3473	34	9.7804	34	80.6458	31	79.8623	34

Source: authors' calculation, 2017

The choice of which weighting method to select is difficult since each method has strengths and weaknesses. The optimal weighting method of the indicators can be easily applied to sub-indices, on the other hand, there is no reason to assume that the optimal method of

weighting the indicators has to be the same for the sub-indices. Generally, in the theory of information *Entropy method* is the criterion of uncertainty posed by a discrete probability distribution. It 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. A possible disadvantage of the method is related to proper problem sizing (preserving that the decision matrix contains the sufficiently large set of alternatives). CRITIC method uses correlation analysis to detect contrasts between criteria. It incorporates to the weights both contrast intensity and conflict which are contained in the structure of the problem (Minarčíková, 2016). The *equal weighting* is another individual set of subjective weights which are unlikely to represent the true valuations of regional development. If we do not have the theoretical framework of regional development equal weighting proposes the least conflict for a summary index, however, this approach must be justified.

Conclusion

The advantages of composite indices are that enable to summarize multi-dimensional regional data; easily compare the level of regional development and analyse the trends over time; significantly reduce the number of variables and simplify the interpretation. On the other hand, as disadvantages are considered: improper construction may result in the wrong conclusions; influence of the selection of regional indicators and their weights (it may lead to an attempt to influence the statistical methods, e.g. by political decisions at regional level); the rank of regions can easily change with alternative weighting systems. The literature on the weighting method of composite indices is continually extended but reaching the agreement is still the major challenge and difficulty in the EU countries and regions. The case study showed the integration of the sub-indices weights into regional analysis can enable to better differentiate the results. However, there is no universal recipe for weighting of sub-indices or indicators. Therefore, it is useful to illustrate how the values of composite indices and regions' rankings change with the use of alternative weighting systems. Within case study of weighted composite aggregate indices of regional disparities, Entropy and CRITIC were considered as suitable weighting methods of sub-indices because they represent objective methods without subjective judgements. To decide which method is the most appropriate it is necessary to analyse the change of weights in the longer time period and provide sensitivity tests. To eliminate the

differences in results, the combination of objective and subjective approach could be a good solution. For example, the aggregation of Entropy method and pairwise comparison provides the possibility to combine the actual importance of regional indicators with experts' preferences.

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