IMPACT OF ALTERNATIVE ATTITUDE TO AGGREGATION ON THE EU-28 RESULTS IN GCI (GLOBAL COMPETITIVENESS INDEX)

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Abstract

Competitiveness rankings are a generally accepted method of evaluating countries' position in a global economy. The Global Competitiveness Index (GCI), the composite indicator of national competitiveness discussed in this paper, is accepted by policymakers and other authorities for its ability to integrate different variables describing the positive and negative aspects of countries' competitiveness. The explanatory power of this international ranking is strongly influenced by the choices made during the construction of the composite index (CI). In every composite indicator analysis, the final index is the result of several decisions: the framework (usually driven by theoretical models and experts' opinions), the indicators included, their normalisation, the weights assigned to each indicator, and the aggregation method. The purpose of this paper is to examine how the ranking of countries (in the original GCI and the new WEF's composite index – the GCI4.0) changes when alternative aggregation methods are used. The paper presents two alternative approaches to the final aggregation. The first method is based on data envelopment analysis. This attitude determines endogenously the "best" weights for a given country based on its revealed performance on each sub-index (Basic requirements, Efficiency enhancers, Innovation, and sophisticated factors) underlying a composite index. The second method uses the geometric mean and enables us to reduce the methodological problem of compensability among the pillars.

Key words: national competitiveness, a composite indicator, Global Competitiveness Report, GCI, GCI4.0

JEL Code: E60, F40, F60

Introduction

Composite indicators (CI) are recognised as a helpful tool in policy analysis and public communication primarily due to their expected ability to summarise and condense the complexity of the economic and social environment in the global context. The CI construction is a relatively complicated process based on several steps (decisions): choice of a framework (usually based on theoretical models and experts' opinions), choice of suitable variables (mix of hard and soft data), choice of normalisation's method, choice of weighting system (i.e. decision about the aggregation method). The specific decisions made during the CI construction have an important impact on the explanatory power of the final CI. The main pros and cons of using composite indicators have been widely debated. The literature review concerning the CI methodological framework is provided, e.g. by Greco et al. (2019), the partial steps during the CI building are analysed, e.g. by OECD (2008). The explanatory power of the CI has also been widely discussed. Some studies are focused on the explanatory power of the Global Competitiveness Index (GCI) as a predictive tool for economic performance. Using a statistical analysis, Posta and Necadova (2021) detected many statistically significant relationships between economic performance and WEF's competitiveness indicators in African economies (specifically African middle-income economies). On the other hand, the statistical analysis on the reduced sample of WEF's economies (118 countries) by Posta and Necadova (2019) shows that in many cases, there is a relatively high probability of inferring systematically wrong expectations about the economic performance given the information contained in the WEF's competitiveness indicators (in the final GCI and its sub-indices).

Since our aim is to show the influence of different aggregation methods on the countries' ranking, a brief description of the often-used aggregation techniques will be presented in the first (theoretical) part of our paper. The second chapter brings brief descriptions of our dataset and methods which are then used in the third and last chapter.

1 Literature review

Applying multi-criteria decision making (MCDM) techniques is generally considered to be a suitable attitude in multidimensional frameworks when it is necessary to aggregate single indicators into a composite one. Within MCDM approaches, it is possible to identify several attitudes to classification. E.g. classification of El Gibari et al (2018) is based on the technique used for the aggregation of the criteria. From this point of view it is possible to identify: 1) the elementary methods - e.g. the Simple Additive Weighting (SAW) and the Weighted Product (WP), 2) the value and utility-based methods, 3) the *outranking relation approach* including methods based on comparisons between pairs of options to determine whether "alternative *a* is at least as good as alternative *b*", 4) the *Data Envelopment Analysis (DEA) based methods* (DEA), a non-parametric approach using linear programming for the purpose, initially, of evaluating the efficiency of a set of comparable units 5) the *distance functions based methods*, whose basic idea consists of substituting the maximisation of a utility function by the minimisation of the distance existing between an alternative and a point or points enjoying good preferential properties. (El Gibari et al., 2018)

Respecting our aim, we concentrate on the discussion of the elementary methods, the DEA based methods, and the geometrical mean as the method for final aggregation.

The elementary methods are based on the underlying idea that the global performance is computed as the weighted sum of its values for each criterion. This way of aggregation means total compensation among the different criteria in the case of the SAW method and partial compensation in the WP method. The SAW and WP methods usually require to normalise the variables before aggregating them. (El Gibari et al. 2018)

This attitude to the CI construction assumes that the weights attached to the different variables 1) add up to one and 2) reflect the importance of the variables. As Kuc-Czarnecka et al. (2020) emphasise, both assumptions mentioned above are highly questionable. Using mathematical theory, Becker et al. (2017b) prove that the sum of the squared weights (and not the sum of the weights) should be one. Becker et al. (2017a, 2017b) doubt the ability of nominal weights to reflect the importance of partial indicators in the CI (they point out the linear aggregation method's ineptitude at translating the weights into "effects"). These authors argue that different variances and correlations among variables prevent the weights from corresponding to the variables' importance and propose using measures drawn from the global sensitivity analysis (the Pearson correlation ratio)[1].

Similarly, Paruolo et al. (2013) show that the real importance of variables in the CI may considerably deviate from its weights. Saltelli et al. (2008) and Paruolo et al. (2013) find the possible solution of this problematical aspect in mathematical modelling. From their perspective, sensitivity analysis proves that the importance of a given variable is given by the square of its weight divided by the sum of all squared weights for the ideal case of uncorrelated and standardised variables. The importance of non-standardised and non-independent variables meanwhile depends on the interplay of the relative variances and correlation among the variables. (Saltelli et al. 2008, p. 47)

E.g. Rogge (2018) points out the distortion of final results caused by linear aggregation (WEF uses this method). From his point of view, the geometrical mean is considered a better

[1] The *Pearson correlation ratio* is a variance-based measure which accounts for (possibly nonlinear) dependence between input variables and the composite indicator (see e.g. Paruolo et al., 2013)

method of final aggregation. One of the main reasons is the reduction in the level of substitutability (the rate of compensation) among sub-indicators. As we mentioned above, the linear aggregation (SAW method) imposes the strong assumption of perfect substitution (or compensability) among the different sub-indicators. In those conditions, marginal rates of substitution (MRS) among the sub-indicators are constant and independent of the country's real performance in the sub-indicators. As, e.g. Rogge (2018), says, this fact implies that a bad result in one of the sub-indicators can be linearly compensated by good achievements in other sub-indicators. Moreover, an arithmetic weighted average does not penalise countries for variability among sub-indicators. (Rogge, 2018)

Bowen and Moesen (2011) show another problematic aspect of the WEF's linear aggregation: uniform application of weights may incorrectly penalise some countries and favour other countries so that the final CI and the countries' ranking is biased. They were inspired by the DEA methods[2] and recommended using implicit (shadow) weights computed from observed sub-index values. The weights are calculated to maximise (for country i) the value of an objective function. (Bowen and Moesen, 2011)

2 Aims and methods

This paper aims to compare the countries' results (ranks) according to the original WEF's methodology and alternative attitudes based on different methods of final aggregation. We used time series 2007-17 for the GCI and time series 2017-19 for the GCI 4.0. The countries' final values, ranking in individual pillars, and the composite indicators were obtained by counting the countries' average results in the periods mentioned above (the output of this attitude is our indicator AGCI12). Inspired by the paper of Bowen and Moesen (2011), we use the endogenously determined country-specific weights (the highest weight, 50 %, is assigned to the sub-index with the highest value, the weight for the sub-index with the second-best value is 30 %, the remaining 20 % is the weight for the third sub-index). This weighting scheme enables us to obtain the Revealed competitive index (RCI) for all EU28 countries. To decrease a distortion caused by the substitution among the pillars in the GCI, other alternative attitude to the final aggregation of pillars' values (the geometrical mean) is applied (the final indicator GAGCI12 is obtained). For each composite index (GCI4.0, GCI, RCI, GCI12, GAGCI12), the final value of the ideal hypothetical country (country" N1") was calculated to compare the

[2] DEA was designed to measure the relative efficiency of organizations when multiple outputs are produced with several inputs and when there is no objective way of aggregating either inputs or outputs into meaningful index of productive efficiency. (Bowen, Moesen, 2011)

results of the EU28 member states with the benchmark. Firstly, we took into account the best result (the value of the country with the best evaluation) in the sub-indices (for calculation of RCI) and individual pillars (for calculation of other composite indicators). Secondly, using the aggregation methods described above, we obtained the final value for this hypothetical country.

3 Results and discussion

The aim of the Global Competitiveness Report (the GCR) is to identify the microeconomic and macroeconomic foundations of national competitiveness. According to both the original and the new methodology, the determinants of competitiveness are grouped into 12 pillars of competitiveness (for brief insight into the original WEF methodology, see Table 1). The WEF draws its data from two sources: international hard data sources and the Executive Opinion Survey (the EOS)[3].

The first and the second column in Table 1 show the structure of the GCI and different weights for pillars in the sub-indices for the countries in the 3rd stage of development. The column "best value" and the column "Country (best value)" enable us to identify our hypothetical country "N1" and calculate the final value of the CI for this hypothetical country. The individual member states' relative performance is then calculated by comparing their values with this benchmark(= 100).

Tab. 1: WEF pillars and "N1"

\WEF Sub -indices	Pillars	The best value	Country (the best value) = parts of „N1“
A. Basic requirements (16/37) Nominal weight of the pillar: 5 % *The best value: Finland*	1. Institutions (0/21)*	6.08	Finland
	2. Infrastructure (3/6)*	6.32	Germany
	3. Macroeconomic environment (5/0)	6.07	Luxembourg
	4. Health and primary education (6/4)	6.75	Finland
B. Efficiency enhancers (13/36) Nominal weight of the pillar: 8.5 % *The best value: United \Kingdom*	5. Higher education and training (2/6)	6.12	Finland
	6. Goods market efficiency (5/11)	5.41	Luxembourg
	7. Labour market efficiency (2/8)*	5.33	UK
	8. Financial market development (0/8)	5.47	Finland
	9. Technological readiness (4/3)*	6.18	Sweden
	10. Market size (2/0)	6.00	Germany

[3] The EOS captures the perception of business executives about the environment in which they operate. Participants in the EOS evaluate on a scale of 1 to 7 where 1 represents the worst possible evaluation and 7 represents the best.

C. Innov. and soph. factors (1/17)	11. Business sophistication (0/10)*	5.74	Germany
Nominal weight of the pillar: 15 % *The best value: Germany*	12. Innovation (1/7)*	5.68	Finland
Composite indicator (A:B:C)	**GCI 4.0 (mean)**	**86.66**	**CI values for "N1 "**
	GCI (20:50:30)	**5.60**	
	RCI (50:20:30)[4]	**5.77**	
	GCI12 (mean)	**5.93**	
	GAGCI12 (geomean)	**5.92**	

Source: WEF (2017b), author's processing. Note: The quantities of the two types of variables used in sub-indices and pillars (hard data/soft data) are mentioned in the 1st and 2nd column (in brackets). Weights of pillars for the third stage of development are listed in the first column. Pillars with '*' sign contain indicators which enter into the GCI in two different pillars. Avoiding double counting is assured by giving a half-weight to this variable.

The original methodology applied different weights in different pillars and countries, from 5 to 15 per cent, according to (1) the sub-index to which the pillar belonged and (2) the country's stage of development. In the Global Competitiveness Report 2017-18 (the last yearbook, which applied the original methodology with the different stages of development), most EU28 countries (20-member countries) were included in the Stage 3 (Innovation Driven), for which the following weights of sub-indices were relevant: A. Basic Requirements (20 %), B: Efficiency enhancers (50 %), C. Innovation and sophistication factors (30 %)[5]. The changes of the economic environment have led to the new WEF attitude to the measurement of national competitiveness. The last three editions of GCR are based on adjusted WEF's methodology and brought a new final composite indicator (GCI 4.0)[6]. Since we chose to measure the country's relative performance compared to the hypothetical country "N1", our analysis was started with the final value for our benchmark. The final values for hypothetical country "N1" are listed in the grey-coloured section of Table 1. The following table (Table 2) shows a) the results of the comparison with the benchmark (a grey hint indicates the country's best result); b) country's ranking based on the relative performance (compared to benchmark). In general, countries showing a relative performance decline in the alternative CIs (compared to the results in

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[4] The weights for the hypothetical country are given in parentheses. “N1“ is composed of Finland (the highest score in Basic requirements), United Kingdom (the highest score in Efficiency enhancers), and Germany (the highest score in Innovation and sophistication factors).

[5] In the above mentioned yearbook, the following EU countries were considered as transit countries: Croatia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia. The weights of the sub-indices were adapted to the level of development and oscillated in the following intervals: A (20 - 40%), B (50%), C (10 - 30%). Bulgaria was the only EU country that belonged to the 2nd stage of development with the following weights of sub-indices: A (40%), B (50%), C (10%).

[6] In the GCI 4.0, the pillars are grouped into four sub-indices: enabling environment, human capital, markets, and innovation ecosystem. These four components are used only for presentation and analytical purposes; the SAW method (linear aggregation) is used for the final aggregation of 12 pillar scores (i.e., each pillar is weighted equally, the weight is 8.33 per cent). For more detailed description of the new methodology see WEF (2019b).

columns named GCI, which capture the evaluation based on the original WEF methodology) are not penalised by the WEF's weighting scheme (i.e., Belgium, Bulgaria, Denmark, Hungary, Ireland, Latvia, Lithuania, Poland, Romania, United Kingdom).

Tab. 2: Countries' results and ranking in composite indicators

EU28	GCI	RCI	GCI12	GAGCI12	GCI4.0	GCI	RCI	GCI12	GAGCI12	GCI4.0
	Relative to "N1"					Country's rank				
Austria	92.34	93.09	88.47	88.26	88.12	7	8	7	7	10
Belgium	92.14	91.85	88.07	87.77	88.30	8	10	8	8	9
Bulgaria	75.34	72.30	69.90	68.99	73.40	25	26	26	26	25
Croatia	73.45	73.59	70.16	69.49	70.07	27	25	25	25	28
Cyprus	77.34	79.69	75.69	74.61	75.65	21	18	19	20	23
Czechia	82.09	82.13	79.31	78.90	81.90	14	14	14	14	13
Denmark	95.93	96.53	92.08	91.84	92.98	6	5	5	5	5
Estonia	83.66	85.61	81.55	80.45	81.71	12	12	12	12	15
Finland	97.69	98.97	93.41	92.98	92.41	3	2	2	4	6
France	91.72	91.88	88.07	87.67	90.09	9	9	9	9	7
Germany	97.93	98.38	93.29	93.10	95.11	2	3	4	3	1
Greece	71.36	72.22	69.56	68.67	71.73	28	27	27	27	27
Hungary	76.37	75.27	72.83	72.43	74.16	23	24	24	24	24
Ireland	88.61	88.19	84.86	84.49	87.22	11	11	11	11	11
Italy	78.83	78.66	75.63	74.58	81.82	18	20	20	21	14
Latvia	77.28	76.80	73.84	72.90	76.16	22	22	22	23	22
Lithuania	79.60	79.23	75.96	75.31	77.65	15	19	18	18	20
Luxembourg	90.45	93.15	87.88	86.84	88.34	10	7	10	10	8
Malta	78.51	80.92	76.91	75.38	79.14	19	15	16	16	18
Netherlands	97.32	97.74	93.30	93.14	95.00	4	4	3	2	2
Poland	79.34	77.22	75.33	74.65	78.82	17	21	21	19	19
Portugal	79.54	80.89	77.35	76.77	80.90	16	16	15	15	16
Romania	74.30	71.06	69.23	68.51	73.08	26	28	28	28	26
Slovakia	75.95	76.07	73.66	72.96	76.89	24	23	23	22	21
Slovenia	78.20	80.40	76.22	75.35	80.11	20	17	17	17	17
Spain	82.20	83.19	79.99	79.30	85.85	13	13	13	13	12
Sweden	98.38	99.05	93.94	93.76	94.04	1	1	1	1	4
UK	96.03	94.16	91.60	91.45	94.35	5	6	6	6	3

Source: WEF (2017a, 2019a), author's processing.

Our results in Table 2 show that 15 countries of EU28 achieve better performance relative to "N1" when the endogenous weighting scheme is applied (see results for RCI). Following Bowen and Moesen (2011), we consider the weighting scheme of "N1" a valuable benchmark for examining the pattern of the revealed weighting scheme for each country. Countries with the same weighting scheme as "N1" (Sweden, Germany, Finland, Netherlands, Denmark, Belgium) are generally top-ranked countries. Our detailed results also confirm the following conclusions of Bowen and Moesen (2011): 1) since most countries show their best performance on Basic Requirements and their worst performance on Innovation, the original WEF weighting scheme appears to favour countries with higher scores (and higher relative performance) on these sub-indices; 2) the countries benefitting from using the best weights (endogenous weighting scheme)[7] are those whose performance differs the most across the three sub-indices; 3) the countries with the most significant decline in rank (i.e. worse position in RCI compared to GCI) generally performed poorly on each dimension relative to other countries (Lithuania, Poland, Italy, Romania, Belgium).

It is also clear that the impact of alternative weighting schemes on the relative distance between the country and "N1 "depends on the extent of the improvement or deterioration compared to the benchmark. If using the alternative weighting scheme represents a greater improvement for a given country, this country is approaching "N1" (this country is converging to benchmark due to chosen weighting scheme). Countries diverging from "N1" when the geometric mean was applied show higher variability among pillars than the benchmark. Finally, the obtained results enable us to evaluate the impact of the new WEF methodology on the country's ranking. Only four countries (Italy, Portugal, Slovakia, Spain) are the closest to "N1" according to the GCI 4.0. This fact is explained by the significant change of variables (new variables, lower representation of soft data) and final aggregation allowing compensation among pillars (SAW method).

Conclusion

The explanatory power of composite indicators depends on several decisions of their constructors. It is necessary to choose: the framework (typically driven by theoretical models and experts' opinions), the indicators to be included, their normalisation method, the weights assigned to each indicator, and the aggregation method. This paper deals with the changes in

[7] Countries with the largest difference between relative values of GCI and RCI are: Luxembourg, Malta, Cyprus, Slovenia. These countries also show the largest change (improvement) in the ranking.

the rankings brought by applying alternative aggregation methods (weighted arithmetic mean, simple arithmetic mean, geometric mean, endogenous weighting scheme inspired by the DEA method).

Our main results are following: 1) the original WEF weighting scheme (represented by the GCI) favours countries with higher values in the sub-indices Basic requirements and Innovation and Sophistication factors; 2) the countries benefitting from endogenous weighting scheme are those whose performance differs the most across the three sub-indices; 3) the countries with the most significant deterioration in the RCI rank (compared to the GCI) generally performed worse on each dimension relative to other countries; 4) the relative distance between the country and benchmark "N1" depends on the extent of the improvement or deterioration compared to the country "N1". If the application of alternative weighting scheme results in greater improvement for a given country, this country is approaching "N1" (this country is converging to benchmark due to the chosen weighting scheme).

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