THE EVALUATION OF COMPETITIVENESS PERFORMANCE FOR DEVELOPING EIGHT COUNTRIES BY GREY TOPSIS

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Abstract

The World Economic Forum has developed the Global Competitiveness Index to measure the countries' competitiveness and rank the countries according to their level of competition. This index is calculated separately for each country starting from 2007 considering the 12 indicators. In this study, a new ranking has been obtained for 8 countries (D-8) developed with TOPSIS-G method by using the annual Global Competitiveness Index data published by the World Economic Forum over the period of 2007 to 2017. The relationship between the ranking of TOPSIS-G and observed ranking was investigated by Spearman-Rank correlation coefficient and Kendall Tau nonparametric correlation coefficients. As a result, it was determined that the ranking found with TOPSIS-G method was strongly related to the annual published rankings. In addition, the new ranking is less affected by competing rankings over the years. While the country with the highest level of competitiveness with Topsis-G method is Malaysia, Turkey is third. Pakistan is the lowest competitiveness country.

Keywords: Global Competitiveness Index, D8, TOPSIS-G, Correlation Analysis

Jel Code: C6

D8 ÜLKELERİNİN KÜRESEL REKABETÇİLİK DÜZEYLERİNİN GRİ TOPSIS YÖNTEMİ İLE DEĞERLENDİRİLMESİ

Öz

Dünya Ekonomi Forumu, ülkeleri rekabet düzeylerine göre sıralamak amacıyla Küresel Rekabetçilik Endeksini geliştirmiştir. Bu endeks 2007 yılından itibaren 12 göstergeye bağlı olarak her ülke için ayrı ayrı hesaplanmaktadır. Çalışmada Gri *TOPSS* yöntemi ile gelişen 8 ülkenin rekabet düzeyleri tekrar sıralanmıştır. Bu amaçla Dünya Ekonomi Forumu tarafından yayımlanan 2007-2017 yılları arasındaki veriler kullanılmıştır. Gri TOPSIS yöntemi ile elde edilen yeni sıralama ile Dünya Ekonomi Forumunun yayımladığı sıralama arasındaki ilişki Spearman Sıra Korelasyon Katsayısı ve Kendall Tau korelasyon katsayıları ile incelenmiştir. Yeni sıralamanın incelenen yıllar ile ayrı ayrı ilişkisinin, yılların kendi aralarındaki ilişkisinden daha güçlü olduğu saptanmıştır. Ayrıca elde edilen bu yeni sıralamaya göre rekabetçilik düzeyi en yüksek olan ülke Malezya iken Türkiye üçüncü sırada yer almaktadır. Pakistan ise bu grupta rekabetçilik düzeyi en düşük ülke olarak gözlenmiştir.

Anahtar Kelimeler: Küresel Rekabetçilik Endeksi, Gelişen 8 Ülke, Gri TOPSİS, Korelasyon Analizi

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Introduction

Rapid globalization has led to countries being ranked for competitiveness. The meaning, scope, measurement, and relevance of competitiveness have been widely discussed so it is not possible to reach a single definition of competitiveness. The most intuitive definition of competitiveness is a country's share of world markets for its products. This makes competitiveness a zero-sum game, because one country's gain comes at the expense of others (Porter et al, 2007). Competitiveness is broadly considered as an important factor in creating national prosperity (Hong, 2009) The World Economic Forum rated countries annually in terms of various competitiveness indicators since 2005. Global Competitiveness Index (GCI) shows the factors determining efficiency and competitiveness with different weighted averages according to their severity. The GCI analyses competitiveness along 12 pillars which are institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labor market efficiency, financial market development, technological readiness, market size, business sophistication and innovation. These are, organized into three sub-indices in line with three main stages of development: basic requirements, efficiency enhancers, and innovation and sophistication factors.

However, there are another factors in the literature affecting global competition. According to Lee and Peterson (2000), culture and entrepreneurship orientation are other important factors affecting global competitiveness. Developing countries' policy makers worry about national competitiveness and closely watch indices ranking international competitive performance (Lall, 2001).

In this study D-8, also known as Developing-8, is an organization for development cooperation among the following countries: Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey were ranked with TOPSIS-G method. Between the years 2007-2017, individual competitiveness rankings of the countries for each year are available on the world economy forum. However, in this study, a single ranking was obtained from the value of each year. The relationship of this ranking with years was tested with correlation coefficients.

1. Literature Review

Multi-criteria techniques applicability has been shown widely throughout the literature. Real-world decision problems are rarely uni-criterion based. Therefore, multi-criteria decision making techniques take a large part in the literature.

Crouch (2011) used the AHP to determine the relative importance of competitiveness attributes. Ulengin et al. (2011) evaluated 45 countries using Data Envelopment Analysis (DEA) and Artificial Neural Network (ANN) analysis. ANN results show that the most important criteria affecting a country's efficiency score are per capita GDP and life expectancy. Focusing on these factors can thus have significant effects on increasing a nation's DEA score. Zhang et al (2011) evaluated of tourism destination competitiveness by TOPSIS and they have determined the tactics and means for the cities to improve their tourism competitiveness. Adıgüzel (2013) between the years of 2000-2011 Turkish Manufacturing Industry competitiveness measurement results for Turkey's more competitive advantage in labor-intensive sectors is available. Moreno et al. (2016) carry out an approach based on the double reference point methodology (aspiration and reservation), and calculate three alternative indices: a weak index that allows total substitutability, a strong index that measures the state of the worst component and a mixed index that is a linear combination of the first two and allows different degrees of substitutability. Comparing the resulting country ranks with regard to the GCI rank, the latter is closer to the results of the weak index than to those of the strong index. Poveda-Bautista et al. (2012) used Analytic Network Process (ANP) to set competitiveness indicators and Hong (2009) measured global competitiveness with the AHP for the tourism sector.

In the literature, there are many studies which TOPSIS method has been extended by using grey numbers. TOPSIS-G studies in different disciplines and areas are summarized below.

Lin et al. (2008a) suggested that TOPSIS-G method should be used to solve high quality group decision making (MAGDM) problems in case of insufficient information. Lin et al. (2008b) examined the problem of subcontractor performance selection in more than one period using grey numbers. In this study, Minkowsi distance was used in combining multiple period data and in removing ambiguous information. Zolfani and Antucheviciene (2012) used TOPSIS-G approach in selecting drum players for a rock band. AHP in the weighting of the specified criteria, TOPSIS-G method was used to evaluate the potential 4 candidates. Zolfani et al. (2012), in a similar study, used a model to integrate ANP and TOPSIS-G methods and examined the problem of multi-role artist selection for a rock group operating in Iran. Sadeghi et al. (2013) used the TOPSIS-G approach for the selection of business plans defined on the Balanced Score Card and Strategy Map for an enterprise. The work plan prioritization process is considered as group decision problem. In the study of the value chain performance of the tea processing process, Nyaoga et al. (2016) Performance indicators of firms were evaluated with TOPSIS-G method using grey numbers. Zare et al. (2018) used TOPSIS-G and Fuzzy VIKOR methods to select the most suitable Computerized Maintenance Management System (CMMS) for an enterprise. Zavadskas et al. (2010) compared the results obtained by using TOPSIS-G and COPRAS-G methods in risk assessment of building projects. Wang (2009) determined the most suitable candidate for R & D department using TOPSIS-G method. Zolfani et al. (2012) used SAW-G and TOPSIS-G methods in the performance evaluation of Rural Information and Technology Center (ICT) Centers operating in Iran. They used Fuzzy AHP method to determine the severity of the criteria. Zolfani et al. (2012) used Fuzzy AHP and TOPSIS-G methods to integrate to determine Ad Strategy based on product life cycle. Jiang et al. (2015) used TOPSIS-G and WOF methods to evaluate the quality of the sediment which is of great importance for the aquatic living ecosystem. Oztaysi (2014) used TOPSIS-G method integrated with AHP method in the selection of Content Management System. Jafarnejad and Salimi (2013) solved the problem of supplier selection in automotive sector by TOPSIS-G method.

2. Methodology

2.1. TOPSIS

TOPSIS is a practical and useful technique for ranking and selecting a number of possible alternatives via measuring Euclidean distances. The TOPSIS was first developed by Yoon, 1980, Hwang and Yoon, 1981. The working principle of TOPSIS is based on the fact that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution for solving MCDM problems. In short, the ideal solution is composed of all the best indices, whereas the negative ideal solution is made up of all the worst attainable indices.

2.2. TOPSIS-G

Step 1. Determining the decision attributes and describing the alternatives. Construct the decision matrix D with decision criteria, Grey number matrix D can be defined as

$$D=\begin{bmatrix} \otimes x_{11} & \cdots & \otimes x_{1m} \\ \vdots & \ddots & \vdots \\ \otimes x_{n1} & \cdots & \otimes x_{nm} \end{bmatrix} \quad i=1,...,n \quad j=1,...,m \qquad (1)$$

where $\otimes x_{ij}$ denotes the grey evaluations of the i^{th} alternative with respect to the j^{th} attribute;

Step 2. Constructing the normalized grey decision matrix. The normalized values are calculated based on the optimization direction of attributes. The normalized grey evaluations of

maximizing (benefit type) attributes are calculated with using Eq (2). For the minimizing (cost type) attributes Eq (3) used.

$$\otimes r_{ij} = \frac{\otimes x_{ij}}{\max_i \left(\overline{r}_{ij}\right)} = \left(\frac{\underline{x}_{ij}}{\max_i (\overline{x}_{ij})}; \frac{\overline{x}_{ij}}{\max_i \left(\overline{x}_{ij}\right)} \right) \quad (2)$$

$$\otimes r_{ij} = 1 - \frac{\otimes x_{ij}}{\max_i \left(\overline{r}_{ij}\right)} = \left(1 - \frac{\underline{x}_{ij}}{\max_i (\overline{x}_{ij})}; 1 - \frac{\overline{x}_{ij}}{\max_i \left(\overline{x}_{ij}\right)} \right) \quad (3)$$

where $\underline{x}_{ij}$ represents the lower limit value of the interval and $\overline{x}_{ij}$ represents the upper limit value of the interval.

Step 3. Determining weights of the attributes w_j which can be determined by attribute weight determination methods.

Step 4. Determining the positive ideal alternative A^+ and negative ideal alternative A^-. The positive and negative ideal alternatives can be defined as

$$A^+ = \left\{ \left(\max_i \overline{r}_{ij} \mid j \in J \right), \left(\min_i \underline{r}_{ij} \mid j \in J' \right) \mid i \in n \right\} = \left[r_1^+, r_2^+, \ldots, r_m^+ \right] \quad (4)$$

$$A^- = \left\{ \left(\min_i \underline{r}_{ij} \mid j \in J \right), \left(\max_i \overline{r}_{ij} \mid j \in J' \right) \mid i \in n \right\} = \left[r_1^-, r_2^-, \ldots, r_m^- \right] \quad (5)$$

$J = \{ j = 1,2,\ldots,n \mid j \text{ associated with benefit type attribute} \}$

$J' = \{ j = 1,2,\ldots,n \mid j \text{ associated with cost type attribute} \}$

Step 5. Calculating the separation measure from the positive ideal d_i^+ and negative ideal d_i^- alternatives using Eq(7) and (8)

$$d_i^+ = \sqrt{\frac{1}{2} \sum_{j=1}^{m} w_j \left[\left| r_j^+ - \underline{r}_{ij} \right|^2 + \left| r_j^+ - \overline{r}_{ij} \right|^2 \right]} \quad (6)$$

$$d_i^- = \sqrt{\frac{1}{2} \sum_{j=1}^{m} w_j \left[\left| r_j^- - \underline{r}_{ij} \right|^2 + \left| r_j^- - \overline{r}_{ij} \right|^2 \right]} \quad (7)$$

Step 6. Calculating the relative closeness index measure c_i^+, to the positive ideal alternative is expressed as

$$c_i^+ = \frac{d_i^-}{d_i^+ + d_i^-} \quad (8)$$

where $0 \le c_i^+ \le 1$ and larger the index value is the better the evaluation of alternative will be.

Step 7. Rank the preference order. Alternatives now can be ranked by the descending order of the closeness index value of c_i^+.

2.3. Rank Correlation Coefficients

The Spearman rank-order correlation is special case of Pearson's r. This index assesses the relationship between two sets of true ranked scores. r_{rank} can also be calculated by Equation 9.

$$r_{rank} = 1 - \frac{6 \sum d^2}{n^3 - n} \quad (9)$$

where d is the difference between X and Y. Also Kendall's τ coefficient, a rival of r_{rank}, assesses the relationship between two ordinal variables.

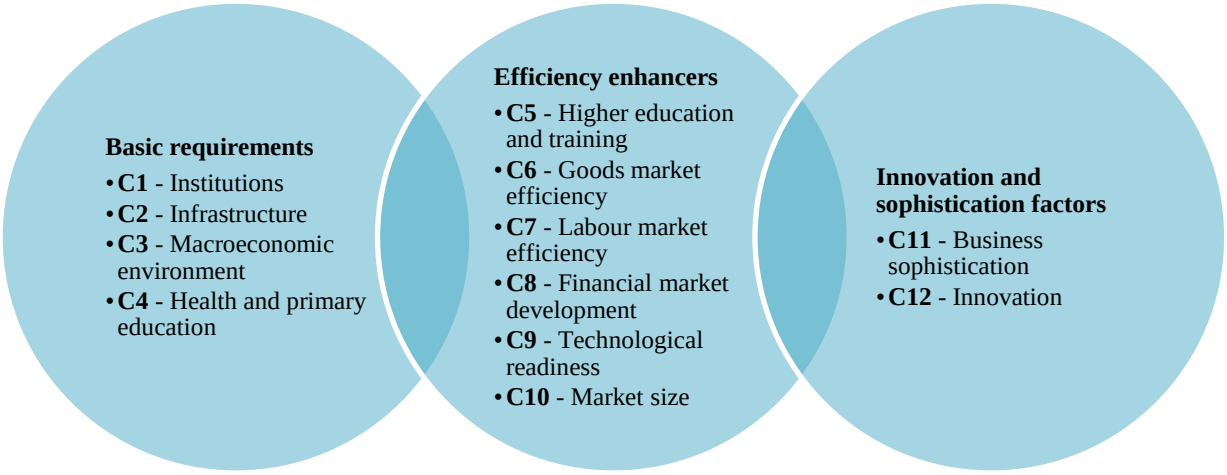
$$\tau = \frac{P - Q}{n(n-1)/2} \quad (10)$$

Let P be the number of concordant pairs and let Q be the number of discordant pairs. The sign of (P-Q) determines the direction of a relationship (Cheni Popovich, 2002). In this study Spearman and Kendall Correlation Coefficients were examined because of the data set consisted of ordinal variables.

3. Application

The Global Competitiveness Index, created by the World Economic Forum, is used in many studies evaluating competitiveness. In the application part of the study, the global competition levels of the D8 countries were examined by using the indicators of the global competition index published by WEF in 2007-2017. A set of 12 indicator benchmarks that are comprehensive in the indicators used in the calculation of the Global Competitiveness index. D8 countries constitute an alternative set of decision problems. WEF's Global Competitiveness Index is calculated 3 main headings which are Basic Requirements, Efficiency Enhancers, Innovation and Sophistication Factors, and 12 criteria used in this study are shown in Figure 1. The importance of the criteria is considered equal.

Figure 1: *Sub-indices and pillars of competitiveness*



Source: WEF

In multi-criteria decision making problems where the time dimension is included in the decision process, annual data are converted into a single decision matrix using arithmetic or geometric mean. Another approach is to analyze each year separately and make an overall evaluation based on the rankings obtained over the years. In this study using different grey decision matrix in the conversion of countries' performance over a 11-year period into a single decision matrix, grey numbers are used instead of the crisp number.

Since a certain range of operations is performed with grey numbers, errors that may arise from the calculation are minimized. This allows for more effective decision-making. It is also used in the numerical expression of situations where there is lack of information and uncertainty.

11-year data is combined into a single decision matrix to reflect the country's performance over the years as a whole. When creating the decision matrix, the mean and standard deviations of the

performance scores of the countries are calculated. The grey numbers are formed with a ± standard deviation.

For example, indicators of performance criteria for Turkey C1 are distributed with mean 3.83 and standard deviation of 0.1862 at 11 years. Here the C1 criterion of performance for Turkey in grey value is calculated as [3.643 4.016]. The integrated grey decision matrix which shows the competitive performance of the D8 countries is given Table 1.

Table 1: *Grey Decision Matrix*

Optimization Direction	Max		Max		Max		Max		Max		Max		Max		Max		Max		Max		Max		Max	
Countries [D8]	C1		C2		C3		C4		C5		C6		C7		C8		C9		C10		C11		C12	
	l	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*	*l*	*u*
Bangladesh	2,95	3,27	2,16	2,65	4,42	4,83	4,75	5,29	2,60	2,98	3,87	4,14	3,66	4,04	3,62	4,10	2,43	2,78	4,27	4,61	3,41	3,57	2,49	2,72
Egypt	3,51	4,11	3,35	3,95	2,80	3,59	5,24	5,44	3,24	3,61	3,83	4,05	3,07	3,34	3,33	3,89	3,07	3,40	4,66	4,99	3,72	3,97	2,74	3,06
Indonesia	3,87	4,13	3,20	4,34	4,95	5,73	5,30	5,72	4,01	4,47	4,28	4,71	3,78	4,42	4,13	4,49	3,15	3,67	5,14	5,60	4,31	4,55	3,54	3,94
Iran, Islamic Rep.	3,52	3,83	3,92	4,27	4,51	5,22	5,93	6,04	3,89	4,49	3,89	4,01	3,07	3,33	2,92	3,29	2,97	3,38	5,09	5,22	3,52	3,65	3,12	3,26
Malaysia	4,73	5,12	5,09	5,44	5,14	5,47	6,04	6,28	4,61	4,91	4,93	5,33	4,75	4,88	5,13	5,54	4,18	4,67	4,65	4,99	4,90	5,21	4,21	4,69
Nigeria	3,12	3,36	2,08	2,27	4,03	5,44	2,87	3,36	2,87	3,18	4,04	4,25	4,35	4,56	3,77	4,34	2,86	3,12	4,37	4,94	3,69	4,04	2,84	3,12
Pakistan	3,24	3,50	2,67	3,02	3,15	4,07	3,98	4,32	2,76	2,96	3,92	4,03	3,34	3,68	3,67	4,25	2,79	2,94	4,59	4,87	3,73	3,84	3,02	3,24
Turkey	3,64	4,02	3,89	4,55	4,61	4,93	5,41	5,77	3,94	4,61	4,34	4,57	3,43	3,68	3,94	4,37	3,68	4,29	5,12	5,40	4,05	4,34	3,16	3,40

The grey decision matrix obtained in the study was analyzed using TOPSIS method. The TOPSIS method is known for its effectiveness in decision-making processes, including fuzzy, grey, intuitistic fuzzy, hesitant fuzzy, rough set theory like system theories which can be easily integrated.

Table 2: *Separation measures and the relative closeness of each country*

Countries [*i*]	d_i^+	d_i^-	c_i^+	*Rank*
Bangladesh	1,06	0,41	0,277	7
Egypt	0,89	0,51	0,363	5
Indonesia	0,50	0,82	0,620	2
Iran, Islamic Rep.	0,78	0,71	0,478	4
Malaysia	0,19	1,30	0,870	1
Nigeria	1,05	0,42	0,284	6
Pakistan	1,00	0,28	0,220	8
Turkey	0,53	0,79	0,597	3

According to separation measures and the relative closeness of each country which summarized in Table 2, the most competitive country of D8, according to GCI indicators, is Malaysia. Indonesia follows Malaysia. Among D8 countries, Turkey ranks 3rd in the competitiveness rankings. According to the findings, the country with the lowest level of competitiveness is Pakistan.

In this study, it is aimed to measure the efficiency of the rankings obtained by TOPSIS-G method in comparison with the rankings of the annual data. Spearman and Kendall Tau correlation coefficients were used for this comparison. The relationships between the annual global competitiveness index rankings published by the World Economic forum for the D8 countries and the new ranking obtained by the TOPSIS-G method is given in Table 2 and Table 3. The aim of this part to determine how much the representation power of the new ranking is related to the actual rankings.

Table 3: *Kendall's Tau Correlation Coefficient*

	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	TOPSIS G
2017	1,000	1,000	0,929	0,929	0,929	0,714	0,929	0,929	0,619	0,619	0,619	0,786
2016	1,000	1,000	0,929	0,929	0,929	0,714	0,929	0,929	0,619	0,619	0,619	0,786
2015	0,929	0,929	1,000	1,000	1,000	0,786	0,857	0,857	0,714	0,714	0,524	0,857
2014	0,929	0,929	1,000	1,000	1,000	0,786	0,857	0,857	0,714	0,714	0,524	0,857
2013	0,929	0,929	1,000	1,000	1,000	0,786	0,857	0,857	0,714	0,714	0,524	0,857
2012	0,714	0,714	0,786	0,786	0,786	1,000	0,786	0,786	0,810	0,810	0,810	0,929
2011	0,929	0,929	0,857	0,857	0,857	0,786	1,000	1,000	0,714	0,714	0,714	0,857
2010	0,929	0,929	0,857	0,857	0,857	0,786	1,000	1,000	0,714	0,714	0,714	0,857
2009	0,619	0,619	0,714	0,714	0,714	0,810	0,714	0,714	1,000	1,000	0,810	0,905
2008	0,619	0,619	0,714	0,714	0,714	0,810	0,714	0,714	1,000	1,000	0,810	0,905
2007	0,619	0,619	0,524	0,524	0,524	0,810	0,714	0,714	0,810	0,810	1,000	0,714
TOPSIS G	0,786	0,786	0,857	0,857	0,857	0,929	0,857	0,857	0,905	0,905	0,714	1,000

When the Kendall Tau Correlation matrix is examined, it is seen that the relationship between the successive years is very strong but as the years get distant from each other, the relationship becomes weaker. For example, while the relationship between 2017 ranking and ranking in 2016 was very strong, the ranking in 2007 was very low in the ranking in 2017. On the other hand, when the relationship between the new ranking obtained with TOPSİS-G and the ranking published by the World Economic Forum every year, the difference between the correlation coefficient is not high. The relationship between the ranking of TOPSIS-G and the rankings observed in 2007-2017 ranged from 71% to 93%, The relationship between the rankings published by WEF for 2007 and 2017 ranges from 61% to 100%.

Table 4: *Spearman Rank Correlation Coefficient*

	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	TOPSİS G
2017	1,000	1,000	0,976	0,976	0,976	0,857	0,976	0,976	0,750	0,750	0,750	0,881
2016	1,000	1,000	0,976	0,976	0,976	0,857	0,976	0,976	0,750	0,750	0,750	0,881
2015	0,976	0,976	1,000	1,000	1,000	0,905	0,952	0,952	0,786	0,786	0,714	0,929
2014	0,976	0,976	1,000	1,000	1,000	0,905	0,952	0,952	0,786	0,786	0,714	0,929
2013	0,976	0,976	1,000	1,000	1,000	0,905	0,952	0,952	0,786	0,786	0,714	0,929
2012	0,857	0,857	0,905	0,905	0,905	1,000	0,905	0,905	0,929	0,929	0,893	0,976
2011	0,976	0,976	0,952	0,952	0,952	0,905	1,000	1,000	0,857	0,857	0,857	0,929
2010	0,976	0,976	0,952	0,952	0,952	0,905	1,000	1,000	0,857	0,857	0,857	0,929
2009	0,750	0,750	0,786	0,786	0,786	0,929	0,857	0,857	1,000	1,000	0,929	0,964
2008	0,750	0,750	0,786	0,786	0,786	0,929	0,857	0,857	1,000	1,000	0,929	0,964
2007	0,750	0,750	0,714	0,714	0,714	0,893	0,857	0,857	0,929	0,929	1,000	0,857
TOPSİS G	0,881	0,881	0,929	0,929	0,929	0,976	0,929	0,929	0,964	0,964	0,857	1,000

The Spearman correlation coefficients are also very similar to Kendall Tau. However, here the range of correlation coefficients is narrower. The relationship between the ranking of TOPSIS-G and the rankings observed in 2007-2017 ranged from 86% to 98%, The relationship between the rankings published by WEF for 2007 and 2017 ranges from 75% to 100%.

4. Conclusion

Increasing Research & Development activities and adoption of technology intensive methods will give the economy a great acceleration and accordingly increase in competitiveness is inevitable. In this study, the competitiveness level of the D8 countries was analyzed by the TOPSIS-G method by converting the 11-term GCI data to grey numbers. The mean and standard deviations of the yearly performance scores of the countries were calculated. And a standard deviation above the mean and a standard deviation below the mean formed the limits of the grey number. In this study, the competitiveness levels of the countries were analyzed by TOPSIS method using grey decision matrix. The results showed that the highest level of competitiveness country, while Malaysia, Turkey was ranked in 3rd. The country with the lowest competitiveness is Pakistan.

To measure the effectiveness of the country ranking according to the TOPSIS-G results, annual GCI rank of countries and TOPSIS-G's rank correlation analysis was performed. When Spearman Rank Correlation and Kendall Tau correlation coefficients were examined, it was found that TOPSIS-G rankings were closely related to all years. The relationship between the ranking of TOPSIS-G and the ranking of the World Economic Forum was investigated by Spearman-Rank correlation coefficient and Kendall Tau nonparametric correlation coefficients. In this respect, it can be said that TOPSIS-G results reflect the ranking of D8 countries in all years.

When using the TOPSIS-G method, the criteria of the decision matrix were considered equal. In the following studies, it can be suggested that the importance degree of the criteria should be determined by the MCDM methods such as AHP, ANP, DEMATEL then included in the decision process. Also outranking methods like VIKOR, ELECTRE, PROMETHEE can be expanded with grey numbers and analyzes can be repeated comparatively.

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