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RESEARCH ARTICLE

Assessment of Global Competitiveness Performance of G20 Countries with Two-Stage Analytical Method

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ABSTRACT

With globalization, the structure of competition conditions has changed considerably, and countries have had to maintain their leadership in different areas in order to stand out. Objective assessment tools are needed for countries to better assess and evaluate their position relative to each other in the face of fierce competitiveness. International competitiveness indices are important measures that help to achieve strategic objectives more effectively.

In this study, the Global Sustainable Competitiveness Index (GCI) performances of G20 countries, including Turkey, are evaluated using a practical two-stage entropy-based Simple additive weighting (SAW) method to obtain a consistent result. Firstly, the criteria were weighted using the entropy method and then the countries were ranked by descending order of GCI scores using the SAW method. The most influential indices on sustainable competitiveness performance are resource intensity index, intellectual capital and social capital, while governance index has the lowest impact. The United Kingdom, Japan and Germany had the best sustainable competitiveness performance among G20 countries. Saudi Arabia ranked last among G20 countries, while Turkey ranked 14th.

Keywords: Sustainability, Global Competitiveness Index, Entropy, SAW

1. Introduction

Sustainable competitiveness is the ability to maintain or enhance current levels of prosperity without reducing it in the future. Sustainable competitiveness can be described as the ability to generate and preserve general success without undermining the potential to sustain or improve future prosperity (Thore and Tarverdyan, 2016). The Global Sustainable Competitiveness Index (GSCI) expands on the traditional concept of competitiveness by incorporating sustainability factors (Solability, 2023). Each year, the Sustainable Competitiveness Index leads the way in determining and reporting to the world the ranking of countries in terms of development, innovation, sustainability, and social responsibility.

The Global Competitiveness Index (GCI), created by the World Economic Forum (WEF), is designed to measure the competitiveness of nations within the global economy (WEF, 2019). It assesses the determinants that influence a country's financial performance and commercial activities (Qazi, 2023). The GCI relies on statistics collected through surveys of professionals, managers, and experts, evaluating key areas such as infrastructure, macroeconomic strength, health, education, and market productivity (Benítez-Márquez et al., 2022). The goal of the index is to offer a comprehensive understanding of a country's strengths and challenges in fostering a conducive environment for business and economic development. Its main objective is to evaluate the environmental, social, and governance performance of nations, assessing how they manage natural resources, encourage social well-being, and implement effective governance (Ng et al., 2023). It considers an extensive range of signs across various measurements, comprising economic sustainability, environmental stewardship, social capital, and governance, among others (Kostakis et al., 2023).

Numerous studies have highlighted the importance of separate competitiveness pillars, such as intellectual capital (Alvino et al., 2021), governance (Omri and Ben Mabrouk, 2020), and social capital (Mishchuk et al., 2023), in fostering national growth and sustainability. However, few have examined the connection between international competitiveness components and sustainable development, with some identifying "innovation capability," "skills," and "labor market" as essential factors (Qazi, 2024). These studies, however, often fail to integrate competitiveness pillars through the sustainability framework suggested by SolAbility (Solability, 2023), often taking a fragmented approach. Additionally, the relative significance of the pillars of sustainable competitiveness has yet to be fully explored. Notably, no research has modeled these pillars within a probabilistic network framework that captures their potential relationships. While some recent studies have examined

interdependencies between global competitiveness pillars, they generally do not focus specifically on the sustainability-based aspects of these pillars (Qazi, 2023, 2024).

This research is motivated by the urgent need to comprehend and calculate the criteria of sustainable competitiveness, which form the foundation for a nation's longstanding financial and social well-being. Although the significance of these components is broadly recognized, there is a critical gap in quantitatively assessing their individual contributions and the complex relationships between them. The goal of this study is to provide policymakers with valuable insights for resource share and to enable scholars to further investigate the sub-components related to the key pillars specified here. By measuring the relative importance of each pillar and its interconnections, this research seeks to deepen our understanding of the main determinants of sustainable competitiveness, thereby supporting more informed and strategic decision-making in the pursuit of national prosperity.

In this study, the Entropy-Based Simple additive weighting (SAW) method provides a robust framework for evaluating and comparing the global competitive performance of G20 countries, offering insights into their relative strengths and weaknesses across multiple dimensions. The entropy method provides an objective way to assign weights to indicators based on their information content, rather than arbitrary or subjective choices. The SAW method aggregates multiple indicators, allowing for a holistic assessment of competitiveness. The method can be adapted to different sets of countries and indicators, making it widely applicable.

The structure of the paper is as follows: Section 2 provides a concise review of the relevant literature and background of global sustainable competitiveness. Section 3 outlines the research methodology, while Section 4 provides the findings and discusses their implications. Finally, Section 5 addresses the study's conclusion and future directions.

2. Background of Global Sustainable Competitiveness

The Global Competitiveness Index and the World Competitiveness Index have been criticized for being insufficiently objective due to the qualitative data on which they are based, insufficient sample size in some countries, and focusing on economic factors rather than sustainability (Mate et al., 2022). To address this gap, an independent organization called Solability has developed a new tool that measures the sustainable competitiveness performance of countries by combining six different indices. This tool, called the Global Sustainable Competitiveness Index (GSCI), has been accepted by researchers and practitioners and has become one of the main tools used to measure the sustainable competitiveness performance of countries (Solability, 2023).

Since it is based on comparable and measurable performance data gathered by international organizations, the GCI is free from any subjectivity. While other indices focus on development, the GCI focuses on green development (Solability, 2023). The superiority of the GCI is its inherent focus on sustainability and its basis as an index, along with each of its sub-dimensions, on a sustainability philosophy.

GCI is designed to offer insights into a country's strengths and weaknesses regarding its capacity to foster a promising environment for business development and economic progress. It assesses the factors that influence a country's economic competitiveness and business context. The GSCI is organized into six key development pillars: natural capital, resource efficiency, social capital, intellectual capital, economic sustainability, and governance (Solability, 2023). It uses only quantitative data, drawing on indicators from trusted global sources like the World Bank, various United Nations agencies, and the International Monetary Fund (IMF) (Benítez-Márquez et al., 2022). The indicators within each pillar are assigned weights and combined to form a total score for each country, which is then applied to rank nations based on their sustainable competitiveness. The sustainable competitiveness index is built upon six equally important pillars as follows:

• Natural Capital: The inherent natural environment, containing resource availability and the extent of resource depletion.

• Resource Efficiency: The effectiveness of utilizing available resources, serving as a measure of operational competitiveness in a world with limited resources.

• Social Capital: Factors such as health, security, freedom, equality, and life satisfaction, all of which support development.

• Intellectual Capital: The ability to create wealth and employment through innovation and value-added businesses in a globalized market.

• Economic Sustainability: Reflects the capacity to create wealth through sustainable economic practices that fully leverage available potential.

• Governance Performance: The creation of a framework that ensures long-term and sustainable wealth generation through the allocation of resources, infrastructure development, and guidance of market and employment structures.

Figure 1 illustrates the sustainable competitiveness model with its components.

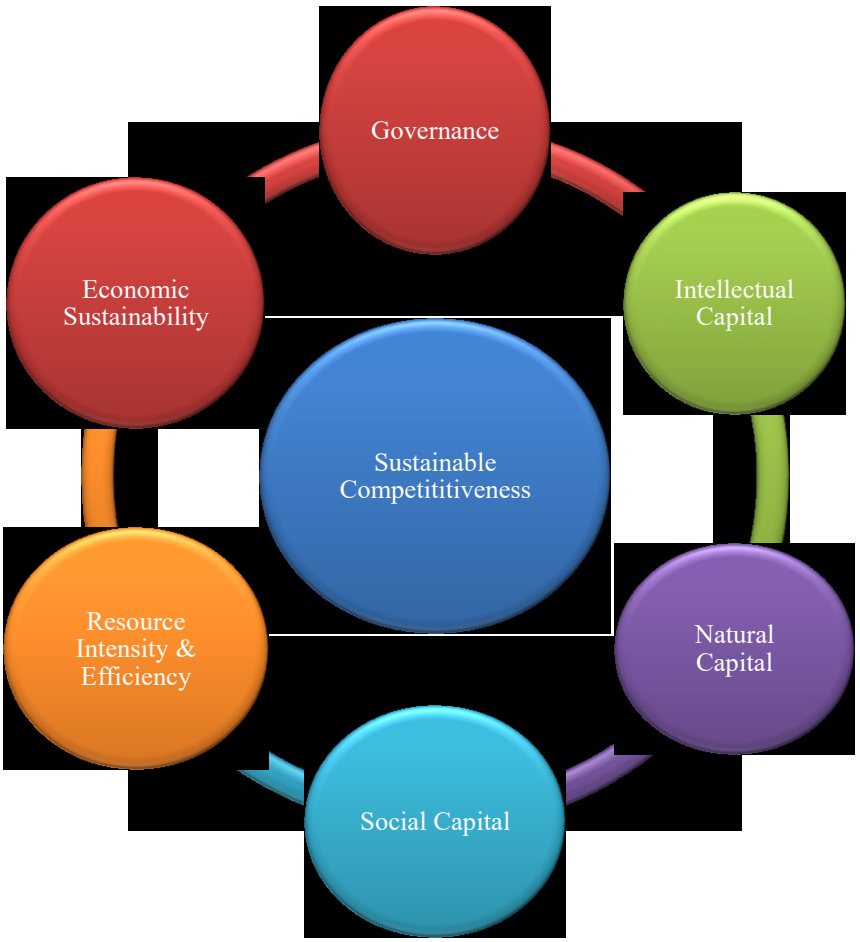

Figure 1. The sustainable competitiveness model

According to the literature review, some important studies on the subject were identified. Demir (2020) aimed to evaluate the effectiveness of countries' innovation outputs on their ability to build competitiveness by using the panel stochastic frontier analysis method. Using data for the 2003-2015 period, the study concluded that innovation outputs have increased over the years in terms of the competitiveness variable. In line with the analysis, it is concluded that Germany, China, Malaysia, Mexico, and Singapore are the five most effective countries in the world in terms of the contribution of innovation outputs to competitiveness.

Sergi et al. (2021) used linear regression and ANOVA methods in their study examining the impact of the subcomponents of the Global Competitiveness Index on the Logistics Performance Index. In the model where the logistics performance index is the dependent variable, it was concluded that the human factor, infrastructure, and institutions sub-variables have a central role in the logistics development for countries. Stating that the key to increasing the international competitiveness of countries is the production and export of high-tech products that are in demand in international markets, Konak (2018) stated that the export revenues obtained in this way are critical for the economic growth, development and economic future of countries. The study compares the size and productivity of Turkey's exports of high-tech products to those of certain OECD countries and finds that Turkey lags far behind other OECD countries.

Auzina-Emsina (2014) investigated the impact of changes in labor productivity on global competitiveness for countries experiencing economic crisis. Although the findings of the study show that there is a weak or no relationship between productivity growth and economic growth in the pre-crisis period and the first post-crisis period, the study concludes that productivity growth during the crisis period creates a driving force by creating a leverage effect in the country's economy after a while.

In the literature search, there is no study analyzing the competitiveness performance of G20 countries with a two-stage analytical approach. In this respect, the study is expected to contribute to researchers working on this subject.

3. Methodology

In this section, first, the Entropy method and then the SAW method are explained.

3.1 Entropy Method

The concept of entropy is employed in diverse scientific areas (e.g., physics, chemistry, mathematics, and information theory), and in information theory, this concept plays an important role in determining the ambiguity related to arbitrary occurrences of the expected information content. The Entropy technique is used to calculate the relative ranking of criteria based on the Decision Matrix (DM) produced from the hierarchical model. The basic steps of the Entropy method are summarized as follows:

Step 1 – Building the decision matrix.

$$\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}_{m*n}$$

where x_{ij}: The success value of alternative i according to criterion j, i = 1,2, …, m and j = 1,2, …, n.

Step 2- Normalization of decision matrix.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{j} x_{ij}}$$

where r_{ij} is the normalized value of the criteria/sub-criteria rate

Step 3- Obtaining entropy values of the criteria.

The entropy value measures the degree of uncertainty among the set of alternatives in the DM when no choice can be made between the criteria

$$e_j = -k \sum_{j=1}^{n} r_{ij} \ln(r_{ij}) \qquad i = 1 \ldots m \; j = 1 \ldots n$$

$$k = 1/\ln(m)$$

where k is the entropy constant, e_j is entrophy value

Step 4- Calculating the degree of diversification based on the entropy values.

$$d_j = 1 - e_j$$

Step 5-Measurement of entropy criteria weights.

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_j}$$

$$\sum_{i=1}^{n} w_j = 1$$

where w_j is the degree of importance of criterion j.

3.2 SAW Method

The Simple Additive Weighting (SAW) method, also referred to as the weighted addition method, involves calculating a weighted sum of the performance ratings for each alternative across all attributes. The SAW method involves normalizing the decision matrix (X) to a scale that allows for comparison with the ratings of all available alternatives. In the SAW method, the global (total) score is calculated by summing the contributions from each attribute. The value (global score) of an alternative can be represented as:

$$\boldsymbol{V(a_i) = V_i = \sum_{j=1}^{n} w_j r_{ij}}$$

where V_i represents the ranking of each alternative, w_j denotes the weighted value of each criterion, and r_{ij} is the normalized performance rating. A higher V_i value signifies a preference for alternative A_i.

4. Application of The Method

This research aims to evaluate the sustainable competitive performance of G20 countries by using the entropy-based SAW method. The aim of the research is to provide insights to researchers and practitioners by evaluating the global sustainable competitive performance of G20 countries, including Turkey. One of the possible benefits of competitiveness indices is that they contain clues shed light on strategic managerial decisions. In addition, to reach more useful results, comparisons are made between G20 countries in this study.

The performance scores obtained from Solability for 2023 are used, first the sub-indices are weighted by the entropy method, and then the countries are ranked according to their GCI scores using the SAW method. Thus, it is believed that an original study in which the hybrid method is applied has contributed to the literature. Table 1 provides GCI values for G20 countries obtained from Solability.

Table 1. Decision matrix (GCI values for 2023 year) (Solability)

Country	Natural capital	Resource Intensity	Social capital	Intellectual capital	Economic Sustainability	Governance
Japan	42.848	42.146	63.620	68.648	49.022	65.241
Germany	40.520	47.421	55.331	65.200	53.282	68.526
United Kingdom	45.860	57.963	53.793	65.222	46.219	59.894
France	45.910	49.786	57.195	61.582	46.650	65.162
South Korea	35.858	33.957	59.119	75.223	48.694	66.291
Canada	59.324	44.716	52.298	55.726	43.352	63.370
Italy	45.447	45.248	58.946	57.414	46.324	60.566
Australia	46.235	52.675	51.713	53.456	42.626	67.027
China	40.613	34.759	51.399	68.768	51.991	58.530
USA	50.639	42.620	42.469	64.562	49.853	55.180
Argentina	52.145	42.016	49.214	41.834	45.503	54.109
Russia	58.269	29.166	43.121	53.295	46.333	52.010
Turkey	45.910	26.845	39.415	58.571	49.891	51.030
Brazil	59.172	41.962	35.896	41.901	40.047	49.939
Indonesia	45.509	32.172	49.784	40.351	34.825	54.053
Mexico	43.259	33.420	36.994	42.069	43.462	47.672
India	41.547	36.626	40.380	39.869	32.163	50.674
Saudi Arabia	42.670	25.773	44.144	43.581	31.144	51.699
South Africa	43.096	34.451	32.405	43.451	32.837	51.441

Table 2 shows the normalized decision matrix.

Table 2. Normalized Decision matrix

Country	Natural capital	Resource Intensity	Social capital	Intellectual capital	Economic Sustainability	Governance
Japan	0.0484	0.0559	0.0694	0.0660	0.0588	0.0597
Germany	0.0458	0.0629	0.0603	0.0626	0.0639	0.0627
United Kingdom	0.0518	0.0769	0.0586	0.0627	0.0554	0.0548
France	0.0519	0.0661	0.0624	0.0592	0.0559	0.0596
South Korea	0.0405	0.0451	0.0645	0.0723	0.0584	0.0607
Canada	0.0670	0.0593	0.0570	0.0535	0.0520	0.0580
Italy	0.0514	0.0600	0.0643	0.0552	0.0555	0.0554
Australia	0.0523	0.0699	0.0564	0.0514	0.0511	0.0614
China	0.0459	0.0461	0.0560	0.0661	0.0623	0.0536
USA	0.0572	0.0565	0.0463	0.0620	0.0598	0.0505
Argentina	0.0589	0.0557	0.0537	0.0402	0.0545	0.0495
Russia	0.0659	0.0387	0.0470	0.0512	0.0555	0.0476
Turkey	0.0519	0.0356	0.0430	0.0563	0.0598	0.0467
Brazil	0.0669	0.0557	0.0391	0.0403	0.0480	0.0457
Indonesia	0.0514	0.0427	0.0543	0.0388	0.0417	0.0495
Mexico	0.0489	0.0443	0.0403	0.0404	0.0521	0.0436
India	0.0470	0.0486	0.0440	0.0383	0.0386	0.0464
Saudi Arabia	0.0482	0.0342	0.0481	0.0419	0.0373	0.0473
South Africa	0.0487	0.0457	0.0353	0.0418	0.0394	0.0471

Table 3 shows the entropy values of the decision matrix.

Table 3. Entropy values

Country	Natural capital	Resource Intensity	Social capital	Intellectual capital	Economic Sustainability	Governance
Japan	-0.147	-0.161	-0.185	-0.179	-0.167	-0.168
Germany	-0.141	-0.174	-0.169	-0.174	-0.176	-0.174
United Kingdom	-0.153	-0.197	-0.166	-0.174	-0.160	-0.159
France	-0.154	-0.179	-0.173	-0.167	-0.161	-0.168
South Korea	-0.130	-0.140	-0.177	-0.190	-0.166	-0.170
Canada	-0.181	-0.168	-0.163	-0.157	-0.154	-0.165
Italy	-0.152	-0.169	-0.176	-0.160	-0.161	-0.160
Australia	-0.154	-0.186	-0.162	-0.152	-0.152	-0.171
China	-0.141	-0.142	-0.161	-0.180	-0.173	-0.157
USA	-0.164	-0.162	-0.142	-0.172	-0.168	-0.151
Argentina	-0.167	-0.161	-0.157	-0.129	-0.159	-0.149
Russia	-0.179	-0.126	-0.144	-0.152	-0.161	-0.145
Turkey	-0.154	-0.119	-0.135	-0.162	-0.168	-0.143
Brazil	-0.181	-0.161	-0.127	-0.129	-0.146	-0.141
Indonesia	-0.153	-0.135	-0.158	-0.126	-0.133	-0.149
Mexico	-0.148	-0.138	-0.129	-0.130	-0.154	-0.137
India	-0.144	-0.147	-0.137	-0.125	-0.126	-0.142
Saudi Arabia	-0.146	-0.115	-0.146	-0.133	-0.123	-0.144
South Africa	-0.147	-0.141	-0.118	-0.133	-0.127	-0.144

Table 4 provides a summary of entropy, weight values, and their rankings. The most important criterion is resource intensity, followed by intellectual capital and social capital.

Economic sustainability, natural capital and governance were found to be the 4th, 5th and 6th most important factors respectively.

Table 4. Entropy and weight values of factors

Entropy	0.997	0.992	0.994	0.993	0.996	0.998
Weight	0.104	0.266	0.185	0.237	0.133	0.075
Ranks	5	1	3	2	4	6

After obtaining the criteria weights using the Entropy method, alternatives were made by assigning six important criteria according to the importance of the weights obtained using the SAW method in the second stage. In the SAW method, after linear normalization of the decision matrix, the weights obtained from the Entropy are multiplied and are then sorted in descending order according to the value obtained to rank the alternatives (in Table 6). Table 5 presents the obtained entropy-based SAW scores.

Table 5. Entropy based SAW results

Weights	0.104	0.266	0.185	0.237	0.133	0.075	SAW Values	Rank
Japan	0.722	0.727	1	0.912	0.920	0.952	0.863	2
Germany	0.683	0.818	0.869	0.866	1	1	0.863	3
United Kingdom	0.773	1	0.845	0.867	0.867	0.874	0.889	1
France	0.773	0.858	0.899	0.818	0.875	0.950	0.857	4
South Korea	0.604	0.585	0.929	1	0.913	0.967	0.821	5
Canada	1	0.771	0.822	0.740	0.813	0.924	0.814	8
Italy	0.766	0.780	0.926	0.763	0.869	0.883	0.821	6
Australia	0.779	0.908	0.812	0.710	0.800	0.978	0.821	7
China	0.684	0.599	0.807	0.914	0.975	0.854	0.790	10
USA	0.853	0.735	0.667	0.858	0.935	0.805	0.796	9
Argentina	0.878	0.724	0.773	0.556	0.854	0.789	0.731	11
Russia	0.982	0.503	0.677	0.708	0.869	0.758	0.701	12
Turkey	0.773	0.463	0.619	0.778	0.936	0.744	0.683	14
Brazil	0.997	0.723	0.564	0.557	0.751	0.728	0.687	13
Indonesia	0.767	0.555	0.782	0.536	0.653	0.788	0.645	15
Mexico	0.729	0.576	0.581	0.559	0.815	0.695	0.629	16
India	0.700	0.631	0.634	0.530	0.603	0.739	0.619	17
Saudi Arabia	0.719	0.444	0.693	0.579	0.584	0.754	0.592	19
South Africa	0.726	0.594	0.509	0.577	0.616	0.750	0.602	18

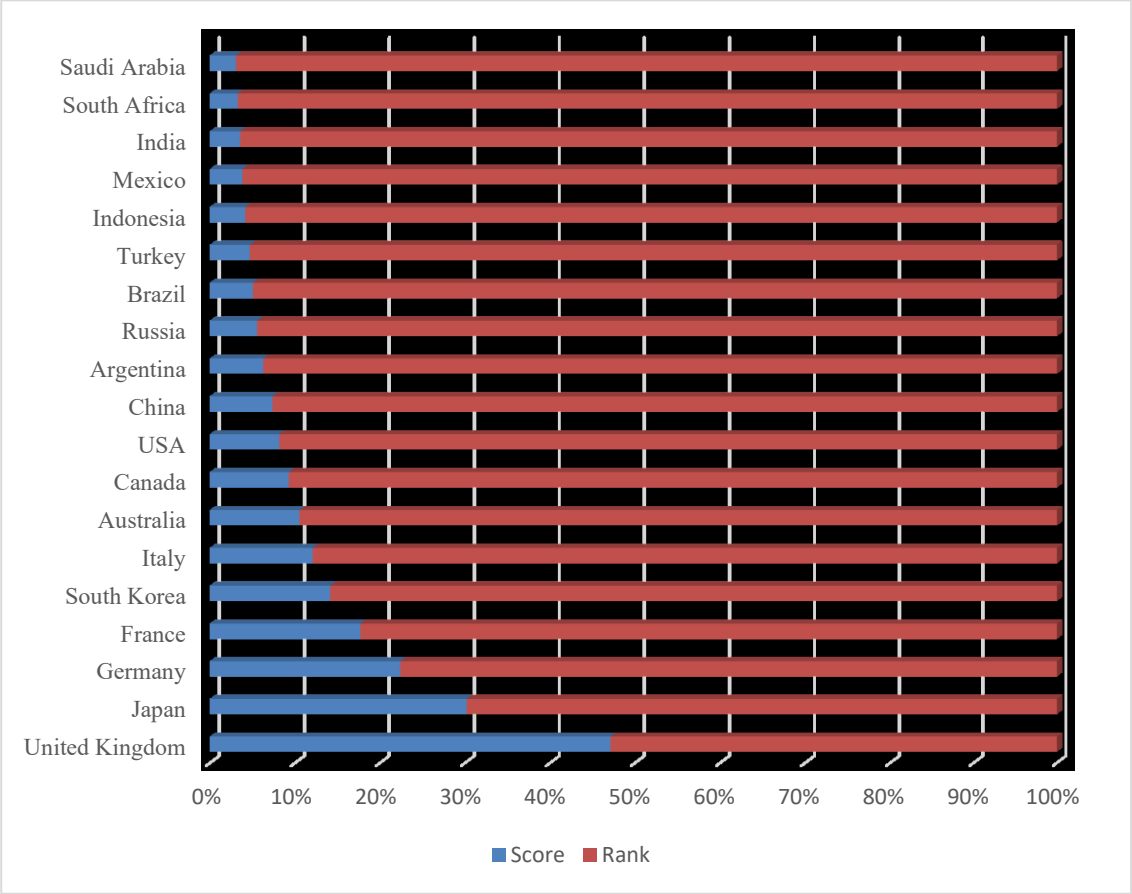

Figure 2. Ranks of the G20 countries using column graph

The results of G20 countries are shown in bar charts and radar charts in ascending order.

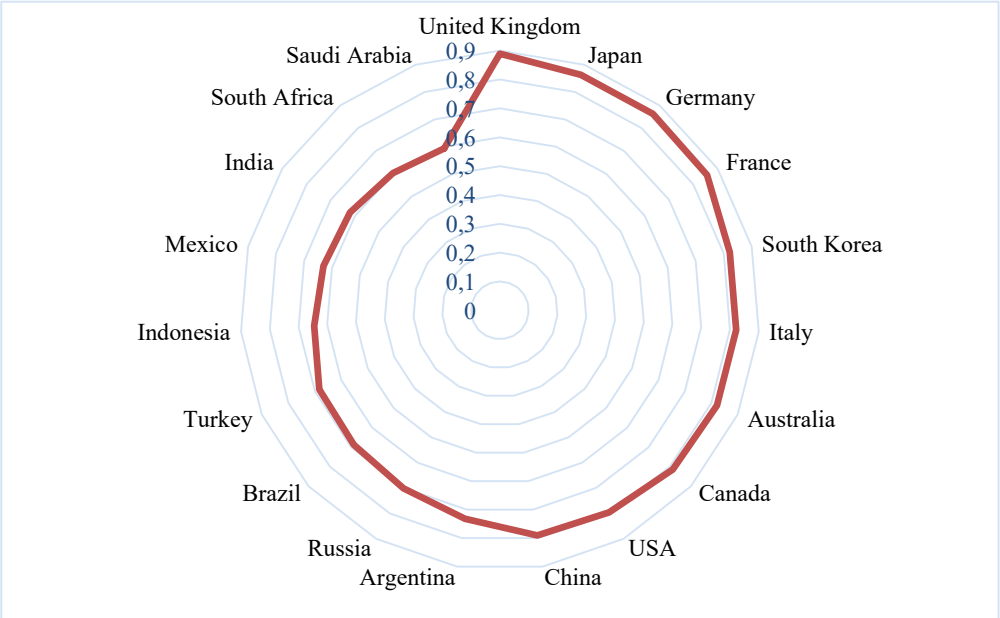

Figure 3. Ranks of the G20 countries using radar graph

Table 6 presents the comparison between the Entropy-weighted SAW method and GCI scores to provide a comprehensive perspective.

Table 6. Comparison results

GCI		**Entropy weighted SAW**	
Country	**Rank**	**Country**	**Rank**
Japan	1	United Kingdom	1
Germany	2	Japan	2
United Kingdom	3	Germany	3
France	4	France	4
South Korea	5	South Korea	5
Canada	6	Italy	6
Italy	7	Australia	7
Australia	8	Canada	8
China	9	USA	9
USA	10	China	10
Argentina	11	Argentina	11
Russia	12	Russia	12
Turkey	13	Brazil	13
Brazil	14	Turkey	14
Indonesia	15	Indonesia	15
Mexico	16	Mexico	16
India	17	India	17
Saudi Arabia	18	South Africa	18
South Africa	19	Saudi Arabia	19

As can be seen from Table 6, the United Kingdom, Japan and Germany emerge as the top three most important G20 countries in the Entropy-weighted SAW method. On the other hand, India, South Africa, Saudi Arabia have emerged as the last-ranked G20 countries. According to the GCI results, Japan, Germany, and the United Kingdom are the top three G20 countries, while India, Saudi Arabia, and South Africa are ranked in the bottom three. Comparing the results of the methodology yields similar rankings. In the results, the United Kingdom, Japan, and Germany are the most important G20 countries ranked in the top three in both methods, while South Africa and Saudi Arabia are ranked last as the least important G20 partners. As can be seen in the comparison table, the analysis yields very similar results. Turkey ranks 13th according to the GCI score assessment and 14th in the entropy-based SAW method.

5. Conclusions and Future Directions

The GCI methodology, developed by Solability, to measure the competitive performance of countries in terms of global competition and sustainability is a composite index consisting of six sub-indices. Measuring sustainable competitiveness, the GCI obtains the quantitative data it needs from institutional sources such as the World Bank, the IMF and various UN agencies

In this study. A more objective and consistent assessment is achieved through a two-stage integrated approach instead of averaging the six factors included in the GCI score calculation provided by Solability. In this study, Entropy and SAW methods were used to achieve objective analysis in a multidimensional direction. Initially, the importance levels (weights) of the criteria to be used in the comparison were determined by the Entropy method, and then the competitive rankings of the countries were established using the SAW method with the criteria weights.

In order for Turkey to rank higher in competitive performance comparisons, authorities need to take into account the competitive performance of other countries. The government needs to give importance to the three most important criteria used in the comparison (resource intensity, intellectual capital and social capital indices); in this context, resource intensity needs to be improved with some incentives and infrastructure works.

While many parameters such as real exchange rates, wage movements, and relative prices affect competitiveness, the most fundamental condition for a country's long-term competitiveness to be sustainable is closely related to the structural reforms that the country will make in technology and productivity. Productivity growth is related to a number of factors such as education, skilled labor and the country's technology production capacity. In this context, for a country to maintain its competitiveness, it must focus on productivity growth and ensure technological transformations.

For future research, methods that include more criteria and alternatives, and integrate different fuzzy approaches can be used to evaluate a wider range of aspects. Furthermore, examining other important factors such as digital transformation, data analytics, education policies, society 5.0, and infrastructure investments will aid in determining strategies to increase the competitiveness of countries.

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