International Journal of Business & Economic Studies
Year: 2025, Vol: 7, No: 1, pp.33-55
https://doi.org/10.54821/uiecd.1618200

Analysis of Business Sophistication Performance in G7 Countries: An Application of the MIEXCF-based CODAS Method

G7 Ülkelerinde İş Dünyası Sofistikasyonu Performansının Analizi: MIEXCF Tabanlı CODAS Yöntemi Uygulaması

Furkan Fahri ALTINTAŞ
Asst. Prof. Dr., Aydın Provincial Gendarmerie Command
furkanfahrialtintas@yahoo.com
https://orcid.org/ 0000-0002-0161-5862

Received : 12.01.2025
Revised : 10.03.2025
Accepted : 14.03.2025
Type of Article : Research

Keywords:
Business Sophistication,
G7,
MIEXCF,
MIEXCF-Based CODAS
Jel Codes:
F29, M19, C44

ABSTRACT

The business sophistication (BS) performance of major economies significantly influences global BS and the global economy. Consequently, analyzing the BS performance of these economies is crucial. Therefore, the aim of this study is to evaluate the BS performance of G7 countries using the MIEXCF-based CODAS method, based on the most recent Global Innovation Index - Business Sophistication (GII-BS) criteria. Empirical findings reveal that "Knowledge Workers" and "Knowledge Absorption" are the most significant criteria for countries, according to the MIEXCF method. Therefore, G7 countries should place greater emphasis on the "Knowledge Workers" and "Knowledge Absorption" BS criteria to make a greater contribution to global business development and the economy. Furthermore, the BS performance of countries was measured using the MIEXCF-based CODAS method, and the performance rankings were determined as follows: USA, Japan, UK, France, Germany, Canada, and Italy. Additionally, the study calculated the average BS performance value, and it was found that Germany, Canada, and Italy had below-average BS performance values. Therefore, it is concluded that these countries need to improve their BS performance to contribute more to global BS and the global economy. Methodologically, sensitivity, comparative, and simulation analyses indicate that the MIEXCF-based CODAS method can be effectively used to measure the BS performance of countries using the GII-BS criteria.

Anahtar Kelimeler:
İş Gelişmişliği,
G7,
MIEXCF,
MIEXCF Tabanlı CODAS
Jel Kodları:
F29, M19, C44

ÖZET

Büyük ekonomilerin iş dünyası sofistikasyonu (BS) performansı, küresel BS ve küresel ekonomi üzerinde önemli bir etkiye sahiptir. Bu nedenle, bu ekonomilerin BS performanslarının analiz edilmesi kritik bir öneme sahiptir. Dolayısıyla bu çalışmanın amacı G7 ülkelerinin BS performansını, en güncel Küresel İnovasyon Endeksi-İş Dünyası Sofistikasyonu (GII-BS) kriterlerine dayalı olarak MIEXCF tabanlı CODAS yöntemiyle ölçmektedir. Ampirik bulgular, MIEXCF yöntemine göre "Bilgi İşçileri" ve "Bilgi Emme" kriterlerinin ülkeler için en önemli kriterler olduğunu ortaya koymaktadır. Bu nedenle, G7 ülkelerinin, küresel iş dünyası gelişimine ve ekonomiye daha büyük katkı sağlamak için "Bilgi İşçileri" ve "Bilgi Emme" BS kriterlerine daha fazla önem vermesi gerekmektedir. Ayrıca, MIEXCF tabanlı CODAS yöntemi kullanılarak ülkelerin BS performansları değerlendirilmiş ve performans sıralaması şu şekilde belirlenmiştir: ABD, Japonya, Birleşik Krallık, Fransa, Almanya, Kanada ve İtalya. Çalışma ayrıca ortalama BS performans değerini hesaplamış ve Almanya, Kanada ve İtalya'nın ortalama BS performans değerinin altında kaldığını ortaya koymuştur. Bu nedenle, bu ülkelerin küresel BS ve küresel ekonomiye daha fazla katkıda bulunabilmek için BS performanslarını iyileştirmesi gerektiği sonucuna varılmıştır. Metodolojik olarak, duyarlılık, karşılaştırmalı ve simülasyon analizleri, MIEXCF tabanlı CODAS yönteminin GII-BS kriterlerini kullanarak ülkelerin BS performansını ölçmede etkili bir şekilde kullanılabileceğini doğrulamaktadır.

Suggested Citation: Altıntaş, F. F. (2025). Analysis of business sophistication performance in G7 countries: an application of the MIEXCF-based CODAS method. *International Journal of Business and Economic Studies*, 7(1), 33-55, Doi: https://doi.org/10.54821/uiecd. 1618200

1. INTRODUCTION

Assessing a nation's business sophistication (BS) is crucial for understanding its global competitiveness and developing strategies for sustainable growth (Schwab & WEF, 2019). BS encompasses productivity, innovation, labor efficiency, and firm competitiveness (WIPO, 2022), making it a key indicator of economic well-being. It aids policymakers in crafting effective economic policies and supports businesses in making informed investment decisions and integrating into global value chains (Kindersley, 2018). By identifying a nation's strengths and weaknesses, BS benchmarks are vital in recognizing competitive advantages and promoting long-term prosperity (Joshi & Klein, 2018).

BS performance of G7 nations, key players in global trade, finance, and innovation (Oldani & Wouters, 2018), has significant implications for the global economy. The BS of these countries not only influences their own economic growth and competitiveness but also impacts the business performance of other nations (Fälth & Rañola, 2021). Success in G7 business development can enhance global business environments and innovation capacities, making BS performance a critical indicator of global economic health (Hajnal, 2020).

This research employed the MIEXCF-based CODAS Multi-Criteria Decision Making (MCDM) method to evaluate the BS performance of G7 countries using the BS criteria from the latest 2023 Global Innovation Index (GII-BS). The primary motivation behind this study was to identify the specific BS criteria that G7 countries should prioritize to foster positive contributions to global business and the economy. Secondly, the research aimed to determine which G7 country or countries needed to enhance their BS performance to drive global business and economic growth. Finally, the study sought to assess the feasibility of using the MIEXCF-based CODAS method with GII-BS data to measure the BS performance of G7 countries.

A comprehensive review of the BS literature revealed an absence of studies employing any MCDM method to evaluate the BS performance of countries. Consequently, given its novel subject matter and methodology, this study is considered to be a contribution to the field of BS research. As such, it is expected to make significant contributions to both the business sophistication and MCDM literatures. The literature review section of the study provides a detailed overview of business sophistication and related research, while the methodology section outlines the research design. In the results and discussion section, a quantitative analysis of the findings is presented, followed by a comprehensive discussion.

2. LITERATURE REVIEW

BS encompasses all activities aimed at fostering growth, profitability, and market strength (Cherunilam, 2015; Daum, 2020). The literature offers various perspectives on BS (Spender, 2014). Strategically, BS involves implementing effective organizational strategies for improved business performance (Siegfried, 2021; Hermanni, 2022). Operationally, it focuses on process improvement and cost efficiency (Brown et al., 2018; Robosky, 2023). Financially, BS emphasizes profit maximization and resource allocation (Sofat & Hiro, 2015; Chandra, 2014). From an innovation standpoint, it involves developing new products or models (Amit & Zott, 2020; Velu, 2024). Competitively, BS leads to creating a competitive edge (David & David, 2022; Dinçer, 2013). Lastly, from a human resources perspective, it includes enhancing employee competencies and motivation (Henderson, 2017; Ghosh & Ghosh, 2022).

At a macro level, a nation's BS is a crucial factor shaping its economic, social, and political landscape (Schwab and WEF, 2017). BS enhances international competitiveness and innovation capacity, positively impacting economic growth. Empirical studies show that countries with strong BS demonstrate higher innovation and competitiveness, key drivers of economic development (Terzić, 2021; Doroudi et al., 2022; Mariš, 2022; Alexandroa & Basrowi, 2024; Omonovich, 2023; Hysai & Sulçaj, 2024). Thus, measuring a country's BS performance is vital (Cornell University et al., 2020).

Evaluating BS performance is instrumental in enabling countries to gain deeper insights into their strengths and weaknesses, formulate more effective future plans, and assume a more prominent role in the global arena. These evaluations serve as a compass for both governments and the private sector in their decision-making processes (Cornell University et al., 2016). Specifically, nations leverage BS performance metrics to inform policy and strategy development aimed at enhancing economic power and competitiveness, attracting investment, fostering sustainable development, promoting employment and social welfare, and driving innovation and technological advancements. Consequently, countries seek metrics to measure their BS performance to bolster their economic attractiveness and competitiveness on the global stage (Schwab & WEF, 2015).

Two primary metrics have been employed internationally to assess countries' BS performance: the World Economic Forum's (WEF) Global Competitiveness Index (GCI) and the Global Innovation Index (GII). The GCI, developed by the WEF, measured countries' competitiveness from 2006 to 2020. The index included a criterion for measuring countries' BS performance, but the latest data on this criterion was available up to 2017 (Schwab et al., 2020). While the GCI continued to measure countries' competitiveness until 2020, the "business dynamism" criterion replaced BS as a key indicator from 2018 onwards (Schwab & WEF, 2018; Schwab and WEF, 2019; Schwab et al., 2020). The GII, initially developed by INSEAD in 2007, has been used to assess countries' innovation performance since then. The World Intellectual Property Organization (WIPO) joined the initiative in 2011, followed by Cornell University in 2013 (Cornell University et al., 2020). WIPO has been solely responsible for measuring countries' innovation performance from 2021 to 2023 (WIPO, 2021; WIPO, 2022; WIPO, 2023). The GII includes a BS criterion as an input indicator, which is assessed based on three sub-criteria: knowledge workers, innovation linkages, and knowledge absorption. Knowledge workers refer to individuals employed in knowledge-intensive roles. Innovation linkages represent the connections that facilitate the sharing of knowledge, technology, and innovations among different actors. Finally, knowledge absorption refers to a company or organization's ability to acquire, comprehend, assimilate, and apply external knowledge (WIPO, 2023). Methodologically, the values for each criterion range from 0 to 100, providing a standardized measure of a country's BS performance.

As the world's largest economies, the G7 nations play a pivotal role in shaping the global economic landscape. Consequently, measuring the BS performance of these countries holds immense significance for the global economy. Their business practices and policies not only influence their domestic economies but also exert a direct impact on the BS of other nations (Schwab & WEF, 2018). The economic decisions made by G7 countries significantly shape global trade, investment flows, and innovation processes, thereby influencing the overall state of the global economy. Monitoring the BS performance of G7 countries is thus crucial for understanding global economic dynamics and forecasting future economic trends. Moreover, these countries serve as benchmarks for other nations seeking to develop successful business models and policies (WIPO, 2022). According to the latest 2023 GII report, the average BS performance of G7 countries is 56.8, compared to the global average of 40.8. This indicates that the G7 nations' BS performance is 39% higher than the global average. Such a significant disparity underscores the substantial influence of these major economies on the overall global BS score, thereby highlighting the importance of analyzing their BS performance (WIPO, 2023).

Upon reviewing the literature, it is evident that numerous studies have explored the economic and social dimensions of BS. However, no research has been identified in the literature that evaluates the BS performance of countries using any MCDM method. Accordingly, this study is the first in the literature to evaluate the BS performance of countries using an MCDM method. Therefore, it is considered that this research contributes to both the BS and MCDM (MIEXCF-CODAS) literature. A review of the literature reveals that studies on the measurement of countries' BS performance are limited, while the BS dimension has been examined in relation to social and economic aspects. In this context, Gaile-Sarkane & Andersone (2011) proposed a mathematical model to analyze corporate investment returns, identify key investment areas, and enhance BS, claiming it would improve consumer behavior analysis. Vesal et al., (2013) explored the relationship between labor market factors and BS using canonical correlation analysis on 142 countries within the framework of the GCI, finding a significant positive relationship between the labor market and BS. Similarly, Razavi et al., (2012) analyzed the relationship between business sophistication (BS) and innovation using GCI data from 142 countries (2011-2012), finding a significant positive canonical correlation between the two. Suryaman et al., (2015) examined BS and labor market efficiency in Southeast Asia (2008-2014) using MANOVA, revealing a positive link. Balotić et al., (2016) explored the impact of BS on macroeconomic performance in six countries (2006-2014), showing BS positively affected exports and industrial value according to Wald and Wooldridge's tests. Cuellar & González (2015) found a significant linear regression influence of culture on BS using Hofstede's Cultural Index (1969-2009) and GCI (2006-2012) data. Bazargan et al., (2017) demonstrated a positive canonical correlation between "Higher Education and Training" and BS for 144 countries (2014-2015), where 77.85% of BS changes could be predicted by education improvements. Mussina & Bachisse (2018) investigated the relationship between business sophistication (BS) and macroeconomic environment dimensions for 102 countries using GII data from 2016-2017 through canonical correlation analysis, finding a significant positive relationship. Salas-Velasco (2018) assessed the impact of macroeconomic conditions and innovation on BS in OECD countries with a stochastic frontier model, concluding that countries with more sophisticated production processes and higher innovation capacity demonstrated greater efficiency. Çetingüç et al., (2020) employed structural equation modeling to explore the effect of BS on long-term orientation across 86 countries, utilizing GII and Hofstede Culture Index data for 2019. Their findings indicated a significant, positive, and moderate influence of BS on long-term orientation. Rahayu (2020) explored the relationship between business sophistication (BS) and technology readiness across 139 countries using GII data from 2010, finding a significant positive canonical correlation. Ceko (2022) analyzed the link between global innovation and BS for 131 countries with 2021 GII data through regression analysis, concluding a significant positive relationship. Pedro & Rodrigues (2022) examined the impact of BS on market sophistication in 50 countries based on GII components using multiple linear regression, revealing a significant positive effect. Lastly, Kırıkkaleli & Ozun (2019) investigated the connections among innovation capacity, BS, and macroeconomic stability in OECD countries employing various methodologies (Pedroni and Kao cointegration, fully modified ordinary least squares, dynamic ordinary least squares, Granger causality, and Dumitrescu-Hurlin causality tests). Their findings indicated that enhancements in BS fostered innovation capacity and contributed to macroeconomic stability.

A comprehensive review of the literature reveals a dearth of studies, aside from WIPO's 2023 report, that have explicitly measured the BS performance of countries. In its 2023 GII, WIPO provided a ranking of countries based on their BS performance using specific criteria within the index. The study found that the United States, Japan, the United Kingdom, Germany, France, Canada, and Italy ranked highest in terms of BS. Additionally, the research calculated the average BS performance across all countries and identified the United States, Japan, the United Kingdom, and Germany as having above-average performance (WIPO, 2023).

3. MATERIAL AND METHOD

3.1. Data Set and Analysis of the Research

The dataset for this study comprises the BS criterion scores of G7 countries as reported in the latest 2023 Global Innovation Index. To facilitate analysis, the abbreviations for the business sophistication criteria are presented in Table 1.

Table 1. Abbreviation of BS Criteria

BS Criteria	Abbreviation
Knowledge Workers	KW
Innovation Linkages	IL
Knowledge Absorption	KA

This study evaluated the BS performance of G7 countries using the MIEXCF-based CODAS MCDM method. The GII was selected as the data source due to its more current data compared to the GCI. The MIEXCF method possesses a unique nonlinear structure that accurately models complex relationships among variables compared to other objective weighting methods. Therefore, unlike conventional objective weighting approaches, considering the nonlinear and intricate relationships among criteria provides a more accurate and realistic explanation for criterion weighting. Its integral-based approach evaluates the mutual interactions between variables without requiring additional transformations, ensuring that the criterion weights reflect the true relationships. Moreover, unlike traditional linear methods, MIEXCF has the capability to enhance the influence of less significant criteria (Altıntaş, 2024). The CODAS method combines the strengths of the SAW and WPM methods, enabling precise evaluation of decision alternatives. Therefore, since the CODAS method incorporates the advantages of SAW and WPM in performance assessment, it proves to be an effective approach for measuring the performance of decision alternatives (Ecer, 2020; Demir et al., 2021). Accordingly, based on the benefits of the aforementioned methods, the weights of BS criteria for each country were determined using the MIEXCF method, while the BS performance of countries was assessed using the MIEXCF-based CODAS method.

3.2. MIEXCF Method

The MIEXCF (Measurement Relying on the Impacts of an Exponential Curve Function) method is an innovative MCDM approach based on exponential functional relationships among criteria. It employs an integral-based mathematical model to precisely calculate the exponential values assigned to criteria and their influence. This nonlinear method effectively captures complex relationships between variables (Altıntaş, 2024). However, due to its recent development, literature specifically focused on the MIEXCF method is limited. The application stages of the method are outlined below (Altıntaş, 2024).

Step 1: Constructing the decision matrix (DM)

$i: 1, 2, 3 \ldots p$: where p indicates the number of decision alternatives

$j: 1, 2, 3 \ldots r$: where r indicates the number of criteria

DM: Decision matrix

CR: Criterion

dm_{ij}: The decision matrix is formulated based on Equation 1, where "ij" denotes the performance of $i-th$ decision alternative on $j-th$ criterion.

$$DM = [dm_{ij}]_{pxr} = \begin{bmatrix} CR_1 & CR_2 & \dots & CR_r \\ x_{11} & x_{12} & & x_{1r} \\ x_{21} & x_{22} & \dots & x_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} & x_{p2} & \dots & x_{pr} \end{bmatrix} \quad (1)$$

Step 2: Decision matrix normalization (dm^*_{ij})

Benefit oriented criteria:

$$dm^*_{ij} = \frac{min.\, d_{ij}}{d_{ij}} \quad (2)$$

Cost oriented criteria:

$$dm^*_{ij} = \frac{d_{ij}}{max.\, d_{ij}} \quad (3)$$

Step 3: Exponential function generation

Exponential curve functions ($f(x) = y = t.u^{zx}$) were generated for up to r variables using SPSS regression, based on the exponential relationships.

(1) $f(CR_1) = CR_2, f(CR_1) = CR_3, \dots \dots f(CR_1) = CR_r$ (4)

(2) $f(CR_2) = CR_1, f(CR_2) = CR_3, \dots \dots f(CR_2) = CR_r$ (5)

(3) $f(CR_3) = CR_1, f(CR_3) = CR_2, \dots \dots f(CR_3) = CR_r$ (6)

$\vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots$

(r) $f(CR_r) = CR_1, f(CR_r) = CR_2, \dots \dots f(CR_r) = CR_{r-1}$ (7)

Step 4: Determining the exponential curve impact score for criteria

To understand the effect of an independent variable on a dependent variable within its minimum and maximum values, we employ definite integral calculations. The exponential curve impact score, $''E''$ is obtained from this analysis.

$$(1)\ f(CR_1) = CR_2 , \int_{CR_{1min.}}^{CR_{1maks.}} (f'(CR_1))\, dx = |E_{CR_1 \to CR_2}| \quad (8)$$

$$(2)\ f(CR_1) = CR_3 , \int_{CR_{1min.}}^{CR_{1maks.}} (f'(CR_1))\, dx = |E_{CR_1 \to CR_3}| \quad (9)$$

$$(3)\ f(CR_1) = CR_4 , \int_{CR_{1min.}}^{CR_{1maks.}} (f'(CR_1))\, dx = |E_{CR_1 \to CR_4}| \quad (10)$$

$\vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots$

$$\left(\frac{r!}{(r-2)!}\right) f(C_r) = C_{r-1}, \int_{CR_{rmin.}}^{CR_{rmaks.}} (f'(CR_r))\, dx = \left|E_{CR_r \to CR_{r-1}}\right| \tag{11}$$

Step 5: Computing the cumulative exponential curve impact value per criterion (S_{CR})

By computing the aggregate exponential curve impact value for each criterion, we assess the combined effect of a criterion on the remaining ones.

$$(1)\ S_{CR_1}: \left|E_{CR_1\to CR_2}\right| + \left|E_{CR_1\to CR_3}\right| + \left|E_{CR_1\to CR_4}\right| \dots + \left|E_{CR_1\to CR_r}\right| = \left(\sum_{j=1}^{r-1} \left|E_{CR_1\to CR_{j+1}}\right|\right) \tag{12}$$

$$(2)\ S_{CR_2}: \left|E_{CR_2\to CR_1}\right| + \left|E_{CR_2\to CR_3}\right| + \left|E_{CR_2\to CR_4}\right| \dots + \left|E_{CR_2\to CR_r}\right| = \left(\sum_{\substack{j=0 \\ j\neq 1}}^{r-1} \left|E_{CR_2\to CR_{j+1}}\right|\right) \tag{13}$$

$$(3)\ S_{CR_3}: \left|E_{CR_3\to CR_1}\right| + \left|E_{CR_3\to CR_2}\right| + \left|E_{CR_3\to CR_4}\right| \dots + \left|E_{CR_3\to CR_p}\right| = \left(\sum_{\substack{j=0 \\ j\neq 2}}^{r-1} \left|E_{CR_3\to CR_{j+1}}\right|\right) \tag{14}$$

$$\vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots$$

$$(r)\ S_{CR_3}: \left|E_{CR_r\to CR_1}\right| + \left|E_{CR_r\to CR_2}\right| + \left|E_{CR_r\to CR_3}\right| \dots + \left|E_{CR_r\to CR_{r-1}}\right| = \left(\sum_{j=1}^{r-1} \left|E_{CR_r\to CR_j}\right|\right) \tag{15}$$

Step 6: Determination of Criterion Weight Values (w)

The relative importance of each criterion is determined by dividing its total exponential curve impact by the sum of the impacts of all criteria.

$$w_j = \frac{S_{CR_j}}{\sum_{j=1}^{r} S_{CR_j}} \tag{16}$$

3.3. CODAS Method

CODAS (Combinative Distance-based Assessment) is an effective MCDM method that ranks decision alternatives by integrating two established techniques: SAW (Simple Additive Weighting) and WPM (Weighted Product Method). This hybrid approach leverages the strengths of both methods. Performance scores are derived using Euclidean and Taxicab distances from the negative-ideal solution (Keshavarz-Ghorabaee et al., 2016; Ecer, 2020). Euclidean distance measures the shortest path between two points, represented mathematically in a right-angled triangle as the square root of the sum of the squares of its sides. In contrast, Taxicab distance is calculated by summing the absolute differences of the coordinates of the two points (Demir et al., 2021; Alpar, 2017). A review of the literature reveals that many researchers have utilized the CODAS method in measuring decision alternatives or solving selection problems. Relevant studies on the CODAS MCDM method are presented in Table 2.

Table 2. CODAS Literature

Author's	Method(s)	Theme
Amari et al., 2023	CRITIC-CODAS	New parking lot selection
Aal et al., 2024	CODAS	Optimal charcoal company selection
Alkan & Kahraman, 2024	CODAS	Assessment of strategy for IOT-based sustainable supply chain
Amusan et al., 2024	CRITIC-CODAS	Determining of hybrid energy system

Azim et al., 2024	q-Spherical Fuzzy Rough CODAS	Renewable energy site selection
Elsayed & Arain, 2024	OWCM-CODAS	Assessment of healthcare waste treatment devices
Fan et al., 2024	COPRAS-CODAS	Optimization of railway transportation scheme
Hussain & Hussain, 2024	CODAS	Novel modified CODAS
Kannan et al., 2024	Linear diophantine fuzzy CODAS	Analysis of logistic specialist
Kavitha et al., 2024	q-rung orthopair hesitant fuzzy CODAS	Evaluation of multi-label feature
Khargotra et al., 2024	BMW-CODAS	Analysis of design parameter of V-shaped perforated blocks

The application steps of the method are detailed below, as outlined in previous studies (Keshavarz-Ghorabaee et al., 2016; Ecer, 2020; Demir et al., 2021).

Step 1: Constructing the decision matrix (DM)

i: $1, 2, 3 \ldots p$: where p indicates the number of decision alternatives

j: $1, 2, 3 \ldots r$: where r indicates the number of criteria

DM: Decision matrix

$$DM = \left[dm_{ij}\right]_{pxr} = \begin{bmatrix} CR_1 & CR_2 & \cdots & CR_r \\ x_{11} & x_{12} & & x_{1r} \\ x_{21} & x_{22} & \cdots & x_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} & x_{p2} & \cdots & x_{pr} \end{bmatrix} \tag{17}$$

Step 2: Decision matrix normalization (n_{ij})

Benefit oriented criteria:

$$n_{ij} = \frac{x_{ij}}{mak. x_{ij}} \tag{18}$$

Cost oriented criteria:

$$n_{ij} = \frac{min. x_{ij}}{x_{ij}} \tag{19}$$

Step 3: Construction of the Weighted Normalized Decision Matrix (k_{ij})

$$k_{ij} = w_j n_{ij} \tag{20}$$

In Equation 3, w_j $(0 < w_j < 1)$ represents the weight of the j. criterion. Additionally, it must satisfy the condition $(\sum_{j=1}^{m} w_j = 1)$.

Step 4: Calculation of the Negative Ideal Solution (n_{sj})

$$ns = \left[ns_j\right]_{1xr} \tag{21}$$

$$ns_j = min_{k_{ij}} \tag{22}$$

Step 5: Measurement of Euclidean (E_i) and Taxicab Distances (T_i)

$$E_i = \sqrt{\sum_{j=1}^{r} \left(k_{ij} - ns_j\right)^2} \tag{23}$$

$$T_i = \sum_{j=1}^{r} \left| k_{ij} - ns_j \right| \quad (24)$$

Step 6: Construction of the Relative Evaluation Matrix (REM)

$$REM = [h_{iu}]_{pxp} \quad (25)$$

$$h_{it} = (E_i - E_u) + (\psi(E_i - E_u)x(T_i - T_k) \quad (26)$$

In Equation 26, ψ is a threshold function used to distinguish the equality of Euclidean distances between two alternatives, and it is defined as indicated in Equation 27.

$$\psi(x) = \begin{cases} If\ |x| \geq \tau, 1 \\ If\ |x| < \tau, 0 \end{cases} \quad (27)$$

In Equation 27, τ is a threshold parameter determined by the decision-maker, and it is recommended to take a value between 0.01 and 0.05. If the difference between the Euclidean distances of two alternatives is less than τ, these alternatives are compared using Taxicab distances. In the literature, a value of $\tau = 0.02$ is generally accepted.

Step 7: Measurement of the Performance Scores of Alternatives (H_i)

$$H_i = \sum_{j=1}^{r} h_{it} \quad (28)$$

According to the equation given in Equation 28, the alternative with the highest H_i value is identified as the best alternative.

4. RESULTS

4.1. Computational Analysis

Initially, the MIEXCF method was employed to calculate the weights of the BS criteria for each country. In this regard, the decision matrix was computed using Equation 1 as the first step of the MIEXCF method, followed by the calculation of the normalized decision matrix using Equation 2. The decision and normalized decision matrices are presented in Table 2.

Table 2. Decision and Normalized Decision Matrix Value

Decision Matrix			
G7	**KW**	**IL**	**KA**
Canada	50.7	65.7	51.6
France	69.1	47.3	51.9
Germany	59	63.1	48.6
Italy	37.9	45.6	40.4
Japan	62.9	50.2	66.6
UK	67.1	62.4	45.7
USA	76.8	75.8	57.2
Normalized Decision Matrix			
Criteria	**KW**	**IL**	**KA**
Criteria Directions	**Benefit**	**Benefit**	**Benefit**
Canada	0.748	0.694	0.783
France	0.548	0.964	0.778
Germany	0.642	0.723	0.831
Italy	1.000	1.000	1.000
Japan	0.603	0.908	0.607
UK	0.565	0.731	0.884
USA	0.493	0.602	0.706

In the third step, exponential curve functions, which describe the relationships between criteria, were generated using SPSS 23 (curve estimation). These functions, corresponding to Equations 4 through 7, are presented in Table 3.

Table 3. Exponential Curve Functions Inferred from the Interrelationship of Criteria

IDC (x)	DC (y)	Function
KW→	IL	$y = 38.10\ e^{(0.007x)}$
	KA	$y = 33.14\ e^{(0.007x)}$
IL→	KW	$y = 33.20\ e^{(0.01x)}$
	KA	$y = 43.69\ e^{(0.003x)}$
KA→	KW	$y = 26.28\ e^{(0.016x)}$
	IL	$y = 49.34\ e^{(0.003x)}$

IDC: Independent criteria, DC: Dependent criteria

In the fourth step, the exponential curve influence values among the criteria were calculated using Equations 8 to 11. Subsequently, the total exponential curve influence values of the criteria were determined using Equations 12 to 15. Finally, the last step of the method involved measuring the criteria using Equation 16. The calculated exponential curve influences values among the criteria, the total exponential curve influences values of the criteria, and the criteria weights are presented in Table 4.

$$\boldsymbol{KW}$$

$\boldsymbol{KW \rightarrow IL}$

$$y = 38.1\ e^{(0.007x)}$$

$$\frac{dy}{dx} = \frac{2667\boldsymbol{e}^{\frac{7x}{1000}}}{10000}$$

$$\int_{0.493}^{1} \frac{2667\boldsymbol{e}^{\frac{7x}{1000}}}{10000} dx = \frac{381\boldsymbol{e}^{\frac{7}{1000}} - 381\boldsymbol{e}^{\frac{3451}{1000000}}}{10} = 0{,}136$$

$\boldsymbol{KW \rightarrow KA}$

$$y = 33.14\ e^{(0.007x)}$$

$$\frac{dy}{dx} = \frac{11599\boldsymbol{e}^{\frac{7x}{1000}}}{50000}$$

$$\int_{0.493}^{1} \frac{11599\boldsymbol{e}^{\frac{7x}{1000}}}{50000} dx = \frac{1657\boldsymbol{e}^{\frac{7}{1000}} - 1657\boldsymbol{e}^{\frac{3451}{1000000}}}{50} = 0{,}118$$

$$\boldsymbol{IL}$$

$\boldsymbol{IL \rightarrow KW}$

$$y = 33.20\ e^{(0.01x)}$$

$$\frac{dy}{dx} = \frac{83\boldsymbol{e}^{\frac{x}{100}}}{250}$$

$$\int_{0.602}^{1} \frac{83\boldsymbol{e}^{\frac{x}{100}}}{250} dx = \frac{166\sqrt[100]{\boldsymbol{e}} - 166\boldsymbol{e}^{\frac{301}{50000}}}{5} = 0{,}133$$

$\boldsymbol{IL \rightarrow KA}$

$$y = 43.69\ e^{(0.003x)}$$

$$\frac{dy}{dx} = \frac{13107\boldsymbol{e}^{\frac{3x}{1000}}}{100000}$$

$$\int_{0.602}^{1} \frac{13107\boldsymbol{e}^{\frac{3x}{1000}}}{100000} dx = \frac{4369\boldsymbol{e}^{\frac{3}{1000}} - 4369\boldsymbol{e}^{\frac{903}{500000}}}{100} = 0{,}052$$

$\boldsymbol{KA}$

$\boldsymbol{KA \rightarrow KW}$

$$y = 26.28\ e^{(\ 0.016\text{x}\ )}$$

$$\frac{dy}{dx} = \frac{1314\boldsymbol{e}^{\frac{2x}{125}}}{3125}$$

$$\int_{0.607}^{1} \frac{1314\boldsymbol{e}^{\frac{2x}{125}}}{3125} dx = \frac{657\boldsymbol{e}^{\frac{2}{125}} - 657\boldsymbol{e}^{\frac{607}{62500}}}{25} = 0{,}167$$

$\boldsymbol{KA \rightarrow IL}$

$$y = 49.34\ e^{(\ 0.003\text{x}\ )}$$

$$\frac{dy}{dx} = \frac{7401\boldsymbol{e}^{\frac{3x}{1000}}}{50000}$$

$$\int_{0.607}^{1} \frac{7401\boldsymbol{e}^{\frac{3x}{1000}}}{50000} dx = \frac{2467\boldsymbol{e}^{\frac{3}{1000}} - 2467\boldsymbol{e}^{\frac{1821}{1000000}}}{50} = 0{,}058$$

Table 4. Exponential Curve Impact Scores from the Interrelationship of Criteria

DC	IDC	Impact Score	Total Impact Score	*w*	Rank
KW→	IL	0.136	0.254	0.383	1
	KA	0.118			
IL→	KW	0.133	0.185	0.279	3
	KA	0.052			
KA→	KW	0.167	0.225	0.338	2
	IL	0.058			
	Sum		0.664		
		Mean		0.333	

IDC: Independent criteria, DC: Dependent criteria

An analysis of Table 4 reveals that the criteria are ranked in terms of their weights (importance levels) as KW, KA, and IL. Furthermore, based on Table 4, the average weight values of the criteria were measured, and it was determined that the BS criteria KW and KA had weight values higher than the average. Consequently, considering the weight values of the BS criteria, it was concluded that IL exhibits a significant difference compared to the other BS criteria in terms of having a lower criterion value. Based on these quantitative values, it was concluded that KW and KA criteria have a significant impact on the development of countries' BS performance.

Secondly, the study assessed the BS performance of countries using the CODAS method, building on the MIEXCF method. The decision matrix was created following Equation 17, as shown in Table 2. In the second step of the CODAS method, normalized values were derived from the decision matrix using Equation 18. The third step involved calculating the weighted decision matrix values through Equation 20 and determining the negative ideal solution values of the BS criteria using Equations 21 and 22. The resulting normalized values, weighted normalized values, and ideal solution values within the CODAS framework are summarized in Table 5.

Table 5. Normalized Decision Matrix, Weighted Normalized Decision Matrix and Negative Ideal Solution

Normalized Decision Matrix

G7	KW	IL	KA
Canada	0.660	0.867	0.775
France	0.900	0.624	0.779
Germany	0.768	0.832	0.730
Italy	0.493	0.602	0.607
Japan	0.819	0.662	1.000
UK	0.874	0.823	0.686
USA	1.000	1.000	0.859
Weighted Normalized Decision Matrix			
Criteria	**KW**	**IL**	**KA**
w	0.383	0.279	0.338
Max./Min.	Max.	Max.	Max.
Canada	0.253	0.242	0.263
France	0.345	0.174	0.264
Germany	0.294	0.232	0.247
Italy	0.189	0.168	0.206
Japan	0.314	0.185	0.339
UK	0.335	0.230	0.233
USA	0.383	0.279	0.291
Negative Ideal Solution			
Criteria	**KW**	**IL**	**KA**
Score	0.189	0.168	0.206

In the fourth step, Euclidean and Taxicab distances were computed using Equations 23 and 24, respectively. The calculated values are presented in Table 6.

Table 6. Euclidean Distance and Taxicab Distance Scores

Euclidean Distance Scores				
G7	**KW**	**IL**	**KA**	**Euclidean**
Canada	0.004	0.005	0.003	0.113
France	0.024	0.000	0.003	0.166
Germany	0.011	0.004	0.002	0.130
Italy	0.000	0.000	0.000	0.000
Japan	0.016	0.000	0.018	0.183
UK	0.021	0.004	0.001	0.160
USA	0.038	0.012	0.007	0.239
Taxicab Distance Scores				
G7	**KW**	**IL**	**KA**	**Taxicab**
Canada	0.064	0.074	0.057	0.195
France	0.156	0.006	0.059	0.220
Germany	0.105	0.064	0.042	0.211
Italy	0.000	0.000	0.000	0.000
Japan	0.125	0.017	0.133	0.275
UK	0.146	0.062	0.027	0.234
USA	0.194	0.111	0.086	0.391

In the sixth step, the relative evaluation matrix was constructed considering Equations 25, 26, and 27. In the final step, the BS performance of the countries was measured using Equation 28. Accordingly, the values related to the relative evaluation matrix and the BS performance values of the countries are presented in Table 7.

Table 7. Relative Evaluation Matrix and Performance Scores

G7	Relative Evaluation Matrix							Total (Performance)	Rank
	Canada	France	Germany	Italy	Japan	UK	USA		
Canada	0.000	-0.053	-0.017	0.308	-0.070	-0.047	-0.126	-0.006	6
France	0.028	0.000	0.045	0.387	-0.017	0.006	-0.073	0.376	4
Germany	0.017	-0.036	0.000	0.342	-0.053	-0.030	-0.109	0.131	5
Italy	-0.308	-0.166	-0.130	0.000	-0.182	-0.160	-0.238	-1.183	7
Japan	0.150	0.017	0.117	0.458	0.000	0.063	-0.056	0.750	2
UK	0.087	-0.006	0.053	0.395	-0.023	0.000	-0.079	0.428	3
USA	0.322	0.243	0.288	0.630	0.172	0.235	0.000	1.891	1
Mean								0.353	

An examination of Table 7 reveals that the countries' BS performance values are ranked as follows: the USA, Japan, the UK, France, Germany, Canada, and Italy. According to Table 7, the USA exhibits a significantly higher BS performance compared to other countries, while Italy shows a significantly lower performance. Furthermore, when evaluating Table 7, it is observed that countries with a BS performance higher than the average are the USA, Japan, the UK, and France. Consequently, considering the relationships between innovation, competition, economic growth, and BS dimensions in a global context, the quantitative findings suggest that countries with below-average BS performance, such as Italy, Canada, and Germany, should adopt strategies to enhance their BS performance to contribute to global economic development.

4.2. Sensitivity Analysis

Sensitivity analysis in MCDM entails applying various criteria weighting methodologies to assess a dataset. This approach enables a comparative evaluation of the resultant values and rankings. To validate the sensitivity of the selected weighting method, it is anticipated that the rankings from the objective method will diverge from those derived using alternative objective weighting methodologies, with at least one method displaying a discrepancy (Gigovič et al., 2016). Consequently, the weights for the business sophistication (BS) criteria across countries were calculated using several widely used objective weighting methods in MCDM literature, including ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW, each employing distinct calculation techniques. The resulting values are detailed in Table 8.

Table 8. Weight Values of BS Criteria according to ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW Methods

Method	Score/Rank	KW	IL	KA
ENTROPY	Score	0.344	0.341	0.315
	Rank	1	2	3
CRITIC	Score	0.259	0.405	0.336
	Rank	3	1	2
SD	Score	0.324	0.362	0.314
	Rank	2	1	3
SVP	Score	0.460	0.344	0.196
	Rank	1	2	3
MEREC	Score	0.551	0.184	0.265
	Rank	1	3	2
LOPCOW	Score	0.019	0.589	0.392
	Rank	3	1	2

Secondly, the BS performance values of countries were assessed using the CODAS method based on ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW, and the obtained results are presented in Table 9.

Table 9. BS Performance of G7 according to ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW-based CODAS

G7	ENTROPY-CODAS		CRITIC-CODAS		SD-CODAS	
	Score	Rank	Score	Rank	Score	Rank
Canada	0.083	6	0.216	4	0.120	6
France	0.287	4	0.123	6	0.263	4
Germany	0.160	5	0.185	5	0.170	5
Italy	-1.151	7	-1.096	7	-1.137	7
Japan	0.580	2	0.623	2	0.605	2
UK	0.399	3	0.274	3	0.377	3
USA	1.924	1	1.901	1	1.926	1
G7	**SVP-CODAS**		**MEREC-CODAS**		**LOPCOW-CODAS**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Canada	-0.034	6	-0.242	6	0.639	2
France	0.410	3	0.591	4	-0.356	6
Germany	0.217	5	0.172	5	0.370	4
Italy	-1.296	7	-1.399	7	-1.153	7
Japan	0.382	4	0.707	2	0.509	3
UK	0.628	2	0.683	3	0.260	5
USA	2.166	1	2.117	1	2.043	1

A comparative analysis of Tables 7 and 9 reveals that the rankings of G7 countries' BS performance determined by the MIEXCF-based CODAS method differ from those calculated using the CRITIC, SVP, and LOPCOW-based CODAS methods, despite the limited number of criteria and decision alternatives. Based on the values presented in Tables 6 and 8 and the relevant literature on sensitivity analysis, it is concluded that the MIEXCF-based CODAS method is more sensitive in measuring the BS performance of G7 countries using GGI-BS criteria values.

4.3. Comparative Analysis

A comparative analysis evaluates the relationships and rankings of the proposed method in relation to other techniques used for calculating MCDM methods. The proposed approach should demonstrate credibility and reliability alongside other methodologies, while also exhibiting a favorable and statistically significant correlation with various weight coefficient methods (Keshavarz-Ghorabaee et al., 2021). In this study, the BS performance of G7 countries was assessed using a variety of MCDM methods (MABAC, WASPAS, MAUT, GRA, MARCOS, TOPSIS) that are widely employed in the literature due to their distinct technical characteristics. The resulting performance scores and rankings are tabulated in Table 10.

Table 10. BS Performance of G7 according to MIEXCF-based MABAC, WASPAS, MAUT, GRA, MARCOS and, TOPSIS

G7	MIEXCF MABAC		MIEXCF WASPAS		MIEXCF MAUT	
	Score	Rank	Score	Rank	Score	Rank
Canada	0.002	6	0.754	6	0.156	6
France	0.017	5	0.778	4	0.245	3
Germany	0.021	4	0.773	5	0.162	5
Italy	-0.454	7	0.561	7	0.000	7
Japan	0.173	2	0.832	2	0.459	2
UK	0.057	3	0.794	3	0.237	4
USA	0.425	1	0.951	1	0.766	1
G7	**MIEXCF GRA**		**MIEXCF MARCOS**		**MIEXCF TOPSIS**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Canada	0.489	6	0.637	6	0.420	6
France	0.531	4	0.638	5	0.561	4
Germany	0.494	5	0.647	4	0.501	5
Italy	0.334	7	0.469	7	0.000	7
Japan	0.666	2	0.681	2	0.596	2

UK	0.534	3	0.664	3	0.581	3
USA	0.859	1	0.795	1	0.850	1

A comparative analysis of Tables 7 and 10 reveals that the rankings of countries' BS performance values measured using the MIEXCF-based CODAS method differ from those obtained using the MIEXCF-based MABAC, MAUT, and MARCOS MCDM methods. This finding suggests that the performance calculation techniques employed in the MIEXCF-based CODAS method are substantially different from those used in the MIEXCF-based MABAC, MAUT, and MARCOS MCDM methods. Consequently, the positions of countries determined by the MIEXCF-based CODAS method relative to other MIEXCF-based MCDM methods are illustrated in Figures 1, 2 and 3.

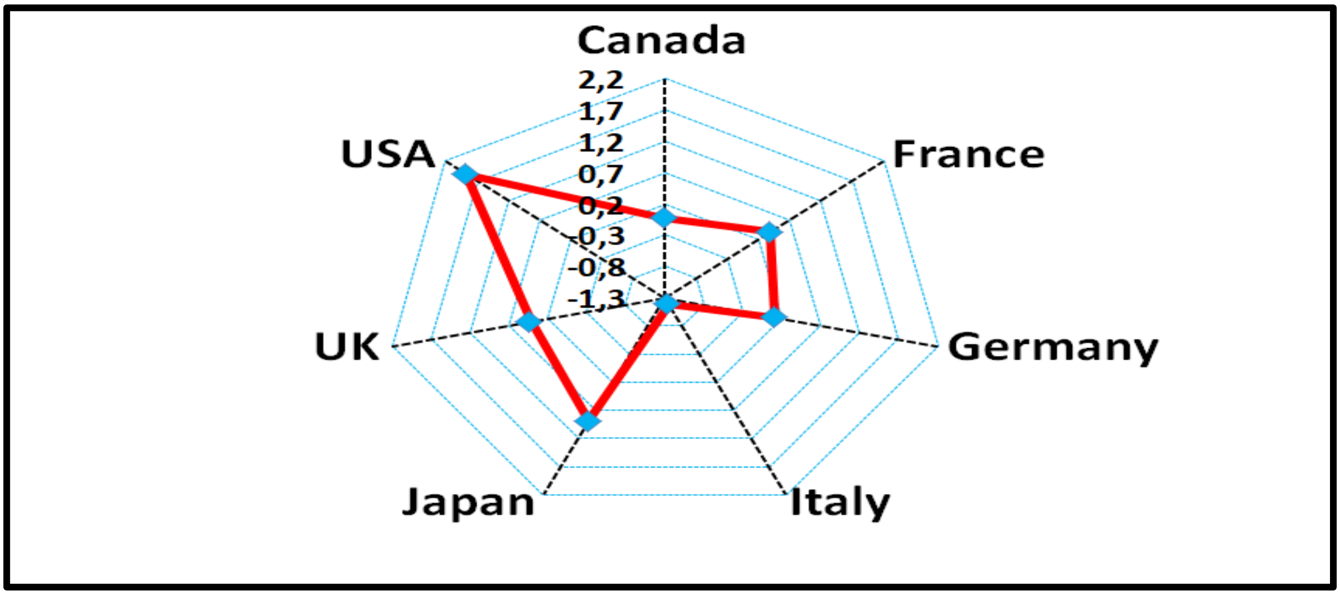

Figure 1. Position of MIEXCF based CODAS Method

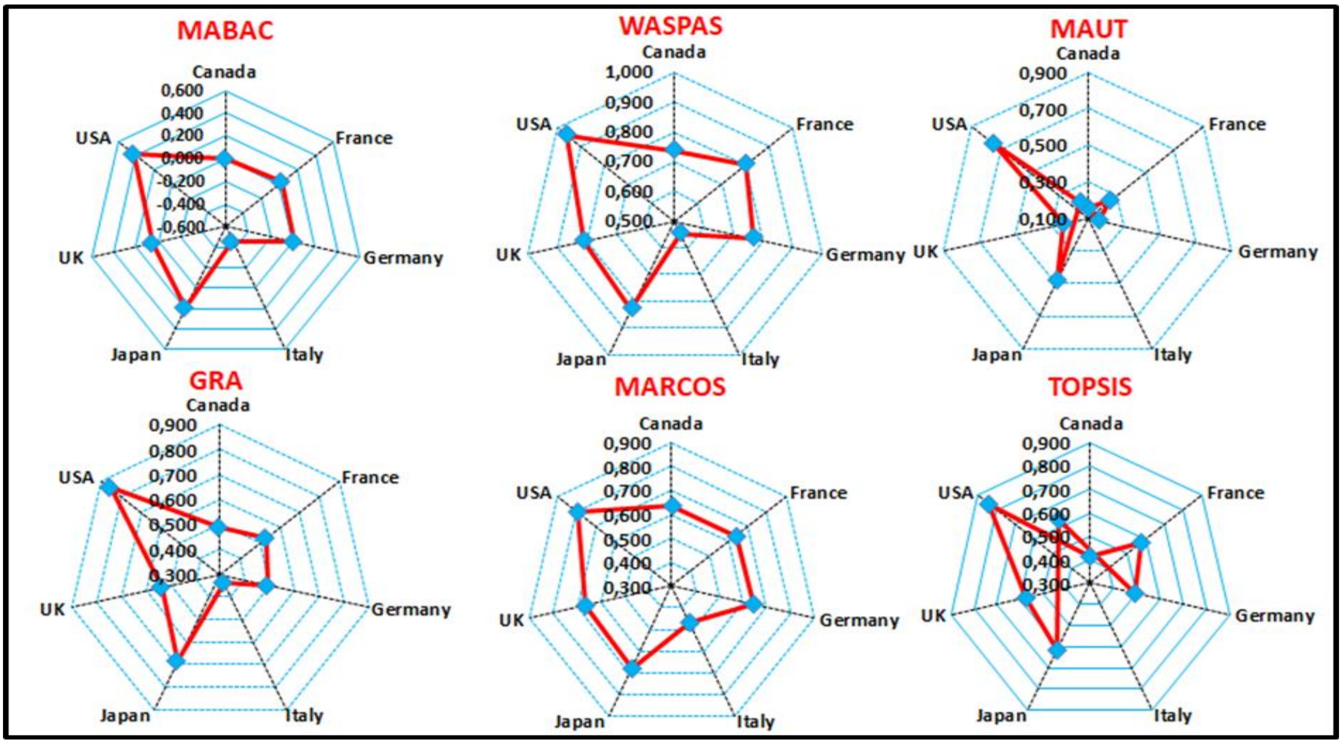

Figure 2. Position of MIEXCF based CODAS Method

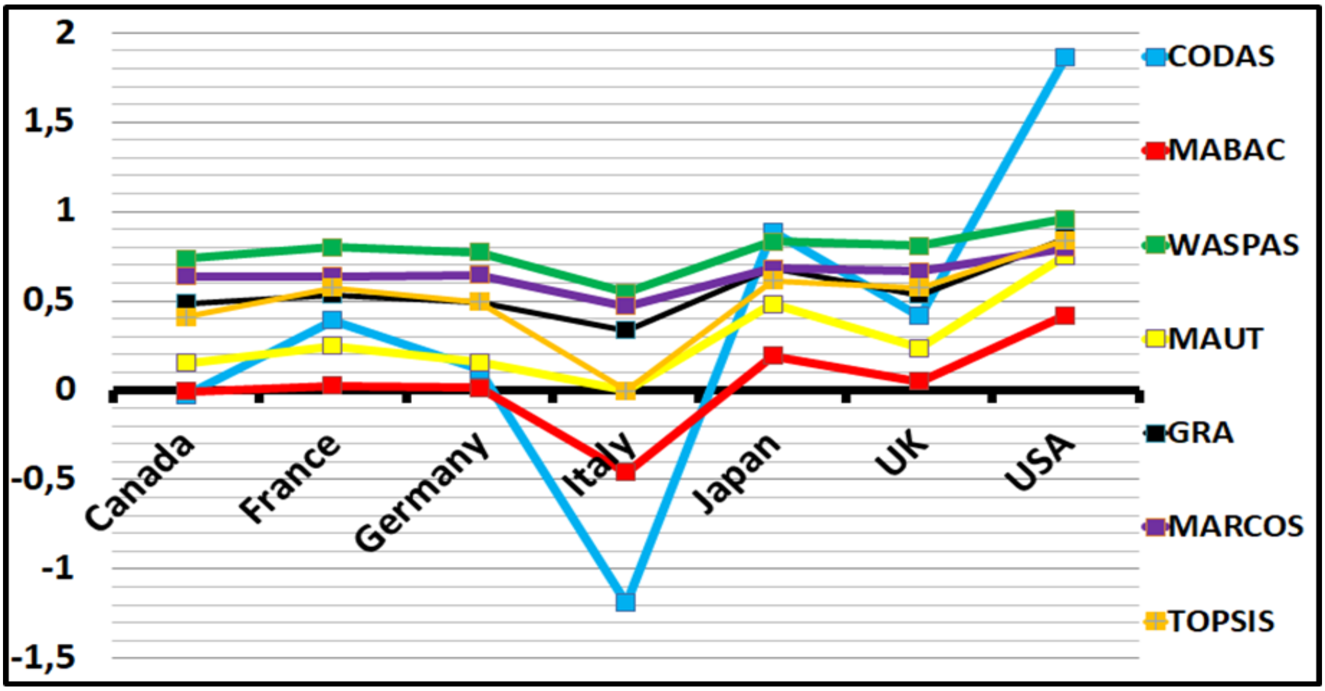

Figure 3. Position of MIEXCF-based MCDM Methods-2

A comparative analysis of Figures 1, 2, and 3 reveals a strong correlation between the health performance rankings derived from the MIEXCF-based CODAS method and those obtained using other MIEXCF-based MCDM techniques. Furthermore, Figure 2 reveals that the disparities in BS performance scores among countries, as assessed by the MIEXCF-based CODAS method, are more pronounced compared to those obtained from other MIEXCF-based MCDM) methods. Consequently, the distinctive characteristics of countries based on their criteria, as determined by the MIEXCF-based CODAS method, are more evident when compared to other MIEXCF-based MCDM approaches. The fluctuations in performance values across countries, as determined by CODAS, closely align with the trends observed in the alternative methods. This consistency suggests a positive association between the BS performance assessments generated by CODAS and those produced by other MIEXCF-based MCDM approaches. Table 11 presents the Spearman Rank Correlation (rho) values between the BS performance scores of countries measured by the MIEXCF-based CODAS method and those obtained using other MIEXCF-based MCDM methods.

Table 11. rho Analysis of the MIXCEF-based CODAS Method in Relation to Other MIXCEF-based MCDM Techniques

rho	MABAC	WASPAS	MAUT	GRA	MARCOS	TOPSIS
CODAS	0.964**	0.999**	0.964**	0.999**	0.964**	0.999**

p*<.05. p**<.01

Upon examining Table 11, it is evident that the rho coefficients between the BS performance scores of countries assessed using the MIEXCF-based CODAS method and those derived from other MIEXCF-based MCDM techniques are significantly positive and exceptionally high. Consequently, it can be concluded that the MIEXCF-based CODAS method is both reliable and credible for evaluating the BS performance of G7 nations within the GII-BS framework.

4.4. Simulation Analysis

To evaluate the robustness and stability of our proposed method, we will conduct a simulation analysis. We will generate various scenarios by changing the values in the decision matrices. A reliable method should show increasing differences in its results compared to others as the number of scenarios grows. Additionally, the average variance of criterion weights calculated by our method should be significantly higher than at least one other weighting method. This demonstrates our method's ability to distinguish the relative importance of criteria. Finally, It has to be checked if the variance of criterion weights is consistent across all methods within each scenario (Keshavarz-Ghorabaee et al., 2021). Table 12 presents the correlation coefficients between the MIEXCF-based CODAS method and other MIEXCF-based MCDM methods, as computed using the first ten scenarios from the simulation analysis.

Table 12. Correlations of the MIEXCF-based CODAS Method with Other MCDM Techniques under Various Scenarios

Methods	MABAC	WASPAS	MAUT	GRA	MARCOS	TOPSIS
1. Scenario	0.968**	0.999**	0.969**	0.999**	0.970**	0.999**
2. Scenario	0.971**	0.999**	0.972**	0.999**	0.966**	0.998**
3. Scenario	0.963**	0.995**	0.961**	0.995**	0.954**	0.993**
Methods	**MABAC**	**WASPAS**	**MAUT**	**GRA**	**MARCOS**	**TOPSIS**
4. Scenario	0.956**	0.996**	0.949**	0.996**	0.951**	0.991**
5. Scenario	0.946**	0.990**	0.937**	0.990**	0.946**	0.982**
6. Scenario	0.941**	0.986**	0.931**	0.986**	0.941**	0.976**
7. Scenario	0.934**	0.982**	0.928**	0.982**	0.933**	0.968**
8. Scenario	0.931**	0.977**	0.925**	0.977**	0.928**	0.956**
9. Scenario	0.926**	0.971**	0.922**	0.971**	0.925**	0.947**
10. Scenario	0.921**	0.966**	0.916**	0.966**	0.924**	0.943**

**p<.01; *p<.05

Table 12 classifies the 10 scenarios into two groups. The initial three scenarios form the first group, while the subsequent scenarios constitute the second. According to Table 12, the correlation values between the MIEXCF-based CODAS method and other methods exhibit a decreasing trend with an increasing number of scenarios. This trend is graphically illustrated in Figure 4.

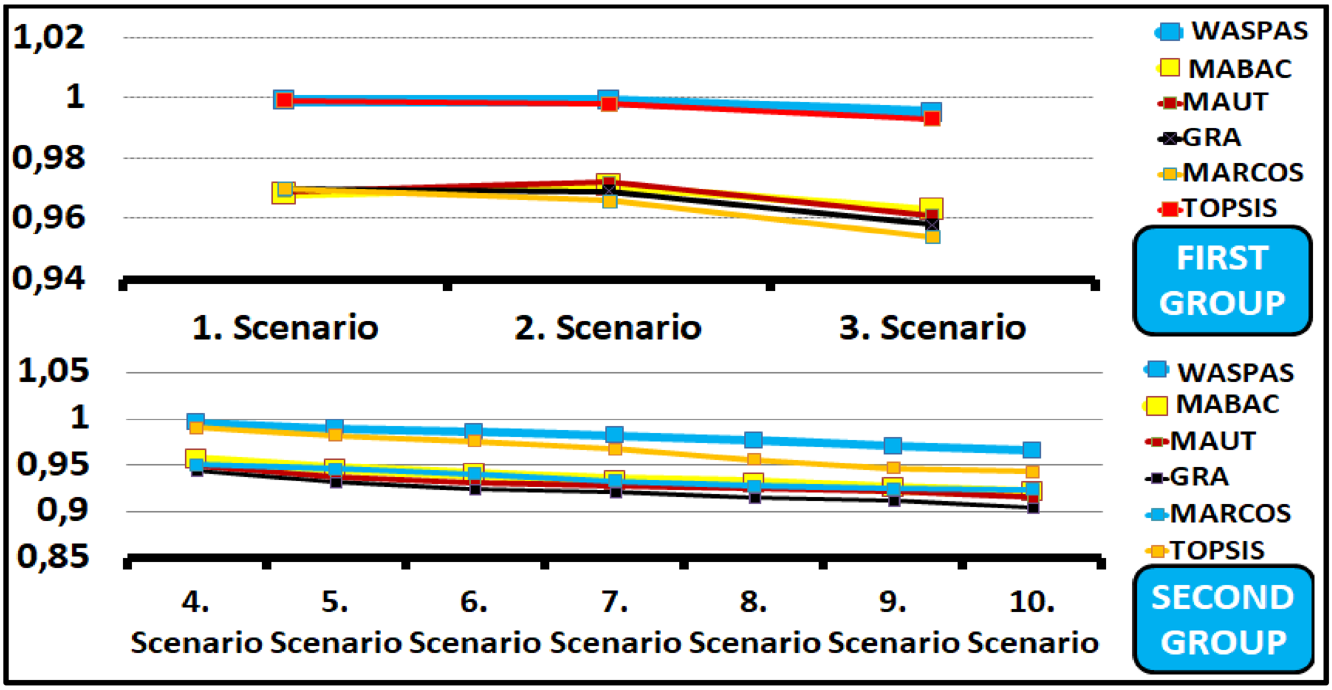

Figure 4. Placement of MIEXCF-based CODAS Relative to Other MIEXCF MCDM Techniques

Figure 4 demonstrates that the MIEXCF-based CODAS method increasingly differentiates itself from other MIEXCF-based MCDM methods as the number of scenarios increases. This observation highlights the unique characteristics of the CODAS method, which become more apparent with a larger number of scenarios.

To further analyze the simulation results, we employed an Analysis of Means (ANOM) for variances, specifically utilizing the Levene statistic (ADM). This statistical method assesses the consistency of variances in the criterion weights assigned by the MIEXCF-based CODAS method across various scenarios. A graphical representation of the ADM findings includes a central line denoting the overall mean ADM, along with upper and lower decision limits (UDL and LDL). If a group's standard deviation falls outside these limits, it signifies a significant deviation from the mean ADM, indicating heterogeneity in variances. In contrast, if all group standard deviations remain within the UDL and LDL boundaries, it confirms variance homogeneity (Keshavarz-Ghorabaee et al., 2021). For this analysis, we calculated variance values for the performance scores of countries, as determined by the MIEXCF-based CODAS and other MCDM methods, for each scenario. These variance values are presented in Table 13.

Table 13. Variance Scores of MCDM Methods across Scenarios

Methods	CODAS	MABAC	WASPAS	MAUT	GRA	MARCOS	TOPSIS
1. Scenario	0.856	0.095	0.018	0.079	0.035	0.015	0.074
2. Scenario	0.87	0.088	0.016	0.074	0.033	0.014	0.071
3. Scenario	0.723	0.81	0.012	0.071	0.034	0.011	0.069
4. Scenario	0.705	0.073	0.012	0.062	0.031	0.009	0.065
5. Scenario	0.654	0.063	0.011	0.058	0.025	0.009	0.064
6. Scenario	0.602	0.061	0.009	0.055	0.022	0.008	0.058
7. Scenario	0.555	0.055	0.009	0.051	0.019	0.008	0.052
8. Scenario	0.501	0.049	0.007	0.046	0.017	0.007	0.047
9. Scenario	0.488	0.044	0.006	0.043	0.016	0.006	0.044
10. Scenario	0.421	0.041	0.006	0.039	0.016	0.006	0.042
Mean	0.638	0.138	0.011	0.058	0.025	0.009	0.059

A closer examination of Table 13 indicates that the MIEXCF-based CODAS method exhibits a notably higher average variance across the analyzed scenarios when compared to other MIEXCF-based MCDM methods. This observation suggests that the CODAS method possesses a greater capacity to differentiate between criteria, potentially resulting in more nuanced performance evaluations.

In the final phase of the simulation analysis, the homogeneity of criterion weight variances in the CSBA method was evaluated using ADM (ANOM for variances based on Levene) analysis across various scenarios. This approach offers a visual tool to assess the consistency of variances. The graphical representation consists of three key elements: the overall average ADM as the central reference line (Average Decision Limit: ADL), along with the upper decision limit (UDL) and the lower decision limit (LDL). If the standard deviation of a particular group (or cluster) exceeds these decision limits, it signifies a significant divergence from the overall average decision ADM, indicating variance heterogeneity. Conversely, if the standard deviations for all clusters remain within the UDL and LDL boundaries, it confirms the presence of variance homogeneity. Figure 5 presents the graphical outcomes of the ADM analysis.

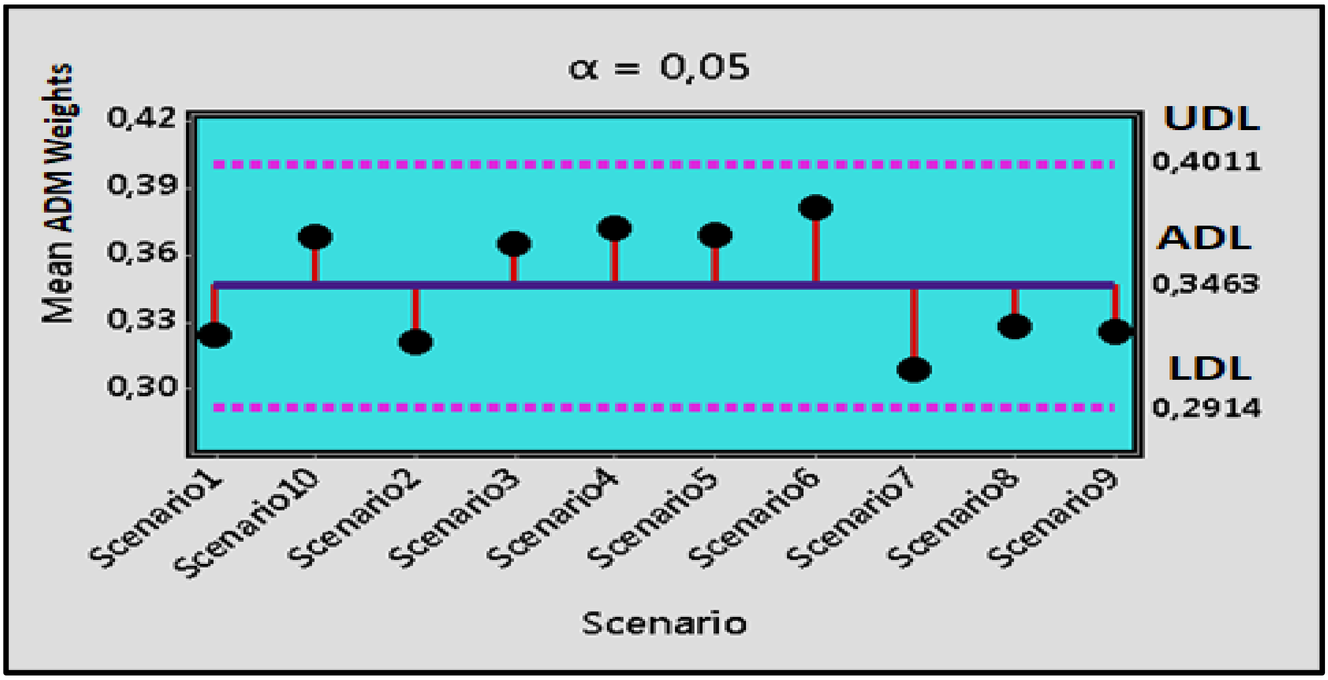

Figure 5. ADM Chart

A homogeneous band of calculated ADM values is depicted in Figure 5 for all scenarios. Crucially, all values are contained within the established UDL and LDL. This observation suggests consistent weight variances across the scenarios. Levene's Test, with its key statistics reported in Table 14, provides further evidence in support of this conclusion.

Table 14. Levene's Test

Levene Statistic	df1	df2	p (Significant)
0.312	2	10	0.191

p*<.05

A closer examination of Table 14 indicates that the Levene Statistic value is 0.312, with a p-value greater than 0.05 (p=0.191>0.05). This suggests that the variances are homogeneous. Consequently, when considering the overall results of the simulation analysis, it can be concluded that the MIEXCF-based CODAS method demonstrates robustness and stability in evaluating countries' climate change performance within the GII-BS framework.

5. CONCLUSION

Assessing the business development performance of major economies is of paramount importance for understanding global business development and its impact on the world economy. As significant players in the international market, these countries exert a substantial influence on economic trends, innovation, and competitiveness. Consequently, the business development performance of major economies has been deemed crucial. Within this context, the study measures the BS performance of these countries using the MIEXCF-based CODAS method, based on the latest and most up-to-date 2023 GII-BS criteria values.

The empirical findings indicated that, according to the MIEXCF method, the weights of the BS criteria for countries were ranked as follows: Knowledge Workers (KW), Knowledge Absorption (KA), and Innovation Linkages (IL). Significant differences were observed between KW and KA, with both exhibiting above-average weight values. This suggests that KW and KA could enhance the BS performance momentum of G7 countries. To optimize their contributions to the global economy, it is recommended that G7 countries prioritize fostering creativity and problem-solving abilities among KW, enhancing technology utilization, continuous learning, and innovative thinking and promoting collaboration, risk-taking, and effective leadership practices. Additionally, G7 countries should focus on improving their ability to access and monitor information, evaluate and internalize knowledge, transform this knowledge into gains, solicit stakeholder feedback, integrate an internal innovation culture, and support organizational learning within the context of KA.

Secondly, the MIEXCF-based CODAS method was employed to measure the BS performance of countries, resulting in the following performance rankings: the USA, Japan, the UK, France, Germany, Canada, and Italy. Notably, the USA exhibited significantly higher BS performance values compared to other countries, while Italy displayed the lowest values. Furthermore, the study calculated the average BS performance value, revealing that the USA, Japan, the UK, and France outperformed this average. WIPO (2023) ranked the G7 countries' BS performance based on the 2023 GII-BS data as follows: USA, Japan, Germany, France, Canada, and Italy. Considering both studies, the ranking of the USA, Japan, France, and Canada was consistent. Additionally, WIPO (2023) found that the USA, Japan, and UK exceeded the average performance value. Based on these findings from both studies, it can be concluded that the USA, Japan, and the UK have achieved higher BS performance compared to other G7 countries. These quantitative results suggest that the USA, Japan, and the UK have placed greater emphasis on BS criteria in developing their BS performance. Apart from WIPO (2023), no study in the literature has been found that analyzes the BS performance of countries. Furthermore, no research has been identified that evaluates the BS performance of countries using any BS-related criteria within an MCDM framework. Therefore, this study contributes to both the BS and MCDM literature by examining and measuring the BS performance of countries. A review of the literature reveals that the BS dimension has generally been analyzed in relation to other social and economic dimensions. In this context, Gaile-Sarkane and Andersone (2011), Razavi et al., (2012), Vesal et al., (2013), Suryaman et al., (2015), Balotić et al., (2016), Ceko (2022), Cuellar & González (2015), Kırıkkaleli & Ozun (2019), Mussina & Bachisse (2018), Pedro & Rodrigues (2022), and Salas-Velasco (2018) have examined the relationship between the BS dimension and economic factors, as well as dimensions directly linked to the economy (such as innovation, the labor market, and industrial values). Bazargan et al., (2017) and Çetingüç et al., (2020) have investigated the relationship between the BS dimension and culture as a social structure. Thus, a comprehensive review of the BS-related literature indicates that, apart from WIPO (2023), no study has exclusively focused on describing the BS structure of countries. This highlights the significant impact of BS capacities both at the national and global levels in terms of spatial implications. Consequently, this study aligns with WIPO (2023) in its exclusive focus on the BS performance of countries, while it differs from other studies that address the BS dimension in relation to broader socioeconomic factors. In the study, BS criterion weights for the countries were measured using the ENTROPY, MEREC, SD, SVP, LOPCOW, and CRITIC methods. Subsequently, the BS performance of the countries was evaluated using the CODAS method based on these weighting techniques. Furthermore, According to the research findings, the BS performance rankings obtained through the MIEXCF-based CODAS method were found to be fully consistent with those measured using the ENTROPY, MEREC, and SD-based CODAS methods. Therefore, considering the ranking of countries' BS performance from a methodological perspective, it has been concluded that the MIEXCF-based CODAS method exhibits similar characteristics to the ENTROPY, MEREC, and SD-based CODAS methods.

The observed BS performance differences among G7 countries stem from various structural factors when analyzed in terms of economic and social dynamics. Primarily, countries' innovation ecosystems, investment policies, R&D expenditures, and education systems directly influence their BS performance. For instance, countries such as the United States and Japan enhance their BS performance through high-tech investments, an entrepreneurial culture, and R&D incentives. In contrast, countries like Italy and Canada exhibit relatively limited incentive mechanisms and investment deficiencies in these areas, which may result in lower performance. Furthermore, when assessed within the framework of the Knowledge Workers criterion, significant differences exist among countries regarding their education systems and talent development policies. The United States and the United Kingdom, for example, possess globally prestigious universities and a robust academic research infrastructure. Meanwhile, in other countries, regional disparities in education quality and policies that fail to fully align with labor market demands contribute to a decline in BS performance. From a social perspective, factors such as innovation culture, digitalization levels, and flexibility in the business environment vary across countries. In the USA and Japan, strong collaborations between the private sector and academia play a crucial role in enhancing BS performance.

Conversely, in countries like Germany and France, stricter bureaucratic constraints and regulatory processes may slow down innovation, thereby limiting BS performance. Lastly, macroeconomic stability and industrial policies are also critical determinants of these performance differences. The United States, the United Kingdom, and Japan have adopted a knowledge-based economic growth model, whereas countries like Italy and Canada have a higher reliance on traditional industries. The relatively limited investments in digitalization and innovation in these nations contribute to their lower BS performance. Thus, BS performance disparities are not solely reflected through MCDM-based performance indicators but are also deeply intertwined with the broader economic and social structures of the respective countries.

Considering the relationship between economic growth and improvement and BS performance, the current research findings suggest that Italy, Canada, and Germany, in particular, need to implement measures, strategies, methods, and practices to enhance their BS performance in order to contribute more significantly to the global economy. In this context, it is particularly recommended that these countries, especially Italy, prioritize the development of KW and KA criteria and undertake innovative activities to enhance these criteria. Additionally, to improve their overall BS performance, these countries should focus on increasing investments in innovation and technology, education, and talent development programs, as well as expanding international market access. Furthermore, they should optimize their supply chains and collaborations, strengthen their management and organizational structures, and develop strategies to promote collaboration and clustering in the business world. Policy recommendations for countries with low BS performance should focus particularly on the Knowledge Workers and Knowledge Absorption criteria.

First, these countries need to implement structural reforms in their education systems to enhance the quality of their knowledge workers. For instance, incentive mechanisms should be established to strengthen university-industry collaboration, and technology-driven regional development projects should be promoted. Additionally, greater investments in digitalization processes should be made to support collaboration between the public and private sectors. Specifically, for countries with low BS performance, policies should focus on strengthening the innovation ecosystem through the development of incubators, technology transfer offices, and startup support programs. Moreover, interactions between large-scale corporations and innovative startups should be encouraged to facilitate knowledge exchange and technological advancements. At the macroeconomic level, policies that attract foreign direct investment (FDI) should be adopted, ensuring that global corporations direct their R&D investments toward these countries. In particular, countries such as Italy, Canada, and Germany could enhance tax incentives and funding mechanisms to support innovation and knowledge transfer, thereby fostering the growth of technology-driven industries. In summary, policy recommendations for countries with low BS performance should be formulated by considering their economic and social structures. Education reforms, increased R&D investments, the restructuring of industrial policies with an innovation-oriented approach, and stronger collaboration between the private and public sectors will play a crucial role in enhancing these countries' global competitiveness and BS performance.

Thirdly, from a methodological perspective, sensitivity analysis revealed that the measurement of BS performance of G7 countries is sensitive, comparative analysis indicated it is credible and reliable, and simulation analysis confirmed its robustness and stability. Consequently, these findings support the conclusion that the MIEXCF-based CODAS method can be effectively employed to measure the BS performance of G7 countries using the GII-BS criteria.

In terms of the study's limitations, only the BS criterion values of G7 countries for the year 2023 have been considered. To enhance the scope and comprehensiveness of the research, it is recommended that the BS performance of countries be analyzed by incorporating data from multiple years.

To enhance the comprehensiveness of future studies, different objective weighting techniques such as CILOS and IDOCRIW can be employed to measure the weights of BS criteria. Additionally, to assess the BS performance of countries, various performance calculation methods beyond CODAS and the other MCDM methods discussed in this study can be utilized, including WASPAS, EDAS, MOOSRA, ROV, COPRAS, DNMA, MABAC, MARCOS, MAIRCA, RAFSI, PIV, WEDBA, SECA, OPA, VIKOR, ELECTRE, COCOSO, OWA Operator, TODIM, and MULTI-MOORA. This will allow for a comparative analysis of countries' BS performance values and rankings based on different methods. Furthermore, instead of limiting the analysis to G7 countries, the BS performance of member countries of supranational and international economic organizations that influence the global economy (such as the EU, G20, BRICS, OECD, SCO, MERCOSUR, and EAEU) can be measured and compared on an organizational basis.

AUTHORS' DECLARATION:

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support.

AUTHORS' CONTRIBUTIONS:

The entire research is written by the author.

REFERENCES

Aal, S. A., Shreyas, J., & Udayaprasad , P. K. (2024). Selecting optimal charcoal company using multi-criteria decision making methodology. *Multicriteria Algorithms with Applications, 3*, 15–22. https://doi.org/10.61356/j.mawa.2024.311561

Alexandroa, R., & Basrowi. (2024). The influence of macroeconomic infrastructure on supply chain smoothness and national competitiveness and its implications on a country's economic growth: evidence from BRICS countries. *Uncertain Supply Chain Management, 12*, 167–180. https://doi.org/10.5267/j.uscm.2023.10.007

Alkan, N., & Kahraman , C. (2024). CODAS extension using novel decomposed Pythagorean fuzzy sets: Strategy selection for IOT based sustainable supply chain system. *Expert Systems with Applications, 237*, 1-15. https://doi.org/10.1016/j.eswa.2023.121534

Alpar, R. (2017). *Uygulamalı çok değişkenli istatistiksel yöntemler*. Detay Yayıncılık.

Altıntaş, F. F. (2024). A novel method for assessing the weight coefficients of criteria within the framework of multi-criteria decision-making: Measurement relying on the impacts of an exponential curve function (MIEXCF). *Gazi University Journal of Science Part A: Engineering and Innovation, 11*(1), 173-202. https://doi.org/10.54287/gujsa.1419551

Amari, A., Moussaid, L., & Tallal, S. (2023). New parking lot selection approach based on the multi-criteria decision making (mcdm) methods: Health Criteria. *Sustainability, 15*, 1-18. https://doi.org/10.3390/su15020938

Amit, R., & Zott , C. (2020). *Business model innovation strategy: Transformational concepts and tools for entrepreneurial leaders.*Wiley.

Amusan, O. T., Nwulu, N. I., & Gbadamosi, S. L. (2024). Multi-criteria decision-based hybrid energy selection system using CRITIC weighted CODAS approach. *Scientific African, 26*, 1-12. https://doi.org/10.1016/j.sciaf.2024.e02372

Azim, A. B., Ali, A., Khan, A. S., Awwad, F. A., Ali, S., & Ismail, E. A. (2024). Applications of q-spherical fuzzy rough codas to the assessment of a problem ınvolving renewable energy site selection. *IEEE, 12*, 114100-114122. https://doi.org/10.1109/ACCESS.2024.3412193

Balotić, G., Paunović, S., & Mićić, J. (2016). Impact of the business sophistication ındicators on the real economic indicators. In *International Scientific Conference: The Priority Directions of National Economy Developmen, 13-14 October 2016*, University of Niš Publications.

Bazargan, A., Ghasemi, R., Ardebili, M. E., & Zarei, M. (2017). The relationship between higher education and training and business sophistication. *Economic Review, 21*(2), 319-341.

Brown, S., Bessant, J., & Jia, F. (2018). *Strategic operations management.* Routledge.

Ceko, E. (2022). A regressive analysis of relations between ınnovation and business. *City Review Journal*(11), 40-55.

Chandra, P. (2014). *Strategic financial management: managing for value creation.* McGraw Hill Education (India) Private Limited.

Cherunilam, F. (2015). *Business policy and strategic management.* Himalaya Publishing House.

Cornell University, INSEAD, & WIPO. (2016). *The Global innovation index 2016: Winning with global innovation.* Cornell University, INSEAD, and the World Intellectual Property Organization.

Cornell University, INSEAD, & WIPO. (2020). *The global innovation index 2020: Who will finance innovation?* Cornell University, INSEAD, and the World Intellectual Property.

Cuellar, L. P., & González, M. D. (2015). Cultural traits and business sophistication. *Revista Tinerilor Economişti (The Young Economists Journal), 1*(25), 49-56.

Çetingüç, B., Çalık, E., & Çalışır, F. (2020). The moderating effect of long-term orientation on the relationship among human capital research, In *business sophistication, and knowledge & technology outputs* (pp. 291-296. Springer.

Daum, C. (2020). *Business strategy essentials you always wanted to know.* Vibrant Publishers.

David, F. R., & David, M. E. (2022). *Stratejik yönetim rekabet avantajı yaklaşımı, (İ. Şener and A. A. Karapolatgil Trans. Ed.).* Palme Yayınevi.

Demir, G., Özyalçın, A. T., & Bircan, H. (2021). *Çok kriterli karar verme yöntemleri ve ÇKKV yazılımı ile problem çözümü.* Nobel.

Dinçer, Ö. (2013). *Stratejik yönetim ve işletme politikası*. Alfa Yayınları.

Doroudi, H., Goudarzi, F. H., & Kandel, B. K. (2022). The effect of the competitiveness ındex on economic growth, with an emphasis on institutional and structural variables: 10 selected countries exporting oil. *Philosophy, Economics And Law Review., 2*(2), 85-95. https://doi.org/10.31733/2786-491X-2022-2-85-95

Ecer, F. (2020). *Çok kriterli karar verme.* Seçkin Yayıncılık.

Elsayed, A., & Arain, B. (2024). A systematic approach for evaluating and selecting healthcare waste treatment devices using OWCM-CODAS and triangular neutrosophic sets. *Neutrosophic Systems with Applications, 19*, 67-79. https://doi.org/10.61356/j.nswa.2024.19325

Fälth, A., & Rañola, D. (2021). *Women empowerment principles.* UN Woman.

Fan, J., Yuan, Y., & Wu, M. (2024). Railway transportation scheme selection based a CODAS-COPRAS method in triangular dense fuzzy linguistic term lock environment. *International Journal of Fuzzy Systems*, 1-12. https://doi.org/10.1007/s40815-024-01778-0

Gaile-Sarkane, E., & Andersone, I. (2011). *Modeling of consumer behavior for business sophistication. modeling of consumer behavior for business sophistication.* In *15th World Multi-Conference.15-16 August 2011*. Riga Technical University.

Ghosh, A. K., & Ghosh, A. (2022). *Effective human resource development.* Manas Publications.

Gigovič, L., Pamučar, D., Bajič, Z., & Milicevič, M. (2016). The combination of expert judgment and GIS-MAIRCA analysis for the selection of sites for ammunition depots. *Sustainability, 8*(232), 1-30.

Hajnal, P. (2020). *The G7/G8 system evolution, role and documentation.* Routledge.

Henderson, I. (2017). *Human resource management for mba and business masters.* CIPD.

Hermanni, A. J. (2022). *Business guide für strategisches management.* Springer Gabler.

Hussain, R., & Hussain, Z. (2024). Belief and plausible divergence measures: A novel approach to multicriteria decision making with modified CODAS. *Computational and Applied Mathematics, 43*(329), 1-10. https://doi.org/10.1007/s40314-024-02781-9

Hysai, A., & Sulçaj, K. (2024). Impact of innovation on economic growth in Balkan countries. *AGORA International Journal of Economical Sciences, 18*(1), 65-73.

Joshi, M., & Klein, J. R. (2018). *Global Business.* Oxford University Press.

Kannan, J., Jayakumar, V., & Pethaperumal, M. (2024). Advanced fuzzy-based decision-making: The linear diophantine fuzzy CODAS method for logistic specialist selection. *Spectrum of Operational Research, 2*(1), 41-60. https://doi.org/10.31181/sor2120259

Kavitha, S., Satheeshkumar, J., & Amudha, T. (2024). Multi-label feature selection using q-rung orthopair hesitant fuzzy MCDM approach extended to CODAS. *Mathematics and Computers in Simulation, 222*, 148-173. https://doi.org/10.1016/j.matcom.2023.07.032

Keshavarz-Ghorabaee, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2016). A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making. *Economic Computation and Economic Cybernetics Studies and Research, 3*(50), 25-44.

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2021). Determination of objective weights using a new method based on the removal effects of criteria (MEREC). *Symmetry, 13*, 1-20. https://doi.org/10.3390/sym13040525

Khargotra, R., Alam, T., Thu, K., András, K., & Singh, T. (2024). Optimization of design parameter of v-shaped perforated blocks in rectangular duct of solar air heater by using hybrid BWM-CODAS technique. *Solar Energy Materials and Solar Cells, 264*, 1-15. https://doi.org/10.1016/j.solmat.2023.112627

Kindersley, D. (2018). *The business book: Big ideas simply explained.*DK Publishing.

Kırıkkaleli, D., & Ozun, A. (2019). Innovation capacity, business sophistication and macroeconomic stability: empirical evidence from OECD countries. *Journal of Business Economics and Management, 20*(2), 351–367. https://doi.org/10.3846/jbem.2019.9602

Mariš, M. (2022). An empirical study of competitiveness and international economic growth: The case study of EU. *Mathemetics in Education, Research and Applications, 2*(8), 74-85. https://doi.org/10.15414/meraa.2022.08.02.74-85

Mussina, K. P., & Bachisse, M. (2018). Canonical correlation analysis between business sophistication and macroeconomic environment: A secondary study of countries global competitiveness. *Revista ESPACIOS, 39*(18), 1-10.

Oldani, C., & Wouters, J. (2018). *The G7, anti globalism and the governance of globalization (global governance).* Routledge.

Omonovich, T. B. (2023). The Role of increasing competitiveness in ensuring economic development. *World Economics & Finance Bulletin (WEFB), 28*, 145-150.

Pedro, F. X., & Rodrigues, R. G. (2022). The Impact of business sophistication on marketing knowledge. In *Disruptive innovation and emerging technologies for business excellence in the service sector* (pp. 130-263). IGI Global.

Rahayu, G. N. (2020). Correlation between technological readiness and business sophistication in global competitiveness. *Journal of Industrial Engineering and Halal Industries (JIEHIS), 1*(2), 110-120.

Razavi, S. M., Abdollahi, B., Ghasemi, R., & Shafie, H. (2012). Relationship between "Innovation" and "Business Sophistication": A secondary analysis of countries global competitiveness. *European Journal of Scientific Research, 79*(1), 29-39.

Robosky, D. (2023). *Strategic operations management: aligning processes with organizational goals*. Independently published.

Salas-Velasco, M. (2018). Production efficiency measurement and its determinants across OECD countries: The role of business sophistication and innovation. *Economic Analysis and Policy, 57*, 60-73. https://doi.org/10.1016/j.eap.2017.11.003

Schwab, K., & WEF. (2015). *The global competitiveness report 2015-2016.* World Economic Forum.

Schwab, K., & WEF. (2017). *The global competitiveness report 2017-2018.* World Economic Forum.

Schwab, K., & WEF. (2018). *The global competitiveness report 2018.* World Economic Forum.

Schwab, K., & WEF. (2019). *The global competitiveness report 2019.* World Economic Forum.

Schwab, K., Zahidi, S., & WEF. (2020). *The global competitiveness report 2020-how countries are performing on the road to recovery.* World Economic Forum.

Siegfried, P. (2021). *strategic management business cases and management concepts paperback*. Norderstedt: BoD - Books on Demand.

Sofat, R., & Hiro, P. (2015). *Strategic financial management.* Prentice Hall.

Spender, J. C. (2014). *Business strategy: Managing uncertainty, opportunity, and enterprise*. Oxford University Press.

Suryaman, D. W., Kuncoro, H., & Sebayang, K. D. (2015). Interaction between the labour market effeciency with business sophistication in the dynamic global competitiveness in Southeast Asia. *International Journal of Business, Economics and Law, 8*(3), 19-24.

Terzić, L. (2021). Revealing the effects of competitiveness and innovation on economic growth:Evidence from European leading and following countries. *Theoretical and Applied Economics, 29*(4), 19-30.

Velu, C. (2024). *Business model innovation.* Cambridge University Press.

Vesal, S. M., Nazari, M., Nazari, M., Hosseinzadeh, M., Shamsaddini, R., & Nawasen, K. (2013). The relationship between labor market efficiency and sophistication in global competitiveness. *International Journal of Business and Management, 8*(13), 83-92.

WIPO. (2021). *Global innovation index 2021.* World Intellectual Property Organization (WIPO).

WIPO. (2022). *Global innovation index 2022-What is the future of innovation-driven growth?* WIPO.

WIPO. (2023). *Global innovation index 2023-innovation in the face of uncertainty*. World Intellectual Property Organization.