A Performance Analysis in Circular Economy for the Selected EU Countries

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Abstract

The circular economy is a highly important contributor to the environment and economic growth. Therefore, countries attach great importance to this issue in order to balance environmental protection and economic growth. In this study, we aim to evaluate the circular economy performance of the developed EU countries via an MCDM approach. We employ an integrated approach. Initially, we use an objecting weighting method namely the Shannon entropy method for weight criteria. Secondly, we use the MABAC method to rank alternatives. As per analysis results, Germany is found as the best-performing country in terms of circular economy performance. We may conclude that MCDM methods are feasible alternatives to evaluate circular economy performance.

Keywords: Circular economy, performance, MCDM, MABAC, EU countries

1. Introduction

The conventional economy depends on solely the production and consumption of materials (Ūsas et al., 2021). This approach causes exhaustion of resources and excessive production of waste. As a result, countries face critical economic, environmental difficulties. The fact of finite energy sources has called for countries to act more cautiously in terms of resource use. To this end, the circular economy (CE) makes important contributions to both the economy and the environment. The CE is a concept affiliated with acquiring the regeneration of sources and enabling to retain product values as high as possible (Gunarathne et al., 2021). Today, one of the main problems for developed and developing countries is to balance economic growth and environmental protection (Gao et al., 2021). The CE is a remarkable contributor to this purpose. The principal aim of a CE is to conserve the environment and preserve finite sources through efficient waste management. In this regard, the transition to a CE is indispensable for a sustainable and low-carbon economy (Mazur-Wierzbicka, 2021). In this study, we aim to determine to what extent the developed EU countries perform efficiently as regards the CE. In this framework, Multi-Criteria Decision Making (MCDM) techniques are suitable approaches as they can deal with benefit and cost criteria concurrently (Triantaphyllou, 2000). To this end, the basic motive of this study is to analyze the actual CE performance of the developed EU countries with the framework of the MCDM approach.

Our study continues in that way. After we complete our presenting introduction, we continue with a literature review about CE performance. Then, we present the analysis method used in our study to evaluate countries. Lastly, we come to an end with conclusions.

2. Literature Review

To date, different studies have focused on the performance and efficiency of countries. We summarize these studies as follows.

Škrinjarić (2020) evaluated the CE performance of some European countries from 2010 to 2016 via the grey relational analysis. Škrinjarić (2020) used energy recovery, recycling material, gross investment, the share of people employed in the CE, circular material use rate, and the number of patents in relation to recycling as performance evaluation criteria. Škrinjarić (2020) concludes that Germany, Denmark, and the Netherlands are found the best-performing countries in terms of the CE. The best-performing countries have a similar feature of high Gross Domestic Product (GDP) per capita and possess superior infrastructure and Research and Development (R&D) levels. Garcia-Bernabeu et al., (2020) formed an index based on the TOPSIS approach to evaluate the CE performance of the European Union (EU) countries. They compose different scale indexes based on the EU directives to evaluate the EU countries. Their indicators focus on the generation and use, waste governance, secondary raw materials, and competitiveness and innovation. They conclude that Germany and United Kingdom are found successful while Malta and Estonia are found the most unsuccessful as regards CE performance. Ding et al., (2020) analyzed the CE efficiency of China via the network DEA and extended Malmquist methods. They determine industrial labor force and capital stock as inputs, industrial added value is represented as the economic output and industrial pollution is determined as undesirable output. The analysis results suggest that the average efficiency level in the investigated area is not very high. Besides, the Malmquist index results indicate a remarkable efficiency discrepancy among the investigated areas.

Stanković et al., (2021) assessed the CE development in the EU countries via the Principal Component and PROMETHEE methods. They use municipal waste production per capita, recycling rates of wastes, trade in recyclable raw material, the share of circular material uses, private investments, and gross value added in relation to CE sections, patents in relation to recycling, and secondary raw materials as performance evaluation criteria. They conclude that Germany is found as the best country among the EU countries. They also conclude that a positive correlation exists between the CE and the socio-economic development of a country. Mavi and Mavi (2019) evaluated the CE performance of the OECD countries via the Data Envelopment Analysis (DEA) and Malmquist index. They conclude that Switzerland performed as the best country in terms of the CE. Besides, they also infer that Ireland and the USA have enhanced their CE performance throughout the analysis period.

3. Research Methods

3.1 The Shannon Entropy Method

The criteria weighting is a crucial step in MCDM approaches. Several methods exist to calculate weights for MCDM techniques and the Shannon entropy technique is one of those approaches used to attribute criteria objectively. The Shannon entropy method can overcome the subjective judgment deficiency of some weighting methods (Alemi-Ardakani et al., 2016). Presume that m options exist to assess n criteria. $(x_{ij})_{m*n}$ can be regarded as the initial matrix. The normalized decision matrix is obtained below (Mavi et al., 2016).

$$p_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij} \quad (1)$$

The information entropy for every criterion is revealed below.

$$E_j = - (\ln m)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (2)$$

The weight obtained from information entropy is calculated below.

$$w_j = (1 - E_j)/(n - \sum_{j=1}^{n} E_j) \quad (3)$$

$$0 \leq w_j \leq 1 \text{ and } \sum_{j=1}^{n} w_j = 1 \quad (4)$$

where w_j is the weight attributed to criteria.

3.2 The Multi-Attributive Border Approximation Area Comparison (MABAC) Method

The MABAC approach is an MCDM technique developed by Pamučar and Ćirović (2015) to analyze the performance of alternatives. MCDM methods are beneficial techniques employed in many different fields due to their ability to deal with many alternatives using specific criteria. The main attribute of the MCDM approach is to find a compromise solution based on conflicting criteria, which take into consideration both benefit and cost attributes. Thereby, a compromise solution is obtained based on these attributes (Stević et al., 2020). To this end, several methods exist in literature introduced by practitioners. The MABAC method is one of those approaches, which was newly introduced in decision-making literature. The main advantages of the MABAC method are that it obtains stable results due to its plain structure and acquires comprehensive outcomes as it considers possible advantages and disadvantages (Hashemizadeh et al., 2021). The main feature of the MABAC method is that the criteria function value and its remoteness from the border approximation region are calculated (Pamučar & Ćirović, 2015). The MABAC approach steps are presented below (Gigović et al., 2017).

Step 1. The First Decision-Making Matrix Establishment. The initial step of the MABAC approach is to form the first decision-making matrix.

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{matrix} C_1 & C_2 & C_3 & \dots & C_N \\ \end{matrix} \begin{bmatrix} x_{11} & \cdots & x_{12} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{21} & \dots & x_{22} & \cdots & x_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (5)$$

where $X, m,$ and n denote initial decision-making, alternatives, and criteria respectively.

Step 2. Normalization of the Decision-Making Matrix. The normalization step is given as follows for benefit and cost indicators respectively.

$$t_{ij} = \frac{x_{ij} - x_i^+}{x_i^+ - x_i^-} \quad \text{(for benefit indicators)} \quad (6)$$

$$t_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \quad \text{(for cost indicators)} \quad (7)$$

where x_i^+ and x_i^- denote the highest and lowest values of the criterion for each alternative.

Step 3. Computation of the Weighted Decision Matrix. The weighted decision matrix is computed as follows.

$$v_{ij} = w_i . t_{ij} + w_i \quad (8)$$

where w_j denotes the weight coefficient of criteria and v_{ij} weighted matrix elements.

Step 4. Computation of the value of border approximation region. The border approximation region for each criterion is calculated as follows.

$$g_i = \left(\prod_{j=1}^{m} v_{ij}\right)^{1/m} \quad (9)$$

where v_{ij} denotes the components of the weighted matrix, m signifies the number of options.

Step 5. Computation of the remoteness of the options from border approximation region

$$Q = V - G = \begin{bmatrix} V_{11} & \cdots & v_{12} & \cdots & v_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ V_{21} & \dots & v_{22} & \cdots & v_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ V_{m1} & \dots & v_{m2} & \dots & v_{mn} \end{bmatrix} - \begin{bmatrix} g_1 & g_2 & \cdots & g_n \end{bmatrix} \quad (10)$$

$$Q = \begin{bmatrix} V_{11} - g_1 & \cdots & v_{12} - g_2 & \cdots & v_{1n} - g_n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ V_{21} - g_1 & \cdots & v_{22} - g_2 & \cdots & v_{2n} - g_n \\ \vdots & & \ddots \; \vdots & & \ddots \; \vdots \\ V_{m1} - g_1 & \cdots & v_{m2} - g_2 & \cdots & v_{mn} - g_n \end{bmatrix} = \begin{bmatrix} q_{11} & \cdots & q_{12} & \cdots & q_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ q_{21} & \cdots & q_{22} & \cdots & q_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ q_{m1} & \cdots & q_{m2} & \cdots & q_{mn} \end{bmatrix} \quad (11)$$

where g_i denotes border approximation region values and n signifies the number of criteria.

Step 6. Rating of the Options. The ultimate ranking of alternatives is obtained by the total remoteness of alternatives from border approximation regions.

$$S_i = \sum_{j=1}^{n} q_{ij}, \; j = 1,2, \ldots, n, \quad i = 1,2, \ldots, m \quad (12)$$

4. Empirical Analysis

In this study, we aim to assess the CE performance of the developed EU countries from 2016 to 2018 via a novel MCDM approach namely the MABAC method. We retrieve our dataset from the Eurostat statistics website. We select the countries used in our analysis based on the GDP per capita level and analyze the most developed EU countries. We determine our performance evaluation criteria considering previous studies about CE performance and EU CE priorities. In this context, we determine the generation of municipal waste (GMW), recycling rate of municipal waste (RRMW) import of the recyclable raw materials (IRRM), export of the recyclable raw materials (ERRM), circular material use rate (CMUR) as our performance evaluation criteria.

Initially, we present the unit and definitions of the performance indicators to reveal an overview as shown in Table 1.

Table 1. The Unit and Definitions of the Performance Indicators.

Performance Indicators	Units	Definitions
GMW	Kilograms per capita	This criterion gauges the waste collected by municipal authorities and disposed through the waste management structure.
RRMW	Thousand Tonnes	This criterion gauges the rate of resources recovered and taken back into the economy.
IRRM	Tonnes	This criterion gauges the quantities of specific waste classifications and by-products, which are brought into EU countries.

ERRM	Tonnes	This criterion gauges the quantities of specific waste classifications and by-products that are sent by EU countries.
CMUR	Percentage	This criterion gauges the rate of material recovered and taken back into the economy.

We present the CE performance of the MABAC method results in the developed EU countries over the 2016-2018 period in Table 2.

Table 2. The MABAC Method Performance Results over the 2016-2018 Period.

Countries	***2016 S_i***	**Ranking**	***2017 S_i***	**Ranking**	***2018 S_i***	**Ranking**
Germany	0,1545	1	0,1599	1	0,1655	1
Sweden	0,0164	2	-0,0124	3	0,0071	2
Austria	-0,0010	3	-0,0011	2	-0,0098	3
France	-0,0058	4	-0,0247	4	-0,0516	4
Netherlands	-0,0651	5	-0,0581	5	-0,0834	6
Luxembourg	-0,0815	6	-0,0640	6	-0,0660	5
Finland	-0,0912	7	-0,0858	7	-0,0973	7
Denmark	-0,1058	8	-0,1070	8	-0,1096	9
Malta	-0,1160	9	-0,1074	9	-0,1161	10
Italy	-0,1417	10	-0,1224	10	-0,1057	8
Ireland	-0,1492	11	-0,1454	11	-0,1578	12
Belgium	-0,1715	12	-0,1700	12	-0,1327	11
Czechia	-0,4606	13	-0,4761	13	-0,4836	13

Source: Authors' Calculations.

According to the analysis results of the MABAC method, Germany, Sweden and Austria are found as the best-performing country in terms of CE while Czechia remained the least performing country among the developed EU countries. Most countries performed a stable inclination throughout the analysis period.

5. Conclusions

The transition to sustainable development is a prerequisite for developed countries (Huysman et al., 2017). The notion of CE is a significant contributor to sustainable development as it focuses on the minimal loss of material and energy via reuse, recycling, and recovery (Haupt et al., 2017). In this study, we aim to assess the CE performance of the developed EU countries via the MCDM techniques. We adopt an integrated pattern. Initially, we use the Shannon entropy method to objectively weight criteria. Then, we employ a novel MCDM method namely the MABAC approach to analyze the CE performance of the developed EU countries. As per the MABAC results, Germany is found as the best country in terms of CE performance among the developed EU countries. Our analysis results are consistent with the recent studies in this field (Ogunmakinde 2019, Škrinjarić, 2020; Giannakitsidou et al., 2020). Germany is a pioneer country with its Waste Management Act, which supports the complete implementation of CE necessities (Silvestri et al., 2020). The European parliament has imposed the legislation of a 65% recycling rate for 2035. Germany has already reached this target with its ambitious pattern (Giannakitsidou et al., 2020). Besides, Sweden and Austria shared the second and third-rank over the investigated period. Sweden has strict environmental and recycling policies to maintain sustainable development. Sweden has a high share of recycling rate in comparison to most EU countries. The Swedish government has implemented extensive policies to enhance CE performance. For instance, it has attempted to develop a CE via treating solid waste and wastewater, recycling (Heshmati & Rashidghalam, 2021). EU countries such as Germany, Sweden, and Austria perform successfully with landfill ban as it contributes to the amount of recycled and incinerated by 95% (Van Eygen et al., 2018). The CE is a different concept from the linear economy, which solely focuses on the production and consumption of resources. This concept neglects to recycle and reuse of materials and, waste treatment. This notion increases the dependency on such materials. As a result, this handicap harms the sustainable development of countries (Sauvé et al., 2016).

We may conclude that the countries with successful CE performance enhance the sustainable development of countries. The CE is a significant aim set by the EU as well. Therefore, it is significant to evaluate the CE performance of the EU countries. In this regard, MCDM methods are feasible options to assess the CE performance as it is a research field consisting of conflicting criteria.

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