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SUSTAINABLE DEVELOPMENT PERFORMANCE ANALYSIS BY ENTROPY-BASED COPRAS METHOD: AN APPLICATION IN THE EUROPEAN UNION COUNTRIES

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Abstract: This study aims to examine the sustainable development performance of European Union countries for the years 2018, 2019, and 2020 by the Entropy-based COPRAS Method, one of the hybrid multi-criteria decision-making (MCDM) techniques. The weights of the criteria has been calculated by the entropy method. The performances of countries have been measured via the COPRAS Method. Some selected sustainable development indicators, which are available for all the European Union countries, have been used. The most important criterion by the Entropy Method is the Net Greenhouse Gas Emissions for all years studied. Sweden has the best sustainable development performance by the COPRAS Method in all the years studied. Croatia was the country with the worst performance in 2018 and 2019, but Malta is in 2020. Some policy recommendations to increase sustainable development performance have been presented at the end of the study It should be noted that these findings do not indicate a cause-and-effect relationship among the variables. When criteria and years change, the ranking may also change. In order to explore why some countries perform better than others, some new studies using econometric methods can be implemented.

Keywords: sustainable development, Entropy Method, COPRAS Method, MCDM Methods

1 INTRODUCTION

Through environmental preservation, protection, and the reduction of unnecessary use, sustainable development is a method of development that not only encourages environmental friendliness but also enhances the quality of human existence. One fundamental human right is development. Man is abusing this privilege granted to him by other creatures and using natural resources without restriction. It is seriously harming not only the environment but also him. (Aher, 2022).

Although there is little clarity in sustainable development, most attempts to define it involve some mix of equity, the environment, and development. The focus of proponents of sustainable development varies, though, with regards to what needs to be created, what needs to be sustained, how to connect development

and environment, and how long these connections should last. A lot of effort has gone into creating quantitative indicators of sustainable development despite the ongoing definitional uncertainties around the concept (Parris and Kates, 2003).

Various studies have been made to put forth sustainable improvement fulfillment of districts, municipalities, provinces and states. Lamichhane et al. (2014) introduced a structure to determine the condition of sustainable improvement fulfillment of Organization for Economic Co-operation and Development (OECD) states towards meeting the 2030 plan established on the 17 Sustainable Development Goals (SDGs). Each SDG focusses on a crucial sector of sustainable improvement and is demonstrated with various social, fiscal, or environmental indexes. Megyesiova and Lieskovska (2018) proposed in another study on OECD states that the primary objective of the analysis was the state of affairs and the modification of parameters that constitute the component of the OECD nations' sustainable development goals. Regression analysis and the Pearson's correlation coefficient were used to find the linear relationship between two variables. In addition to employing univariate statistical approaches, a multivariate approach was also used to compare the OECD countries.

Huan et al. (2021) implemented a methodological framework to 15 countries along the "Belt and Road" utilized 108 parameters to determine the fulfillment of accomplishing SDGs for mentioned states. Ultimately, different national improvement systems and relevant strategy proposals were done. The three indicators which are involved in the scientific structure improved in this paper can efficiently increase the worldwide partners' reciprocal perceptive of the advancement of accomplishing SDGs to assist provincial cooperative planning and nationwide key decision-making.

D'Adamo et al. (2021) proposed a nationwide outlook where multi-criteria decision analysis (MCDA) is employed to evaluate present performance. A sustainability result is assessed using 175 indicators that are included in all 17 SDGs for each region. Furthermore, sustainability outcomes are divided into the three parts – social, environmental, and fiscal. The outcomes demonstrated the constructive performance of the provinces in the North Italy and of Trentino Alto Adige, which is in first place in the two situations. Furthermore, the analysis of personal SDGs highlights several major provinces in relation to the geographical specificities that were raised. In contrast to the social and economic subgroups, it was important to highlight how well the environmental subdivision of the SDGs performed in the southern region of Italy.

Since it is very popular area for authors to study and for the international organizations and institutions to examine, many reports and papers are published about sustainable development performance of the countries.

The introduction and the literature review have been written by T. Genç. Methodology, implementation of Entropy and COPRAS Methods and conclusion have been written by M. Masca.

2 THE LITERATURE REVIEW

In order to ascertain the objective weight of criteria in the decision-making process based on value dispersion, the entropy method was introduced. Shannon (1948) created the idea of entropy in communication theory to address ambiguous and incomplete data. Nonetheless, the irreversible motion that takes place in thermodynamics science was explained by the idea of entropy. Subsequently, the idea of entropy was discovered to be useful in solving decision-making issues (Zeleny, 2012). The strategy is based on the numerical data that decision makers have acquired in order to establish the relative value of each criterion. In particular, the Shannon's entropy was extended

to create the entropy weight method, an objective process for determining the weights of criteria (El-Araby et al., 2022)

It has been applied to many areas such as economy, risk assessment, selection problems, etc. Sun (2021) proposed that because of some calculations, it is required to use the Entropy Method to make a complete evaluation and valuation of provincial fiscal improvement. Genç and Arıcak (2022) utilized the Entropy and TOPSIS methods to evaluate the selected skidding methods in forestry. The TOPSIS method's results vary depending on how the criteria are weighted. As a result, the Entropy method's weights for the criteria were determined by an impartial assessment. Ultimately, the performance of the skidding procedures was ascertained for both topsoil and subsoil after these weight values were integrated into the TOPSIS method solution process.

Moreover, the examples mentioned above the Entropy Method have been used for various fields like selection problem (Kaur et al., 2022; Vaid at al., 2022; Hussain and Mandal, 2016); risk assessment (Wu et al., 2022); location problem (El-Araby et al., 2022) and ranking (Lee and Chang, 2018).

One of the most popular and widely applied MCDM techniques was created by Zavadskas and Kaklauskas (1996) and is called COPRAS. By utilizing the utility rate of the alternatives and the combined criteria weights, it is utilized to align the options depending on several criteria. Respecting both ideal and anti-ideal outcomes is how the optimal option is chosen and carried out (Das et al, 2012). The significance and efficiency scale of the types under examination are directly and relatively dependent on the values and weights of the criteria as well as on an efficient technique of presenting the options, according to the COPRAS technique (Yazdani et al, 2011). COPRAS has various benefits as having less calculations, easy and deterministic calculation method (Ayrım et al, 2018).

A hybrid multi-criteria decision making model was utilized by Zolfani et al. (2012) to select a contractor. COPRAS is applied to numerous articles for multiple decision-making methods. The first step is to assign a weight to each criterion using the AHP. In order to select and order the suppliers, the COmplex PRoportional ASsessment of alternatives to Grey relations (COPRAS-G technique) is used. A generic material selection problem MCDM-based procedure utilizing TOPSIS, COPRAS, and DEA was proposed by Nasab and Anvari (2017). As Nasab and Anvari, many authors used COPRAS Method for the selection problems like (Datta et al., 2009: Petkovic et al., 2015; Patel et al., 2020; Goswami et al., 2021) However selection problems are not the only area for the COPRAS Method, the other fields are listed as follows; risk assessment, evaluating, ranking, prioritizing, locating, etc.

MDCM techniques do not show a cause-and-effect relationship. The effects of variables on each other are not determined with this technique. No predictions for the future can be made using these techniques. Therefore, it is not used to test a hypothesis. These techniques allow ranking among the alternatives according to specific criteria.

In MCDM, there are many methods in the literature, such as ELECTRE, TOPSIS, PROMETHEE, VIKOR, etc. These models differ from each other by the procedures they have. They have the capability to determine the ranking among many alternatives however, one of the weakest points of these techniques is the weight that decision makes need to apply subjectively. To overcome this problematic area, some MCDM methods are introduced to the literature such as CRITIC and Entropy which determines the weights objectively. Moreover, these methods are used with other MCDM methods in a hybrid way to rank the alternatives without the decision maker’s subjective judgements.

3 METHODOLOGY AND DATASET

This study aims at ranking the European Union countries (27) according to sustainable development performance using Entropy and COPRAS methods. The objective importance of the criteria is calculated by Entropy Method. The sustainable development performance of the countries has been measured by COPRAS Method. The dataset has been selected among the sustainable development criteria by Eurostat Database. Six sustainable development criteria belong to 2018, 2019, 2020 for each country have been used in the calculations. It cannot be possible to use more indicators and newest data because of the lack of data for all European Union countries.

3.1 Dataset and Their Explanations

Six sustainable development indicators and their explanations and orientations in the data set used for the decision matrix of the study can be explained as follows (European Comission).

People at risk of poverty or social exclusion (PRPSE): This indicator corresponds to the total population that is susceptible to poverty, significantly disadvantaged in terms of money and society, or living in a home where virtually little effort is done after social transfer. People are only counted once, even if they are affected by more than one phenomenon. The orientation of this criterion should be minimum.

Agricultural factor income per annual work unit (AWU): This indicator only represents a portion of the worker productivity in agriculture. The income produced by agriculture to offset owned (land, labor, and capital) as well as borrowed (wage, capital, and land rent) factors of production is measured as agricultural factor income. The real net value added of agricultural factor costs, deflated, equals factor income. As a deflator, the GDP implicit price index is employed. The orientation of this criterion should be maximum.

Healthy life years at birth by sex (HLY): This indicator shows how many years at a certain age a person is predicted to live without experiencing serious or moderate health issues. The orientation of this criterion should be maximum.

Seats held by women in national parliaments and governments (SWNP): The percentage of women in national governments and parliaments is indicated by this indicator. The orientation of this criterion should be maximum.

Perceived independence of the justice system (PIJS): This indicator seeks to investigate respondents' opinions regarding the judicial independence of member states of the EU, with an emphasis on perspectives pertaining to the independence of judges and courts within a country. This criterion should have maximum orientation.

Net greenhouse gas emissions (NGGE): This indicator calculates all of the nation's emissions, including the so-called "Kyoto basket" greenhouse gases—carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and others—that are released into the atmosphere during international aviation. -F gases, which include sulfur hexafluoride (SF_6), hydrofluorocarbons, perfluorocarbons, and nitrogen trifluoride (NF_3), are emitted from all sectors of the greenhouse gas emissions inventory, including indirect carbon dioxide and international aviation. The orientation of this criterion should be minimum.

3.2 Entropy Method

Entropy is one of the well-known weight methods that has been extensively researched and used. The primary benefit of EWM over other subjective weighting models is its ability to eliminate the influence of human factors on indicator weighting, which enhances the overall evaluation results' impartiality. EWM has therefore been utilized extensively in decision-making in recent years. (Zhu, Tian and Yan:

2020). The Entropy Method can be applied in the following phases. (Wang and Lee 2009):

Step 1: Making a decision matrix is the initial step. In the evaluation, there are defined m indicators and n samples. The value of the *i*th indicator measured in the *j*th sample is denomineted as x_{ij}.

$$D = [x_{ij}]_{mn} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Step 2: This step contains the standardization of measured values. For the *j*th sample, the standardized value of the *i*th index is nominated as p_{ij}. For calculation of standardized values, the following formula is used:

$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (2)$$

Step 3: The *i*th index's entropy value is denominated as E_i, and is described as follows:

$$E_i = -k \sum_{j=1}^{n} P_{ij} \,.\, lnP_{ij} \,, \quad k = \frac{1}{\ln n} \quad (3)$$

Step 4: W_i for each criterion by dividing the degree of differentiation for each criterion by the sum of the degree of differentiation for all criteria weight values are obtained.

$$W_i = \frac{d_i}{\sum_{i=1}^{m} d_i}, \; d_i = 1 - E_i \quad (4)$$

3.3 COPRAS Method

In 1996, Zavadskas and Kaklauskas released a study that introduced the COPRAS technique. (Zavadskas and Kaklauskas: 1996). The primary distinction between COPRAS and other MCDM techniques is the percentage that indicates the relative merits of each choice alternative when comparing them. The following is a list of the benefits of the COPRAS approach (Kraujaliene: 2019):

- Values are maximized and minimized in multi-criteria variable systems by using this technique.
- This method makes it easy to compare and check the final measurements.
- Typical features of this tool allow the comparison and assessment of variables at the same hierarchical level that describe quantities that are hierarchically complicated.
- The data transformation does not distort because the tool does not require any transformation, such as minimizing variables; the tool is suitable for evaluating a single alternative.

The following are the steps in applying the COPRAS Method:

Step 1: Organization of the decision matrix.

$$D = [x_{ij}]_{mn} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (5)$$

Step 2: Normalization of the decision matrix

$$x_{ij}^{*} = \frac{x_{ij}}{\sum_{k=1}^{m} x_{ij}} \quad (6)$$

Step 3: Calculation of weighted decision matrix. To produce the weighted normalized decision matrix (D'), multiply the weight value (*wj*) of each evaluation criterion by the element of the normalized decision matrix.

$$D' = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mn} \end{bmatrix} \quad (7)$$

Equation 8 is used for the weighting of the normalized decision matrix.

$$d_{ij} = x_{ij}^{*} . w_j \quad (8)$$

Step 4: Finding the total value of the criteria. In this step, the total value of the criteria for the choice problem in the weighted, normalized decision matrix is determined. (S_{+i}) equation 9 is used to calculate the total value of the criteria in the normalized decision matrix that are taken into account in circumstances where maximizing is the desired outcome., and the total value of the criteria in the normalized decision matrix

that are taken into consideration when minimization is the goal is determined using (S_{-i}) equation 10.

$$S_{+i} = \sum_{j=1}^{k} d_{+ij} \quad (9)$$

$$S_{-i} = \sum_{j=k+1}^{n} d_{-ij} \quad (10)$$

Step 5: Determine the relative significance value (Q_i) of every option for making a decision.

$$Q_i = S_{+i} + \frac{S_{-min}\sum_{i=1}^{m} S_{-i}}{S_{-i}\sum_{i=1}^{m}\frac{S_{-min}}{S_{-i}}} \quad (11)$$

Step 6: Determine each decision alternative's performance index value (P_i).

$$P_i = \frac{Q_i}{Q_{max}} 100 \quad (12)$$

4 FINDINGS

Using data from the years 2018, 2019, and 2020, To compare the countries' results in sustainable development, the Entropy Method was employed to ascertain the significance levels of the criterion. Later, the COPRAS Method was used to rank the countries' sustainable development performances using the weights assigned by the Entropy Method to the criteria. It is feasible to track the development of each nation's performance over time by using multi-year statistics.

4.1 Results of Entropy Method

When comparing the performance levels of sustainable development across nations, the Entropy Method is employed to objectively ascertain the importance of the criterion. Table 1 shows the importance levels of the Entropy approach. The most important criterion is the Net Greenhouse Gas Emissions for all years studied.

Table 1. The Importance Levels of Criteria

Criteria	Wj					
	2018	**Rank**	**2019**	**Rank**	**2020**	**Rank**
PRPSE	0,1309	5	0,1226	5	0,1108	5
AWU	0,1649	4	0,1397	4	0,1750	4
HLY	0,0152	6	0,0147	6	0,0103	6
SWNP	0,2240	3	0,2321	3	0,2114	3
PIJS	0,2298	2	0,2409	2	0,2289	2
NGEE	0,2352	1	0,2499	1	0,2637	1

PRSP: People at risk of poverty or social exclusion, **AWU**: Agricultural factor income per annual work unit, **HLY**: Healthy life years at birth by sex, **SWNP**: Seats held by women in national parliaments and governments, **PIJS**: Perceived independence of the justice system, **NGGE**: Net greenhouse gas emissions

4.2 Results of COPRAS Method

Table 2 lists the ratings and rankings of nations based on their performance in sustainable development over the examined years.

Table 2. Scores and Rank of Countries

Countries	Pj					
	2018	**Rank**	**2019**	**Rank**	**2020**	**Rank**
Belgium	86,32	8	82,45	5	66,19	9
Bulgaria	80,39	15	75,78	13	66,84	8
Czechia	86,93	6	77,68	11	65,17	12
Denmark	97,36	**2**	96,89	**2**	80,76	**2**
Germany	90,14	**3**	88,32	**3**	68,72	6
Estonia	82,02	13	81,93	7	70,27	5
Ireland	79,26	17	72,81	18	61,37	16
Greece	67,86	23	66,69	23	55,87	23

Countries	Pj					
	2018	**Rank**	**2019**	**Rank**	**2020**	**Rank**
Spain	75,01	22	69,14	22	59,06	20
France	88,69	5	80,52	9	64,83	13
Italy	77,42	20	72,48	19	57,83	22
Cyprus	62,66	**26**	57,18	**26**	48,99	**25**
Latvia	75,72	21	75,65	14	59,72	19
Lithuania	82,39	12	81,98	6	74,95	**3**
Luxembourg	79,30	16	75,17	15	64,57	14
Hungary	78,14	18	69,73	21	60,55	18
Malta	63,50	**25**	60,17	**25**	46,92	**27**
Netherlands	89,64	4	81,51	8	65,96	11
Austria	84,61	10	80,06	10	66,16	10
Poland	77,93	19	71,18	20	58,74	21
Portugal	83,51	11	75,01	16	61,24	17
Romania	81,43	14	74,83	17	62,99	15
Slovenia	63,76	24	63,59	24	52,72	24
Slovakia	85,86	9	76,63	12	68,14	7
Finland	86,88	7	87,33	4	71,42	4
Sweden	100,00	**1**	100,00	**1**	100,00	**1**
Croatia	62,66	**27**	56,96	**27**	48,92	**26**

The findings show that Sweden has had the best performance in sustainable development across the whole study period. Denmark takes the second rank then Germany follows it in 2018 and 2019 but Lithuania takes the third rank in 2020.

The countries with the worst performance are Croatia with 27th rank in 2018 and 2019 but Malta in 2020. Cyprus follows them in 2018 and 2019 but Croatia again in 2020 with 26th rank. The counties with 26th rank are Malta in 2018 and 2019, and Cyprus in 2020. It can be said that Cyprus, Malta, and Croatia have the worst performances in terms of sustainable development.

The findings obtained have some limitations. It does not show the overall economic performance of the countries. The ranking is based on specific criteria in certain years. The ranking will change when the criteria and the studied years are changed. The result is an assessment of the situation of countries in a particular year. However, it is possible to make suggestions about the policies that countries should follow according to their performance.

5 CONCLUSION

The principle of sustainability focuses on ensuring economic growth that will bring prosperity to societies without harming the environment. Thanks to economic sustainability, it is aimed to increase the level of welfare while increasing the consumption of goods and services. Therefore, it is essential to increase the sustainable development performance of countries.

The following policies can be recommended for nations with poor performance in sustainable development:

The implementation of the reinforced Youth Guarantee by the countries will enhance prevention and activation of youth from disadvantaged groups and will help reduce their poverty or social exclusion.

The strengthened Youth Guarantee is an agreement among all Member States to guarantee that, within four months after losing their jobs or their training, young people under 30 have access to excellent services such as apprenticeships, traineeships, continuing education, and high-quality employment.

In order to preserve farmers' incomes and boost agricultural output while preserving rural landscapes and the environment, the countries should implement the Common Agricultural Policy (CAP), which offers income support, market measures, and rural development measures.

Improving and fostering health, protecting people, making easier to access to medicinal products and medical devices, strengthening health systems will help increasing healthy life years at birth.

The number of seats held by women in national government and parliaments should be increased to achieve gender balance in decision-making and in politics.

For people and companies to be able to fully enjoy their rights, judges must be free from intervention or pressure from political, governmental, or commercial entities. This will help to increase the level of perceived independence of the justice system.

A safe, sustainable, affordable, and secure energy system that relies on the deployment of renewable energy, a functioning internal energy market, and improvements in energy efficiency while reducing energy poverty must be ensured given the significance of energy production and consumption for the amount of greenhouse gas emissions (Regulation, 32021R1119).

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