RANKING OF EU COUNTRIES AND TURKEY IN TERMS OF SUSTAINABLE DEVELOPMENT INDICATORS: AN INTEGRATED APPROACH USING ENTROPY AND TOPSIS METHODS

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Abstract

The purpose of this study is to analyze the level of development of Turkey, which is in the process of full membership, against member countries of the European Union, and to rank countries in terms of sustainable development indicators by using an integrated approach. Ranking of alternatives for several criteria is a multi-criteria evaluation problem. Ranking of countries in terms of several sustainable development indicators is a multi-criteria evaluation problem. In this paper, an integrated approach composed of Entropy and TOPSIS methods is used. Entropy method is an objective way for determination of criteria weights. TOPSIS method is one of the useful multi-criteria decision making techniques that is very simple and easy to implement, so that it is used when the user prefers a simpler weighting approach. The basic principle of TOPSIS method is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. The integrated approach is applied to 28 European Union countries and Turkey with 19 sustainable development indicators. According to selected sustainable development indicators, Sweden is the most sustainable country among EU countries. Turkey is scored as 20th in sustainability development ranking of EU countries and Turkey.

Key words: Sustainable Development, European Union, Entropy, TOPSIS method

JEL Code: C02, Q01

Introduction

Sustainable development has entered in the global agenda towards the end of the 20th century and become a global implementation plan by the international treaties signed in 1990s. As a multidimensional concept, sustainable development requires ensuring compliance of a country's entire economic and social policies with the environment and identification of national strategies and targets in this area. Determination of to what extent these strategies and targets are achieved by identifying a comprehensive set of indicators and indices is important for the evaluation of changes in the field of sustainable development and taking the necessary measures in this direction (Yıkmaz, 2011).

Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs (Our Common Future, 1987). Sustainable development, a concept that emerged in the context of a growing awareness of an imminent ecological crisis, seems to have been one of the driving forces of world history in the period around the end of the 20th century (Pisani, 2006:83).

In the extensive discussion and use of the concept since then, there has generally been a recognition of three aspects of sustainable development:

(1) Economic: An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectorial imbalances which damage agricultural or industrial production.

(2) Environmental: An environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources.

(3) Social: A socially sustainable system must achieve distributional equity, adequate provision of social services including health and education, gender equity, and political accountability and participation.

The object of this paper is to rank EU countries and Turkey in terms of several sustainable development indicators. This paper is organized as follows. In Section 1 it is given methodology. In Section 2, the data and findings are given. Section 3 summarizes and concludes the paper.

1 Methodology

Decision making is the process of selecting a possible course of action from all of the alternatives. Many decision problems have conflicting criteria. Multi criteria decision making (MCDM, hereafter) can help us to decide ranking when criteria are conflicting in nature.

MCDM structures complex problems by considering multi criteria explicitly, which leads to more informed and better decisions. MCDM methods have been applied to different applications and find the best solution to choose the best alternative (Aruldoss et al., 2013). The widely used MCDM methods are Analytic Hierarchy Process(AHP), Analytic Network Process(ANP), ELECTRE, TOPSIS and PROMETHEE.

MCDM methods can be viewed as alternative methods for combining the information in a problem's decision matrix together with additional information from the decision maker to determine a final ranking, screening, or selection from among the alternatives. Besides the information contained in the decision matrix, all but the simplest MCDM techniques require additional information from the decision maker to arrive at a final ranking, screening, or selection(Kahraman, 2008).

1.1 Entropy method

Entropy method firstly appeared in thermodynamics and was introduced into the information theory later by Shannon (1948). Shannon (1948) used the concept of informational entropy to measure message uncertainty. Entropy theory is an objective way for weight determination (Zou, Yun and Sun, 2006). The calculation steps of Entropy method are as follows:

(1) Calculation of the entropy value for each criterion

In decision matrix D,

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

feature weight r_{ij} is of the *i*th alternatives to the *j*th criterion is calculated by

$$r_{ij} = \frac{x_{ij} - \min_j(x_{ij})}{\max_j(x_{ij}) - \min_j(x_{ij})} \qquad i = 1,\dots,m;\ j = 1,\dots,n \quad \text{for benefit} \tag{1}$$

$$r_{ij} = \frac{\max_j(x_{ij}) - x_{ij}}{\max_j(x_{ij}) - \min_j(x_{ij})} \qquad i = 1,\dots,m;\ j = 1,\dots,n \qquad \text{for cost}$$

(2)

The output entropy e_j of the *j*th criterion becomes

$$e_j = -K\sum_{i=1}^{m} r_{ij}\ln(r_{ij}) \quad , \quad j = 1,\dots,n$$

(3)

where $K = \frac{1}{\ln(m)}$ is a constant that assures $0 \le e_j \le 1$ and e_j indicates the entropy value with respect to criterion C_j.

(2) Variation coefficient of the *j*th criterion

$$d_j = 1 - e_j, \; j = 1,\dots,n \quad (4)$$

(3) Calculation the objective weight of each criterion

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad , \sum_{i=1}^{n} w_j = 1 \; j = 1,\dots,n$$

(5)

where w_j indicates the objective weight for criterion C_j.

1.2 TOPSIS Method

TOPSIS is one of the useful MCDM techniques that are very simple and easy to implement, so that it is used when the user prefers a simpler weighting approach. TOPSIS method was firstly proposed by Hwang & Yoon (1981). The basic principle of TOPSIS method is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution (Opricovic and Tzeng, 2003).

The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. The TOPSIS method consists of the following steps:

(1) Construction of the decision matrix

TOPSIS Method builds on the assumption that mxn decision matrix D includes *m* alternatives and *n* criteria as follows:

$$D = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \end{matrix}$$

(6)

(2) Normalization of the decision matrix

The decision matrix is normalized by vector normalization as shown in below:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}, \qquad i = 1,\dots,m;\ j = 1,\dots,n$$

(7)

This results normalized decision matrix as follows:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}_{m\times n}$$

(8)

(3) Weighted normalized decision matrix is formed as:

$$v_{ij} = w_i * r_{ij},\ i = 1,\dots,m;\ j = 1,\dots,n\ .$$

(9)

(4) PIS (positive ideal solution) and NIS (negative ideal solution) are determined as:

$$A^{*} = \left(v_1^{*}, v_2^{*},\dots, v_j^{*},\dots, v_n^{*}\right),$$

$$v_j^{+} = \begin{Bmatrix} \text{mak}(v_{ij}),\ j \in N \quad i = 1,\dots,m \quad \text{for benefit criterion} \\ \\ \min(v_{ij}),\ j \in N \quad i = 1,\dots,m \quad \text{for cost criterion} \end{Bmatrix}$$

(10)

$$A^{-} = \left(v_1^{-}, v_2^{-},\dots, v_j^{-},\dots, v_n^{-}\right),$$

$$v_j^{-} = \begin{Bmatrix} \min(v_{ij}),\ j \in N \quad i = 1,\dots,m \quad \text{for benefit criterion} \\ \\ \text{mak}(v_{ij}),\ j \in N \quad i = 1,\dots,m \quad \text{for cost criterion} \end{Bmatrix}$$

(11)

(5) The distance of each alternative from PIS and NIS is calculated as:

$$d_i^{*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{*})^2}, \quad i = 1,2,\dots,m. \qquad (12)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, \quad i = 1,2,\ldots,m.$$

(13)

(6) The closeness coefficient of each alternative (CC_i) is calculated as:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}$$

(14)

(7) The ranking of alternatives is determined by comparing CC_i values.

2 Analysis and Findings

The Sustainable Development Indicators (SDIs) are used to monitor the EU Sustainable Development Strategy (EU SDS) in a report published by Eurostat every two years. They are presented in ten themes. Of more than 100 indicators, twelve have been identified as headline indicators. They are intended to give an overall picture of whether the European Union has achieved progress towards sustainable development in terms of the objectives and targets defined in the strategy. For a more complete picture it is necessary to look at the progress of all indicators within a theme (http://ec.europa.eu/eurostat/web/sdi/indicators). SDIs used in this study are given in Table 1.

Tab. 1: Sustainable Development Indicators

Criteria	Theme	Indicators(year)	Benefit/Cost
C1	**Socio-economic development**	Real GDP per capita, growth rate(2013)	Benefit
C2		Total R&D expenditure(2012)	Benefit
C3	**Sustainable consumption and production**	Resource productivity(2010)	Benefit
C4	**Social Inclusion**	Long-term unemployment rate(2013)	Cost
C5		Lifelong Learning(2012)	Benefit
C6		People at risk of poverty or social exclusion(2012)	Cost
C7	**Demographic changes**	Total Fertility rate(2012)*	Cost
C8		Employment rate of old workers(2012)	Benefit
C9		Old age dependency ratio(2013)	Cost
C10	**Public health**	Healthy life years at birth(2012)	Benefit
C11		Life expentancy at birth (2012)	Benefit
C12		Life expentancy at age 65 (2012)	Benefit
C13	**Climate change and energy**	Greenhouse gas emissions(2011)	Cost
C14		Energy Dependence (2012)	Cost

C15		Primary energy consumption(2012)	Cost
C16	**Sustainable transport**	Greenhouse gas emissions from transport (2011)	Cost
C17	**Global partnership**	Official development assistance as share of gross national income(2012)	Benefit
C18		CO2 emissions per inhabitant in the EU (2011)	Cost
C19	**Good governance**	E-Government usage by individuals(2010)	Benefit

Source: http://ec.europa.eu/eurostat/web/sdi/indicators (accepted at 03/01/2015)

*Worldbank

Using Eqs. (6)-13, positive, negative ideal solutions and ranking of countries according to the closeness coefficients. All those are shown in Table 2.

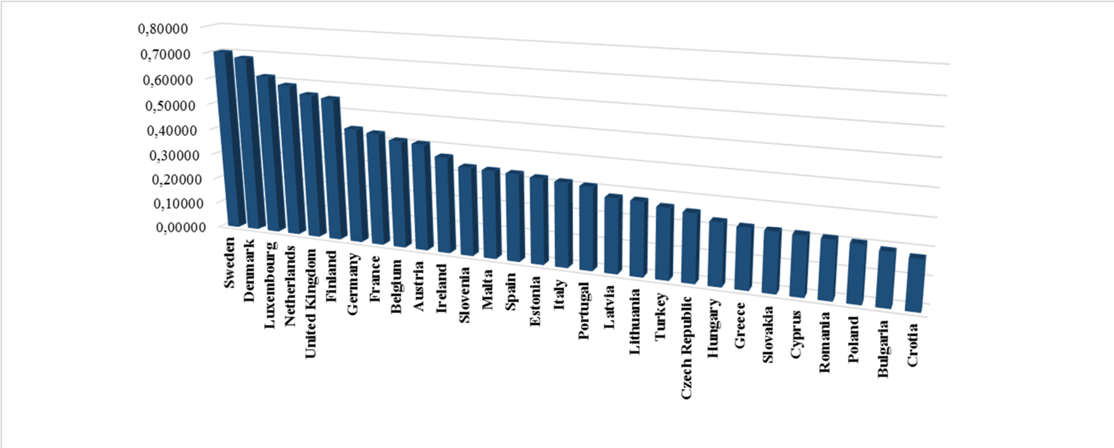
Tab. 2: Positive-Negative Ideal Solutions and Ranking

Countries	$d_i(+)$	$d_i(-)$	CCi	Rank
Austria	0,06154	0,04217	0,40664	**10**
Belgium	0,06132	0,04288	0,41151	**9**
Bulgaria	0,08997	0,02118	0,19057	**28**
Croatia	0,08861	0,01917	0,17786	**29**
Cyprus	0,08438	0,02305	0,21457	**25**
Czech Republic	0,07692	0,02609	0,25324	**21**
Denmark	0,03662	0,07876	0,68262	**2**
Estonia	0,07465	0,03541	0,32174	**15**
Finland	0,04940	0,06033	0,54981	**6**
France	0,06035	0,04577	0,43133	**8**
Germany	0,05986	0,04729	0,44136	**7**
Greece	0,08404	0,02389	0,22134	**23**
Hungary	0,08290	0,02489	0,23092	**22**
Ireland	0,06543	0,03776	0,36591	**11**
Italy	0,07449	0,03438	0,31578	**16**
Latvia	0,08305	0,03197	0,27797	**18**
Lithuania	0,08136	0,03094	0,27549	**19**
Luxembourg	0,04576	0,07361	0,61666	**3**
Malta	0,07235	0,03602	0,33243	**13**
Netherlands	0,04319	0,06180	0,58866	**4**
Poland	0,08429	0,02182	0,20562	**27**
Portugal	0,07033	0,03148	0,30921	**17**
Romania	0,09115	0,02434	0,21078	**26**
Slovenia	0,07083	0,03580	0,33572	**12**
Slovakia	0,08459	0,02350	0,21744	**24**
Spain	0,06948	0,03405	0,32893	**14**
Sweden	0,03385	0,07920	0,70056	**1**
United Kingdom	0,04575	0,05790	0,55863	**5**
Turkey	0,07916	0,02816	0,26244	**20**

Source: author calculation

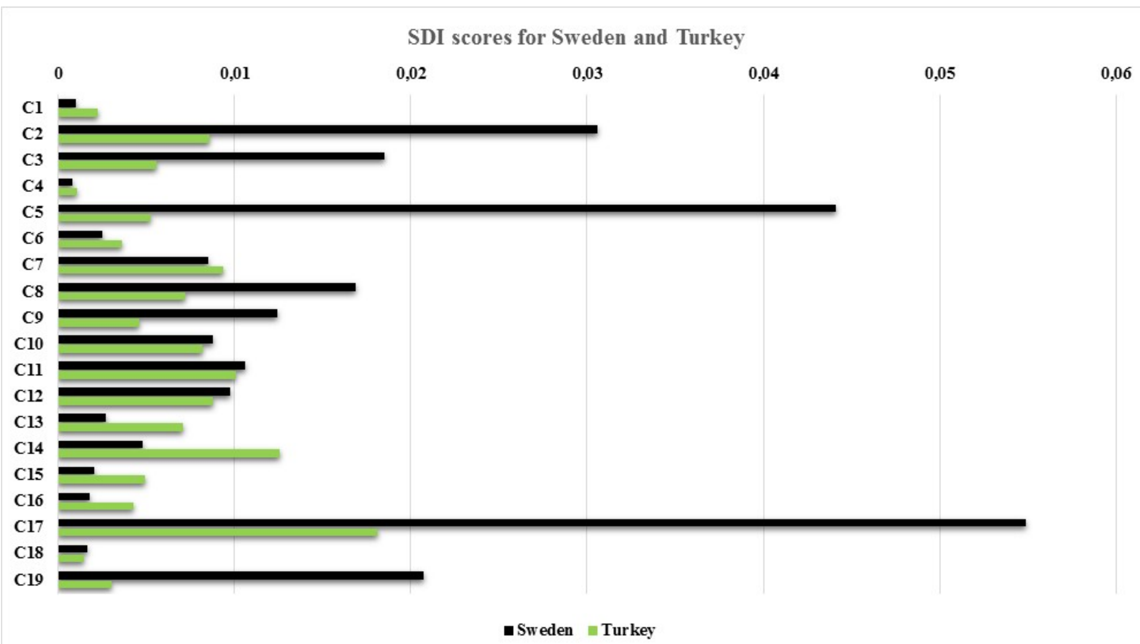
Ranking of countries according to selected SDIs by using integrated approach entropy and TOPSIS methods is given in Figure 1.

Fig. 1: Ranking of Countries



Source: author calculation

Fig. 2: Country Comparison: Sweden and Turkey



Source: author calculation

Comparison between Sweden and Turkey according to their SDIs is given in Figure 2. Sweden is the most sustainable country among EU countries. Sweden earned for its low carbon dioxide and greenhouse gas emissions as well as social and governence practices such as labor participation, education and health. Turkey is scored as 20th country in sustanability development ranking of EU countries.

Conclusion

Sustainable development assessment of countries is a multi-criteria decision making task, involving economic, environmental, and social goals and perspectives. Thus, MCDM encompasses a set of approaches that can assist sustainable development assessment. The object of this paper is to rank EU countries and Turkey in terms of several sustainable development indicators.

In this paper, an integrated approach using Entropy and TOPSIS methods is used. Entropy method is an objective way for weight determination. TOPSIS method is one of the useful MCDM techniques that are very simple and easy to implement, so that it is used when the user prefers a simpler weighting approach. The integrated approach is applied to 28 EU countries and Turkey with 19 SDIs. According to Entropy method the most important SDI is found as "Official development assistance as share of gross national income". According to SDIs, Sweden is the most sustainable country among EU countries. Sweden earned for its low carbon dioxide and greenhouse gas emissions as well as social and governence practices such as labor participation, education and health. Turkey is scored as 20th country in sustanability development ranking of EU countries.

Turkey is scored weakly on a number of SDIs. Noteworthy examples include Total R&D expenditure, lifelong learning, official development assistance as share of gross national income and e-goverment usage by individuals. Turkey's scores on resource productivity, demographic changes and greenhouse gas emissions are also lower. The only exception is for the higher Real GDP per capita, growth rate and lower carbondioxide emissions.

References

Aruldoss, M., Lakshmi, T.M. & Venkatesan, V. P. (2013). A Survey on Multi Criteria Decision Making Methods and Its Applications. *American Journal of Information Systems,* 1(1), 31-43.

Behzadian, M., Otaghsara, S. K., Yazdani, M. and Ignatius, J. (2012). A state –of the- art survey of TOPSIS Applications. *Expert Systems with Applications*, 39(17), 13051-13069.

Bond, R., Curran, J., Kirkpatrick, C., Lee, N., & Francis, P. (2001). Integrated Impact Assessment for Sustainable Development: A Case Study Approach. *World Development,* 29(6), 1011-1024.

Bouyssou, D., Marchant, T., Pirlot, M., Tsoukias, A., & Vincke, P. (2006). *Evaluation and decision models with multiple criteria stepping stones for the analyst*. New York: Springer Science Business Media.

European Union Sustainable Development Indicator, Retrieved from: http://ec.europa.eu/eurostat/web/sdi/indicators

Harris, Jonathan M. (2000). Basic principles of sustainable development, Retrieved from: http://www.ase.tufts.edu/gdae/publications/working_papers/Sustainable%20Development.PDF

Hedlund-de Witt, A. (2012). Exploring worldviews and their relationships to sustainable lifestyles: Towards a new conceptual and methodological approach. *Ecogical Economics,* 84, 74–83.

Hedlund-de Witt, A. (2014). Rethinking Sustainable Development: Considering How Different Worldviews Envision "Development" and "Quality of Life". *Sustainability*, 6(11), 8310-8328.

Hwang, C.L. & Yoon, K. (1981). *Multiple attributes decision making methods and applications*. Berlin: Springer.

Kahraman, C. (2008). Multi-criteria decision making methods and fuzzy sets. In *Fuzzy multi-criteria decision making theory and applications with recent developments*. New York: Springer.

Pisani, Jacobus A. D. (2006). Sustainable development – historical roots of the concept. *Environmental Sciences*, 3(2), 83-96.

Yıkmaz, Rıza F. (2011). Measuring of Sustainable Development and Development of a method for Turkey, Retrieved from: http://sgb.aile.gov.tr/data/5434f337369dc31d48e42dc8/surdurulebilir_kalkinma.pdf

Waas, T. Hugé, J. Verbruggen, A. and Wright, T. (2011). Sustainable development: A bird's eye view. *Sustainability*, *3*, 1637–1661.

Waas, T., Hugé, J., Block, T., Wright, T., Francisco Benitez-Capistros, F. and Verbruggen, A. (2014). Sustainability Assessment and Indicators: Tools in a Decision-Making Strategy for Sustainable Development. *Sustainability*, 6(9), 5512-5534.

Zou, Z., Yun, Y. & Sun, J. (2006). Entropy method for determination of weight of evaluating indicators in fuzzy synthetic evaluation for water quality assessment. *Journal of Environmental Sciences,* 18(5), 1020-1023.

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