

Assessing Euro 2020 Strategy Using Multi-criteria Decision Making Methods: VIKOR and TOPSIS

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Abstract The European Union (EU) 2020 Strategy aims at forming the conditions for smart, sustainable and inclusive growth targets. Assessment of the EU countries' situation is of vital importance in attaining the EU 2020 Strategy. This paper presents an impartial evaluation of the performance of 27 EU member countries in terms of each EU 2020 Strategy. For the basis of the evaluation, we propose an effective and easily practicable measure for ranking and monitoring the countries according to their performance by using the VIKOR and the TOPSIS methods, multi-criteria decision making (MCDM) methods, which allows for the integration of the 22 indicators, and be capable of considering such a broad spectrum of criteria including various economic, financial, demographic, educational and innovational. Our study provides a comparative analysis of the above-two methods. The contribution of the study to the literature is that these methods can be applied for assessing countries in terms of the EU 2020 Strategy which have the multi-dimensionality targets. The results point out new EU member countries such as Slovenia and Romania have attained higher scores than many of the 15 EU countries.

Keywords EU 2020 strategy · EU growth priorities and targets · Multi-criteria decision making

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1 Introduction

Beginning to deepen in 2008, one of the largest and most complex the US-based financial crisis influenced the whole world through financial markets. In the years following the drop in financial wealth, banks were forced to restrain credit, cutting down credit further, economic activity plummeting and all potential output affected, and global trade began to shrink across western countries.

The financial crisis experienced globally shook European economy severely; economic growth observed for the last 10 years and stability in employment opportunities disappeared; industrial production declined to the levels of the year 1990, and 10% of the population (23 million people) became unemployed (Barroso 2010). The financial crisis thus came together to make a “great global recession”.

Fiscal stimulus package adopted by the EU governments, aiming to diminish the effects of the crisis did not yield results and added further pressure on the member countries’ budget deficits and public debts in the period between 2009 and 2011. The Maastricht criteria include targets for inflation, interest rates, budget deficits and debt rates, interest rates and exchange rates (Kontolomis 2003). The Maastricht criteria, which are assumed to sustain the EU in the future, were exceeded in many countries during this period.

The EU 2020 strategy has been designed to replace Lisbon Strategy, constituting the EU’s long-term program for socioeconomic growth of the last 10 years and contributing the EU to recover from the effects of the crisis. The strategy was widely interpreted to be a “fundamental transformation” of the EU socio-economic problems (unemployment, stagnation, productivity and weak macroeconomic performance) as well as to the new emerging challenges (population ageing, fast technological innovation, financial growing and economic globalization) of the Lisbon Strategy in terms of economic, social and environmental dimensions (Tucker 2003; Zeitlin 2008; Sapir 2004; Rodrigues 2002).

It was emphasized in the Lisbon report presented in the European Council meeting held in 2000 that the economies of the member countries had to undergo a serious structural change. How and through what instruments those changes could be made during 2000–2010 were determined according to this report, which recommended economy should be formed on the basis of two main political targets. One of the economic reforms goals was to transform economy into a knowledge-based economy, and the second one was to re-design the priorities of European Social Model, considering investment in human especially investment in education (Inan 2005). After the strategy was accepted, the attained achievements and progress were evaluated. However, such serious problems as employment and social security had still continued; in addition, attained achievement was not adequate. Following the disappointing impacts of the strategy, experts agreed that the EU’s growth target in the future and the basic goals of its strategies should be more realistic (Codogno et al. 2009; Erixon 2010; Fischer et al. 2010).

The European Commission suggested a new strategy package called “Euro 2020 Smart, Sustainable and Inclusive Growth Package” in 2010 to escape the effects of the crisis rapidly, besides, coping with the structural fragility of the EU and implementing long-term sustainable economic process-which was its biggest priority. This package includes the policies to be implemented for the purpose of overcoming the crisis and boosting the growth potential of the EU and defeating structural weaknesses in EU economy in a long term (Colak and Ege 2013).

The EU 2020 strategy is a “growth” and “employment” focused strategy, just as in the Lisbon Strategy, revised in 2005. The strategy set three priorities supportive of each other.

They were economy based on knowledge and innovation (smart growth), green and competitive economy (sustainable growth) using more efficient resources, and high employment economy assuring economic, social and marginal integration (inclusive growth). Some targets in employment, innovation, education, poverty, climate, and energy policy have been achieved by the member states, and achievements are included in the growth strategy of the EU 2020 (Rappai 2016). An examination of the targets makes it clear that the EU economic targets for 2020 are about: (a) increasing employment rate of the population in the aged 20–64 ranging from 69 to 75%; (b) allocating 3% of gross domestic product to research and development, improving the conditions so that private sector could invest in research and development and creating a new indicator to monitor innovativeness; (c) reducing greenhouse gases by at least 20% (and if possible by 30%) compared to the one in 1990, increasing EU's share of renewable energy to 20% in energy consumption and attaining energy efficiency at the rate of 20%; (d) dropping the rate of early school leavers from 15 to 10%, increasing the rate of university graduate population of aged 30–34 ranging from 31% to at least 40%; and (e) reducing the number of EU citizens living below poverty line by 25% with taking 20 million people out of poverty in 2020 (Europe 2020 Strategy 2010).

Besides, benefiting from new resources for sustainable growth with new tools in hand, the new instruments considered will help to create new jobs to balance the high level of unemployment which EU has predicted to encounter in the future. In addition, the EU 2020 is planning to make use of the benefits created by the coordinated response given to the crisis in the European Economic Recovery Plan. The Commission believes that the “The EU 2020 Strategy” should focus on key policy areas where best results can be achieved through cooperation between the EU and its member states and on achieving better results through more effective use of available instruments.

The member countries should contribute to the actualization of the mentioned targets and they should act collectively in terms of the strategies so that the union can be stronger than before, as aimed. Therefore, in order to assess the negativity dominant throughout the countries in detail, it is important to know the place each member country occupies in the community and their share in the formation of the negative picture for the precautions to be taken.

Performance measurement carried out regularly gives critical feedback to the countries. The most important benefit of measuring and comparing the countries' performance is thought to see what can be learnt from those which are good and to target those having the high performance scores to attain a better level (Navarro 2000). Measuring countries' performances and comparing them have long attracted considerable academic interest and various methods have been used for this purpose. Although there are many composite indicators or models used for assessing the countries according to the EU 2020 strategy, there are not numerous studies which assess the countries with using the multi-criteria and multi-objective decision making methods. These methods are frequently preferred by the researchers due to their success in terms of choice, ranking and classification. The study provides a comparative analysis of the VIKOR and the TOPSIS methods which are applicable and suitable for assessing the similar problems. The methods have a rational evaluation due to capable of considering such a broad spectrum of criteria including various economic, financial, demographic, educational and innovational (Deng et al. 2000; Jee and Kang 2000; Tong et al. 2007; Cristóbal 2011). One contribution of the study is that these methods can be used for the country ranking in terms of the EU 2020 strategy which have the multi-dimensionality targets. The methods are both based on an aggregating function representing closeness to the

ideal. The TOPSIS determines a compromise solution with the shortest distance to the ideal solution and the farthest distance from the negative-ideal solution. In contrast, the VIKOR determines the ranking index based on the particular measure of “closeness” to the ideal solution. Moreover, these two methods use different normalization techniques, the normalization is a prerequisite for aggregation of the indicators due to having different units and scales. Whereas the VIKOR uses linear normalization, the TOPSIS uses vector normalization. The methods have almost the same success setting priorities by weight. However, the results show that no significant difference is observed between the results of two methods.

While comparing these MCDM methods to the other ones, it can be seen that the TOPSIS method is one of the well-known classical MCDM methods with respect to have a simple algorithm or easy to use (Boran, et al. 2009; Malekly et al. 2010; Velasquez and Hester 2013). Besides, the method allows easily incorporate benefit and cost criteria into the analysis, and there are extensive applications in a wide variety of areas such as design, engineering and manufacturing system, human resources management, supply chain management and logistics, health, safety and environment management fields over the last two decades (Vahdani et al. 2011; Behzadian et al. 2012). On the other hand, the VIKOR method is an updated version of TOPSIS, and is developed for multi criteria optimization of the complex structure (Opricovic and Tzeng 2004, 2007; Mir et al. 2016; Kumar et al. 2017). The method responds to the need for an effective tool in MCDM problems where there are conflicting and non-commensurable criteria by providing a compromise ranking and solution (Sayadi et al. 2009; Shemshadi et al. 2011; Zhang and Wei 2013).

This paper suggests assessing the 2020 strategies performance of 27 EU member countries in terms of smart, inclusive and sustainable growth. Thus, the smart growth is described under the headings of economic, financial, demographic, education and innovation with 16 indicators; the sustainable growth is described under the headings of employment, poverty and the social isolation with three indicators; and finally the sustainable growth is described under the headings of climate change and energy with three indicators during 2010–2012.

In most cases, the goals and flagship initiatives of the strategy are in conflict with each other. Several examples could be mentioned in this regard, the emerging conflict between “competition” and “public procurement policy” (Graells 2015); the “industrial policy” initiative and the “resource-efficient Europe” initiative (Renda 2014). Any kind of change in one category is likely to affect the change in other categories. For example, the model of consumption (more local and more environment-friendly), the model of production (regulations to ensure efficient production) and CO₂ emissions (the automotive sector being only the most obvious example) affect each other. These indicators should be taken into consideration when selecting the method to be used in practice. This paper intends to fill this gap by providing a comparative analysis of the MCDA methods, a useful and impartial tool for evaluating of 27 EU member states towards the goals of the EU 2020 strategy. The results of this paper is thought to contribute significantly to further analyses in this field as an alternative evaluating method based on simple algorithm whereas previous studies commonly use composite performance index in evaluation of the country (Freudenberg 2003; Pasimeni 2013; Colak and Ege 2013; Pasimeni and Pasimeni 2016; Rogge and Konttinen 2018).

This paper uses the VIKOR and the TOPSIS methods to rank the EU member countries towards the achievements of the objectives set. Section 2 gives an overview of the most prevalent literature focusing on the EU 2020 strategy. The next section outlines the methodological framework widely used as a data ranking tool. Section 4 shows economic,

financial and demographic variables and the country scores. The final section summarizes the results and discusses how the level groups of the EU countries are assessed.

2 Literature Review

The widespread interest in political, economic, and social performance of the EU members has attracted a great deal of academic interest. In recent years, numerous studies have been published, ranking countries by using some macro-economic and composite indicators. The studies have used such methods as ANP, TOPSIS, VIKOR, ELECTRE, PROMETHEE, MULTIMOORA, and weighted sum approach.

There are various studies into the assessment of the EU member countries and of the candidate countries. Kaya et al. (2011), using VIKOR method, evaluated the EU countries and candidate countries in terms of 49 standard of living indicators for the year 2003, 21 standard of living indicators for the year 2005, and 36 standard of living indicators for the year 2007. In a similar way, Zhou and Ang (2009), used MCDA aggregation methods and shannon-spearman measure in constructing composite indicators. Dincer (2011) ranked the member and candidate countries on the basis of 5 macro-economic indicators such as gross domestic product, import, export, the rate of inflation and the rate of unemployment by using weighted sum approach. Ozden (2012), Urfalioglu and Genc (2013) evaluated the candidate EU countries' performance with 6 macro-economic indicators by using TOPSIS, ELECTRE and PROMETHEE methods, and compared the economic performance of EU member countries with that of the candidate countries. A remarkable finding is that Turkey is in a better position than such member countries as Portugal, Ireland and Southern Cyprus in terms of economic indicators, and that it is economically worse than such older members as Spain and Italy and newer members such as Romania and Bulgaria.

Although the numbers of the studies assessing the performance of the countries in terms of the general goals of the EU by using macro-economic indicators in particular attracts researchers' attention, very few of them are concerned with the new strategy of EU.

There is an increase in the number of studies evaluating the basic goals of the Lisbon strategy and the EU 2020 strategy, a continuation of it, pointing out its shortcomings and the precautions to be taken comprehensively. Examples of such research include Erixon (2010), Martens (2010), Gros and Roth (2012) focusing on detailed evaluation and criticisms while Parker (2010), Böhringer et al. (2009), Warleigh-Lack (2011) investigating climate change and economic effects. While Nolan and Whelan (2011), Copeland and Daly (2012) evaluated the policy of struggling with poverty and social inclusion policy, Granieri and Renda (2012) researched governments' innovation policy targets and economic effects.

There are limited number of analytic studies dealing with the EU 2020 strategy because the EU targets were put forward in 2010 and the issue is still new. Brauers and Zavadskas (2013) analyzed the performance of the member countries under financial, economic and demographic headings in accordance with EU 2020 targets by using 22 indicators by means of MULTIMOORA- one of the multi-objective optimization methods.

Many authors recommend using the EU 2020 Index to evaluate the progress in implementing in EU 2020 targets. Pasimeni (2013) suggests a composite index that aggregates eight indicators proposed by the European Commission. These indicators are normalized and created the so-called Smart Growth Index, the Sustainable Growth Index and the Inclusive Growth Index, reflecting the three pillars of the EU 2020 strategy. All the three dimensions transform the new index from 2006 to 2008. Moreover, Pasimeni and Pasimeni (2016), performed a quantitative evaluation of countries' performances, using the EU 2020

Index. On a similar topic, Colak and Ege (2013) evaluated the EU 2020 strategy in detail and analyzed the performance of 27 member and 4 membership candidate countries in the period between 2002 and 2009 by using the indices for the targets of countries' research and development spending, educational status, climate change, unemployment rate and struggle with unemployment through composite index.

3 Methodology

3.1 VIKOR Method

Suggested by Opricovic (1998), Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) is one of the multi criteria methods in which alternatives can be ranked using an index when criteria are in conflict and optimization of complex systems. Choosing and ranking in the method is based on the principle of creating a compromise solution (Chu et al. 2007; Demirel and Yucenur 2011). "Maximum group utility" and "minimum individual regret" were included in the method by using combining function.

The steps of the method have been given as follows (Opricovic and Tzeng 2004; Cristobel 2012):

- Step 1 Decision matrix is formed. All the alternatives (countries) available in the model can be assessed in terms of each criteria in this matrix. The criteria are included in the rows of the matrix, while countries are included in the columns of the matrix
- Step 2 Considering the benefits and costs of the model for which the criteria are set, the best values f_i^+ and the worst value f_i^- , ($i = 1, 2, \dots, n$) are determined for all criteria function

If the function for the model is benefit directional, $f_i^+ = \max_j f_{ij}$ and $f_i^- = \min_j f_{ij}$ are taken into consideration but if it is cost directional, $f_i^+ = \min_j f_{ij}$ and $f_i^- = \max_j f_{ij}$ are taken into consideration.

- Step 3 For each alternative, S_j and R_j are computed by the relations:

$$S_j = \sum_{i=1}^n \frac{w_i (f_i^+ - f_{ij})}{(f_i^+ - f_i^-)}, \tag{1}$$

$$R_j = \max_i \left[w_i \frac{(f_i^+ - f_{ij})}{(f_i^+ - f_i^-)} \right], \tag{2}$$

where w_i , are the weights of criteria, indicates the relative importance of each criteria ($j = 1, 2, \dots, J$).

- Step 4 Q_j values are calculated by using Eq. (3) ($j = 1, 2, \dots, J$)

$$Q_j = v \frac{(S_j - S^+)}{(S^- - S^+)} + (1 - v) \frac{(R_j - R^+)}{(R^- - R^+)}, \tag{3}$$

S^+ and R^+ given in Eq. (3) indicate the minimum values, whereas S^- and R^- indicate the maximum values. In addition, v is introduced as the weight of the strategy which is to

create maximum group utility while $(1 - \nu)$ represents the weight of minimum individual regret.

Step 5 The S , R and Q values are ranked in decreasing order with three ranking indices created

Step 6 The below shown conditions are checked by using the Q index to come up with the compromise solution a' . Firstly, condition C1 acceptable advantage and condition C2 acceptable stability in decision making are obtained

C1 Acceptable advantage
$$Q(a'') - Q(a') \geq DQ, \quad (4)$$

a'' is the alternative with second position in the ranking list by Q . $DQ = \frac{1}{m-1}$ (m is the number of alternative. If $m \leq 4$ then $DQ = 0.25$).

C2 Acceptable stability in decision making Alternative a' must be the best ranked by S or/and R . This compromise solution is stable within a decision making process, which could be: "voting by majority rule" (when $\nu > 0.5$ is needed), or "by consensus" $\nu \approx 0.5$, or "with veto" $\nu < 0.5$).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of

- If only condition C2 is not satisfied, alternatives a' and a'' ; or
- If condition C1 is not satisfied, alternatives $a', a'', \dots, a^{(M)}$; $a^{(M)}$ is determined by the relation $Q(a^{(M)}) - Q(a') < DQ$ for maximum M .

Unless condition 1 is satisfied and is $Q(a^{(M)}) - Q(a') < DQ$, then $a^{(M)}$ and a' are the compromise solutions. Because the compromise solutions $a', a'', \dots, a^{(M)}$ are similar, they have no comparative superiority.

Unless condition 2 is satisfied, there is no stability in decision-making even though a' has comparative superiority. Therefore, the compromise solutions for a' and a'' are the same.

Step 7 The minimum value of Q index is chosen as the best alternative

3.2 TOPSIS Method

Suggested in Hwang and Yoon (1981), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a method based on the principle of searching for a compromise solution in which the alternative closest to the positive ideal solution and the farthest from the negative ideal solution is preferred (Li et al. 2011).

The steps of the method have been given as follows (Yoon and Hwang 1985; Lai et al. 1994):

Step 1 Evaluation criteria are set

Step 2 Decision matrix X_{ij} containing alternatives in its rows and criteria in its columns is created on the dimension of $m \times n$.

Step 3 Square root of squares total for the criteria is taken, and thus the decision matrix is normalized. The normalized value r_{ij} is calculated as

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} (i = 1, 2, \dots, m; j = 1, 2, \dots, n), \quad (5)$$

Step 4 Criteria weight W_j is determined by the decision maker and each value in the normalized decision matrix are multiplied by criteria weight, and thus the weighted normalized decision matrix shown in Eq. (7) is generated

$$\sum_{j=1}^n W_j = 1, \quad (6)$$

$$V_{ij} = W_j \times R_{ij} (i = 1, 2, \dots, m; j = 1, 2, \dots, n). \quad (7)$$

Step 5 Positive ideal solution (A_i^+) is determined with Eq. (8) and negative ideal solution (A_i^-) is determined with Eq. (9)

$$\begin{aligned} A_i^+ &= \{v_1^+, v_2^+, \dots, v_n^+\} \\ &= \{(max_i v_{ij} | j \in J_1), (min_i v_{ij} | j \in J_2) | i = 1, 2, \dots, m\}, \end{aligned} \quad (8)$$

$$\begin{aligned} A_i^- &= \{v_1^-, v_2^-, \dots, v_n^-\} \\ &= \{(min_i v_{ij} | j \in J_1), (max_i v_{ij} | j \in J_2) | i = 1, 2, \dots, m\}, \end{aligned} \quad (9)$$

where J_1 is associated the benefits criteria and J_2 is associated the cost criteria in (8) and (9).

Step 6 Distance from the positive ideal solution and the negative ideal solution is calculated for each alternative. d_i^+ in Eq. (10) represents the distance from the maximum ideal point whereas d_i^- in Eq. (11) represents the distance from the minimum ideal point

$$d_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2} (i = 1, 2, \dots, m; j = 1, 2, \dots, n), \quad (10)$$

$$d_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} (i = 1, 2, \dots, m; j = 1, 2, \dots, n). \quad (11)$$

Step 7 Closeness coefficients (CC_i) are calculated for each alternative with the formula given in Eq. (12)

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} (i = 1, 2, \dots, m). \quad (12)$$

Step 8 Alternatives are ranked according to the CC_i values. The maximum CC_i value is chosen as the best alternative

4 Research Findings and Application

4.1 Data

The economic-financial criteria set with Maastricht Agreement, whose important macro-economic indicators came into force on November 1, 1993, were taken into consideration in determining the criteria to rank the countries in the study. The data, which include economic, financial and demographic variables in 2010–2012 period, contained 22 indicators previously described to reflect to performance of EU countries to achieve the competitiveness goals set in the EU 2020 Strategy.

A literature review for assessing the EU 2020 strategies performance of the countries in terms of smart, inclusive and sustainable growth is constituted. The headline indicators of the flagship initiatives of some selected studies are presented in Table 1.

Employment and poverty struggle indicators under the heading of inclusive growth of the EU 2020 strategy, energy and climate change indicators under the heading of sustainable growth, and investment in innovation, education and youth in mobility indicators under the heading of smart growth were collected from the database of EUROSTAT, IMF and World Bank. Table 2 shows each indicator used as a criteria in the study, and presents the values of the indicators for major goals at a cross-national level at the time of the announcement of the EU 2020.

4.2 Country Scores on VIKOR and TOPSIS

The seven flagship initiatives shows different aspects of development, and their units and scales are different. Before using methods, we normalized the indicators between one and zero with the intent of fulfilling the prerequisite for aggregation of the indicators. The indicators can now be aggregated in order to build the two indices. These, in turn, can be further aggregated to produce a synthetic index. In the aggregation process, we use equal weights, giving the same relevance to all the components of the index. Accordingly, the ranking for countries has been calculated by applying all the steps of VIKOR and TOPSIS. Table 3, presents the calculated values of the ranking for countries with both methods.

Although ranking obtained with one method is not completely identical with the other, the results are relatively similar. It is considered that obtained results are different due to the different normalization techniques used in the methods.

In an attempt to answer which EU countries are at the similar level of the implementation of the EU 2020, they have divided into such groups as high, medium–high, medium–low, and low (Table 4). Stec and Grzebyk (2016) suggest a grouping method based on the arithmetic mean and standard deviation of the ranking value of TOPSIS and VIKOR (Q_j and CC_i respectively) methods. For VIKOR method:

First group:	$Q_j \geq MQ_j + SQ_j$	High level
Second group:	$MQ_j + SQ_j > Q_j \geq MQ_j$	Medium–high level
Third group:	$MQ_j > Q_j \geq MQ_j - SQ_j$	Medium–low level
Last group:	$Q_j < MQ_j - SQ_j$	Low level

where MQ_j mean value of overall measure of VIKOR's Q_j values and SQ_j standard deviation of the overall measure of VIKOR's Q_j values. This allocation scheme can be constituted for results of TOPSIS methods as well. Figure 1 and Table 4, present which EU countries are at a similar level of the implementation of the Europe 2020.

Table 1 Indicators used in the literature review

	Flagship initiatives	Headline indicators
Brauers et al. (2012) Brauers and Zavadskas (2013)	Economic and financial	Current account deficit of the balance of payments GDP per capita GDP growth rate Inflation Employment rate Unemployment rate Government budget deficit Government debt Government bond yields Tertiary education
	Demographic	Median age of total population Proportion to population aged 0–14 of total population Proportion to population aged 15–64 of total population Proportion to population aged 65 or more of total population
Colak and Ege (2013)	R&D Employment Education Climate change and energy Poverty and social exclusion	R&D expenditures Employment rate Early school leavers Tertiary education Greenhouse gas emissions Renewable energies Energy efficiency Poverty rate

Table 1 (continued)

	Flagship initiatives	Headline indicators
European Commission Pasimeni (2012)	Employment	Employment rate, total
Gros and Roth (2012)	R&D	Gross domestic expenditure on R&D
Pasimeni (2013)	Climate change and energy	Greenhouse gas emissions
Bere et al. (2015)		Share of renewable energy in Gross final energy
Pasimeni and Pasimeni (2016)		Primary energy consumption
Rappai (2016)	Education	Final energy consumption
Stec and Grzebyk (2016)		Early leavers from education and training, total
	Poverty and social exclusion	Tertiary educational attainment, total
		People at risk of poverty or social exclusion

Table 2 Indicators Used in the Model

Goals pillars	Flagship initiatives	Headline indicators	Criteria
Smart growth	Economic and financial	Current account deficit of the balance of payments ^a	Min
		GDP per capita in purchasing power parity ^b	Max
		GDP growth rate (percentage to a base year) ^b	Max
		Inflation ^b	Min
		GDP per capita with basis EU-15 = 100 (prospective compared to a base year) ^b	Max
		Government budget deficit as a % of GDP ^a	Min
		Government debt as a % of GDP ^b	Min
		Government bond yields as a % ^a	Min
		Government budget deficit as a % of GDP (prospective compared to a base year) ^b	Min
		Government debt as a % of GDP (prospective compared to a base year) ^a	Min
Demographic		Proportion of population aged 0–14 to total population ^b	Max
		Proportion of population aged 15–64 to total population ^b	Max
		Proportion of population aged 65 or more to total population ^b	Min
		Early leavers from education and training (% of population aged 18–24 with at most lower secondary education and not in further education or training) ^b	Min
Education		Tertiary education as a % of age group 30–34 ^b	Max
		Gross domestic expenditure on R&D (% of GDP) ^b	Max
Inclusive growth	Innovation Employment	Unemployment rate ^b	Min
		Employment rate ^b	Max
Sustainable growth	Poverty and social exclusion	People at risk of poverty or social exclusion (percentage of total population) ^b	Min
		Final energy consumption (million TOE (tons of oil equivalent)) ^b	Max
	Climate change and energy	Greenhouse gas emissions (Index (1990 = 100)) ^b	Min
		Share of renewable energy in gross final energy consumption (%) ^b	Max

^aIMF and World Bank (2017)^bEUROSTAT (2017)

Table 3 Ranking based on VIKOR and TOPSIS

	VIKOR				TOPSIS			
	S_j	R_j	Q_j	Rank	d^+	d^-	CC_i	Rank
Belgium	0.48519	0.0413	0.398219	13	0.0472	0.05441	0.53548	10
Bulgaria	0.57211	0.04545	0.57566	20	0.05674	0.05207	0.47854	20
Czech R.	0.45667	0.04216	0.340032	10	0.0507	0.05539	0.5221	11
Denmark	0.35429	0.04233	0.13107	3	0.04077	0.06287	0.60662	5
Germany	0.41493	0.04545	0.254855	6	0.03441	0.06923	0.66799	2
Estonia	0.44082	0.04495	0.307701	8	0.04719	0.06352	0.57375	8
Ireland	0.54697	0.04545	0.524348	18	0.06502	0.04201	0.39251	26
Greece	0.78005	0.04545	1	27	0.07776	0.02773	0.26287	27
Spain	0.6054	0.04545	0.643618	24	0.05524	0.04321	0.4389	23
France	0.46165	0.04545	0.350169	11	0.04404	0.05382	0.54997	9
Italy	0.61485	0.04303	0.662907	25	0.04988	0.05012	0.5012	16
Cyprus	0.5095	0.04545	0.447894	16	0.05964	0.04677	0.43953	22
Latvia	0.55245	0.04471	0.535524	19	0.05316	0.05544	0.5105	14
Lithuania	0.51544	0.04453	0.459992	17	0.05223	0.05365	0.50671	15
Luxemburg	0.29005	0.04462	0	1	0.04024	0.07377	0.64705	3
Hungary	0.57339	0.04545	0.578237	21	0.05521	0.05221	0.48604	19
Malta	0.59359	0.04545	0.61948	22	0.05751	0.05095	0.46976	21
Netherlands	0.36991	0.04294	0.16296	5	0.04177	0.06231	0.59867	6
Austria	0.42525	0.03965	0.275952	7	0.04135	0.05956	0.59023	7
Poland	0.50138	0.04271	0.431292	15	0.05248	0.05171	0.4963	17
Portugal	0.63717	0.04391	0.708466	26	0.06107	0.04154	0.40483	25
Romania	0.59972	0.04545	0.632012	23	0.06352	0.04401	0.40928	24
Slovenia	0.45369	0.04447	0.333948	9	0.04963	0.05416	0.52182	12
Slovakia	0.47896	0.0432	0.38555	12	0.05247	0.05556	0.5143	13
Finland	0.35649	0.0401	0.135578	4	0.03763	0.06562	0.63554	4
Sweden	0.29461	0.04303	0.009253	2	0.03317	0.0757	0.69532	1
U.K.	0.49099	0.04323	0.410109	14	0.05098	0.04846	0.48733	18

A high level of implementation is showed by Luxemburg, Sweden, Denmark, Finland and Netherlands for each method. While Germany is classified in medium–high level group for VIKOR method, TOPSIS method classifies Germany in the high level group. Table 4, reports other classified countries. Both methods classify countries—Austria, Estonia, Slovenia, Czech R., France, Slovakia, and Belgium—as a medium–high performance. The medium–low performance countries are U.K., Poland, Cyprus, Bulgaria, Hungary, and Malta, with the same achievement level for two methods. Finally, Portugal and Greece have been found as the low performance countries. Additionally, the countries in different achievement groups for each method are written in bold.

The difference between level groups can stem from such reasons as educational investments, productivity, and digital technology. The fact that educational investments and well-educated young population carry the countries of Finland, Sweden, Belgium, Netherlands and Germany to an upper order in ranking. At this point, it may be stated that educational policies implemented in those countries are influential and that they

Table 4 Levels of the Implementation of the EU 2020 Strategy

Level	Methods	
	VIKOR	TOPSIS
High	Luxemburg, Sweden, Denmark, Finland, Netherlands	Sweden, <i>Germany</i> , Luxembourg, Finland, Denmark, Netherlands
Medium-high	<i>Germany</i> , Austria, Estonia, Slovenia, Czech R., France, Slovakia, Belgium	Austria, Estonia, France, Belgium, Czech R., Slovenia, Slovakia, <i>Latvia</i> , <i>Lithuania</i>
Medium-low	U.K., Poland, Cyprus, <i>Lithuania</i> , <i>Ireland</i> , <i>Latvia</i> , Bulgaria, Hungary, Malta, <i>Romania</i>	<i>Italy</i> , Poland, U.K., Hungary, Bulgaria, Malta, Cyprus, <i>Spain</i>
Low	<i>Spain</i> , <i>Italy</i> , Portugal, Greece	<i>Romania</i> , Portugal, <i>Ireland</i> , Greece

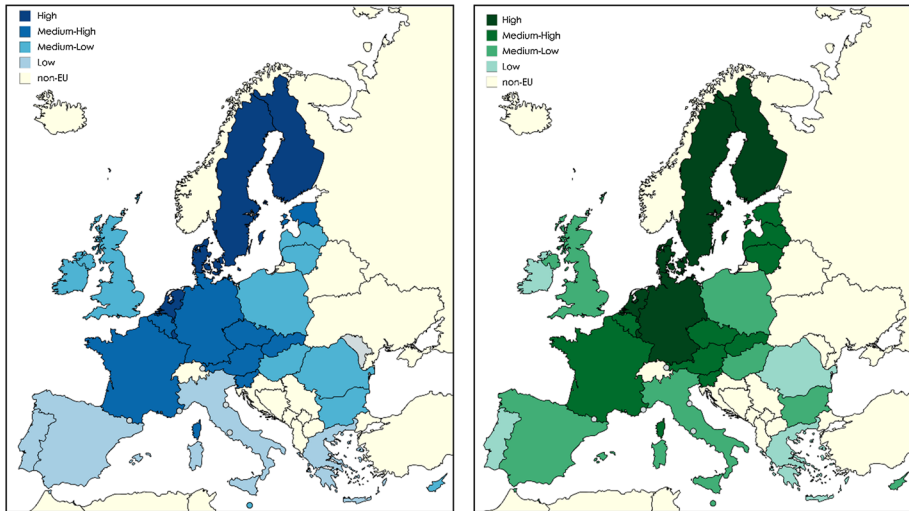


Fig. 1 Groups of EU Countries with similar levels of implementation of the EU 2020 strategy with VIKOR (left) and TOPSIS (right) methods (color by score 2010–2012). (Color figure online)

can set a model for other low performance countries in Southern and Central Europe and even for the EU membership candidates.

The reason why the quality of education and good design of educational system is so important in placing countries at the higher levels is that they prevent young population from being unemployed. Therefore, they contribute to social inclusion and innovation. Sweden, the driving force in the fields of education, productivity and digital technology, is the best example of this and ranks at the top.

The fact that those countries are in the group of the best ten countries can be attributed to the fact that they have a competitive national market and strong entrepreneurship culture. It is remarkable that UK with developed and service-driven economy is well behind in ranking. This may be put down to a high level of unemployment ratio stemming from such problems as failure to offer profitable and encouraging jobs to some parts of its population.

In the final category, PIIGS countries (Portugal, Ireland, Italy, Greece and Spain) are at the lower order of ranking, as expected. Those countries can only change their order in this ranking by strengthening their economies in addition to making policy decisions on education, innovation and energy. The overlap between the results set of the both methods is given in Fig. 2.

Although there is no perfect overlap, it is seen that both methods reveal close results. In addition, the correlation between ranking results of VIKOR and TOPSIS is significant, Spearman's $\rho(25) = 0.912, p < 0.01$. This result indicates a high correlation between both ranking methods. Besides, it is easy to figure out which countries take different rank from one method to the other by this figure. Although some countries' rank can sometimes vary by one method to the other (Italy, Ireland and Cyprus), some are not (Bulgaria, Estonia, Greece, Austria and Finland). As we show high-level group, result in VIKOR method, are Luxemburg, Sweden, Denmark, Finland, Netherlands—the same group of states as in TOPSIS, but again there is movement within. With Germany rising up the levels, Ireland and Romania have fallen. This movement reflects the need for confirmation.

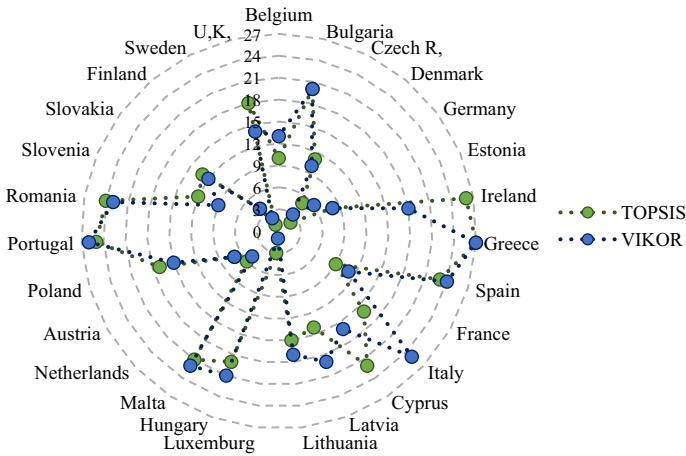


Fig. 2 Differences in country rankings between VIKOR and TOPSIS methods

In the paper, *k*-means method is used for confirming the performance of the multi criteria applications as a robustness check. The basis of this method comes from the definition of a distance that takes into account the multi criteria nature of the problem. The steps of this method are shown in Appendix. As depicted in Table 5, the accuracy values are given to compare the results. The accuracy is one of the most widely used metric for performance evaluation and it represents the percentage of units that are correctly classified according the levels (Han et al. 2012). Here, where higher value means better accuracy.

From Table 5, we can say the all subgroups have relatively high probability of correct classification (except the medium–low subgroup of the TOPSIS) according to the robustness check results. Especially, the low subgroup of both two method have a high probability of correct classification. For *k*=4 we can see that the countries belonging to the Low level, with 0.750 accuracy value, are better ranked than those belonging to the other levels. Medium–Low level has ten countries, are U.K., Poland, Cyprus, Lithuania, Ireland, Latvia, Bulgaria, Hungary, Malta, Romania (as depicted in Table 4) and its accuracy score is 0.600. This means that the method correctly classifies 6 out of 10 countries.

Lastly, we compare the results of the VIKOR and TOPSIS with the ranking of the EU member states published in the Europe 2020 Competitiveness Report: Building a More Competitive Europe (World Economic Forum 2012). This report selected for the statistics and indicators are at the national level. Spearman’s rho is used to measure the strength of association between the results with the aim of comparing.

Table 5 Robustness check: the accuracy with *k*-means method

Level	Methods	
	VIKOR	TOPSIS
High	0.600	0.500
Medium–high	0.500	0.667
Medium–low	0.600	0.375
Low	0.750	0.750

As shown in Table 6, there are highly significant correlation among the three methods. For the correlation between the TOPSIS and Rank 2012, the Spearman's Rho value is 0.724, highlighting a strong and a direct connection. Similarly, correlating the countries ranks between VIKOR and Rank 2012, we discover a significant and positive connection, with the Spearman's Rho value of 0.779. This means that, the two methods have a sufficient performance while comparing with the ranking of the EU member states in 2012.

5 Conclusion

The EU 2020 strategy is the development strategy of the EU that aimed to transform Europe into a smart, sustainable and inclusive economy delivering high employment rates, social cohesion and high labor productivity. In this paper, we statistically evaluate the progress in meeting the EU 2020 strategy by individual EU member states, and by using the TOPSIS and the VIKOR method, so that decision makers could compare the results obtained from both methods.

Although many studies are frequently criticized for considering only a simple aggregation of indices likely to be biased, this paper presents an alternative two indices to quantify, measure and monitor the progress towards the objectives of the strategy realized by the member states of the EU.

Since there are a great number of conflicting criteria in relation to countries' economic, financial, demographic, education, innovation, workforce, poverty, social inclusion, climate change and energy, and differences of measurement units of the indicators, it is impossible to reach an ideal solution. The TOPSIS and the VIKOR methods based on compromise and group utility, which present objective results with equal variable weights obtained from the structure of the data, have been preferred in this study. In this way, the strategies of the countries in relation to three growth targets are assessed in a holistic way, and the countries are ranked by using multi-criteria decision making methods. When considering the quantitative structure of the decision matrix or the conflicting indicators, the TOPSIS and the VIKOR methods responses to the need for assessing a rational evaluation. It is believed that the ranking results are likely to contribute to both academic literature and policy making studies. Besides, the ranking results provide solutions to the problems involving conflicting criteria, and can be considered as the scientific base result. As well as it is showed that an effective alternative measure for ranking the countries according to their performance by using the VIKOR and the TOPSIS methods are recommended. Although both MCDM methods are based on the aggregating function describing "closeness to the ideal solution", the VIKOR demonstrates the ranking index which is a special measurement of "closeness to the ideal solution" by using linear normalization. On the other hand, the TOPSIS, performing vector normalization, determines the alternatives which are "the closest to the positive ideal solution", and "the farthest to the negative ideal solution", and performs the ranking according to

Table 6 Spearman's Rho nonparametric correlation coefficient

	VIKOR	TOPSIS	Rank 2012
VIKOR	1.000	0.912*	0.779*
TOPSIS	0.912*	1.000	0.724*
Rank 2012	0.779*	0.724*	1.000

*Correlation is significant at the 0.01 level (2-tailed)

these two reference points (Opricovic and Tzeng 2004). The paper contributes to the literature by presenting an easily practicable methods for ranking and monitoring of the countries in the direction of the EU 2020 Strategy containing different goals such as smart, inclusive and sustainable growth. Since the simplicity and flexibility of use, the easily understandable procedure based on the geometric representation, capability to deal with each kind of judgment criteria, the clarity of their results, and the reduced difficulty to deal with parameters, the TOPSIS and the VIKOR methods seem to be suitable for our decision problem regarding the country ranking of structures.

Finally, the countries are categorized into groups of high, medium–high, medium–low and low performance to eliminate difficulties in interpreting different solutions when ranking. The fact that the education investment, productivity and prevalence of using digital technology and well-educated young population carry the countries of Nordic and Central Europe to an upper order in ranking. It is seen that the Nordic countries can and do excel in securing high education investments with their economies. Southern countries and especially PIIGS countries are at the lower order of ranking. Through this categorization, our results can be compared to the results obtained in other studies. Future studies, ranking countries by the same data set, might be implemented with the other multi-criteria ranking methods such as ELECTRE and PROMETHE based on superiority.

Appendix

The *k*-means or hard *c*-means clustering is one of the unsupervised learning algorithms, and a set of statistical methods for determining new structure when investigating data sets (Flynt and Dean 2016). The algorithm is based on a constrained optimization problem with the locally minimum of the objective function $J(U, v)$, where U is the partition matrix and the parameter v is the cluster centers. That constrained problem follows a simple way to classify a given data set on the assumption that where the number of clusters namely c , is known (Ross 2010; Velmurugan 2014). In the method the *k*-partition space and the objective function as following:

$$M_c = \left\{ U \mid \chi_{ik} \in \{0, 1\}, \sum_{i=1}^c \chi_{ik} = 1, 0 < \sum_{k=1}^n \chi_{ik} < n \right\}, \tag{13}$$

$$J(U, v) = \sum_{k=1}^n \sum_{i=1}^c \chi_{ik} (d_{ik})^2, \tag{14}$$

where d_{ik} , is chosen distance measure between *k*. data point x_k and *i*. cluster center v_i .

$$d_{ik} = d(x_k - v_i) = x_k - v_i = \left[\sum_{j=1}^m (x_{kj} - v_{ij})^2 \right]^{1/2}, \tag{15}$$

$$v_{ij} = \frac{\sum_{k=1}^n \chi_{ik} x_{kj}}{\sum_{k=1}^n \chi_{ik}}. \tag{16}$$

The optimization method is composed of the following steps (Ross 2010):

- Step 1* $2 \leq c \leq n$, and initialize the U matrix. $U_0 \in M_c$
- Step 2* Calculate the cluster center $\left\{v_i^{(r)}\right\}$, ($r = 0, 1, \dots$) and the distance $\left\{d_{ik}^{(r)}\right\}$ between data point and cluster center
- Step 3* Update the $U^{(r)}$ matrix for the r . step, $U^{(r)}$, as follows:
- $$\chi_{ik}^{(r+1)} = \begin{cases} 1, d_{ik}^{(r)} = \min\left\{d_{jk}^{(r)}\right\} \text{ for all } j \in c \\ 0, \text{ otherwise} \end{cases} \quad (17)$$
- Step 4* If $U^{(r+1)} - U^{(r)} \leq \varepsilon$ stop; otherwise set $r = r + 1$ and return to step 2

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