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ENVIRONMENTAL TOTAL-FACTOR ENERGY EFFICIENCY IN THE EU COUNTRIES[1]

UKUPNA FAKTORSKA ENERGETSKA EFIKASNOST S OBZIROM NA UTJECAJ NA OKOLIŠ U ZEMLJAMA EUROPSKE UNIJE

ABSTRACT

Governments of all countries are under pressure due to environmental issues like global warming and climate change. That is why one of the most important objectives for any energy policy is the improvement of total-factor energy efficiency. The purpose of this research is to evaluate the total-factor energy efficiency in EU countries and to examine the impact of undesirable outputs on these countries` energy efficiency. We used DEA (Data Envelopment Analysis) SBM Bad output model, incorporating multiple inputs and two kinds of multiple outputs: desirable and undesirable as the result of input utilization. Undesirable outputs are an anomaly, which should not be ignored when measuring total-factor energy efficiency. Namely, in case of emissions or pollution, regulatory standards define the maximum amount of undesirable outputs. The empirical results confirm that the DEA scores for total-factor energy efficiency incorporating undesirable outputs are more realistic then those obtained based only on desirable outputs as they do not calculate the negative impact on the environment. Results show significant differences in environmental total-factor efficiencies among developed and less developed EU countries. For every relatively inefficient country the projected values on efficient frontier are determined, as targets. These targets are useful in policy decision- making regarding environmental total-factor energy efficiency. Therefore, in order to solve their environmental problems, inefficient countries should aim to change their energy structure and consume

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behaviour. On the other hand, efficient countries whose governments have already directed their energy policy to environmental energy should serve as good practice examples.

Key words: *Total-factor energy efficiency, EU countries, DEA, undesirable output.*

SAŽETAK

Vlade svih zemalja su pod pritiskom zbog ekoloških pitanja kao što su globalno zagrijavanje i klimatske promjene. Zato je jedan od najvažnijih ciljeva za svaku energetsku politiku poboljšanje ukupne energetske efikasnosti. Svrha ovog istraživanja je procijeniti ukupnu faktorsku energetsku efikasnost u zemljama EU te ispitati utjecaj nepoželjnih izlaza na njihovu energetsku efikasnost. U radu smo koristili model Analize omeđivanja podataka (AOP), SBM s nepoželjnim outputima, koji uključuje više ulaza i dvije vrste višestrukih izlaza: poželjnih i nepoželjnih koji predstavljaju rezultat korištenja ulaza. Nepoželjni izlazi su anomalija, koju ne treba zanemariti kod mjerenja ukupne faktorske energetske efikasnosti. Naime, u slučaju ispuštanja plinova ili onečišćenja, regulatorni standardi određuju moguću količinu neželjenih izlaza kao rezultata proizvodnog procesa. Empirijski rezultati potvrđuju da su vrijednosti ukupne faktorske efikasnosti, dobiveni korištenjem Analize omeđivanja podataka, koji uključuju neželjene izlaze realniji nego rezultati koji su dobiveni na temelju samo poželjnih izlaza jer se u tom slučaju ne uzimaju u obzir negativni utjecaji na okoliš. Ustanovljene su i značajne razlike u ocjeni ukupne energetske efikasnosti s obzirom na okoliš između razvijenih i manje razvijenih zemalja EU. Za svaku neefikasnu zemlju su određene projicirane vrijednosti na efikasnu granicu koje određuju potencijalne ciljeve. Ti ciljevi su korisni u politici donošenja odluka koje se tiču ukupne faktorske energetske efikasnosti s obzirom na okoliš. Stoga, da bi riješile probleme ukupne faktorske efikasnosti vezane za okoliš, neefikasne zemlje bi trebale imati za cilj promjenu svoje energetske strukture kao i njezine potrošnje. S druge strane, efikasne zemlje čije su vlade već usmjerile svoju energetsku politiku prema očuvanju okoliša bi trebale poslužiti kao primjeri dobre prakse.

Ključne riječi: *ukupna faktorska efikasnost, države EU, AOP, neželjeni izlaz.*

1. Introduction

International concern over environmental issues such as climate change and global warming, i.e. increasing of greenhouse gases has put economic and political pressures on governments of both developed and developing countries. Therefore, one of the most important objectives for any energy policy is the improvement of energy efficiency, especially for those countries with high dependency on imported energy, and the impact of energy resources on the environment. The objective of improving energy efficiency is not only for environmental benefits, such as reducing CO_2 emissions, but also to achieve the development of national economy, enhancement of industrial competitiveness and energy conservation.

Regarding the mentioned above, the European Union advocated the ambitious targets, so-called as 20/20/20 goals (Council of the European Union, 2007): 1) reduce greenhouse gas (GHG) emissions by 20% in 2020 compared to 1990 levels; 2) increase energy efficiency so as to achieve the objective of saving 20% of the EU's energy consumption compared to projections for 2020; 3) a binding target of a 20% share of renewable energies in overall EU energy consumption by 2020. Energy efficiency appears to be the only energy item in these fundamental EU goals; the improvement of energy efficiency not only that can lead to reduce GHG emissions, but also it can increase the renewable energy share without new investment. Measures to ensure energy efficiency becoming a priority for any nation willing to develop their economy.

In this sense, the purpose of this research is to evaluate the total-factor energy efficiency in the EU countries and to examine the impact of undesirable outputs on these countries' energy efficiency. It should be noted that most studies assessing the energy efficiency at the macroeconomic level using a total factor structure adopt the Data Envelopment Analysis (DEA) method, as it provides an appropriate mechanism for dealing with multiple inputs and multiple outputs to measure the efficiency ratio of each Decision Making Unit (DMU) under evaluation (Camioto, Rebelatto, Rocha, 2016). So, the analysis tool used in this study is the Data Envelopment Analysis, through the SBM Bad output model, incorporating multiple inputs and two kinds of multiple outputs: desirable and undesirable as the result of input utilization. Undesirable outputs are often occur in the environmental context, and represent an anomaly, which should not be ignored when measuring total-factor energy efficiency. In contrast to the "desirable" outputs which should have as high as possible value, "undesirable" outputs, or environmentally unfavorable outputs, achieve as low as possible value. Also, in case of emissions or pollution, regulatory standards define the maximum amount of undesirable outputs as a result of the production process.

DEA method was developed to analyse the relative efficiency of a DMU, by constructing a piecewise linear production frontier and projecting the performance of each DMU onto that frontier. A DMU that is located on the frontier is efficient, whereas a DMU that is not on the frontier is inefficient. For every relatively inefficient DMU the projected values on efficient frontier are determined, as targets. These targets are useful in policy decision-making regarding environmental total-factor energy efficiency. Therefore, in order to solve their environmental problems, inefficient DMUs, i.e. inefficient countries should aim to change their energy structure and energy consumption. On the other hand, efficient countries whose governments have already directed their energy policy to environmental energy should serve as good practice examples.

2. Measuring environmental total-factor energy efficiency using dea method

The concept of efficiency plays a vital role in contemporary ecological economic theory (Jollands, 2006). Depending on the context in which it appears, different representations of eco-efficiency have been discussed in the existing literature. Eco-efficiency can be defined as a measure of efficiency that takes undesirable aspects of evaluation or operational assessment of environmental performance of DMUs into account (You, Yan, 2011). Preferred output values mean preferred targets for outputs of a decision-making unit, while undesirable (bad) outputs represent undesirable targets for the evaluated units in a production process. According to commonly accepted World Business Council for Sustainable Development's definition, eco-efficiency is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with Earth's estimated carrying capacity (DeSimone, Popoff, 1997, p. 47). Eco-efficiency is measured by environmental indicators that can involve material and energy issues. It should be noted that assessment of the environmental efficiency may also include certain economic indicators to extend the standard eco-efficiency model (DeSimone, Popoff, 1997, p. 47).

There might be some challenges associated with measurement and assessment of the environmental efficiency. First, although there are numerous data concerning environmental issues, the data must be standardized. Furthermore, besides being standardized and reliable, the question then arises whether environmental data are actually available in the public, especially at enterprise or economic activity level (Dyckhoff, Allen, 2001). On the other hand, international institutions such as The International Energy Agency or EU databases provide environmental data at the national level. Due to a range of issues related to research methodologies, until recently it was difficult to compare one country's performance to others based on environmental indicators. In particular, data used to be divided into different indicator group sets based on a weighted value or index, which also applied to selecting the best indicators. The process was very difficult having in mind that the data or indicator sets may be extensive and complex. Deriving weighted relations, for example, in functional relations, proved to be extremely challenging due to lack of knowledge on the effects of natural resource depletion and pollution emission (Dyckhoff, Allen, 2001).

The DEA method provides a measure of efficiency that allows for assessing the performance of a set of different entities or decision-making units that operate under similar conditions (Cooper, Seiford, Zhu, 2004). Data envelopment analysis is a powerful approach in measuring and comparing relative efficiency that avoids a need for a priori choices of weights and does not require specifying the form of relation between inputs and outputs. Data envelopment analysis tailored to assess environmental performance tends to use preferred and undesirable output values such as, for example, waste disposal, pollution or harmful emissions. Likewise, undesirable outputs can be measured in health care (complications that can occur during surgery) or economics (tax rates).

3. Literature review

Evaluation and measurement of environmental efficiency provide valuable information that can be used with the aim of creating preconditions for development of a society, while preserving environment. This information is particularly intended for public authorities, organizations and companies that are directly or indirectly related to environmental management and performance.

One of the early studies on environmental efficiency, which was conducted in 1995, involved 19 OECD countries during the period from 1970 to 1990. Initially, the study included the following variables: Real GDP Per Capita, Inflation Rate, Unemployment Rate and the Balance of Trade (the difference between a country's imports and its exports for a given period). Additional two variables were eventually included (nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions as undesirable outputs) and further analysis was carried out to determine changes in the efficiency trend. The study focused on the comparison of efficiency among 14 European and 5 non-European OECD countries. The expanded additive model approach revealed that European countries have lower relative efficiency after including the environmental issues (Lovell, Pastor, Turner, 1995).

Färe, Grosskopf and Tyteca (1996) were the first authors to include the variable of pollution in the DEA methodology at the microeconomic level, involving electric power industry. They analysed environmental efficiency of the U.S. electric companies that produce electrical energy from fossil fuels, including total world emissions of SO_2, NO_x and CO_2 (in tonnes) as undesirable outputs. The study was based on two different sets of data comprising of 49 respectively 90 DMUs. Since then a considerable number of researches on electricity production have been conducted using the DEA method involving various variables of environmental pollution (cf. Zhou, Ang, Poh, 2008, cf. Ramli, Munisamy, 2013).

In 2003, a survey was conducted across 103 Italian regions, divided into four groups based on the geographic zones, to evaluate relative environmental efficiency. The study included three sets of factors or variables: number of employees as input, gross domestic product as desirable output, with ambient concentrations of nitrogen dioxide and particulates as undesirable output. The findings revealed that only a few regions have a significantly low environmental efficiency (Nissi, Rapposelli, 2006).

In the period from 2000 to 2010, Vlahinić-Dizdarević and Šegota (2012) examine the macroeconomic level of the energy efficiency changes in the EU countries and compare results with the traditional energy efficiency indicator. The DEA CCR multiple input-oriented model is applied in order to analyse the efficiency of the use of three inputs (capital stock, labour and energy consumption) in producing GDP as the output. In order to obtain the dynamics of data from 2000 to 2010 in calculating energy efficiency the extended DEA method - window analysis - is adopted. The empirical results show that the hypothesis on considerable differences in measuring energy efficiency between traditional one-factor and total-factor approach is confirmed. The findings on total-factor energy efficiency scores reflect the possibility of substitution among factors in a medium run and changes in the composition of energy use.

By using the input-oriented data envelopment analysis approach with the assumption of a variable returns-to-scale, Fang, Hu and Lou (2013) compute the pure technical efficiency and energy-saving target of Taiwan's service sectors during 2001–2008. Besides the analyzing the effects of industry characteristics on the energy-saving target by applying the DEA method, they also calculate the pre-adjusted and environment-adjusted total-factor energy efficiency scores in service sectors. Results show that the most energy efficient service sector is finance, insurance and real estate, which has an average total-factor energy efficiency of 0.994 and an environment-adjusted total-factor energy efficiency of 0.807. The study also utilizes the panel-data, random-effects Tobit regression model with the energy-saving target (EST) as the dependent variable.

Zhang, Kong and Yu (2015) propose a metafrontier slack-based efficiency measure (MSBM) approach to model ecological total-factor energy efficiency. They conduct an empirical analysis of regional ecological energy efficiency by incorporating carbon dioxide (CO_2) and sulfur dioxide (SO_2) emissions and the chemical oxygen demand (COD) of China during 2001-2010. The results indicate that most of the provinces are not performing at high ecological energy efficiency. Also, significant regional technology gaps in ecological energy efficiency exist in three areas.

4. Description of data and the model

A panel dataset of 28 EU countries from 2008 to 2014 is collected for the analysis. Panel data enable a DMU to be compared with other counterparts, but also because the movement of efficiency of a particular DMU can be tracked over a period of time. Therefore the panel data are more likely to reflect the real efficiency of a DMU than cross-sectional data. Annual series used in the analysis as inputs are: gross fixed capital formation in current prices in million euro as a proxy for capital, labour employment annual series in thousands persons employed and energy consumption in thousands tons of oil equivalent, all obtained from EUROSTAT (European Commission, 2017). Annual series used as outputs are: GDP at market prices in million euro and two undesirable outputs: carbon dioxide and sulphur oxides emissions in tonnes, all collected from the EUROSTAT.

Table 1 presents the summary statistics of the inputs and outputs used in the DEA model. In our model three production factors (labour-employment, capital-gross fixed capital formation and energy-energy consumption) produce one desirable output (GDP) and two undesirable outputs (CO_2 and SO_x emissions). The correlation matrix is shown in the Table 2.

Table 1 *Statistics on input and output variables in 2014*

Value of variable	Capital	Employment	Energy	CO_2 emissions	SO_x emissions	GDP
Max	5851470	349602	3132393	6750739430	59660131	29239300
Min	14525	1545	8858	52276040	46561	84263
Average	967671.4	64331	574076,5	1039153924	10428786	5000398
SD	1471057	86017.26	774666.1	1450904194	15607209	7627750.2

Source: Authors' calculation

Table 2 *Correlation coefficients of input and output variables*

Variable	Capital	Employment	Energy	CO_2 emissions	SO_x emissions	GDP
Capital	1	0,971566	0,988942	0,903501147	0,6291712	0,9918128
Employment	0,971566	1	0,984658	0,956703296	0,7618548	0,9767951
Energy	0,988942	0,984658	1	0,931836383	0,7028478	0,9797972
CO_2 emissions	0,903501	0,956703	0,931836	1	0,8114032	0,9136125
SO_x emissions	0,629171	0,761855	0,702848	0,811403179	1	0,6333703
GDP	0,991813	0,976795	0,979797	0,913612549	0,6333703	1

Source: Authors' calculation

As it is shown in the table 2, inputs and outputs are highly positive correlated. The highest coefficient of correlation between inputs and outputs is between capital and GDP (0.99) while the lowest coefficient of correlation is between capital and SO_x emissions (0.63). High values of coefficients of correlation between inputs and outputs have approved their choice, implying that increasing values of inputs result with increasing values of outputs.

A number of modelling techniques have been developed to address energy efficiency dilemmas because energy efficiency is a difficult concept to define. It is often confused with energy conservation, although conservation indicates the use of less energy, while efficiency implies reaching a given output with a lower use of resources. Evaluating energy efficiency is a very important tool in energy and economic policy and it is usually done by two indicators: energy intensity and energy efficiency. Energy intensity is defined as the energy consumption divided by the economic output (GDP). It is the most commonly used basis for assessing trends in energy efficiency since a truly technical definition of energy efficiency can only be obtained through measurements at the level of a particular process or plant. Energy intensity is thought to be inversely related to efficiency, the less energy required to produce a unit of output or service, the greater the efficiency. A logical conclusion, then, is that declining energy intensities over time may be indicators of improvements in energy efficiencies. Trends in energy intensities are influenced by changes in the economic and industrial activities of the country (structural changes), the energy mix and the efficiency of the end-use equipment and buildings. The second indicator – energy efficiency, sometimes called energy productivity – is the reciprocal value of energy intensity and is measured as the economic output divided by the energy input (consumption). The energy efficiency is in fact more an indicator of "energy productivity" than a true indicator of efficiency from a technical viewpoint. Its level reflects the nature of the economic activity (the economic structure), the structure of energy mix and the technical energy efficiency. In order to overcome these problems, data envelopment analysis (DEA) as a relatively new non-parametric approach to efficiency evaluation has been applied very often for benchmarking energy performance that is capable of handling multiple inputs and outputs. It is also applied in order to compare the energy efficiency performance of different countries/regions from the viewpoint of production efficiency. New researches have combined total factor energy efficiency with undesirable emissions like CO_2 and So_x in order to analyse environmental impacts that have become crucial issue for the economic policy.

DEA is linear programming method for measuring the relative efficiency of DMUs in converting multiple inputs into multiple outputs. Let us suppose that *n* DMUs having three factors: inputs, good outputs and bad (undesirable) outputs as represented by three vectors $x \in R^m$, $y^g \in R^{s_1}$ and $y^b \in R^{s_2}$, respectively. In the presence of undesirable outputs efficiency can be defined as "capacity" of DMU to produce more desirable outputs and less undesirable outputs with less input resources or, more precisely, by following definition (Cooper, Seiford, Zhu, 2004):

Definition: A DMU_o (x_o, y_o^g, y_o^b) *is efficient in the presence of undesirable outputs if there is no vector* (x, y^g, y^b) *element production possibility set such that* $x_o \geq x$, $y_o^g \leq y^g$, $y_o^b \leq y^b$ *with at least one strict inequality.*

Bad-output model, as modified SBM model (Tone, 2001), is used to estimate relative efficiency of 28 EU countries in converting three selected inputs into selected desirable output and two undesirable outputs:

$$\rho^* = \min \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_{io}^-}{x_{io}}}{1+\frac{1}{s}\left(\sum_{r=1}^{s_1}\frac{s_r^g}{y_{ro}^g}+\sum_{r=1}^{s_2}\frac{s_r^b}{y_{ro}^b}\right)}$$

$$\text{s.t.} \quad x_o = X\lambda + s^-$$

$$y_o^g = Y\lambda - s^g \quad y_o^b = Y\lambda + s^b \quad L \leq e\lambda \leq U \quad s^- \geq 0,\ s^g \geq 0,\ s^b \geq 0,\ \lambda \geq 0,$$

where λ is intensity vector, *L* and *U* are the lower and upper bounds of the intensity vector, s^- and s^b excesses in inputs and bad outputs, s^g expresses shortages in good outputs while s_1 and s_2 denote the number of elements in s^b and s^g with equality $s=s_1+s_2$. If the above program has the optimal solution $(\rho^*, s^{-*}, s^{g^*}, s^{b^*})$ the DMU is efficient in the presence of undesirable outputs if and only if $\rho^* = 1, s^{-*} = 0, s^{g^*} = 0, s^{b^*} = 0$. If the DMU is not efficient it can become efficient by following projections: $x_o \Leftarrow x_o - s^{-*}$ $y_o^g \Leftarrow y_o^g + s^{g^*}$ $y_o^b \Leftarrow x_o - s^{b^*}$

It follows that Bad-output model is useful in indicating sources and amounts of relative inefficiencies for each inefficient country under estimation. In order to capture the dynamics of efficiency and changes during the 2008-2014 periods in EU we have conducted DEA for each year using DEA- Solver- Pro 13.0.

5. Empirical results and discussion

After selecting input and output variables, in the first stage the efficiency scores of countries in each year of the 2008-2014 period are analysed. This is followed by identifying sources and amounts of relative inefficiency. Table 3 contains the summary efficiency score results from the DEA analysis using Bad-output model with constant returns to scale.

Table 3 *Efficiency scores for the EU countries in the period 2008-2014*

Country	2008	2009	2010	2011	2012	2013	2014
Austria	0,663516	1	0,74001	0,699609	0,723701	0,674451	0,67018
Belgium	0,534928	0,587215	0,545269	0,553081	0,581322	1	0,541386
Bulgaria	0,213054	0,23297	0,254522	0,258418	0,205462	0,257659	0,265181
Croatia	0,373642	0,377813	0,384098	0,381578	0,420321	0,361422	0,455309
Czech Republic	0,320896	0,31735	0,29534	0,312374	0,321393	0,330627	0,296302
Cyprus	0,463317	0,484546	0,469846	0,498517	0,635109	1	1
Denmark	1	1	1	1	1	1	1
Estonia	0,269233	0,306817	0,286591	0,262664	0,269915	0,256675	0,277539
Finland	0,498689	0,510376	0,460992	0,476716	0,496961	0,483621	0,634009
France	1	1	1	0,754305	1	0,790614	1
Germany	0,668043	0,662622	1	0,581279	0,598044	0,557702	0,551806
Greece	0,550205	0,612406	0,577596	1	1	1	1
Hungary	0,384389	0,505939	0,371177	0,388047	0,403094	0,37405	1
Ireland	1	1	1	1	1	1	1
Italy	0,727997	0,745253	0,670212	0,65436	0,745117	0,860916	1
Latvia	0,355637	0,381917	0,368176	0,375798	0,366448	0,575566	0,373536
Lithuania	0,333581	0,405828	0,420492	0,372025	0,410911	0,403609	0,404398
Luxembourg	1	1	1	1	1	1	1
Malta	0,503298	0,532033	0,436311	0,525848	0,493709	0,555109	0,590428
Netherlands	0,596302	0,623156	0,588249	0,597043	0,654182	0,723316	0,651691
Poland	0,35756	0,339751	0,334179	0,328396	0,366353	0,353003	0,348336
Portugal	0,517744	0,65482	0,688148	1	1	1	1
Romania	0,259823	0,299972	0,284437	0,265795	0,28421	0,286872	0,310934
Slovak Republic	0,341339	0,408747	0,338305	0,326418	1	0,399222	0,409593
Slovenia	0,376174	0,419403	0,408769	0,422727	0,601602	0,410886	0,420429
Spain	0,523972	0,58869	0,559838	0,549304	0,578927	0,593589	0,558316
Sweden	1	0,729566	1	1	1	1	1
United Kingdom	1	1	1	1	1	1	1

Source: Authors' calculations

According to the efficiency scores, the countries with the highest energy efficiency scores in the whole analysed period are Denmark, Ireland, Luxembourg and United Kingdom, while the worst performers in total-factor energy efficiency that takes into account the level of harmful emissions are transition economies. In 2014 the worst relative efficiency was obtained by Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania, Slovak Republic and Slovenia. These worst performers are countries with relatively strong industrial basis and their level of CO_2 and SO_x emissions are relatively high in comparison with the level of inputs and GDP. As one could expect, the results for Croatia are similar to other new EU Member States, although there is a positive change in 2014. Findings for Croatia could be related to decrease in inputs, especially employment and energy consumption, while undesirable outputs (emissions) have been reduced. On the other hand, developed countries with highest energy efficiency that experienced the strongest growth of renewable energy like Denmark, UK and Luxembourg are countries that are graded as the most efficient.

These findings for the analysed period can be related to the possibility of substitution among factors in a medium (7 years) run and to changes in the composition of energy use.

Although these results are more or less expected, the paper tempts to test the differences between one-factor traditional energy efficiency approach and the total-factor energy efficiency that takes into account the environmental costs of economic activity such are CO2 and SOx emissions.

Furthermore, DEA enables us to consider potential improvements (as projections on efficient frontier) for each inefficient country, shown in the table 4. We can see that all inefficient countries should decrease the amounts of undesirable outputs and that present value of GDP should be achieved with fewer amounts of all inputs. It means that inefficient countries do not use their inputs efficiently. For example, Croatia with efficiency score approximately 46% does not use capital, employment and energy efficiently in order to achieve present value of GDP and at the same time produces too much undesirable CO_2 and SO_x emissions. Projections imply that Croatia should use 14.52% less capital, 66.36% less employment and 51.12% less energy, and produce 46.95% less CO_2 and 45.05% less SO_x to achieve the present amount of 429778 GDP.

Table 4 *Efficiency scores, projections and changes for 28 EU countries in 2014*

		(I)capital		(I)employm		(I)energy		(O)Carbon diox		(O)Sulphur		(O)GDP	
Country	Score	Projection	Change(%)	Projection	Change(%)	Projection	Change(%)	Projection	Change(%)	Projection	Change(%)	Projection	Change(%)
Austria	0,67018	642892,9	-14,43%	14913,88	-57,89%	283102,2	-12,80%	443278740	-9,28%	1264836,7	-18,21%	3304176	0,00%
Belgium	0,541386	779845,6	-15,01%	18090,92	-53,21%	343410,3	-35,87%	537708449,5	-25,87%	1534279,3	-56,63%	4008050	0,00%
Bulgaria	0,265181	49564,24	-45,09%	5415,79	-78,94%	58566,28	-66,99%	148987352,2	-65,40%	3197052	-82,54%	427622	0,00%
Croatia	0,455309	71435,22	-14,52%	4425,248	-66,36%	40057,32	-51,12%	67749827,93	-46,95%	80370,537	-45,05%	429778	0,00%
Czech Rep	0,296302	304813,1	-22,58%	7071,079	-82,43%	134226,5	-68,22%	210170546	-75,74%	599693,59	-94,72%	1566600	0,00%
Cyprus	1	20524	0,00%	2960	0,00%	22291	0,00%	55198840	0,00%	1753002	0,00%	175674	0,00%
Denmark	1	508114	0,00%	24251	0,00%	168027	0,00%	657983160	0,00%	2018771	0,00%	2652325	0,00%
Estonia	0,277539	38443,69	-20,15%	891,8198	-83,65%	16928,94	-74,65%	26507166,47	-85,70%	75634,661	-98,28%	197583	0,00%
Finland	0,634009	377955,5	-10,51%	13727,46	-33,97%	181844,6	-47,70%	293740036,3	-37,04%	635784	0,00%	2054740	0,00%
France	1	4659040	0,00%	231843	0,00%	2486283	0,00%	2314288060	0,00%	21449554	0,00%	21399640	0,00%
Germany	0,551806	5689085	-2,78%	131975,9	-62,25%	2505227	-20,02%	3922660313	-41,89%	11192788	-77,50%	29239300	0,00%
Greece	1	206245	0,00%	22536	0,00%	243704	0,00%	619961060	0,00%	13303463	0,00%	1779406	0,00%
Hungary	1	228826	0,00%	36217	0,00%	228533	0,00%	335504340	0,00%	149281	0,00%	1049533	0,00%
Ireland	1	395741	0,00%	15632	0,00%	135607	0,00%	244376420	0,00%	1232385	0,00%	1931596	0,00%
Italy	1	2693304	0,00%	166844	0,00%	1510271	0,00%	2554354590	0,00%	3030190	0,00%	16203811	0,00%
Latvia	0,373536	45933,85	-13,94%	1065,577	-86,01%	20227,28	-54,56%	31671679,01	-52,52%	90370,908	-66,81%	236079	0,00%
Lithuania	0,404398	67704	0,00%	2363,123	-79,20%	32276,24	-51,79%	51977503,92	-65,01%	115974,17	-92,24%	365900	0,00%
Luxembou	1	95870	0,00%	2224	0,00%	42217	0,00%	66102970	0,00%	188616	0,00%	492728	0,00%
Malta	0,590428	14525	0,00%	761,7156	-50,70%	7715,905	-12,89%	12853107,88	-75,41%	19343,269	-58,46%	84263	0,00%
Netherland	0,651691	1195300	0,00%	49242,06	-27,30%	593199,7	-22,77%	967907158,6	-39,72%	1883996,5	-71,62%	6630080	0,00%
Poland	0,348336	799661,9	-1,41%	18550,62	-84,97%	352136,5	-62,67%	551371949,8	-80,44%	1573266,2	-97,36%	4109897	0,00%
Portugal	1	259931	0,00%	35737	0,00%	220850	0,00%	410938000	0,00%	483282	0,00%	1730791	0,00%
Romania	0,310934	292550,3	-19,96%	6786,606	-88,38%	128826,5	-59,94%	201715293,5	-68,20%	575567,66	-96,64%	1503575	0,00%
Slovak Rep	0,409593	147768,8	-4,64%	3427,952	-82,77%	65070,98	-59,78%	101887503,9	-64,94%	290722,39	-32,49%	759464	0,00%
Slovenia	0,420429	72637,58	-0,71%	1685,053	-77,35%	31986,45	-51,92%	50084073,1	-56,27%	142908,22	-82,91%	373324	0,00%
Spain	0,558316	1983350	0,00%	53820,8	-62,18%	897649,6	-23,07%	1419720246	-28,06%	3732279,5	-84,81%	10370250	0,00%
Sweden	1	997355	0,00%	41753	0,00%	482088	0,00%	421413330	0,00%	6526911	0,00%	4326911	0,00%
United Kin	1	3752481	0,00%	252526	0,00%	1897070	0,00%	3668901450	0,00%	41116532	0,00%	22608048	0,00%

Source: Authors' calculations

By incorporating projections we came to useful insights for the policy makers, especially in the context of main conclusions of Paris climate conference in 2015. Namely, all countries committed to a 40% reduction in greenhouse gas emissions by 2030 compared to 1990 and therefore the sustainable economic growth has become the crucial economic issue.

6. Conclusions

In this study, the comparison of environmental total factor energy efficiency between EU countries was performed by DEA methodology. We applied SBM model with undesirable outputs and the results of the research show that only eleven of twenty eight EU countries are relatively efficient. The main contribution of the analysis is potential improvements for inefficient countries. As Camioto, Rebelatto and Rocha (2016) stressed it should be noted that the slacks cannot be interpreted as a rigid target, as it is only an indication of which variable is more detrimental to the efficiency of countries in relation to others.

This study could be further widened to consider the effects of the energy mix of the EU economies and energy prices in order to provide more insights on the aspects of energy efficiency, especially the possibility of energy sources' substitutability, which could significantly alter policy measures and their implications. The obtained results have consequences in implementing measures for improving energy efficiency in the EU in the light of the ongoing desire to reduce greenhouse gas emissions.

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