Re-examining sustainable development in Europe: a data envelopment approach

Tihana Škrinjarić

Department of Mathematics,
Faculty of Economics and Business,
University of Zagreb, Croatia
Email: tskrinjar@net.efzg.hr

Abstract: Sustainable development is a widely known concept in public and academic circles and in macroeconomic policy. This study applies data envelopment analysis to 37 European countries for the period 2004–2016 in order to evaluate sustainable development objectively. The model uses gross domestic product per capita as desirable output, CO_2 emissions and Gini Index as undesirable outputs and three input variables: unemployment rate, fixed capital formation and energy consumption. Thus, all three pillars of sustainable development are included in the analysis. This is the first comprehensive analysis of European countries carried out with this methodology. Several model specifications are observed, in order to check for robustness of results. The results indicate that countries which are already highly ranked by existing world indices are ranked similarly in the empirical results of this research. Moreover, the most inefficient countries have shown an increase in sustainable development efficiency score over the observed period.

Keywords: sustainable development; data envelopment analysis; DEA; performance; undesirable output; robust ranking; EU environmental legislation; efficiency scores; dynamic analysis.

Reference to this paper should be made as follows: Škrinjarić, T. (2020) 'Re-examining sustainable development in Europe: a data envelopment approach', *Int. J. Environment and Sustainable Development*, Vol. 19, No. 1, pp.72–108.

Biographical notes: Tihana Škrinjarić is currently a Postdoctoral Researcher at the Department of Mathematics at Faculty of Economics and Business, University of Zagreb. She focused on financial econometrics and its application in portfolio management. Her research areas are risk management, applied econometrics and financial economics, with focus on regime switching methodology and portfolio management. She has published more than 60 publications in the mentioned areas. Her other areas of research include tourism demand, sustainable development and measuring efficiency within those two areas.

1 Introduction

The concept of sustainable development (SD) and its derivatives such as sustainable tourism, business, management, etc. is not something new today. However, this paradigm is in the focus of academics, politicians and the public now and has been for the last 20 years. The UN adopted a resolution on SD in 2015, in which SD is measured and compared for all countries in the world via an index of 17 sustainable development goals (SDG) and 169 associated targets (UN, 2015a). Thus, SD represents some of the most interesting and important topics today. Sustainable economic development has gained popularity especially since 1987, with the Brundtland Report from the UN (1987). In Europe, environmental policy was officially established in 1973, as a result of the UN Conference on the Human Environment in Stockholm; with the first program (Environmental Action Program – EAP) starting in 1973. Since then, there have been many worldwide conferences on SD (the concept of SD appeared for the first time in World Conservation Strategy (WCS) in 1980; other examples include: The Intergovernmental Panel on Climate Change (IPCC) in 1988; Earth Summit – United Nations Conference on Environment and Development in Rio de Janeiro in 1992; World Summit for Social Development in Copenhagen in 1995; United Nations Millennium Summit in New York in 2000, and others including a few more recent ones, such as: World Summit on Sustainable Development in Johannesburg in 2002 and Rio+20 Summit – UN Conference on Sustainable Development (UNCSD) in 2012, all of which show the importance of SD nowadays.

In order to measure the progress of achieving goals which have been set by the UN, the European Union and other relevant committees, quantitative measures have to be used. In this way, countries and regions can be compared one to another objectively. Moreover, policy makers in countries can observe the measures needed in order to achieve SD goals. Good and bad practices can be tracked over time, so changes can be made in order to facilitate faster achievement of set goals.

The SDG index is based upon 169 targets, making it complicated to calculate. The Sustainable Society Foundation measures the Sustainable Society Index (SSI) and three indices of wellbeing (human, economic and environmental) based upon 21 other indicators (SSF, 2014). The European Commission measures more than a hundred SD indicators (Tampakoudis et al., 2014). Since so many different data have to be measured to interpret and compare, the whole process of constructing different SD indices is cumbersome and time consuming. Policies and practices have to change over time due to changing market, social and other conditions in countries. This is why other approaches of SD measurement and comparison should be used in order to obtain faster results which are both reliable and of good quality. In that way, the policymakers and other involved parties can make timely and good decisions when they are needed.

The purpose of this paper is to empirically evaluate the SD of the European countries through economic, social and environmental variables by applying data envelopment analysis (DEA).

There are several interesting aspects to the study:

Firstly, the majority of European countries have to follow EU legislation and recommendations on social and environmental protection. As a result, unambiguous comparison can be made by applying the same methodology over a group of countries.

The existing literature of evaluating SD components surprisingly does not cover and compare European countries (as will be seen in the second section of the paper, the majority of existing research focuses on OECD countries, examples include Sueyoshi and Yuan (2016) and Aguado and Martinez (2012); or BRICS countries: Santana et al. (2014) and Camioto et al. (2016). Thirdly, by using fewer variables compared to some of the existing indices and rankings, one can observe if the same or similar results can be achieved. This is needed, as public data on all aspects of SD is not fully available.

Lastly, DEA methodology is widely used when relative efficiency needs to be compared amongst different units being compared. Comparison is made by ranking countries (or regions) with respect to SD. Thus, a parsimonious approach is made in this research to see if basic DEA models with several variables can be used, in order to objectively evaluate the SD efficiency of a selected group of countries. If this is found true, the results in this study can be extended in future research to construct time varying SD indices, as well as to get more detailed insights into sources of efficiencies in the countries studied.

Several DEA model specifications were applied in order to fully evaluate the efficiency of observed countries. Analysis determines which variables contribute to the quantitative evaluation of SD, in order for policy makers to be more focused on relevant variables in their own countries. Several approaches to checking robustness were made in order to have reliable results. This was done by comparing several DEA models and their results. The rankings in this paper have been compared to those of two internationally established ranking systems. Finally, reasoning for some anomalies in the results is provided, which is not done often in the literature.

The rest of the paper is structured as follows. The second section gives an overview of previous empirical research relevant to this one. The third section describes the methodology applied in the study, and the fourth section gives results of the empirical analysis. The final section presents the conclusions.

2 Previous research

The empirical literature on SD in Europe can be grouped into research which uses econometric techniques to estimate the relationship between growth and selected variables, and into research which applies DEA to compare relative efficiency of countries or regions. Since econometric research is not of interest in this paper, only a few papers are mentioned here, those which are related to this study and can help with the selection of variables. This research mostly observes panel data and estimates static or dynamic panel models. In most of the literature, the authors have observed just 2 out of the 3 pillars of SD.

Tampakoudis et al. (2014) used 11 indicators of sustainability, and panel regression to observe their impact on gross domestic product (GDP) growth in the Euro zone[1]. The results indicated that factors such as the employment rate of older workers, total renewable electricity net generation, resource productivity and gas emissions were the most influential on GDP growth.

Lopez-Menendez et al. (2014) explored the environmental Kuznets curve for the EU 27 at that time. They examined panel data and focussed on the greatest pollutant, CO_2. Results indicated that only 4 countries exhibited the inverted U shape (meaning that these countries had a somewhat quality of distribution of the income growth or the pollution reduction), whilst 11 countries still had a positive relationship between GDP growth and pollution. 9 countries had a negative relationship (meaning that these countries may already have solved most of their problems). When the authors tried to pool all of the data, it was not possible, meaning that disparities existed between those EU countries.

Analysis like that provided in this paper is needed to study those disparities.

Chang et al. (2014) observed 98 countries across the world (time span: 1990–2007) by. The authors found that the increase in the carbon footprint resulting from economic growth cannot be counterbalanced by technological advances in environmental protection at different stages of economic development. Thus, more reasonable development policies are needed to overcome problems associated with economic development. The conclusions of the paper include emphasising that changes to the structure of the industry are most important for lowering pollution in general.

Fotis and Pekka (2017) focused on the Euro zone countries via panel data system general method of moments (GMM) estimation and found that greater usage of renewable energy in a country leads to lower pollution levels, an expected result.

Armeanu et al. (2017) observed panel data of the 28 EU countries in order to determine drivers of sustainable economic growth (for period 1977–2014). Several variables such as higher education, business environment and infrastructure, as well as technology and demography were used. Real GDP growth rate was used as a SD growth rate. Authors found that the adult literacy rate, expenditures per student (in higher education) and total expenditures on research and development (R&D) are positively related with GDP growth, while a negative relation exists for these variables: infrastructure, technology and demographic changes. However, as the authors acknowledged, GDP growth rate is not the most suitable measure of SD, since it does not cover welfare and income distribution. Thus, a social component is missing here.

Fotis and Polemis (2018) observed panel data, in the same way as their previous research, for 34 European countries in the period 2005–2013. Focus in this study was on GDP per capita, the pillars of SD environmental policy and renewable energy use. Emissions of SO_2 (sulphur dioxide), NO_X[2] (oxides of nitrogen) and NMVOC (non-methane volatile organic compounds) were used as pollution variables, and the share of renewable energy in gross final energy consumption was used as an indicator). Again, the social component is missing. Results, not surprisingly, suggested that there exists a monotonic relationship between pollution and GDP.

Other relevant and related research with econometric methodology can be found in the articles mentioned above. An overview of empirical papers with only an economic and social view is given in Rabar (2017).

Looking at DEA methodology, the majority of existing research on SD is concentrated on development of new models to evaluate specific questions[3]. Here, the focus is on empirical research which investigates the efficiency from an economic, environmental and social point of view. There are also analyses which observe economic and environmental aspects, such as;

- Zhou et al. (2007a, 2007b), in which a non-radial Malmquist index is calculated for 26 OECD countries with labour force and energy consumption as inputs and GDP as output, with CO_2, SOx (sulphur oxides), NO_x and CO emissions as undesirable outputs
- Zhou et al. (2008), where a radial model is applied over GDP as a desirable output and CO_2 emissions as an undesirable output
- Halkos and Tzeremes (2013), who analysed 27 Annex I countries (period 2006-2010) via a two-stage DEA (first stage uses GDP as output and capital stock and labour force as inputs; second stage uses GDP as input and emissions of CO_2, CH_4, N_2O and F-gases[4] as bad outputs).

Since recent SD studies incorporate three aspects of SD, economic, environmental and social, the rest of this section reviews papers with all three components.

As Zhou et al. (2018) observed, the first wave of papers only included two aspects of SD (economic and environmental), whilst the more recent ones observe trade-offs between all three components.

From Table A1 in Appendix, it can be seen that the majority of papers observe mostly developed countries (e.g., OECD). Furthermore, many different DEA models were employed.

Regarding the variables in the models, inputs are usually energy consumption, labour force, gross fixed capital, etc. The outputs are GDP (per capita) or income, bad outputs CO_2 emissions (or other pollutants), poverty indices and Gini Index. In that way, all three components of SD are included in the analysis. It is not clear why Bruni et al. (2011) use GDP as an input in the analysis, while most other studies use GDP as an output variable. It would be interesting to repeat the evaluation with this change in the models. The usage of output variable as an input in the model is found in Tsai et al. (2016), who determine labour force as input and CO_2 emissions as the only output. Other papers separate the desirable from undesirable outputs. It is quite surprising that, to the knowledge of the author, no study exists which compares European countries by including all three pillars of SD.

There exist several approaches when dealing with SD and the treatment of variables. Since some of the variables are basically outputs, such as pollution or Gini[5] Index, their values should be as small as possible. Some authors just translate the data (see Yeh et al., 2010); or treat those variables as inputs (see Zhang et al. 2008). Others apply weak disposability technology (Färe et al., 2004).

By looking at the existing research, several conclusions can be made. Firstly, a holistic approach is missing in the majority of the studies. This means that one out of the three pillars of SD is usually missing when talking about SD, or measuring and comparing efficiencies. The contribution of this paper compared to existing ones is in filling that gap. Secondly, results in this study are presented in greater depth, by comparing and contrasting the characteristics of the most efficient and most inefficient countries in order to get better understanding of the sources of inefficiencies. Finally, the results are compared to previous studies, as well as to the existing rankings of the UN and RobecoSAM Country Sustainability Ranking (CSR) Index, two widely known ranking systems for SD.

3 Methodology

3.1 Theoretical models

Since DEA methodology used in this study is fairly well known, this section will briefly describe the main models. The basic notation and models are given as follows. Data on n decision making units (DMU) is available as follows:

- m inputs and s outputs, with $\boldsymbol{x} \in M_{mn}$ denoting a matrix which contains data on inputs and $\boldsymbol{y} \in M_{sn}$ denoting a matrix which contains data on outputs.

- $\boldsymbol{x}_j \in \mathbb{R}^m$ and $\boldsymbol{y}_j \in \mathbb{R}^s$ are vectors of all inputs and outputs of the DMU under evaluation, $j \in \{1, 2, ..., n\}$, $\boldsymbol{x}_j \geq \boldsymbol{0}$, $\boldsymbol{x}_j \neq \boldsymbol{0}$, $\boldsymbol{y}_j \geq \boldsymbol{0}$, $\boldsymbol{y}_j \neq \boldsymbol{0}$.

The basic models, denoted with CCR (Charnes-Cooper-Rhodes, 1978) and BCC (Banker-Charnes-Cooper, 1984) are models with fixed and variable returns to scale respectively; with each model having the possibility to be input or output oriented. For example, the BCC-O model can be solved in 2 phases. In the first one, the rate of output enlargement (Cooper et al., 2006) is maximised:

$$\left.\begin{aligned} &\max_{\mu,\eta} \eta \\ &s.t. \quad \boldsymbol{x}_j - \boldsymbol{x\mu} \geq \mathbf{0} \\ &\quad \eta \boldsymbol{y}_j - \boldsymbol{y\mu} \leq \mathbf{0} \\ &\quad \boldsymbol{\mu} \geq \mathbf{0} \\ &\quad \sum_{j=1}^{n} \mu_j = 1 \end{aligned}\right\} (BCC-O) \tag{1}$$

and afterwards, in the second phase, the sum of input excesses (vector $\boldsymbol{t}^+$) and output shortfalls ($\boldsymbol{t}^-$) is maximised as:

$$\left.\begin{aligned} &\max_{\mu,t^-,t^+} \boldsymbol{et}^- + \boldsymbol{et}^+ \\ &s.t. \quad \boldsymbol{x}_j - \boldsymbol{x\mu} = \boldsymbol{t}^- \\ &\quad \eta^* \boldsymbol{y}_j - \boldsymbol{y\mu} = \boldsymbol{t}^+ \\ &\quad \boldsymbol{\mu} \geq \mathbf{0}, \boldsymbol{t}^- \geq \mathbf{0}, \boldsymbol{t}^+ \geq \mathbf{0} \\ &\quad \sum_{j=1}^{n} \mu_j = 1 \end{aligned}\right\} \tag{2}$$

with the optimal value of η^* from the first phase being used. DMU_j is said to be BCC efficient if and only if $\eta^* = 1$, $\boldsymbol{t}^{-*} = \mathbf{0}$ and $\boldsymbol{t}^{+*} = \mathbf{0}$. Details on these basic models can be found in Cooper et al. (2006, 2011). The window analysis of Klopp (1985) is suitable for evaluating DMUs over time. In that way, one can observe whether policy makers are managing changes for the better or worse. Moreover, models in which a researcher observes undesirable outputs such as pollution and inequality are as follows. DMUs with more good outputs (such as GDP) and fewer undesirable outputs are more efficient than others with more undesirable (or bad) outputs and fewer good inputs. Now $\boldsymbol{y}^b_j \in \mathbb{R}^w$ is added, a vector of undesirable outputs for DMU_j, with $\boldsymbol{y}^b_j > \mathbf{0}$. The new production possibility set is now defined as:

$$\left\{ \left(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{y}^b \right) \middle| \boldsymbol{x}_j \geq \boldsymbol{x\mu}, \boldsymbol{y}_j \leq \boldsymbol{y\mu}, \boldsymbol{y}_j^b \geq \boldsymbol{y}^b \boldsymbol{\mu}, \boldsymbol{\mu} \geq \mathbf{0}, \sum_{j=1}^{n} \mu_j = 1 \right\}, \tag{3}$$

where $\boldsymbol{y}^b \in M_{wn}$. Slacks-based measure (SBM model) is optimised as follows (Tone, 2001):

$$\left.\begin{aligned}
&\rho = \min_{\mu,t^-,t^+,t^b} \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{t_i^-}{x_{ij}}}{1+\frac{1}{s+w}\left(\sum_{r=1}^{s}\frac{t_r}{y_{ij}}+\sum_{r=1}^{w}\frac{t_r^b}{y_{ij}^b}\right)} \\
&\text{s.t.} \quad \boldsymbol{x}_j = \boldsymbol{x}\boldsymbol{\mu}+\boldsymbol{t}^- \\
&\qquad \boldsymbol{y}_j = \boldsymbol{y}\boldsymbol{\mu}-\boldsymbol{t}^+ \\
&\qquad \boldsymbol{y}_j^b = \boldsymbol{y}^b\boldsymbol{\mu}+\boldsymbol{t}^b \\
&\qquad \boldsymbol{t}^- \geq \boldsymbol{0}, \boldsymbol{t}^+ \geq \boldsymbol{0}, \boldsymbol{t}^b \geq \boldsymbol{0}, \boldsymbol{\mu} \geq \boldsymbol{0} \\
&\qquad \sum_{j=1}^{n}\mu_j = 1
\end{aligned}\right\}\text{(SBM-undesirable)} \qquad (4)$$

where $\boldsymbol{t}^b$ is a vector of excess undesirable outputs. The DMU under consideration is efficient in the presence of undesirable outputs if and only if $\rho^* = 1$, $\boldsymbol{t}^{+*} = \boldsymbol{0}$, $\boldsymbol{t}^{-*} = \boldsymbol{0}$ and $\boldsymbol{t}^{b*} = \boldsymbol{0}$. Weights on inputs and (bad) outputs can be imposed. Thus, the objective function in (4) can be modified to the following expression:

$$\min_{\mu,t^-,t^+,t^b} \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{p_i^- t_i^-}{x_{ij}}}{1+\frac{1}{s+w}\left(\sum_{r=1}^{s}\frac{p_r^- t_r}{y_{ij}}+\sum_{r=1}^{w}\frac{p_r^b t_r^b}{y_{ij}^b}\right)}, \qquad (5)$$

where p^-_i, p^+_i and p^{br} denote weight on input i, output r and undesirable output r, respectively. It holds that:

$$\sum_{i=1}^{m} p_i^- = m, p_i^- \geq 0 \;\; \forall i, \sum_{r=1}^{s} p_r^+ + \sum_{r=1}^{w} p_r^b = s+w, p_r^+ \geq 0 \;\; \forall r, p_r^b \geq 0 \;\; \forall r.$$

More details on DEA methodology and environment efficiency assessment can be found in Ball et al. (1994) or Zhou et al. (2008).

3.2 Data preparation

For the empirical analysis, data on 37 European countries for the period 2004–2016 has been collected from the World Bank (2018) and Eurostat (2018) for the following variables: unemployment rate, energy consumption (terajoule per capita), GDP per capita (2010 fixed prices, Euro), Gini Index, CO_2 emissions (kg per 1 Euro of GDP) and gross fixed capital formation (% of GDP). The countries were: Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and UK.

Variables were chosen based upon previous existing research.

Unemployment rate is observed rather than employment, due to problems with these variables in macroeconomics. For example, higher employment does not necessarily mean lower unemployment (imported labour force, etc.). By choosing to lower the unemployment rate in the economy, policymakers move towards SD (see Aceleanu et al., 2015).

GDP is a basic variable in macroeconomics used to compare countries. This study measures it per capita in order for it to be fully comparable across different countries (regions, etc.).

Energy consumption (again, per capita for comparability purposes) is a typical input variable in the production process.

The Gini Index is used because it incorporates a social component of the SD and inequality.

Gross fixed capital formation is a typical macroeconomic variable used in macro models of GDP growth, due to it being a necessary condition for the production process.

The requirement for the number of DMUs, inputs and outputs is met, whether one follows Golany and Roll (1989): $n \geq 2(m+s)$, Bowlin (1998): $n \geq 3(m+s)$ or Dyson et al. (2001): $n \geq 2ms$. It can be seen that the economic component of the evaluation is satisfied in the variables of energy consumption, GDP and fixed capital; the social component via the Gini Index, and the unemployment rate; and the environmental component in the CO_2 emissions. Some variables which are, in essence, bad outputs can be observed as inputs, as some previous literature suggests. Thus, based upon the model used in this study, some of the variables will be bad outputs in one model and input in another (e.g.CO_2 emissions; see Table 1 for details). Countries were chosen depending on the availability of data and to have a broader base to compare one country to another, especially for those countries which are candidates to join the EU and need to harmonise their policy measures with those of the EU. The models applied in the study are shown in (1) and (2). These are based upon the previous literature which uses the environment components as inputs or reciprocal values of environment components as outputs as undesirable outputs in the production process:

1 Static models – averaged data over the period 2004–2016:

   a SBM, undesirable outputs, constant return to scale, weights: B:G = 1:1

   b SBM, undesirable outputs, constant return to scale, weights: B:G = 5:1

   c SBM, undesirable outputs, constant return to scale, weights: B:G = 1:5

   d SBM, undesirable outputs, variable return to scale, weights: B:G = 1:1

   e SBM, undesirable outputs, variable return to scale, weights: B:G = 1:5

   f SBM, undesirable outputs, variable return to scale, weights: B:G = 5:1

   g BCC-I

   h BCC-O

   i CCR-I

   j CCR-O

2 Window analysis – the length of window is the total time span – this part will include the best models from the first group. Best models will be determined by comparisons of their rankings to the official rankings of UN.

Table 1 Description of inputs and (bad) outputs in the analysis

	Variable:	*Unemployment rate*	*Energy consumption*	*GDP*	*Gini*	*CO2 emissions*	*Fixed capital*
Model	A	I	I	O	Bad O	Bad O	I
	B						
	C						
	D						
	E						
	F						
	G				100-Gini O	1/CO2 O	
	H						
	I						
	J						

Source: Own elaboration

Models with undesirable outputs are the primary ones in the analysis, with the basic BCC and CCR models being used to check the robustness of ranking in models A-F. B:G stands for the ratio of weights on bad (undesirable) outputs relative to good outputs. Ratios were changed in order to see if giving equal values to good and bad outputs affects the ranking of the model[6]. The results are shown for 3 models throughout the paper (D, G and I), whilst other ones are shown in more detail in tables in the Appendix. By observing so many models, more robust results can be achieved and the results in this paper are then comparable to other studies which utilised one of the approaches in this one.

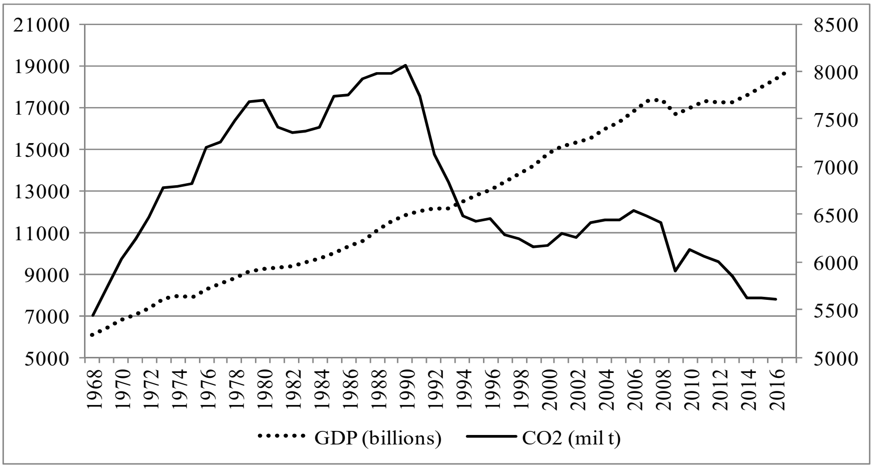
All of the analysis was performed in DEASolver v.12 and other basic calculations in Excel.

4 Empirical results

4.1 Initial results

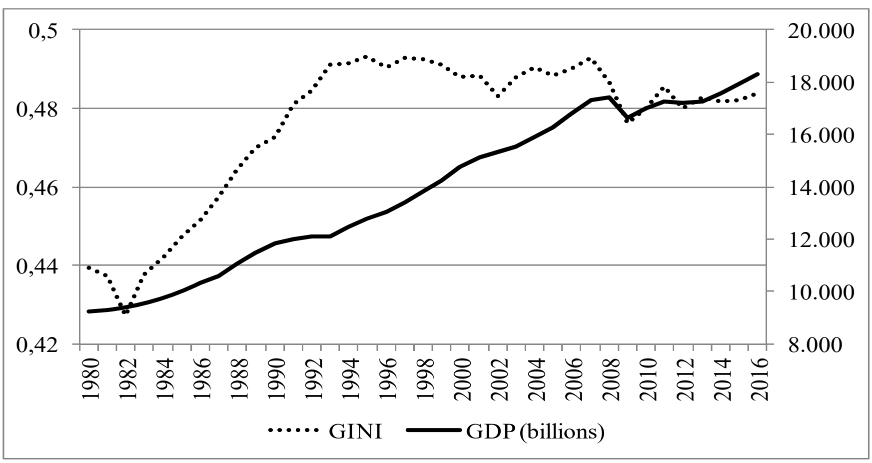
Before the analysis was begun, basic time series for whole Europe for GDP, CO_2 emissions and Gini Index were collected in order to observe general changes over decades. These series are shown on Figures 1 and 2. Data were collected for the period 1968 until 2016 for GDP and CO_2 emissions, and from 1980 for the Gini Index. The GDP in Europe shows a constant growth over several decades, with a minor decline during the last financial crisis in 2007–2008. However, major changes can be seen in the emission of CO_2 as a major pollutant, as mentioned in literature.. It experienced a sharp growth until the 1980s, when it declined (due to WCS mentioned in the introduction) for a short period. A major decline can be observed since publication of the Brundtland Report in 1987. The Gini Index shows an increase over the first third of the observed period, after which it stabilised in 1990s when the majority of the countries in Europe moved to capitalist oriented systems, with opening and deregulation of economies. However, this is only a general picture, without insights into differences which surely exist between countries.

Figure 1 Evolution of GDP (left axis) and CO_2 emissions (right axis) in Europe



Source: World Bank (2018)

Figure 2 Evolution of GDP (right axis) and Gini Index (left axis) in Europe



Source: World Bank (2018) and WID (2018)

The models A–F were optimised first, with the results in Table A2, which show efficiency scores for each country. The most efficient countries across all models were France, Luxembourg, Netherlands, Norway, Switzerland, UK, Ireland and Denmark. These results are not surprising, and are in line with results in previous literature which includes these countries in the analysis [such as OECD countries analysis, see Aguado and Martinez (2012)]. Reasons why these countries are the most efficient ones include

- successful policies for ending poverty
- the share of renewable energy increasing over the years (e.g., Norway had a 58% share of renewable energy in total energy consumption in 2018 [as discussed in Fotis and Pekka (2017) where authors focused on renewable energy]
- increasing the access to clean fuels over the years

- good health policies
- highest net enrolment rates in education (almost 100% in primary education) with the greatest Programme for International Student Assessment (PISA) scores
- the highest indices of corruption perception in the public sector (the greater the values of this index, the greater is public trust and lower corruption)
- the highest government efficiency scores.

These results are in line with Romer's (1986) and Todaro and Smith's (2003) new growth theory in which the economic growth is a result of the internal state of an economy (system), with knowledge having the biggest role. This theory supports investing in human capital, higher learning, and R&D. The most efficient countries listed here, follow these practices.

Although Beck and Wilms (2004) stated that SD is contradictory to the contemporary western culture and lifestyle, the countries which are found to be the most efficient regarding SD are those closest to the western lifestyle, in contrast to the most inefficient ones. These results are in line with Tsai et al. (2016), where the most efficient European countries were found to be France, Germany, Ireland, Iceland, Italy, Luxembourg, Malta, Norway and Sweden. The exceptions are Albania, Montenegro and Romania, but the authors did not include the third pillar of SD, namely the inequalities within a country. Thus, this could lead to wrong conclusions. Moreover, the rankings of inefficient countries found here (Albania and Montenegro amongst others) are in line with the UN and RobecoSAM rankings, while Tsai et al's results are not. Tsai et al. (2016) add that the French government provides subsidies for industries and technologies linked to low-carbon emissions and with low environmental impact. Moreover, since the countries in the efficient group are the high income ones, these results are in line with Costantini and Martini (2006), where the demand side of SD and reduction of pollution are result of the increase in income, when people are more willing to pay for greater living standards, due to seeing a clean environment as a luxury good.

The most inefficient countries were Albania, Macedonia, Serbia, Montenegro, Latvia, Bulgaria and Turkey. The majority of this second group of countries are non-EU members (the exceptions are Latvia and Bulgaria). Their results are in line with most inefficient countries in Tsai et al (2016), where Bulgaria, Bosnia, Belarus and Ukraine were found to be the worst.

The major factor found for each of these countries is that they have the lowest SD scores regarding industry, innovation and infrastructure of the economy. This again, is in line with the new growth theory. The diffusion of information and organisational efficiency are mostly impacted by the quality of the infrastructure, especially the telecommunication infrastructure, as found in Hardy (1980); which reinforces the Romer's (1990) model of the knowledge spillover. Besides, each of the countries in this inefficient group has a much lower value of government efficiency index as well as corruption index, with lower average years of total schooling, as well as a lower PISA score. Thus, education and investment into R&D seem to be crucial factors which influence the rankings of countries in these types of analysis.

Some of the problems the inefficient countries are facing today are related to the statistics and data collection needed for the purpose of SD measurement. Also the quality of the data, not only for the SD measures, but for the total economy For example, Albania today faces problems with data such that only 32% of the indicators from the global indicators framework of constructing measure of the SD index are available. 24% are partially available, 39% are not available at all and 5% are not applicable to Albania (UN, 2018e). In addition, some of the countries within this group belong to the former Soviet economic structure, which was highly inefficient (Gorobets, 2008).

The UN (2015b) states that many national statistical offices lack sufficient money and knowledge, and are vulnerable to political influences. As a result, official data may be of poor quality. Some countries face problems such as state institutions not being set up to facilitate the development of the private sector, and lack of foreign direct investment, with great vulnerability of specific groups in their societies (e.g., Serbia, see CEVES, 2018). Others face rapid pseudourbanisation, for example Turkey. The results for the two contrasting groups are in line with findings by Armeanu et al. (2017), who, by using panel data on the EU 28, found that investment in education and R&D is positively related to SD, and that the Corruption Perception Index (CPI) is negatively correlated.

These results are in line with previous literature which focused on specific aspects of the economy and its link to SD. Psacharopoulos and Patrinos (2004) found that additional schooling (of one extra year) leads to an average rate of return of around 10%, with the greatest returns being found for low and middle income countries. Thus, great opportunities exist for the most inefficient countries. Regarding corruption, results from Mauro (1995) indicate that corruption leads to lower economic growth, which is a characteristic of the majority of the inefficient group of countries. Finally, Mauro (1998) found a negative relationship regarding corruption and public spending on education, which amplifies the aforementioned problems of schooling and SD within Romer's (1990) model.

The differences between these two groups of countries among inputs and outputs are great: for example the average unemployment rate in the inefficient group is 2,74 times greater than the efficient group, energy consumption is 2,95 times greater, and the Gini Index 1,19 times greater. Average GDP per capita in efficient countries is 8,66 times greater.. Standard *t*-test was performed for the equality of means between efficient and inefficient countries regarding the inputs and outputs. Results indicate that on the usual levels of significance, the difference between each of the variables is greater than 0 values[7] with the exception of energy consumption.

Thus, there exists a significant difference between employing the economic inputs on one side and social and environmental standpoints on the other. The rankings in all 6 models are relatively unchanged, with the exception of Ukraine. It is the only country which changes rank significantly when the assumption of constant returns to scale is converted to variable. This country becomes efficient with variable returns to scale. The reason lies in the characteristics of inputs and outputs: GDP per capita for Ukraine is low in the collected sample and CO_2 emissions are very high, which puts it closer to the inefficient group. However, other variable values are much closer to the efficient set of countries. This affects its ranking and the projection on the efficient frontier based upon changing the assumption on the returns to scale. Moreover, there could be a problem of measurement error for some of the variables. Thus, we should be cautious when interpreting results for this country. This was considered in Gorobets (2008), where it is stated that problems regarding SD in Ukraine are due to the Soviet economy inheritance, poor understanding of the concept of SD by the government and public and an absence of clear and focused goals for achieving good national programs of SD. In conclusion it is probable that Ukraine belongs in the inefficient set of countries.

4.2 Robustness checking

In Table 2, detailed results are shown for models D, G and I for comparison. These three were chosen due to the rationale that each country can utilise its input variables to achieve desirable outputs and to minimise the levels of undesirable outputs. The three models are very similar in their ranking of the most efficient countries, as well as the most inefficient. However, the model with undesirable outputs (model D) gives much lower optimal values for the most inefficient countries in the study, because it measures the undesirable output in a different manner compared to the basic BCC or CCR models.

Table 2 Efficiency scores for models D, G and I

VRS, B:G = 1:1 (model D)		*BCC-I (model G)*		*CCR-I (model I)*	
DMU	*Score*	*DMU*	*Score*	*DMU*	*Score*
Luxembourg	1	Denmark	1	Denmark	1
Netherlands	1	France	1	France	1
Norway	1	Iceland	1	Luxembourg	1
Switzerland	1	Italy	1	Netherlands	1
UK	1	Luxembourg	1	Norway	1
France	1	Netherlands	1	Switzerland	1
Denmark	1	Norway	1	UK	1
Italy	0.999	Slovenia	1	Italy	0.993
Sweden	0.999	Sweden	1	Iceland	0.979
Slovenia	0.999	Switzerland	1	Ukraine	0.978
Germany	0.999	Ukraine	1	Austria	0.946
Czech Republic	0.999	UK	1	Sweden	0.930
Ukraine	0.997	Czech Republic	1	Germany	0.920
Iceland	0.994	Slovakia	1	Greece	0.898
Slovakia	0.993	Germany	0.996	Malta	0.892
Austria	0.810	Austria	0.958	Poland	0.877
Ireland	0.792	Malta	0.935	Serbia	0.876
Finland	0.566	Finland	0.923	Cyprus	0.870
Belgium	0.502	Serbia	0.917	Ireland	0.858
Spain	0.453	Greece	0.915	Slovenia	0.839
Cyprus	0.412	Lithuania	0.901	Hungary	0.830
Malta	0.296	Poland	0.897	Lithuania	0.828
Portugal	0.281	Cyprus	0.882	Czech Republic	0.826
Greece	0.225	Hungary	0.875	Finland	0.817
Hungary	0.215	Belgium	0.871	Portugal	0.810
Lithuania	0.211	Ireland	0.865	Belgium	0.805
Estonia	0.199	Portugal	0.847	Slovakia	0.797
Poland	0.189	Spain	0.829	Spain	0.778
Croatia	0.178	Romania	0.797	Montenegro	0.776

Source: Author's calculation

Table 2 Efficiency scores for models D, G and I (continued)

VRS, B:G = 1:1 (model D)		*BCC-I (model G)*		*CCR-I (model I)*	
DMU	*Score*	*DMU*	*Score*	*DMU*	*Score*
Turkey	0.147	Montenegro	0.789	Croatia	0.735
Romania	0.147	Croatia	0.783	Bulgaria	0.714
Bulgaria	0.107	Macedonia	0.766	Macedonia	0.712
Montenegro	0.089	Bulgaria	0.753	Romania	0.688
Latvia	0.088	Turkey	0.692	Estonia	0.617
Serbia	0.085	Estonia	0.654	Albania	0.610
Macedonia	0.058	Latvia	0.627	Latvia	0.593
Albania	0.052	Albania	0.622	Turkey	0.553

Source: Author's calculation

Next, correlation coefficients were calculated between the scores given in Table A2 and the SDG score calculated by the UN. The results are shown in Table 3. All of the coefficients are positive, which means that the rankings are consistent. More importantly, the values are greater than 0.55 for the constant and 0,70 for variable returns to scale and all of them are statistically significant. This gives confidence that the selected variables and models are adequate to measure SD. Another robustness check was made by comparing the results to the RobecoSAM[8] (2018) CSR index, for those countries where this is available. The CSR ranking of the countries, from best to worst, is: Denmark, Sweden, Switzerland, Finland, Norway, Netherlands, Ireland, UK, Luxembourg, Germany, Austria, Belgium, France, Czech, Spain, Portugal, Slovenia, Italy, Slovak, Poland, Hungary, Croatia, Bulgaria, Romania, Greece, Turkey and Ukraine. At both ends of the spectrum the model scores and the CSR rankings show similar clustering of countries (with the exception of Ukraine). These two comparisons, with the UN and CSR ranking systems, help confirm the results of this study and suggest that the rankings are correct, despite different variables being used in construction of the indices and the efficiency scores in this study.

Table 3 Coefficient of correlation of efficiency scores and SDG score

Model:	*CRS, B:G = 1:1*	*CRS, B:G = 5:1*	*CRS, B:G = 1:5*	*VRS, B:G = 1:1*	*VRS, B:G = 5:1*	*VRS, B:G = 1:5*
Correlation	0.582	0.573	0.592	0.714	0.720	0.702
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Source: Author's calculation

Another robustness check was made by applying the BCC and CCR models,as the simplest models, to evaluate efficiency, as shown in Table A4. Almost the same ranking is present in Table A4 as in Table A3, though Ukraine is close to the more efficient countries in all 4 models, regardless of the orientation of the model and assumptions on the returns to scale. It can be concluded that models with variable returns to scale in the presence of undesirable outputs, as in Table A4, provide more reliable results. Moreover, the reliability of models from Table A4 was checked by calculating correlations between their rankings and the SDG index.

The results are shown in Table 4. Again, the coefficients are significant, although lower than the previous ones. This could be due to the characteristics of the basic models of BCC and CCR (they only observe inputs and outputs so undesirable outputs have to be modified). It is interesting to note that yet again, a model with the assumption of variable returns to scale has greater correlation to the UN ranking. This could be a basis for future research which will extend this work by focusing on models with variable returns to scale. These results show that using fewer variables in the model can lead to very similar rankings of SD of observed countries. This will be useful in future work for those countries which still do not measure all of the required factors, or when many variables are not measureable or available to researchers.

Table 4 Coefficient of correlation of efficiency scores and SDG score

Model:	*CCR-I*	*CCR-O*	*BCC-I*	*BCC-O*
Correlation	0.564	0.564	0.612	0.579
p-value	0.000	0.000	0.000	0.000

Source: Author's calculation

4.3 Examining projections onto the efficient frontier

In order to observe detailed projections onto the efficient frontier, model E was chosen because it had the greatest correlation coefficient in Table 3 (model B:G = 5:1). Detailed results are provided in Table 5. Most efficient countries hardly have to make any input reduction or output increase in order to get onto the frontier. However, some of those countries are the greatest emitters of greenhouse gas due to their production and industry. On the other hand, the most inefficient countries have problems with all variables in the model, the economic ones, social and environmental as well. The countries which have the most problems, such as Albania have realised that the main problems to solve are public administration reform, strengthening the independence and efficiency of the judicial institutions, increasing the fight against corruption, etc. (UN, 2018a). Latvia has to increase the productivity in the economy, increase the higher level education rate, increase access to healthcare, recycle more waste, etc. (UN, 2018b). Some countries did not have measurable variables for the SD pillars even in 2016, such as Estonia, which stated that "[in] *an initial overview of 231 global sustainable development indicators [...] approximately 14% of the indicators are measurable right now*" (UN, 2018c). Most efficient countries already have additional measures to help increase SD. For example Denmark, where in June 2018 pension funds spent 650 million US dollars for promoting Danish technology and fighting poverty in developing countries. Other problems for inefficient countries and advantages of the efficient ones were described in Subsection 4.1.

The problems are more prominent in models A–C, where constant returns to scale are assumed. Table A3 in Appendix shows projections for model C (again, due to it having the greatest correlation with the SDG). It can be seen that countries such as the UK, which had an efficiency score of 1 in models D to F now have to make changes, e.g. reduce CO_2 emissions. One possible reason for this result is that the UK is one of the greatest importers of emissions in the world (Committee on Climate Change, 2013). However, this research is more focused on the reliability of ranking of the DMUs; leaving such questions for future research.

Table 5 Projections on to the efficient frontier, for model E (VRS, B:G = 5:1)

DMU	*Score*	*Unemployment*		*Energy*		*Capital*		*GINI*		*CO2*		*GDP*	
		Projection	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*
Denmark	1	5.846	0.00%	0.021	0.00%	20.376	0.00%	26.023	0.00%	0.131	0.00%	43,961.485	0.00%
France	1	9.269	0.00%	0	0.00%	22.208	0.00%	29.108	0.00%	0.130	0.00%	30,948.151	0.00%
Italy	1	9.146	0.00%	0.002	0.00%	19.407	0.00%	32.308	0.00%	0.188	0.00%	26,926.237	0.00%
Luxembourg	1	5.200	0.00%	0.045	0.00%	18.778	0.00%	28.215	0.00%	0.200	0.00%	80,066.978	0.00%
Netherlands	1	5.562	0.00%	0.001	0.00%	20.151	0.00%	26.485	0.00%	0.210	0.00%	38,136.938	0.00%
Norway	1	3.677	0.00%	0.078	0.00%	22.310	0.00%	24.585	0.00%	0.116	0.00%	65,401.047	0.00%
Slovenia	1	7.323	–0.01%	0.043	0.00%	23.051	0.00%	23.807	0.00%	0.318	–0.01%	17,386.622	0.03%
Sweden	1	7.491	–0.01%	0.092	0.00%	22.911	0.00%	25.377	0.00%	0.098	0.00%	40,611.291	0.01%
Switzerland	1	4.375	0.00%	0.059	0.00%	23.817	0.00%	30.225	0.00%	0.067	0.00%	57,215.691	0.00%
UK	1	6.223	0.00%	0.019	0.00%	16.332	0.00%	32.520	0.00%	0.193	0.00%	33,545.403	0.00%
Czech Republic	0.999	6.377	0.00%	0.019	0.00%	26.969	–0.03%	25.126	0.00%	0.529	–0.08%	14,194.105	0.16%
Germany	0.999	7.097	–0.04%	0.019	–0.09%	19.774	0.00%	26.654	0.00%	0.219	–0.01%	32,574.661	0.07%
Ukraine	0.999	7.887	–0.02%	0.010	0.00%	19.562	0.00%	26.139	0.00%	2.073	–0.04%	3,737.481	0.54%
Slovakia	0.996	13.162	–0.52%	0.018	0.00%	23.659	0.00%	25.288	0.00%	0.401	–0.08%	11,903.036	0.97%
Iceland	0.995	4.554	0.00%	0.390	–0.98%	21.359	0.00%	25.323	0.00%	0.147	–0.15%	40,281.584	0.53%
Austria	0.874	5.208	0.00%	0.021	–19.73%	21.063	–7.45%	27.008	0.00%	0.166	0.00%	44,686.981	24.68%
Ireland	0.782	7.262	–26.30%	0.009	–19.27%	20.867	–11.91%	28.073	–8.17%	0.170	0.00%	42,833.749	0.00%
Finland	0.592	5.406	–33.33%	0.033	–40.55%	20.769	–6.74%	25.731	0.00%	0.128	–42.11%	48,313.869	35.97%
Belgium	0.524	5.562	–30.41%	0.001	–97.35%	20.151	–11.04%	26.485	–0.43%	0.210	–0.20%	38,136.557	13.75%
Spain	0.481	9.269	–46.33%	0	–62.93%	22.208	–8.71%	29.107	–12.31%	0.130	–36.21%	30,947.841	35.67%
Cyprus	0.466	5.644	–35.41%	0.003	–84.60%	19.675	0.00%	27.237	–10.73%	0.208	–30.23%	37,564.499	70.55%
Malta	0.451	5.562	–18.03%	0.001	–98.70%	20.151	–1.04%	26.485	–3.79%	0.210	–26.54%	38,136.557	131.55%

Source: Author's calculation

Table 5 Projections on to the efficient frontier, for model E (VRS, B:G = 5:1) (continued)

DMU	*Score*	*Unemployment*		*Energy*		Capital		*GINI*		*CO2*		*GDP*	
		Projection	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*	*Projection*	*Change (%)*
Portugal	0.405	5.711	–50.21%	0.005	–88.17%	19.289	0.00%	27.846	–21.41%	0.206	–7.27%	37,100.444	125.95%
Greece	0.327	5.591	–65.87%	0.035	–79.57%	17.842	0.00%	29.862	–11.65%	0.197	–32.91%	62,271.433	235.37%
Hungary	0.327	5.562	–33.67%	0.001	–96.20%	20.151	–7.76%	26.485	–3.03%	0.210	–42.62%	38,136.557	279.84%
Lithuania	0.314	5.562	–46.44%	0.001	–84.69%	20.151	–4.12%	26.485	–24.59%	0.210	–38.76%	38,136.557	289.85%
Poland	0.282	5.562	–47.69%	0.001	–93.14%	20.151	–0.03%	26.485	–16.74%	0.210	–67.75%	38,136.557	317.85%
Croatia	0.263	5.562	–57.87%	0.001	–94.41%	20.151	–11.88%	26.485	–24.10%	0.210	–37.23%	38,136.557	279.11%
Estonia	0.263	5.562	–37.46%	0.001	–96.05%	20.151	–28.44%	26.485	–20.30%	0.210	–75.05%	38,136.557	212.97%
Romania	0.250	5.562	–18.21%	0.001	–91.34%	20.151	–24.76%	26.485	–27.33%	0.210	–58.08%	38,136.557	509.66%
Turkey	0.233	5.562	–43.79%	0.001	–91.59%	20.151	–26.16%	26.485	–38.64%	0.210	–42.64%	38,136.557	387.73%
Bulgaria	0.195	5.562	–42.44%	0.001	–94.63%	20.151	–15.50%	26.485	–22.26%	0.210	–77.16%	38,136.557	665.49%
Latvia	0.172	5.200	–55.79%	0.045	–91.12%	18.778	–27.86%	28.215	–22.02%	0.200	–29.92%	80,066.177	726.57%
Montenegro	0.165	5.562	–73.48%	0.001	–93.55%	20.151	–12.90%	26.485	–14.70%	0.210	–62.92%	38,136.557	659.81%
Serbia	0.165	5.585	–70.81%	0.001	–93.37%	20.017	0.00%	26.697	–6.46%	0.209	–82.67%	37,975.120	820.42%
Macedonia	0.118	5.562	–82.48%	0.001	–95.33%	20.151	–12.27%	26.485	–26.12%	0.210	–78.89%	38,136.557	999.90%
Albania	0.115	5.562	–63.79%	0.001	–88.84%	20.151	–34.87%	26.485	–11.13%	0.210	–48.49%	38,136.557	999.90%

Source: Author’s calculation

Table 6 Projections on to the efficient frontier, for model BCC-I

DMU	*Score*	*Unemployment*		*Energy*		*Capital*		*GDP*		*GINI*		*CO2*	
		Projection	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*
Turkey	0.553	4.556	53.957	0.005	44.725	15.085	44.725	29,151.610	272.819	56.839	0	3.898	42.302
Latvia	0.593	5.885	49.963	0.018	96.480	15.445	40.664	31,723.750	227.502	63.816	0	4.975	40.719
Albania	0.610	5.510	64.130	0.004	39.047	18.857	39.047	36,157.300	1141.991	70.200	0	4.723	91.637
Estonia	0.617	5.484	38.328	0.011	38.328	17.366	38.328	37,174.510	205.074	66.769	0	4.726	295.659
Romania	0.688	4.676	31.240	0.006	31.240	17.528	34.558	34,683.360	454.457	63.554	0	4.382	106.794
Macedonia	0.712	5.487	82.709	0.011	28.787	16.358	28.787	32,452.420	837.552	64.154	0	4.668	326.172
Bulgaria	0.714	5.534	42.720	0.009	28.653	17.014	28.653	33,488.630	572.193	65.931	0	4.715	321.701
Croatia	0.735	5.466	58.592	0.009	26.534	16.799	26.534	33,067.560	228.724	65.105	0	4.657	53.571
Montenegro	0.776	5.706	72.789	0.009	22.403	17.953	22.403	35,131.010	599.927	68.953	0	4.867	172.551
Spain	0.778	5.951	65.542	0.001	22.233	18.918	22.233	33,321.950	46.073	66.808	0	5.075	0
Slovakia	0.797	6.492	50.935	0.014	20.311	18.854	20.311	37,660.840	219.474	74.712	0	5.515	108.623
Belgium	0.805	6.431	19.529	0.022	19.529	18.228	19.529	42,958.830	28.136	73.400	0	5.547	15.328
Portugal	0.810	5.955	48.082	0.018	55.650	15.627	18.983	32,098.270	95.487	64.569	0	5.034	9.433
Finland	0.817	6.625	18.286	0.025	55.093	18.197	18.286	43,921.460	23.610	74.269	0	5.712	23.544
Czech Republic	0.826	5.264	17.453	0.016	17.453	20.847	22.727	44,029.510	210.698	74.874	0	5.617	190.163
Lithuania	0.828	5.108	50.813	0.004	17.220	17.398	17.220	33,396.840	241.396	64.881	0	4.377	48.105
Hungary	0.830	6.420	23.432	0.016	16.960	18.141	16.960	36,504.610	263.587	72.688	0	5.447	94.789
Slovenia	0.839	6.143	16.119	0.036	16.119	19.336	16.119	64,826.910	272.966	76.193	0	5.623	76.855
Ireland	0.858	6.978	29.189	0.010	14.234	20.316	14.234	42,833.750	0	70.385	1.374	6.051	0
Cyprus	0.870	6.249	28.487	0.017	12.956	17.126	12.956	34,751.400	57.774	69.488	0	5.294	55.632

Source: Author's calculation

Table 6 Projections on to the efficient frontier, for model BCC-I (continued)

DMU	*Score*	*Unemployment*		*Energy*		*Capital*		*GDP*		*GINI*		*CO2*	
		Projection	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*	*Projection*	*Diff. (%)*
Serbia	0.876	6.464	66.218	0.018	12.373	17.540	12.373	35,688.670	765.002	71.459	0	5.473	541.346
Poland	0.877	5.682	46.555	0.009	12.296	17.679	12.296	34,691.170	280.103	68.190	0	4.844	206.427
Malta	0.892	6.052	10.797	0.031	43.314	18.165	10.797	55,760.540	238.549	72.473	0	5.431	52.209
Greece	0.898	6.105	62.739	0.018	89.202	16.022	10.200	32,908.950	77.234	66.200	0	5.161	51.424
Germany	0.920	6.529	8.049	0.017	8.049	18.183	8.049	37,565.490	15.401	73.346	0	5.547	20.295
Sweden	0.930	5.921	20.978	0.039	57.509	21.295	7.053	47,611.670	17.255	74.623	0	10.342	0
Austria	0.946	4.927	5.390	0.024	5.390	20.606	9.454	45,852.060	27.926	72.992	0	6.123	0
Ukraine	0.978	6.164	21.859	0.010	2.209	19.130	2.209	37,563.550	910.438	73.862	0	5.255	963.748
Iceland	0.979	4.458	2.104	0.063	83.943	20.910	2.104	73,322.880	82.988	74.677	0	7.078	1.672
Italy	0.993	6.356	30.512	0.002	0.665	19.278	0.665	33,285.180	23.616	67.692	0	5.406	0
Denmark	1	5.846	0	0.021	0	20.376	0	43,961.480	0	73.977	0	7.890	0
France	1	9.269	0	0	0	22.208	0	30,948.150	0	70.892	0	7.786	0
Luxembourg	1	5.200	0	0.045	0	18.778	0	80,066.980	0	71.785	0	5.102	0
Netherlands	1	5.562	0	0.001	0	20.151	0	38,136.940	0	73.515	0	4.784	0
Norway	1	3.677	0	0.078	0	22.310	0	65,401.050	0	75.415	0	8.683	0
Switzerland	1	4.375	0	0.059	0	23.817	0	57,215.690	0	69.775	0	15.132	0
UK	1	6.223	0	0.019	0	16.332	0	33,545.400	0	67.480	0	5.261	0

Source: Author's calculation

Table 6, in a similar way to Table 4, shows the differences between actual and frontier values for each country. However, due to different definitions of inputs and outputs in the methodology used (since the BCC model does not observe undesirable outputs), a direct comparison cannot be made. This table could provide insights for policy makers on the changes which would have to be made in order to obtain a higher efficiency score. Another robustness check was made by calculating the correlation coefficients between the efficiency score ranking for all models with undesirable output versus the basic models from Table A4. The results are shown in Table 7, with respective *p*-values. It is encouraging that the majority of the coefficients are very high, with all of them being statistically significant. Thus, the ranking within this research is consistent and could be used in further research.

Table 7 Correlation of ranking between models A-F with models G-J

Model 1	*Model B*	*Correlation*	*p-value*	*Model 1*	*Model B*	*Correlation*	*p-value*
G	A	0.671	0.000	I	A	0.539	0.001
G	B	0.659	0.000	I	B	0.524	0.001
G	C	0.685	0.000	I	C	0.557	0.000
G	D	0.759	0.000	I	D	0.832	0.000
G	E	0.774	0.000	I	E	0.849	0.000
G	F	0.749	0.000	I	F	0.821	0.000
H	A	0.671	0.000	I	G	0.914	0.000
H	B	0.659	0.000	J	A	0.531	0.001
H	C	0.685	0.000	J	B	0.516	0.001
H	D	0.759	0.000	J	C	0.548	0.000
H	E	0.774	0.000	J	D	0.791	0.000
H	F	0.749	0.000	J	E	0.793	0.000
				J	F	0.787	0.000
				J	G	0.809	0.000

Source: Author's calculation

4.4 Dynamic analysis

The analysis so far has been static. Now we move on briefly to the window analysis of model E, since it had the greatest correlation with the UN ranking system. The majority of the results are omitted here; only the evolution of the efficiency scores for the most inefficient and most efficient countries from model E over time are shown. Graphical representations are shown in Figures 3 and 4[9].

Although they are the most inefficient, with the exception of one (Montenegro), each country in Figure 3 shows an increase in efficiency score over time (which is encouraging).Montenegro was the only country in the group with an average decrease rate of efficiency index (due to an increase in Gini Index over the observed period). The reason could be poor monitoring of the majority of the SD indicators in 2016. As stated in the Voluntary National Review (UN, 2018d), Montenegro monitored only 12% of SD indicators.

Since efficiency is increasing for other countries, this is good news for them; especially for those who are EU candidate countries. It means that their SD legislation and implementation is more in accordance with that of the EU (and UN). However, , a slowdown in improvement of the lower ranking countries is apparent since the crisis in 2008.

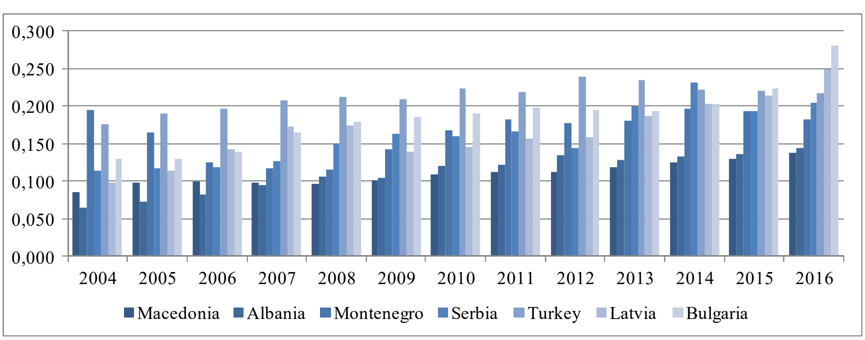
The other interesting group is the most efficient ones, with their efficiency indices shown in Figure 4. Similar conclusions can be made for this group as well. Each tcountry, with the exception of Norway, experienced an increase in the efficiency score over time. Here, the reason is the increase of the unemployment rate. Although Norway has a very low unemployment rate, the slight increase of this rate since 2009 has affected its ranking in the model.

This shows that future research should include in-depth analysis of the sources of efficiencies and inefficiencies within the countries whose results are provided in this study. These countries were affected by the crisis as well, since the overall scores dropped a bit after 2008.

Finally, a graphical representation of all of the countries in the analysis was made via a scatter plot between DEA score from static model E and the UN's SDG index. This is shown on Figure 5. In this way, the clustering can be seen more easily. The most efficient countries can be spotted right away, having a DEA score of unit value and a high SDG index. However, some exceptions can be seen, such as Slovakia, Italy and the UK. The reason why these countries do not have a greater SDG index whilst being efficient within DEA methodology is that their environmental wellbeing indices, measured by RobecoSAM (2018), are lower compared to some other countries. This means that although their overall indices of SD rank them high on the world list, the environmental component is not fully met. This indicates that future research using DEA methodology should include more environmental variables in the analysis.

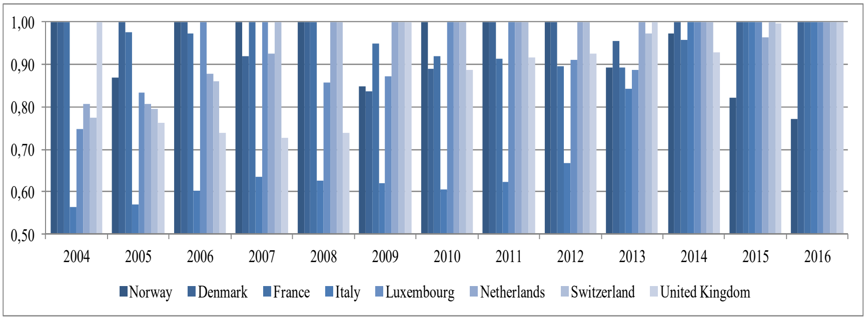
Two other distinct clusters on the figure are the non-EU countries, which have the lowest DEA scores and SDG index values; and the SE (South) cluster – in which some of the southern European countries are included (Spain, Cyprus, Greece, Malta and Portugal). These countries suffer from the highest long-term unemployment rates in the EU, have the lowest trust in institutions, and have a high percentage of people at risk of poverty (Eurostat, 2016).

Figure 3 Efficiency scores over time, most inefficient countries, model E (see online version for colours)



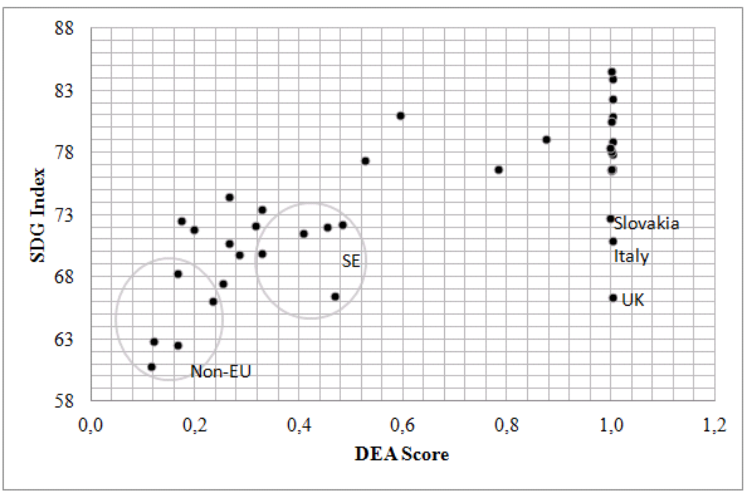
Source: Author's calculation

Figure 4 Efficiency scores over time, most efficient countries, model E (see online version for colours)



Source: Author's calculation

Figure 5 Scatter plot between DEA score from model E and SDG index



Source: Author's calculation

5 Conclusions

The purpose of this paper is to empirically evaluate the SD of European countries through economic, social and environmental variables by applying several DEA models. The reason for evaluating the SD of European countries is that the majority of European countries have to follow EU legislation and recommendations on social and environmental protection. Unambiguous comparison can be made by applying the same methodology over a group of countries.

Surprisingly, the existing literature evaluating SD components does not cover or compare European countries. Thus, a parsimonious approach was made in this research to determine if basic DEA models with several variables can be used in order to objectively evaluate the SD efficiency of a selected group of countries. The main goal of the research was to achieve similar results to the official statistics ranking from international institutions by using fewer variables in the analysis. By comparing the rankings from this study with the existing official ones, this goal was achieved.

Several conclusions can be made based upon the previous results. The more developed countries have better economic results and their scores relating to the economic pillar of SD are greater. However, they have poorer results on average in the environment pillar. The opposite is true for countries in the sample which are less developed.

The results in this research correlate well with the rankings of official world institutions. This means that the results obtained here are reliable, and similar results can be achieved by using fewer variables in the analysis compared to the official statistics. Consequently, such comparisons can be made more often and more easily in future, in order to obtain results and to act on them more quickly. Recommendations can be made to policymakers by reference to good practice in the most efficient countries.

Legislation is being brought in all of the EU countries in order to obtain development goals. However, if this is not put into practice, there is no point in writing the laws. Good practice includes not only setting the goals and sub-goals for each of the SD pillars, but also measurement of what is achieved and ongoing performance, rewarding those who achieve those goals and penalising those who do not. Regular audits can do this, in order to make all those included more accountable. These audits should be not only at a national level, but also an international level.

National and international institutions and banks which finance economic projects with national and higher level interests should focus more on those participants who are acting in accordance with the SDG. This includes, for example, the EU development funds, IBRD (International Bank for Research And Development), etc. It is not surprising that the non-EU countries (on Figure 5) have the lowest scores regarding SD, since they do not need to comply with all of the regulations. However, some of those countries wish to enter the EU and thus, they need to rethink their strategies in order to achieve better SD results. Other concrete measures can be found in the individual country profiles on the United Nations website where individual reports can be found in which countries state the crucial problems which are specific to them.

Today, a greater volume of many different data is available regarding all of the variables which are used to compare countries and their policies regarding SD and all of its pillars. So citizens of a country can be informed in more detail and more quickly than ever before, not only regarding SD, but also all other aspects of an economy. By being more informed and more educated, citizens and non-government institutions can exert more pressure on governments to revise environmental regulations, actions and legislation.

Since this work has focused on European countries, there exists many possibilities of EU funds for member states and those countries which are in the process of negotiating to join the EU, to utilise the EU funding via EFSD (European Fund for Sustainable Development), EAFRD (European Agricultural Fund for Rural Development), ERDF (European Regional Development Fund) and others. The criteria are rigid, thus the best possible outcomes are expected to be achieved if a grant is approved for a company, project, region, etc.

Other possibilities for co-financing are available today, not only from the EU (e.g. EU Sustainable Business for Africa), but also other world regions which have their financing institutions (such as New Development Bank, Islamic Development Bank, Asian Infrastructure Investment Bank etc.).

On an individual country level, major social, economic and other problems from the past which are country specific have to be acknowledged and tackled so that the country can move on to deal with current problems. Problems based upon the country's specific characteristics need to be taken into consideration as well.

It is expected that some improvements for non-EU countries will result from negotiations with the EU, since changes will need to be implemented before entering the EU.

Social implications of policy guidelines include: the education of the policy makers as well as the general public, since they are responsible for introducing and implementing the legislation relating to equal rights; better utilisation of the European Social Fund in order to obtain fair job opportunities for all genders, ages and races. Social implications are shaped by local economic conditions; thus the area of social applications is maybe one of the most difficult to suggest to a wider group of countries. However, ensuring a good educational and health system are necessary conditions for further conditions to be obtained.

Main results indicate that higher income countries, as well as those with a higher ranking according to UN and other world organisation measures, are ranked higher in this empirical study. Moreover, models with variable returns to scale have a more similar ranking compared to the UN's system. Thus, future research could focus more on those models.

Some of the shortfalls of the study are as follows: Several models were used, because there is no clear direction on which model is best to evaluate such questions. However, the results indicated that variable returns to scale could be a starting point,. Not all of the desired variables are included in the analysis, due to lack of available data (especially from the most inefficient countries);. As a result, some problems are evident when ranking the same country using different models. However, for those countries where data measurement problems arise, initial results can provide a starting point for guidance on what to focus on in the future, to achieve the SD goals faster.

One pitfall as well as advantage in the study was using many different variants of several models. This is beneficial because by comparing the rankings, the robustness of the results can be determined; on the other hand, when observing many models, more detailed analysis should be done if differences arise.

One reason why this study employed many models was to be able to make comparisons to previous studies which utilise just some of the approaches used in this study. No consensus exists on which type of returns to scale in the 'production process' should be used when observing such questions. Thus, it is better to compare several aspects at once to get a clearer picture for future work. Taking variable returns to scale as a starting point, extension of this research is going to focus more on the BCC type models.

Since this research represents one of the first comprehensive analysis of SD, focusing on European countries; it is hoped that future related research will extend this analysis in order to provide answers to some questions which still remain unanswered.

Finally, a base is provided in this research which can facilitate future definition and construction of SD indices based upon different aspects of sustainability, as well as evaluating SD more objectively.

Acknowledgements

The author would like to thank Simon and Caroline Durk of the ōbex project for providing language editing support.

References

Aceleanu, M.I., Serban, A.C. and Burghelea, C. (2015) ''Greening' the youth employment – a chance for sustainable development', *Sustainability*, Vol. 7, No. 3, pp.2623–2643, doi.org/10.3390/su7032623.

Aguado, R. and Martinez, J. (2012) 'GDP and beyond: towards new measures of sustainability based on Catholic social thought', *Asia-Pacific Journal of Business Administration*, Vol. 4, No. 2, pp.124–138, doi.org/10.1108/17574321211269270.

Armeanu, D.S., Vintila, G. and Gherghina, S.C. (2017) 'Empirical Study towards the drivers of sustainable economic growth in EU-28 Countries', *Sustainability*, Vol. 10, No. 1, pp.1–22, doi.org/10.3390/su10010004.

Ball, V.E., Lovell, C.A.K., Nehring, R. and Somwaru, A. (1994) 'Incorporating undesirable outputs into models of production: an application to US agriculture', *Cahiers d'economie et sociologie rurales*, Vol. 31, pp.60–74.

Banker, R.D., Charnes, R.F. and Cooper, W.W. (1984) 'Some models for estimating technical and scale inefficiencies in data envelopment analysis', *Management Science*, Vol. 30, No. 9, pp.1078–1092, doi.org/10.1287/mnsc.30.9.1078.

Beck, U. and Wilms, J. (2004) *Conversations with Ulrich Beck*, Polity Press, Cambridge; in Duran, C.D., Gogan, L.M., Artene, A. and Duran, V. (2015) 'The components of sustainable development – a possible approach', *Procedia Economics and Finance*, Vol. 26, pp.806–811

Bowlin, W.F. (1998) 'Measuring performance: an introduction to data envelopment analysis (DEA)', *Journal of Cost Analysis*, Vol. 15, No. 2, pp.3–27, doi.org/10.1080/08823871.1998.10462318 .

Bruni, M.E., Guerriero, F. and Patitucci, V. (2011) 'Benchmarking sustainable development via data envelopment analysis: an Italian case study', *International Journal of Environmental Research*, Vol. 5, No. 1, pp.47–56, doi.org/ 10.22059/IJER.2010.290.

Camioto, F. de C., Rebelatto, D.A.d.N. and Rocha, R.T. (2016) 'Energy efficiency analysis of BRICS countries: a study using data envelopment analysis', *Gestão & Produção*, Vol. 23, No. 1, pp.192–203, doi.org/10.1590/0104-530X1567-13.

Center of Advanced Economic Studies (CEVES) (2018) *Serbia Sustainable Development Issues: A Baseline Review*, Belgrade, Serbia [online] https://ceves.org.rs/wp-content/uploads/2018/10/Serbia-Sustainable-Development-Issues-FINAL-updated.pdf (accessed 5 March 2019).

Chang, D-S., Yeh, L-T. and Chen, Y-F. (2014) 'The effects of economic development, international trade, industrial structure and energy demands on sustainable development', *Sustainable Development*, Vol. 22, No. 6, pp.377–390, doi.org/10.1002/sd.1555.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units', *European Journal of Operational Research*, Vol. 3, No. 4, pp.429–444, doi.org/10.1016/0377-2217(78)90138-8.

Chung, Y.H., Färe, R. and Grosskopf, S. (1997) 'Productivity and undesirable outputs: a directional distance function approach', *Journal of Environmental Management*, Vol. 51, No. 3, pp.229–240, doi.org/10.1006/jema.1997.0146.

Committee on Climate Change (CCC) (2013) *Reducing the UK's Carbon Footprint and Managing Competitiveness Risks* [online] https://www.theccc.org.uk/wp-content/uploads/2013/04/Reducing-carbon-footprint-report.pdf (accessed 5 March 2019).

Cooper, W., Seiford, L. and Tone, K. (2006) *Introduction to Data Envelopment Analysis and Its Uses: With DEA-Solver Software and References*, Springer, New York.

Cooper, W., Seiford, L. and Zhu, J. (2011) *Handbook on Data Envelopment Analysis*, Springer, New York.

Costantini, V. and Martini, C. (2006) *A Modified Environmental Kuznets Curve for Sustainable Development Assessment Using Panel Data*, Department of Economics, University of Roma Tre, FEEM working papers 'note di lavoro' series, Milan, Italy.

Dyckhoff, H. and Allen, K. (2001) 'Measuring ecological efficiency with data envelopment analysis (DEA)', *European Journal of Operational Research*, Vol. 132, No. 2, pp.312–325, doi.org/10.1016/S0377-2217(00)00154-5.

Dyson, R.G., Allen, R., Camanho, A.S., Podinovski, V.V., Sarrico, C.S. and Shale, E.A. (2001) 'Pitfalls and protocols in DEA', *European Journal of Operational Research*, Vol. 132, pp.245–259, doi.org/10.1016/S0377-2217(00)00149-1.

Eurostat (2016) *Sustainable Development in the European Union. A Statistical Glance from the Viewpoint of the UN Sustainable Development Goals*, Publications Office of the European Union, Luxembourg.

Eurostat (2018) [online] https://ec.europa.eu/eurostat/data/database.

Färe, R., Grosskopf, S. and Sancho, H. (2004) Environmental performance: an index number approach', *Resource and Energy Economics*, Vol. 26, No. 4, pp.343–352, doi.org/10.1016/j.reseneeco.2003.10.003.

Fotis, P. and Pekka, V. (2017) 'The effect of renewable energy use and economic growth on pollution in the EUROZONE', *Economic and Business Letters*, Vol. 6, No. 4, pp.88–99, doi.org/10.17811/ebl.6.3.2017.88-99.

Fotis, P. and Polemis, M.L. (2018) 'Sustainable development, environmental policy and renewable energy use: a dynamic panel data approach', *Sustainable Development*, Vol. 26, No. 6, pp.726–740, doi.org/10.1002/sd.1742.

Golany, B. and Roll, Y. (1989) 'An application procedure for DEA', *Omega*, Vol. 17, No. 3, pp.237–250, doi.org/10.1016/0305-0483(89)90029-7.

Gorobets, A. (2008) 'Sustainable development in Ukraine: problem, new vision, solution', in Gonca Coskun, H., Kerem Cigizoglu, H. and Derya Maktav, M. (Eds.): *Integration of Information for Environmental Security*, Springer, Dordrecht.

Halkos, G. and Tzeremes, N. (2013) *An Additive Two-Stage DEA Approach Creating Sustainability Efficiency Indexes*, MPRA working paper, MPRA Paper No. 44231, Munich, Germany.

Hardy, A.P. (1980) 'The role of the telephone in economic-development', *Telecommunications Policy*, Vol. 4, No. 4, pp.278–286, doi.org/10.1016/0308-5961(80)90044-0.

Honma, S. and Hu, J.L. (2009) 'Total-factor energy efficiency of regions in Japan', *Energy Policy*, Vol. 36, No. 2, pp.821–833, doi.org/10.1016/j.enpol.2007.10.026.

Klopp, G.A. (1985) *The Analysis of the Efficiency of Productive Systems with Multiple Inputs and Outputs*, PhD dissertation, University of Illinois, Chicago.

Korohonen, T. and Luptacik, M. (2004) 'Eco-efficiency analysis of power plant: an extension of data envelopment analysis', *European Journal of Operational Research*, Vol. 68, No. 6, pp.1572–1574, doi.org/10.1016/S0377-2217(03)00180-2.

Lopez-Menendez, A., Perez, R. and Moreno, B. (2014) 'Environmental costs and renewable energy: re-visiting the environmental kuznets curve', *Journal Of Environmental Management*, Vol. 145, No. 1, pp.368–373, doi.org/10.1016/j.jenvman.2014.07.017.

Lovell, C.A.K., Pastor, J.T. and Turner, J.A. (1995) 'Measuring macroeconomic performance in the OECD: a comparison of European and non-European countries', *European Journal of Operational Research*, Vol. 87, No. 3, pp.507–518, doi.org/10.1016/0377-2217(95)00226-X.

Mauro, P. (1995) 'Corruption and growth', *The Quarterly Journal of Economics*, Vol. 110, No. 3, pp. 681–712, doi.org/10.2307/2946696.

Mauro, P. (1998) 'Corruption and the composition of government expenditure', *Journal of Public Economics*, Vol. 69, No. 1998, pp.263–279, doi.org/10.1016/S0047-2727(98)00025-5.

Psacharopoulos, G. and Patrinos, H.A. (2004) 'Returns to investment in education: a further update', *Education Economics*, Vol. 12, No. 2, pp.111–134, doi.org/10.1080/0964529042000239140.

Rabar, D. (2017) 'An overview of data envelopment analysis application in studies on the socio-economic performance of OECD countries', *Economic Research-Ekonomska Istraživanja*, Vol. 30, No. 1, pp.1770–1784, doi.org/10.1080/1331677X.2017.1383178.

RobecoSAM (2018) [online] http://www.robecosam.com (accessed 30 August 2018).

Romer, P.M. (1986) 'Increasing returns and long-run growth', *The Journal of Political Economy*, Vol. 94, No. 5, pp.1002–1037.

Romer, P.M. (1990) 'Endogenous technological-change', *The Journal of Political Economy*, Vol. 98, No. 1990, pp.S71–S102.

Santana, N.B., Aparecida, D., Rebalatto, N., Périco, A.E. and Mariano, E.B. (2014) 'Sustainable development in the BRICS countries: an efficiency analysis by data envelopment', *International Journal of Sustainable Development & World Ecology*, Vol. 21, No. 3, pp.1–14, doi.org/10.1080/13504509.2014.900831.

Seiford, L. and Zhu, J. (2002) 'Modeling undesirable factors in efficiency evaluation', *European Journal of Operational Research*, Vol. 142, No. 1, pp.16–20, doi.org/10.1016/S0377-2217(01)00293-4.

Škrinjarić, T. (2018) 'Evaluation of environmentally conscious tourism industry: case of Croatian counties', *Tourism*, Vol. 66, No. 3, pp.254–268.

Sueyoshi, T. and Yuan, Y. (2016) 'Marginal rate of transformation and rate of substitution measured by DEA environmental assessment: comparison among European and North American nations', *Energy Economics*, Vol. 56, No. C, pp.270–287. doi.org/10.1016/j.eneco.2016.01.017.

Sustainable Society Foundation (SSF) (2014) *Sustainable Society Index SSI-2014*, The Hague, Netherlands.

Tampakoudis, I.A., Fylantzopoulou, D. and Nikandrou, K. (2014) 'Examining the linkages between GDP growth and sustainable development in the Eurozone', *East-West Journal of Economics and Business*, Vol. XVII, No. 2, pp.15–37.

Todaro, M.P. and Smith, S.C. (2003) *Economic Development*, 8th ed., Pearson Education limited, Harlow, England.

Tone, K. (2001) 'A slacks-based measure of efficiency in data envelopment analysis', *European Journal of Operational Research*, Vol. 130, No. 3, pp.498–509, doi.org/10.1016/S0377-2217(99)00407-5.

Tsai, W-H., Lee, H-L., Yang, C-H. and Huang, C-C. (2016) 'Input-output analysis for sustainability by using DEA method: a comparison study between European and Asian countries', *Sustainability*, Vol. 8, No. 12, pp.1–17, doi.org/10.3390/su8121230.

Tyteca, D. (1996) 'On the measurement of the environmental performance of firms – a literature review and a productive efficiency perspective', *Journal of Environmental Management*, Vol. 46, No. 3, pp.281–308, doi.org/10.1006/jema.1996.0022.

United Nations (UN) (1987) *Brundtland Report* [online] https://www.are.admin.ch/are/en/home/sustainable-development/international-cooperation/2030agenda/un-_-milestones-in-sustainable-development/1987--brundtland-report.html (accessed 20 April 2019).

United Nations (UN) (2015a) *Resolution adopted by the General Assembly on 25 September 2015*, [online] http://www.un.org/ga/search/view_docasp?symbol=A/RES/70/1&Lang=E. (accessed 30 August 2018).

United Nations (UN) (2015b) *An Action Plan to Finance the Data Revolution for Sustainable Development*, Sustainable Development Solutions Network [online] http://unsdsn.org/wp-content/uploads/2015/07/Data-For-Development-An-Action-Plan-July-2015.pdf (accessed 10 November 2018).

United Nations (UN) (2018a) *Albania Voluntarily National Review 2018* [online] https://sustainabledevelopment.un.org/memberstates/albania (accessed 10 November 2018).

United Nations (UN) (2018b) *Latvia Voluntarily National Review 2018* [online] https://sustainabledevelopment.un.org/memberstates/latvia (accessed 10 November 2018).

United Nations (UN) (2018c) *Estonia Voluntarily National Review 2016* [online] https://sustainabledevelopment.un.org/memberstates/estonia (accessed 10 November 2018).

United Nations (UN) (2018d) *Montenegro Voluntarily National Review 2016* [online] https://sustainabledevelopment.un.org/memberstates/montenegro (accessed 10 November 2018).

United Nations (UN) (2018e) *Albania, Report on the Harmonization of Sustainable Development Goals with Existing Sectoral Policies* [online] http://www.un.org.al/sites/default/files/Albania%20Report%20on%20the%20Harmonization.pdf (accessed November 10 2018).

World Bank (WB) (2018) *Database* [online] http://databank.worldbank.org/data/databases.aspx (accessed 10 November 2018).

World Inequality Database (2018) [online] https://wid.world/data/ (accessed 30 August 2018).

Yeh, C.C., Chi, D.J. and Hsu, M.F. (2010) 'A hybrid approach of DEA, rough set and support vector machines for business failure prediction', *Expert Systems with Applications*, Vol. 37, No. 2, pp.1535–1541, doi.org/10.1016/j.eswa.2009.06.088.

Zhang, B., Bi, J., Fan, Z., Yuan, Z. and Ge, J. (2008) 'Eco-efficiency analysis of industrial system in China: a data envelopment analysis approach', *Ecological Economics*, Vol. 68, No. 1, pp.306–316, doi.org/10.1016/j.ecolecon.2008.03.009.

Zhou, H., Yang, Y., Chen, Y. and Zhu, J. (2018) 'Data envelopment analysis application in sustainability: The origins, development and future directions', *European Journal of Operational Research*, Vol. 264, No. 1, pp.1–16, doi.org/10.1016/j.ejor.2017.06.023.

Zhou, P., Ang, B.W. and Poh, K.L. (2007a) 'A mathematical programming approach to constructing composite indicators', *Ecological Economics*, Vol. 62, No. 2, pp.291–297, doi.org/10.1016/j.ecolecon.2006.12.020.

Zhou, P., Poh, K.L. and Ang, B.W. (2007b) 'A non-radial DEA approach to measuring environmental performance', *European Journal of Operational Research*, Vol. 178, No. 1, pp.1–9, doi.org/10.1016/j.ejor.2006.04.038.

Zhou, P., Ang, B.W. and Poh, K.L. (2008) 'Measuring environmental performance under different environmental DEA technologies', *Energy Economics*, Vol. 30, No. 1, pp.1–14, doi.org/10.1016/j.eneco.2006.05.001.

Notes

1 16 countries and individual country level as well, from 2000 to 2009.

2 Sulphur dioxide and nitrogen oxide.

3 These papers include Chung et al. (1997), Dyckhoff and Allen (2001), Färe et al. (2004), Seiford and Zhu (2002) and Zhu et al. (2007a, 2007b, 2008).

4 CH4 – methane, NOx – nitrous oxide and F-gases – fluorinated gases.

5 Gini Coefficient.

6 The ratios 5:1 and 1:5 were chosen based upon results on similar topic in Škrinjarić (2018). Other values were used, e.g., 3 and 10, but the rankings remained the same.

7 Detailed results are available upon request.

8 RobecoSAM publishes the Dow Jones Sustainability Indices (DJSI). See http://www.robecosam.com.

9 Detailed results on all countries are provided in Appendix in Table A5.

Appendix

Table A1 Summary of previous relevant DEA empirical research on SD

Authors	*Country*	*Time span*	*Model, variables*	*Results, comments*
Lovell et al. (1995)	19 OECD countries	1970–1990	BCC-O, additive and GEM model; window analysis. Variables: inflation, employment, GDP, trade balance; each variable transformed so that the provision of each variable is maximised. CO, NO emissions	Comparison of macroeconomic results only, with the macro and emissions data showing changes in ranking.
Honma and Hu (2009)	47 Japanese prefectures	1993–2003	TFEP index O: total income I: employment, private and public capital stock, electricity used, gasoline, kerosene, gas and heavy oil, city, butane and propane gas, coal, coke	Research mostly concentrated on production and energy (not so much on the total economy); consumption of inefficient energy sources increased, most efficient regions outside Japan's 4 major industrial areas.
Bruni et al. (2011)	20 Italian regions	2007	Radial models: Adaption of Korohonen and Luptacik (2004); adaption of Tyteca (1996); Non-radial models: slacks-based measure; additive model I: Energy consumption, GDP; O: CO2 emissions from road transportation, poverty rate	Consistent results of ordering within all 4 models; southern regions inefficient (Sicilia, Calabria, Puglia, Campania and Abruzzo)
Aguado and Martinez (2012)	29 OECD countries	2005	BCC and CCR, input and output oriented I: education, unemployment, waste recycling rate O: GDP, bad O: CO2 emissions, GINI, poverty	Most efficient with regards to economic, social and environmental conditions: Sweden, Ireland, Denmark, and Norway. Least efficient: Poland, Czech Republic and Slovakia.
Santana et al. (2014)	BRICS countries	2001–2007	BCC-O, window analysis I: gross fixed capital, employment, R&D expenditures, O: GDP, CO2, life expectancy	Three different models observed (for each output 1 model). Brazil most efficient; India most inefficient. Detailed discussion for each of 5 countries provided.
Sueyoshi and Yuan (2016)	25 OECD countries	2008–2012	Marginal Rate of Transformation and Rate of Substitution; Assurance region I: population, energy supply O: GDP, bad O: PM, CO2 emissions	Western Europe outperforms Eastern Europe and North America. Reasoning: limited capital accumulation in Eastern Europe; North America does not pay serious attention to industrial pollution.
Tsai et al. (2016)	37 European and 36 Asian countries	2006–2010	Meta-frontier slacks-based measure, CCR I: labour force, energy consumption, government expenditures O: GDP, bad O: CO2 emissions	Developing countries should establish their own climate change governance and policy frameworks. Developed economies should seek to lower carbon emissions.
Camioto et al. (2016)	BRICS countries	1993–2010	Slack-based measure, window analysis; TFEE index I: workforce, fixed capital, energy consumption O: GDP, undesirable O: CO2 emissions	Brazil most efficient, Russia and India most inefficient across models.

Notes: O – output, I – input, TFEE – Total factor of energy efficiency index, TFEP – Total factor energy productivity change index, GINI – coefficient of income inequality, PM – particulate matter, BCC – Banker-Charnes-Cooper model, CCR – Charnes-Cooper-Rhodes model. Majority of variables are observed per capita

Table A2 Efficiency scores for model with undesirable outputs, constant and variable returns to scale

Table A2 Efficiency scores for model with undesirable outputs, constant and variable returns to scale (continued)

CRS, B:G = 1:1		*CRS, B:G = 5:1*		*CRS, B:G = 1:5*		*VRS, B:G = 1:1*		*VRS, B:G = 5:1*		*VRS, B:G = 1:5*	
DMU	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*
France	1	France	1	France	1	Luxembourg	1	Luxembourg	1	Luxembourg	1
Luxembourg	1	Luxembourg	1	Luxembourg	1	Netherlands	1	Netherlands	1	Netherlands	1
Netherlands	1	Netherlands	1	Netherlands	1	Norway	1	Norway	1	Norway	1
Norway	1	Norway	1	Norway	1	Switzerland	1	Switzerland	1	Switzerland	1
Switzerland	1	Switzerland	1	Switzerland	1	UK	1	UK	1	UK	1
Ireland	0.738	Ireland	0.716	Ireland	0.762	France	1	Italy	1	France	1
Denmark	0.676	Denmark	0.644	Denmark	0.711	Denmark	1	France	1	Denmark	1
UK	0.469	UK	0.407	UK	0.555	Italy	0.999	Denmark	1	Italy	0.999
Italy	0.430	Italy	0.394	Germany	0.498	Sweden	0.999	Sweden	0.999	Sweden	0.999
Austria	0.428	Austria	0.378	Austria	0.493	Slovenia	0.999	Slovenia	0.999	Slovenia	0.999
Germany	0.421	Germany	0.365	Italy	0.473	Germany	0.999	Germany	0.999	Germany	0.999
Belgium	0.340	Sweden	0.298	Belgium	0.399	Czech Republic	0.999	Czech Republic	0.999	Czech Republic	0.999
Sweden	0.317	Belgium	0.296	Spain	0.347	Ukraine	0.997	Ukraine	0.999	Ukraine	0.996
Spain	0.304	Spain	0.271	Sweden	0.338	Iceland	0.994	Slovakia	0.996	Iceland	0.992
Iceland	0.299	Iceland	0.271	Iceland	0.335	Slovakia	0.993	Iceland	0.995	Slovakia	0.990
Finland	0.267	Finland	0.233	Finland	0.312	Austria	0.810	Austria	0.874	Ireland	0.803
Cyprus	0.256	Cyprus	0.215	Cyprus	0.299	Ireland	0.792	Ireland	0.782	Austria	0.732
Czech Republic	0.150	Czech Republic	0.128	Czech Republic	0.183	Finland	0.566	Finland	0.592	Finland	0.501
Slovenia	0.133	Slovenia	0.112	Slovenia	0.164	Belgium	0.502	Belgium	0.524	Belgium	0.482
Portugal	0.123	Portugal	0.103	Portugal	0.152	Spain	0.453	Spain	0.481	Spain	0.399
Malta	0.122	Malta	0.102	Malta	0.151	Cyprus	0.412	Cyprus	0.466	Cyprus	0.369
Estonia	0.104	Estonia	0.087	Estonia	0.129	Malta	0.296	Malta	0.451	Malta	0.212

Notes: CRS stands for constant returns to scale; VRS – variable returns to scale

Source: Author’s calculation

CRS, B:G = 1:1		*CRS, B:G = 5:1*		*CRS, B:G = 1:5*		*VRS, B:G = 1:1*		*VRS, B:G = 5:1*		*VRS, B:G = 1:5*	
DMU	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*
Hungary	0.102	Hungary	0.086	Hungary	0.126	Portugal	0.281	Portugal	0.405	Portugal	0.201
Lithuania	0.099	Lithuania	0.084	Lithuania	0.124	Greece	0.225	Hungary	0.327	Greece	0.172
Slovakia	0.098	Slovakia	0.083	Slovakia	0.120	Hungary	0.215	Greece	0.327	Estonia	0.161
Greece	0.089	Greece	0.075	Poland	0.111	Lithuania	0.211	Lithuania	0.314	Hungary	0.161
Poland	0.089	Poland	0.074	Greece	0.111	Estonia	0.199	Poland	0.282	Lithuania	0.158
Croatia	0.085	Croatia	0.071	Croatia	0.105	Poland	0.189	Croatia	0.263	Poland	0.143
Turkey	0.066	Turkey	0.055	Turkey	0.083	Croatia	0.178	Estonia	0.263	Croatia	0.134
Romania	0.062	Romania	0.052	Romania	0.079	Turkey	0.147	Romania	0.250	Turkey	0.107
Bulgaria	0.044	Bulgaria	0.036	Bulgaria	0.056	Romania	0.147	Turkey	0.233	Romania	0.104
Ukraine	0.039	Ukraine	0.033	Ukraine	0.051	Bulgaria	0.107	Bulgaria	0.195	Bulgaria	0.074
Montenegro	0.036	Montenegro	0.023	Montenegro	0.046	Montenegro	0.089	Latvia	0.172	Montenegro	0.061
Latvia	0.035	Latvia	0.029	Latvia	0.044	Latvia	0.088	Serbia	0.165	Latvia	0.059
Serbia	0.033	Serbia	0.027	Serbia	0.042	Serbia	0.085	Montenegro	0.165	Serbia	0.057
Macedonia	0.023	Macedonia	0.019	Macedonia	0.029	Macedonia	0.058	Macedonia	0.118	Macedonia	0.039
Albania	0.019	Albania	0.016	Albania	0.025	Albania	0.052	Albania	0.115	Albania	0.034

Notes: CRS stands for constant returns to scale; VRS – variable returns to scale

Source: Author's calculation

Table A3 Projections on to the efficient frontier, for model C (CRS, B:G = 1:5)

Table A3 Projections on to the efficient frontier, for model C (CRS, B:G = 1:5) (continued)

DMU	*Score*	*Unemployment*		*Energy*		*Capital*		*GINI*		*CO2*		*GDP*	
		Projection	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*
Albania	0.025	0.425	–97.24%	0	–99.15%	1.538	–95.03%	2.022	–93.22%	0.016	–96.07%	2,911.237	0.00%
Macedonia	0.029	0.505	–98.41%	0	–99.58%	1.829	–92.04%	2.404	–93.29%	0.019	–98.08%	3,461.399	0.00%
Serbia	0.042	0.602	–96.86%	0	–99.62%	2.180	–89.11%	2.865	–89.96%	0.023	–98.12%	4,125.847	0.00%
Latvia	0.044	0.629	–94.65%	0.005	–98.93%	2.272	–91.27%	3.414	–90.57%	0.024	–91.52%	9,686.581	0.00%
Montenegro	0.046	0.732	–96.51%	0	–99.15%	2.652	–88.54%	3.486	–88.77%	0.028	–95.12%	5,019.239	0.00%
Ukraine	0.051	0.542	–93.13%	0	–99.32%	1.964	–89.96%	2.582	–90.12%	0.020	–99.01%	3,717.550	0.00%
Bulgaria	0.056	0.727	–92.48%	0	–99.30%	2.632	–88.96%	3.460	–89.84%	0.027	–97.02%	4,981.998	0.00%
Romania	0.079	0.912	–86.58%	0	–98.58%	3.305	–87.66%	4.344	–88.08%	0.034	–93.12%	6,255.380	0.00%
Turkey	0.083	1.140	–88.48%	0	–98.28%	4.132	–84.86%	5.430	–87.42%	0.043	–88.24%	7,819.231	0.00%
Croatia	0.105	1.467	–88.89%	0	–98.52%	5.315	–76.76%	6.986	–79.98%	0.055	–83.44%	10,059.384	0.00%
Greece	0.111	1.206	–92.64%	0.010	–93.91%	4.355	–75.59%	6.543	–80.64%	0.046	–84.24%	18,568.097	0.00%
Poland	0.111	1.331	–87.48%	0	–98.36%	4.823	–76.08%	6.338	–80.07%	0.050	–92.28%	9,126.786	0.00%
Slovakia	0.120	1.719	–87.01%	0	–98.77%	6.229	–73.67%	8.187	–67.63%	0.065	–83.82%	11,788.384	0.00%
Lithuania	0.124	1.427	–86.26%	0	–96.07%	5.169	–75.41%	6.794	–80.66%	0.054	–84.29%	9,782.421	0.00%
Hungary	0.126	1.464	–82.54%	0	–99.00%	5.305	–75.72%	6.973	–74.47%	0.055	–84.89%	10,040.124	0.00%
Estonia	0.129	1.777	–80.02%	0	–98.74%	6.439	–77.13%	8.462	–74.53%	0.067	–92.03%	12,185.417	0.00%
Malta	0.151	1.070	–84.23%	0.009	–83.26%	3.863	–81.03%	5.804	–78.92%	0.041	–85.61%	16,470.450	0.00%
Portugal	0.152	1.066	–90.70%	0.009	–77.32%	3.851	–80.04%	5.786	–83.67%	0.041	–81.56%	16,419.678	0.00%
Slovenia	0.164	1.129	–84.59%	0.010	–77.27%	4.076	–82.32%	6.125	–74.27%	0.043	–86.34%	17,381.451	0.00%
Czech Republic	0.183	2.067	–67.59%	0	–98.63%	7.488	–72.24%	9.841	–60.83%	0.078	–85.28%	14,171.145	0.00%

Source: Author's calculation

Table A4 Efficiency scores for BCC and CCR models

DMU	*Score*	*Unemployment*		*Energy*		*Capital*		*GINI*		*CO2*		*GDP*	
		Projection	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*	*Projection*	*Change(%)*
Cyprus	0.300	3.212	–63.24%	0	–97.85%	11.638	–40.85%	15.296	–49.87%	0.121	–59.30%	22,026.117	0.00%
Finland	0.312	2.308	–71.54%	0.020	–63.68%	8.333	–62.58%	12.521	–51.34%	0.089	–59.88%	35,532.283	0.00%
Iceland	0.335	2.602	–42.85%	0.022	–94.31%	9.397	–56.00%	14.121	–44.24%	0.100	–31.78%	40,069.881	0.00%
Sweden	0.338	2.665	–64.43%	0.024	–74.14%	9.967	–56.50%	14.739	–41.92%	0.098	0.00%	40,605.364	0.00%
Spain	0.347	3.327	–80.74%	0	–56.97%	12.054	–50.45%	15.842	–52.27%	0.126	–38.44%	22,811.794	0.00%
Belgium	0.399	2.177	–72.76%	0.019	–30.56%	7.863	–65.29%	11.815	–55.58%	0.084	–60.20%	33,526.083	0.00%
Italy	0.473	3.927	–57.07%	0.001	–66.75%	14.228	–26.69%	18.699	–42.12%	0.148	–21.15%	26,926.237	0.00%
Austria	0.493	2.328	–55.30%	0.020	–21.51%	8.406	–63.06%	12.631	–53.23%	0.090	–46.12%	35,842.709	0.00%
Germany	0.497	2.114	–70.22%	0.018	–4.24%	7.634	–61.39%	11.471	–56.96%	0.081	–62.84%	32,552.224	0.00%
UK	0.555	2.179	–64.99%	0.019	0.00%	7.867	–51.83%	11.821	–63.65%	0.084	–56.67%	33,545.403	0.00%
Denmark	0.711	3.410	–41.67%	0.021	0.00%	12.326	–39.51%	17.838	–31.45%	0.130	–0.45%	43,961.485	0.00%
Ireland	0.762	5.560	–43.58%	0.011	0.00%	18.012	–23.96%	24.517	–19.80%	0.170	0.00%	42,833.749	0.00%
France	1	9.269	0.00%	0	0.00%	22.208	0.00%	29.108	0.00%	0.130	0.00%	30,948.151	0.00%
Luxembourg	1	5.200	0.00%	0.045	0.00%	18.778	0.00%	28.215	0.00%	0.200	0.00%	80,066.977	0.00%
Netherlands	1	5.562	0.00%	0.001	0.00%	20.151	0.00%	26.485	0.00%	0.210	0.00%	38,136.938	0.00%
Norway	1	3.677	0.00%	0.078	0.00%	22.310	0.00%	24.585	0.00%	0.116	0.00%	65,401.047	0.00%
Switzerland	1	4.375	0.00%	0.059	0.00%	23.817	0.00%	30.225	0.00%	0.067	0.00%	57,215.691	0.00%

Source: Author's calculation

Table A4 Efficiency scores for BCC and CCR models (continued)

CCR-I		*CCR-O*		*BCC-I*		*BCC-O*	
DMU	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*
Denmark	1	Denmark	1	Denmark	1	Czech Republic	1
France	1	France	1	France	1	Denmark	1
Luxembourg	1	Luxembourg	1	Iceland	1	France	1
Netherlands	1	Netherlands	1	Italy	1	Iceland	1
Norway	1	Norway	1	Luxembourg	1	Italy	1
Switzerland	1	Switzerland	1	Netherlands	1	Luxembourg	1
UK	1	UK	1	Norway	1	Netherlands	1
Italy	0.993	Italy	0.993	Slovenia	1	Norway	1
Iceland	0.979	Iceland	0.979	Sweden	1	Slovakia	1
Ukraine	0.978	Ukraine	0.978	Switzerland	1	Slovenia	1
Austria	0.946	Austria	0.946	Ukraine	1	Sweden	1
Sweden	0.930	Sweden	0.930	UK	1	Switzerland	1
Germany	0.920	Germany	0.920	Czech Republic	1	Ukraine	1
Greece	0.898	Greece	0.898	Slovakia	1	UK	1
Malta	0.892	Malta	0.892	Germany	0.996	Germany	0.998
Poland	0.877	Poland	0.877	Austria	0.958	Austria	0.984
Serbia	0.876	Serbia	0.876	Malta	0.935	Finland	0.983
Cyprus	0.870	Cyprus	0.870	Finland	0.923	Belgium	0.982
Ireland	0.858	Ireland	0.858	Serbia	0.917	Malta	0.976
Slovenia	0.839	Slovenia	0.839	Greece	0.915	Hungary	0.973
Hungary	0.830	Hungary	0.830	Lithuania	0.901	Serbia	0.964
Lithuania	0.828	Lithuania	0.828	Poland	0.897	Ireland	0.963
Czech Republic	0.826	Czech Republic	0.826	Cyprus	0.882	Albania	0.950

Source: Author's calculation

CCR-I		*CCR-O*		*BCC-I*		*BCC-O*	
DMU	*Score*	*DMU*	*Score*	*DMU*	*Score*	*DMU*	*Score*
Finland	0.817	Finland	0.817	Hungary	0.875	Cyprus	0.945
Portugal	0.810	Portugal	0.810	Belgium	0.871	Greece	0.941
Belgium	0.805	Belgium	0.805	Ireland	0.865	Montenegro	0.929
Slovakia	0.797	Slovakia	0.797	Portugal	0.847	Poland	0.922
Spain	0.778	Spain	0.778	Spain	0.829	Spain	0.916
Montenegro	0.776	Montenegro	0.776	Romania	0.797	Estonia	0.893
Croatia	0.735	Croatia	0.735	Montenegro	0.789	Portugal	0.889
Bulgaria	0.714	Bulgaria	0.714	Croatia	0.783	Bulgaria	0.886
Macedonia	0.712	Macedonia	0.712	Macedonia	0.766	Lithuania	0.879
Romania	0.688	Romania	0.688	Bulgaria	0.753	Croatia	0.876
Estonia	0.617	Estonia	0.617	Turkey	0.692	Macedonia	0.861
Albania	0.610	Albania	0.610	Estonia	0.654	Romania	0.858
Latvia	0.593	Latvia	0.593	Latvia	0.627	Latvia	0.839
Turkey	0.553	Turkey	0.553	Albania	0.622	Turkey	0.767

Source: Author's calculation

Table A5 Efficiency score over time, model with undesirable outputs, variable returns to scale, B:G = 5:1

DMU/year	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Albania	0.065	0.073	0.083	0.094	0.106	0.104	0.121	0.123	0.135	0.128	0.132	0.137	0.145
Austria	0.579	0.572	0.667	0.688	0.727	0.700	0.702	0.752	0.755	0.730	0.751	0.776	0.772
Belgium	0.458	0.438	0.449	0.487	0.473	0.488	0.477	0.526	0.540	0.524	0.538	0.548	0.580
Bulgaria	0.130	0.130	0.140	0.165	0.180	0.185	0.190	0.198	0.195	0.193	0.203	0.223	0.280
Croatia	0.204	0.216	0.225	0.243	0.257	0.263	0.276	0.271	0.266	0.260	0.267	0.272	0.290
Cyprus	0.503	0.454	0.442	0.475	0.483	0.433	0.424	0.460	0.692	0.739	1	0.866	0.453
Czech Republic	0.254	0.263	0.317	0.371	0.503	0.379	0.395	0.383	0.417	0.459	0.420	0.469	0.584
Denmark	1	1	1	0.919	1	0.837	0.890	1	1	0.954	1	1	1
Estonia	0.170	0.196	0.230	0.277	0.278	0.235	0.233	0.229	0.235	0.254	0.289	0.318	0.325
Finland	0.426	0.456	0.456	0.476	0.509	0.478	0.475	0.499	0.528	0.550	0.544	0.557	0.559
France	1	0.974	0.972	1	1	0.949	0.920	0.914	0.895	0.893	0.956	1	1
Germany	0.444	0.442	0.454	0.501	0.525	0.543	0.556	0.610	0.638	0.655	0.719	0.904	0.814
Greece	0.262	0.292	0.294	0.296	0.324	0.325	0.318	0.363	0.456	0.481	0.998	1	0.634
Hungary	0.289	0.280	0.270	0.310	0.343	0.352	0.484	0.302	0.306	0.302	0.321	0.347	0.467
Iceland	0.505	0.523	0.455	1	0.505	0.808	1	1	0.927	1	1	1	1
Ireland	0.538	0.604	0.706	0.740	0.569	0.477	0.586	1	0.536	0.664	0.676	1	1
Italy	0.566	0.572	0.602	0.634	0.627	0.619	0.605	0.624	0.669	0.843	1	1	1
Latvia	0.099	0.114	0.143	0.173	0.175	0.140	0.146	0.156	0.158	0.187	0.202	0.214	0.249
Lithuania	0.219	0.250	0.286	0.337	0.322	0.301	0.400	0.294	0.407	0.340	0.347	0.356	0.399
Luxembourg	0.746	0.834	0.999	1	0.856	0.871	1	1	0.909	0.886	1	1	1

Source: Author's calculation

Table A5 Efficiency score over time, model with undesirable outputs, variable returns to scale, B:G = 5:1 (continued)

DMU/year	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Macedonia	0.085	0.098	0.100	0.098	0.096	0.102	0.110	0.112	0.113	0.119	0.125	0.130	0.139
Malta	0.351	0.342	0.352	0.368	0.418	0.430	0.381	0.460	0.468	0.504	0.564	0.433	0.480
Montenegro	0.195	0.165	0.125	0.117	0.116	0.143	0.168	0.183	0.178	0.182	0.196	0.194	0.182
Netherlands	0.807	0.807	0.878	0.926	1	1	1	1	1	1	1	0.962	1
Norway	1	0.870	1	1	1	0.850	0.999	1	1	0.892	0.973	0.823	0.773
Poland	0.191	0.204	0.219	0.244	0.279	0.270	0.278	0.281	0.289	0.303	0.310	0.335	0.458
Portugal	0.322	0.314	0.331	0.337	0.347	0.347	0.360	0.381	0.462	0.532	0.540	0.548	1
Romania	0.147	0.172	0.183	0.191	0.213	0.230	0.221	0.219	0.225	0.248	0.262	0.270	0.310
Serbia	0.115	0.118	0.120	0.127	0.150	0.163	0.161	0.167	0.145	0.199	0.232	0.193	0.205
Slovakia	0.174	0.180	0.203	0.358	0.998	0.357	0.275	0.272	0.304	0.494	0.318	0.999	0.540
Slovenia	0.534	0.435	0.450	0.538	0.538	1	0.515	0.530	0.999	0.453	0.439	0.528	1
Spain	0.447	0.467	0.486	0.502	0.480	0.468	0.464	0.467	0.479	0.526	0.505	0.522	0.565
Sweden	0.611	0.600	0.617	0.999	0.620	0.591	0.597	0.621	0.646	0.677	0.666	0.676	0.677
Switzerland	0.775	0.795	0.860	1	1	1	0.999	1	1	0.971	1	1	1
Turkey	0.177	0.190	0.197	0.208	0.212	0.209	0.223	0.219	0.240	0.235	0.222	0.220	0.218
Ukraine	0.099	0.131	0.145	0.183	0.221	0.199	0.314	0.395	0.334	0.562	1	1	0.436
UK	0.999	0.764	0.740	0.726	0.739	0.999	0.886	0.918	0.926	1	0.929	0.997	1

Source: Author's calculation