Energy Efficiency and Improvement European countries: Data Envelopment Analysis approach

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Abstract-The challenge that all developed countries are facing is how to grow their economies in a sustainable way. To do this, energy efficiency is proposed as one of the keys solutions. In Europe, energy efficiency is one of the key elements; therefore; Europe the world's largest energy importer worldwide. Considering the core role of energy efficiency to Europe, the main objectives of this study are to measure energy efficiency and examine energy improvement of European countries during 2010-2017 by applying Data envelopment analysis (DEA) Slack-based measure model (SBM) and Malmquist Productivity Index (MPI). Findings of this study indicated France, Hungary, Greece, Italy, Netherland, Poland, Portugal, Switzerland and United Kingdom are efficient in terms of energy. Regarding energy improvement, only one country showed the improvement during observed period 2013-2017. This study provides important information of the current status of energy efficiency and improvement of European countries, which can help policymakers and strategy makers in deciding different energy strategies and policies.

Index Terms- Energy efficiency, Data envelopment analysis, Europe, SBM, MPI.

I. Introduction

According to [1], the challenge that all developed countries are facing is how to grow their economies in a sustainable way. To do this, energy efficiency is proposed as one of the keys solutions since energy efficiency is considered as the input that is indispensable in the creation of value-added. Energy efficiency can help to improve economic growth, ensure energy security and sustainability by cutting down greenhouse gas emissions. Considering the importance of energy efficiency, governments all over the world have implemented policy to stimulate energy efficiency, specially, regions where energy efficiency is the greatest concern such as Europe.

It was found that more attention has been devoted to examining energy efficiency at the cross-national level than that to the cross-regional level. The main reason for this might be explained by the limited relevant data. However, a regional level plays the core role in implementing energy policies and action plans. This is especially important for EU that considers the Nomenclature of Territorial Units for Statistics (NUTS) 2 level as the basic level for planning EU Cohesion Policy interventions [2]. Accordingly, energy efficiency is one of the key elements of European energy policy, which is most evident in current policies as well as major targets for 2020 and 2030 [3]. In December 2015, the COP21 meeting and the Paris Agreement stressed more than ever how crucial it is for the future of mankind to hold the increase in the global average temperature to well below 2°C above pre-industrial levels (and even to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels). According to the International Energy Agency (IEA) [4], energy efficiency is central to any two-degree energy scenario. The IEA considers that, by 2035, investments in energy efficiency need to represent nearly half of all the global energy investments required to stay under the two-degree limit. Accordingly, energy efficiency is one of the key elements of the EU's energy policy. This is reflected in existing legislation and in targets to be reached by 2020 and 2030. Energy is an extremely important element of the European Union economy. Europe annually consumes 11% of global energy (i.e. 1,606 million toes in 2014), of which 53% of imported energy costs EUR 400 billion (~3% of EU GDP in 2015) per year, making Europe into the world's largest energy importer worldwide. There are many reports and studies that have shown that the economic potential of Europe has not yet been exploited because energy use has not yet achieved significant efficiency [5].

Putting strong emphasis on energy efficiency is in line with the objectives set in the 2030 climate and energy framework and the energy union strategy. By using energy more efficiently, Europeans can lower their energy bills, reduce their reliance on imported fuels and help protect the environment. This is also good for public health (e.g. by reducing air pollution). Doubling the global rate of improvement in energy efficiency by 2030 is a key objective of the Sustainable Development Goals [6].

Considering the core role of energy efficiency to Europe, this study aims to evaluate energy efficiency of European countries during 2010-2017. In this study Data envelopment analysis (DEA) will be applied to measure and forecast energy efficiency of European countries.

Since energy efficiency is one of the most powerful solutions for the sustainable development, it draws the great attentions of not only policymakers but also academic researchers. Many previous measuring and evaluating energy efficiency were found in literature and classified under three groups: cross-level studies [7-18], sub-national level researches and sectional-level studies [19-24].
Data envelopment Analysis (DEA) is one of the most popular non-parametric method used to measure efficiency with its application in many different fields included energy sector. That is a reason why there are many previous studies used DEA to evaluate energy efficiency sectionally and regionally as well as globally.

A DEA slack-based measure (SBM) model and Malmquist productivity index (MPI) were applied in the study of Wang et al [7] which evaluated the efficiency and improvement in terms of energy of 25 different countries over the world. That study found that developed countries tend to have higher energy efficiency than developing countries. By applying DEAM SBM, study of Rui [8] measured energy efficiency of 87 selected countries. Finding of that study revealed that consuming clean energy increase the emissions reduction efficiency and slightly improve the economic output efficiency. Yaser Iftikhar [9] carried on the study concerning the energy and CO2 emissions efficiency of different countries on the world by using network DEA. In this study, non-energy such as labor forces and gross capital formation and energy consumption were selected as inputs while GDP and CO2 emissions represented good output and bad output respectively. Results of this study indicated none overall efficient country and China was the worst country in terms of energy efficiency. Suzuki and Nijkamp [10] examined efficiency in terms of energy, environment and economic of EU-27, APEC countries. Results of Suzuki's study found that that EU countries appear to generally exhibit a higher efficiency than APEC and ASEAN countries.

Moutiho [11] used two methods to assess the economic and environmental performance of European countries in 2001-2012. The first step is to approach the DEA method to measure the performance of selected countries. Then, the quantum regression technique was applied to point out different efficiency points among European countries through indicators such as domestic material consumption, Resources Productivity, Environmental Taxes Revenues. The article presented the opinion that differences in emissions are significantly affected by the rate of keeping renewable energy and non-renewable energy. Robaina-Alves et al. [12] approached the DEA analysis model to evaluate the energy and environment efficiency problems of European countries in two separate periods 2000-2004 and 2005-2011. Camioto et al. [13] connected the DEA with Slacks-Based Measure demonstrate and the window investigation to quantify and dissect vitality effectiveness in the nations that involve the BRICS gathering and the G7 gathering. Data sources are Workforce, net fixed capital development, Energy utilization, and yields are CO2 and GDP. This examination demonstrated that the G7 has a total-factor energy efficiency record well over the BRICS.

Ceylan et al. [14] calculated the total-factor energy efficiency scores for Turkey, then compared with EU-27 in terms of energy efficiency performance and energy saving potential. The authors found the energy efficiency improvement over the years both in Turkey and EU-27. Vlahinic-Dizdarevic [15] examined the change in energy efficiency of 26 countries in European Union over 2000-2010 by applying DEA with the results indicating the improvement in energy efficiency of all 26 EU countries over the observed years. Makridou et al. [16] used DEA with multiple inputs to measure energy efficiency of 26 EU countries during 2000-2010. Madaleno et al. [17] evaluate the energy efficiency of 26 EU countries during 2001-2012 by using deafferent DEA methods as input-oriented model; output-oriented and non-oriented models. The results of that study indicated that the ranking of these countries were varies and depended on the evaluating model, observed years and the efficiency scale.

II. DATA AND RESEARC METHODOLOGY

2.1. Input and Output Selection

We define energy efficiency as using non-energy inputs such as economic indicators and energy inputs as total energy consumption to effectively enhance economy and reduce greenhouse gases [25]. Therefore, Gross domestic product (GDP) is chosen as desirable output while greenhouse gases represent undesirable outputs. For the inputs, energy consumption and the share of renewable energy are chosen as two energy-input while labor productivity and capital stock are two economic inputs. Since CO2 is the most outstanding emissions of greenhouse gases, we; therefore; chose CO2 emissions to represent bad outputs. Due to the data of Capital stock cannot be obtained from any direct sources; therefore; Gross capital formation is chosen as an alternative indicator. Data of this study was collected from two main sources: Ener Data [26] and the World Bank [207.
Since the data of inputs and outputs of some European countries could not be sufficiently provided, the author used 17 countries that provided sufficient data to make an evaluation. Table 1 shows the inputs; outputs of this research. After DMUs collection of DMUs and setting inputs and outputs, the summary of inputs and outputs is shown in Table 2.

Table 1. Research variables - Inputs and outputs

Variables	Code	Name	Measurement
Inputs	X1	The energy use measured	Ton of oil equivalent per capita
	X2	The labor productivity	GDP per employer (US$)
	X3	The share of renewable energy in total final energy consumption	Percentage (%)
	X4	The Gross Capital Formation productivity	Percentage GDP (%)
Desirable output	Y1	GDP per capita	US$
Undesirable output	Y2	CO2 emissions per capita	Metrics tons per capita

After all needed data is collected and set, the analysis step is started and the summary of all variables in this study is presented as table 2 below.

Table 2. Summary of inputs and outputs during 2013-2017

		X1	X2	X3	X4	Y1	Y2
2013	Max	8.82	122,430.20	57.73	27.90	103,059.20	12.55
	Min	2.05	54,314.94	5.02	11.60	13,667.70	4.25
	Average	4.00	83,189.59	21.75	20.19	43,191.44	7.43
	SD	1.62	17,653.46	14.74	3.84	23,364.31	2.32
2014	Max	9.01	123,591.71	57.20	28.10	97,199.90	11.84
	Min	2.06	54,888.94	5.66	11.90	14,201.40	4.14
	Average	3.87	83,773.83	22.29	20.79	43,476.39	6.99
	SD	1.64	17,986.01	14.76	3.92	22,596.21	2.15
2015	Max	9.06	124,707.10	57.77	28.00	82,016.00	12.24
	Min	2.17	56,277.59	5.89	9.80	12,483.90	4.45
	Average	3.90	84,453.64	22.64	20.91	37,491.58	7.09
	SD	1.65	18,065.87	15.16	4.29	19,189.43	2.20
2016	Max	9.04	126,032.54	58.35	28.28	82,836.16	12.37
	Min	2.24	56,390.05	5.95	9.90	12,608.74	4.50
	Average	3.94	84,849.37	22.86	21.11	37,866.49	7.16
	SD	1.65	18,436.81	15.31	4.33	19,381.32	2.23
2017	Max	9.13	127,292.86	58.93	28.80	80,189.70	12.20
	Min	2.26	56,953.95	6.01	11.70	13,863.20	4.54
	Average	3.98	85,697.86	23.09	21.51	39,097.65	7.19
	SD	1.66	18,621.18	15.46	4.17	18,756.19	2.18

2.2. DEA slack-base measure model

According to Tone [28], in accordance with the environmental conservation awareness, undesirable output should be taken into consideration when evaluating the efficiency. To deal with the present of undesirable output, Tone [28] proposed a model named Slack-based Model (SBM) in 2001, then modified in 2003. According to Tone [28], in SBM, each decision-making unit (DMU) is assumed to have three factors: inputs, good (desirable) outputs and bad (undesirable) outputs and represented by three vectors x $\in R^m$, $Y^g \in R^{s1}$ $Y^b \in R^{s2}$ respectively. The inputs, good outputs and bad outputs matrices are as following:

$$\begin{aligned} X &= [x_1, \ldots, x_n] \in R^{mxn} \\ Y^g &= [y_1^g, \ldots, y_n^g] \in R^{s1xn} \\ Y^b &= [y_1^b, \ldots, y_n^b] \in R^{s2xn} \\ X, Y^g, Y^b &> 0 \end{aligned}$$

For a DMU (x_o, y_o^g, y_o^b), the production possibility set defined by:

$$P = \{(x, y^g, y^b) | x \geq X\lambda, y^g \leq Y^g \lambda,\ y^b \geq Y^b\lambda, L \leq e\lambda \leq U,\ \lambda \geq 0|\}$$

Where $\lambda \in R^n$ is the intensity vector, and L and U are the lower and upper bounds of the intensity vector respectively.

A DMU (x_o, y_o^g, y_o^b) is efficient if and only if there is now vector $(x_o, y_o^g, y_o^b) \in$ P such that $x_0 \geq x, y_o^g \leq y^g, y_o^b \geq y^b$ with at least one strict inequality. SBM of Tone (2001) is modified as follow:

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

$$\begin{gathered} \text{Subject to} \\ xo = X\lambda + S^- \\ y_o^g = Y\lambda - S^g \\ y_o^b = Y\lambda + S^b \\ L \leq e\lambda \leq U \\ S^-, S^g, S^b, \lambda \geq 0. \end{gathered}$$

The vectors S^- refers to the surplusage inputs while S^b indicates the excess in undesirable outputs, S^g represents the shortage in desirable outputs. The DMU_o is efficient with consideration of bad output of and only if ρ* = 1 or in the other words, S^{-*}= 0, S^{g*}= 0 and S^{b*}= 0.

2.3. Malmquist Productivity Index (MPI)

According to [29], the output-based Malmquist productivity index is defined by the following equation:

$$MPI = \left[\frac{d_o^s(x_t, y_t)}{d_o^s(x_s, y_s)} \times \frac{d_o^t(x_t, y_t)}{d_o^t(x_s, y_s)} \right]^{1/2}$$

Where d_o^s is a distance function measuring the efficiency of conversion of inputs xs to outputs ys in the period s. DEA efficiency is considered a distance measure because it reflects the efficiency of converting inputs to outputs [29].

Whereas, if there is a technical change in period t, then,

$d_0^t(x_s, y_s)$ = Efficiency of conversion of input in period s to output in period s$\neq$ $d_0^s(x_s, y_s)$

Malmquist productivity index is defined as a geometric average of the efficiency and technical changes in the regarded two periods. Following [29], the Malmquist productivity index can be also written as follows:

$$MPI = \left[\frac{d_o^s(x_t, y_t)}{d_o^s(x_s, y_s)} \times \frac{d_o^t(x_t, y_t)}{d_o^t(x_s, y_s)} \right]^{1/2}$$

MPI = Efficiency change x Technical change

Malmquist productivity index is used to estimate changes in the overall productivity of each pharmaceutical company over time. MPI >1 show productivity increase; MPI= 1 indicates productivity do not change; MPI < 1 means that productivity decreases.

Efficiency change is called “catch-up effect”, the efficiency change term related to the degree to which a DMU improves or worsens its efficiency. Efficiency change >1 talk progress in relative efficiency from period s to t, while efficiency change = 1 and efficiency change < 1 respectively mean no change and regress in efficiency.

Technical change is called “frontier-shift effect” (or innovation effect indicating the change in efficient frontiers between the two different time periods with the value > 1 indicating the improvement while the value < 1 means the regress.

III. EMPIRICAL RESULTS

DEA-Solver-Pro version 13 software is used in this study to measure energy efficiency and energy improvement under two models SBM model and MPI.

A. Correlation Analysis

Before measuring energy efficiency, a needed step should be done that is to test the correlation between inputs and outputs. This step is needed because of the prerequisite condition of DEA. Input data for the DEA model must meet the isotonicity criteria which requires the level of output must increase or at least the same when inputs increase. Table 3 presents the results of correlation analysis for the year 2017.
As shown at table 4.4, all the Pearson correlation coefficients are estimated to be positive with desirable output-Y1with the correlation coefficient value ranged from 0.5 to 0.8, indicating the explanatory power of the inputs and outputs in the model which means the choice of inputs and outputs is suitable. In contrary, input-the share of renewable energy has the negative correlation with undesirable output. The reason for this phenomenon is that using more renewable energy can reduce the greenhouse gases. Other inputs showed to have positive but insignificant correlation with CO2 emissions.

Table 3. Results of Correlation Analysis-2017

	X1	X2	X3	X4	Y2	Y1
X1	1	0.7636044	0.6306863	0.6709415	0.28292	0.6777861
X2	0.7636044	1	0.4443673	0.5048966	0.0364256	0.8775034
X3	0.6306863	0.4443673	1	0.4940977	-0.3450647	0.5254103
X4	0.6709415	0.5048966	0.4940977	1	0.0585877	0.5153736
Y2	0.28292	0.0364256	-0.3450647	0.0585877	1	-0.0716156
Y1	0.6777861	0.8775034	0.5254103	0.5153736	-0.0716156	1

B. Energy efficiency during 2013-2017 under DEA SBM.

In this section, the results of energy efficiency obtained from DEA SBM model will be presented. DEA SBM is applied in this section as it can deal with the undesirable output-CO2 emissions.

The obtained energy efficiency scores of these selected countries are presented in Table 4 below. The score closer to 1 indicating the more efficient the country is. As shown at table 4, it is obvious that the average energy efficiency score over sample time period 2013-2017 for all seventeen countries is 0.835. This result implies that there is the presence of inefficiency, which requires these countries to improve energy efficiency or reduce inefficiency proportionately by augmenting their outputs by approximately16.5% without changing the inputs levels. As can be seen at table 4, the efficiency score of seventeen countries across sample time is lower than 1. However, for individual years, we found the fluctuation but decrease trend in average score. For instance, average score slightly drops from 0.872 in 2013 to 0.860 in 2014, then it witnessed the rapid decrease to 0.814 in 2015 and continued declining to the bottom of 0.809 in 2016, after that experienced the minor recovery in 2017 to 0.822.

By looking at individual countries, we observe that there is a notable difference in energy efficiency of these seventeen countries. There are some countries that are on the efficiency frontier such as France, Hungary, Greece, Italy, Netherland, Poland, Portugal, Switzerland and United Kingdom. On contrast, Australia, Belgium, Czech Republic, Finland, Germany, Norway, Spain and Sweden showed that they are quite far from the efficiency frontier.

The results at table 4 shows the extreme variation among these countries. On one hand, the best performance countries score 100% averagely in term of efficiency. On the other hand, the poorest performance is just 55.9%. It is worth to note that during 2013-2017, there are 9 reaches the best performance with efficiency score of 1 and this represent 52.9% of the sample of this study. The rest countries in this study accounted for 47.1% have the score which is notably far from the efficiency frontier with average score from 0.559 to 0.704 in which Finland is the country that has the lowest score of 0.559. Figure 4.1. shows the graphical illustration of average efficiency scores.

Table 4. Energy efficiency over period 2013-2017

DMUs	2013	2014	2015	2016	2017	Average
Austria	0.644	0.643	0.604	0.593	0.603	0.617
Belgium	0.671	0.640	0.613	0.603	0.663	0.638
Czech Republic	0.709	0.669	0.617	0.607	0.662	0.653
Finland	0.582	0.581	0.547	0.539	0.548	0.559
France	1	1	1	1	1	1
Germany	0.7181	0.7022	0.6729	0.6685	0.7016	0.693
Greece	1	1	1	1	1	1
Hungary	1	1	1	1	1	1
Italy	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1
Norway	1	1	0.509	0.504	0.507	0.704
Poland	1	1	1	1	1	1
Portugal	1	1	1	1	1	1
Spain	0.783	0.713	0.655	0.625	0.659	0.687
Sweden	0.724	0.675	0.623	0.611	0.622	0.651
Switzerland	1	1	1	1	1	1
United Kingdom	1	1	1	1	1	1
Average	0.872	0.860	0.814	0.809	0.822	0.835

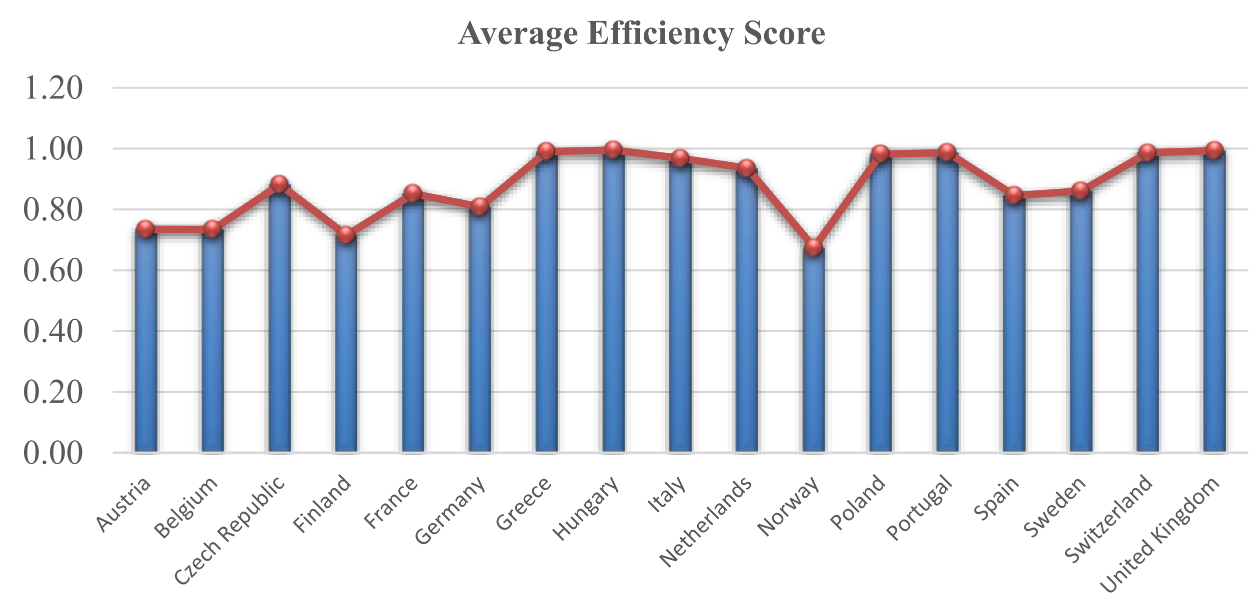

Figure 4.1: Average results of energy efficiency for the period 2013-2017

Conversely, it is observed that there is less variation in efficiency scores for individual countries across the sample years for both top the best performance countries and top the poorest performance ones. For the best performance countries, the efficiency score reached value of 1 in all the year of observation. The same variation is applied for the group having the poor performance. The countries showed the fluctuation in efficiency score year by year. However, this fluctuation is insignificant. Therefore, we can conclude that although all countries experienced the ups-downs momentum but the differences in obtained score over time period 2013-2017 are very little.

In summary, there are nine countries out of total seventeen sample countries in this research are efficient in term of energy efficiency while 8 countries suffered a very poor performance. Such poor performance indicates irregularities in energy efficiency and that a considerable level of improvement in efficiency is needed. However, it is clear that DMU which is efficiency with efficiency value of 1 is just considered as relatively efficient. Therefore; it is still room for all countries to perform better in term of energy efficiency.

C. Energy Efficiency Change under The Malmquist Productivity Index Analysis

This section examines the change of energy efficiency of seventeen sample countries over period 2013-2017. The improvement is examined through three groups included the catch-up indicating technical change, frontier-shift indicating efficiency change and MPI indicating the total productivity change. To obtain the purpose of this, Malmquist Productivity Index (MPI) is applied to measure the change. The change in each group will be presented in the following sub-sections.

- *Malmquist productivity index and its decomposition*

We applied DEA-Solver Pro in this research to run The Malmquist Productivity Index under variable return to scale (VRS) with the input-oriented. The change in efficiency is defined as "catch-up" effect. The annual efficiency change index is collected and presented in Table 5, and then it demonstrated as in figure 4.2.

For the sample periods as a whole, the average efficiency change ranged from 0.2% to 0.8%. Averagely, there is no improvement in term of efficiency for the whole sample period. The average efficiency decrease ranged from 0.2 to 0.8%. The largest decline in efficiency was in period 2014-2015 with 0.8% and the smallest decrease was in 2016-2017 with 0.2%. it is also worth to note that during sample time period 2013-2017, Australia is the countries which always has the decline in efficiency change all the observation time periods while Switzerland showed the unchanged with efficiency change scores equal to 1 for all for subsequent years and Netherland has the best improvement out of seventeen countries with 1.7% improvement for the whole observation time periods.

Table 5. Efficiency change during 2013-2017

Catch-up	2013=>2014	2014=>2015	2015=>2016	2016=>2017	Average
Austria	0.995	0.977	0.987	0.992	0.988
Belgium	1.025	1.038	0.985	0.990	1.009
Czech Republic	0.992	0.990	1.015	1.007	1.001
Finland	1.014	0.970	0.985	1.002	0.993
France	1.004	0.962	0.999	1.002	0.992
Germany	1.025	1.015	0.993	0.996	1.007
Greece	1.015	1.061	1.010	0.943	1.008
Hungary	1.000	0.986	1.009	1.001	0.999
Italy	1.003	0.991	0.997	1.004	0.999
Netherlands	1.026	1.040	1.000	1.000	1.017
Norway	0.925	0.931	0.993	1.004	0.963
Poland	0.992	1.000	0.992	1.000	0.996
Portugal	0.980	0.975	0.994	1.001	0.988
Spain	0.979	0.998	0.992	1.011	0.995
Sweden	0.927	0.946	0.990	1.006	0.967
Switzerland	1.000	1.000	1.000	1.000	1.000
United Kingdom	0.989	0.982	1.001	1.006	0.995
Average	0.994	0.992	0.997	0.998	0.995
Max	1.026	1.061	1.015	1.011	1.017
Min	0.925	0.931	0.985	0.943	0.963
SD	0.029	0.033	0.009	0.015	0.014

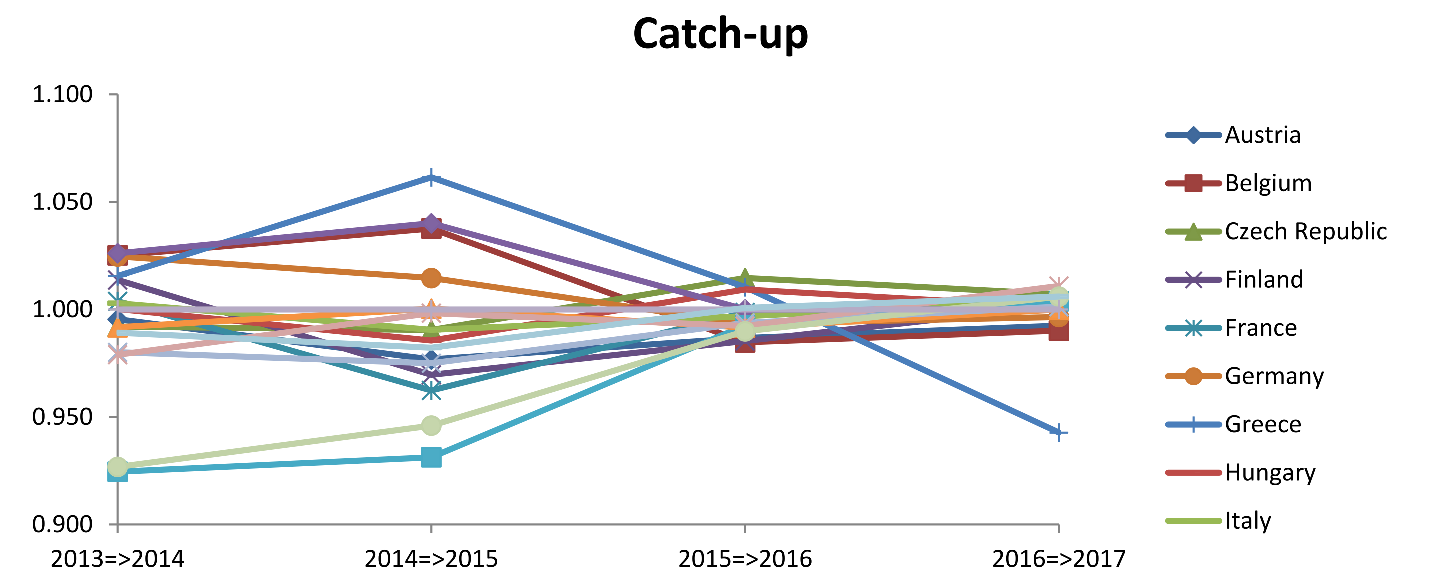

Figure 4.2: Efficiency Change during 2013-2017

- *Analysis of the Malmquist productivity index: technical change*

The results of frontier-shift indicate the change in efficient frontiers between the two different time periods. The results of frontier-shift showed the technical change of sample seventeen countries and these results are presented at table 6.
From 2013-2014, there are ten countries that have the efficiency change scores greater than 1. It indicates that there is a growth in technical efficiency in these ten countries (Australia, Finland, France, Hungary, Italy, Norway, Portugal, Spain, Sweden and Switzerland). The left seven countries in which their technical change scores are smaller than 1 indicating that technical regress or innovation deteriorate in the period. Sweden is the country that has the highest positive change in technical with 6.2% improvement in technical efficiency while Netherland is the country that have the worst technical change with 8% decline.

From 2014-2015, all countries have the technical change smaller than 1 except Switzerland, which reveals that the for sixteen countries and Switzerland has witnessed overall efficiency progression, but this change is so minor that has not reached 1%; therefore; Switzerland's technical change was equates no evidential change. The biggest decline in technical change is from Netherland with 6.3%. the decrease in technical efficiency of sixteen countries leads to the fall of 2.3% in average.

During period 2015-2016, there are three countries (Finland, Sweden and Switzerland) that have the scores greater than 1. However, the change in technical is just too little that we considered there is no change in technical efficiency for these three countries. Other thirteen countries witnessed the negative change with scores lower than 1. Both the positive and negative change is too little. The highest positive change is 0.39% and the largest negative change is 2.9%. The average change of the period is 0.6% of decline in technical efficiency. The same is said for the time period 2016-2017, the decline happened to thirteen countries and the minor improvement is for three countries (Czech Republic, Netherland and Poland). The change is too small that confirm no evidential change.

Table 6. Technical Change during 2013-2017

Frontier	2013=>2014	2014=>2015	2015=>2016	2016=>2017	Average
Austria	1.041	0.984	1.000	0.993	1.004
Belgium	0.946	0.951	0.997	0.995	0.972
Czech Republic	0.984	0.980	0.984	1.004	0.988
Finland	1.020	0.995	1.002	0.983	1.000
France	1.056	0.960	1.000	0.994	1.002
Germany	0.968	0.972	0.998	0.990	0.982
Greece	0.996	0.996	0.994	0.981	0.992
Hungary	1.008	0.992	0.992	0.989	0.995

Italy	1.053	0.956	0.976	0.993	0.994
Netherlands	0.920	0.936	0.988	1.001	0.961
Norway	1.059	0.973	0.999	0.997	1.007
Poland	0.997	0.981	0.986	1.000	0.991
Portugal	1.005	0.996	0.978	0.978	0.989
Spain	1.017	0.993	0.999	0.978	0.997
Sweden	1.062	0.981	1.004	0.990	1.010
Switzerland	1.038	1.000	1.004	0.998	1.010
United Kingdom	0.993	0.970	0.999	0.993	0.989
Average	1.010	0.977	0.994	0.992	0.993
Max	1.062	1.000	1.004	1.004	1.010
Min	0.920	0.936	0.976	0.978	0.961
SD	0.041	0.018	0.009	0.008	0.013

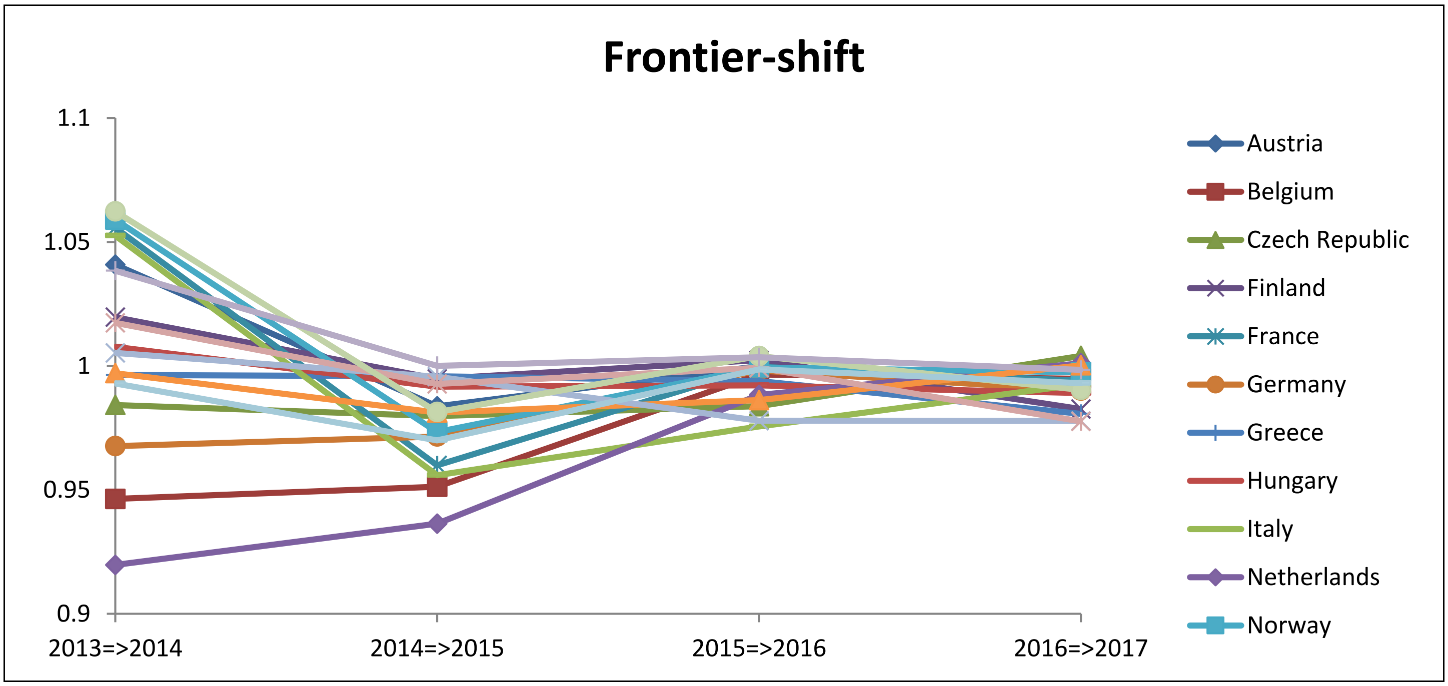

Figure 4.3: Technical change during 2013-2017

- *Productivity changes: the Malmquist productivity index and its decomposition*

The productivity change of energy efficiency of seventeen countries during 2013-2017 is showed at table 7 and figure 4.4 below.

Table 7. Annual productivity change (MPI) from 2013-2017

Malmquist	2013=>2014	2014=>2015	2015=>2016	2016=>2017	Average
Austria	1.036	0.961	0.987	0.985	0.992
Belgium	0.970	0.987	0.981	0.985	0.981
Czech Republic	0.976	0.970	0.998	1.011	0.989
Finland	1.034	0.965	0.988	0.984	0.993
France	1.060	0.924	0.998	0.996	0.994
Germany	0.992	0.986	0.992	0.987	0.989
Greece	1.012	1.057	1.004	0.925	0.999

Hungary	1.008	0.977	1.001	0.990	0.994
Italy	1.056	0.947	0.972	0.997	0.993
Netherlands	0.944	0.974	0.988	1.001	0.977
Norway	0.979	0.906	0.992	1.001	0.970
Poland	0.989	0.982	0.978	1.000	0.987
Portugal	0.985	0.971	0.972	0.979	0.977
Spain	0.996	0.991	0.992	0.988	0.992
Sweden	0.985	0.928	0.994	0.996	0.976
Switzerland	1.038	1.000	1.004	0.998	1.010
United Kingdom	0.982	0.953	0.999	0.999	0.983
Average	1.002	0.969	0.991	0.990	0.988
Max	1.060	1.057	1.004	1.011	1.010
Min	0.944	0.906	0.972	0.925	0.970
SD	0.032	0.034	0.010	0.019	0.010

In summary, there is a very little change in average productivity for the whole sample time periods. During each separate period, we witnessed the minor change, mostly decrease in productivity. However, these changes are so little that have not reached 1%. Therefore, the productivity change during 2013-2017 is considered averagely remain stable.

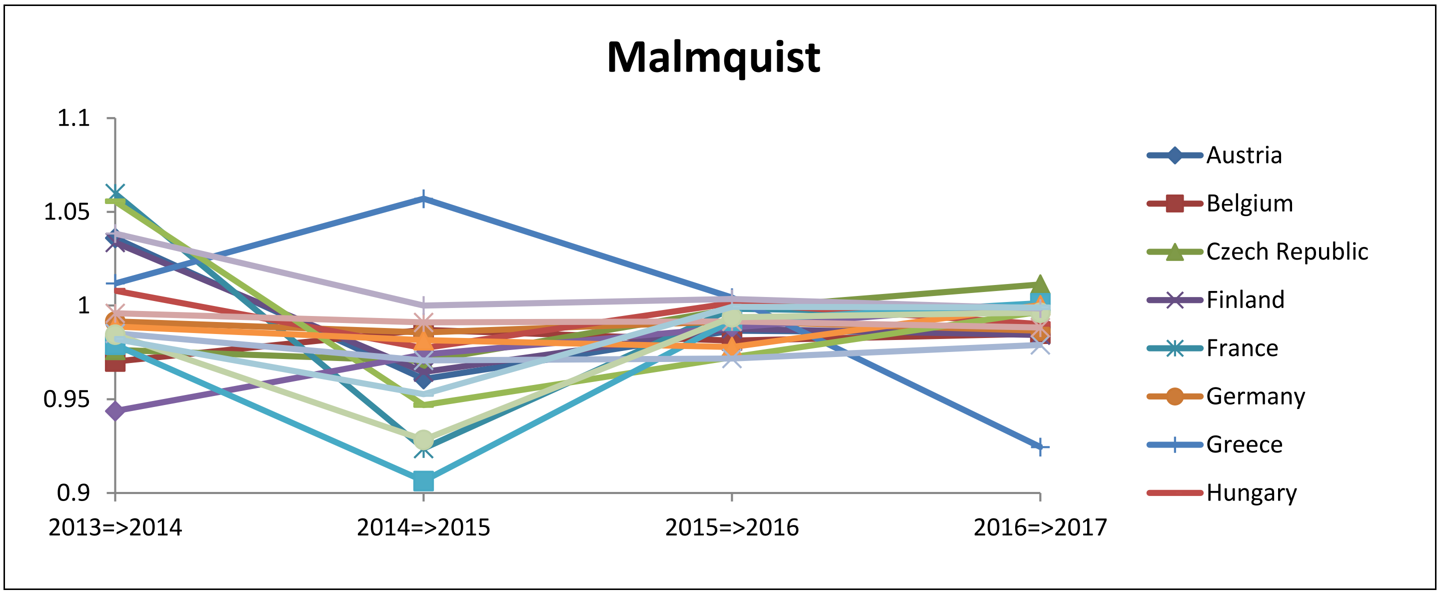

Figure 4.4: Annual productivity change (MPI) from 2013-2017

Since Malmquist productivity index of productivity change is a multiplicative composite of efficiency and technical change. The change in productivity is mainly causes by the value of the efficiency change and technical change or both. In the other words, the growth in productivity can be explained by the increase in efficiency change and technical change while the loss of productivity is the result of the decrease in efficiency change or technical change or both.

Figure 4.5 present the results of these Malmquist productivity indices for the seventeen companies across sample time period 2013-2017.

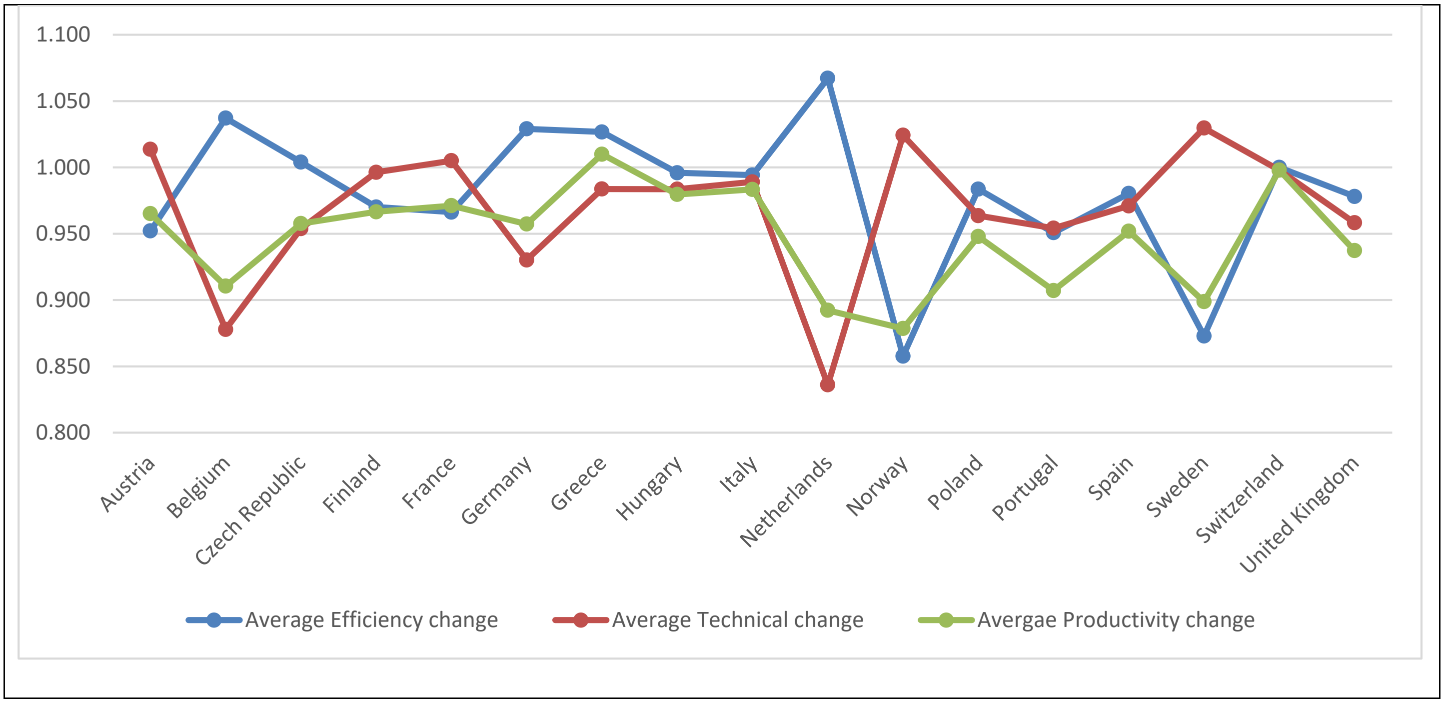

Figure 4.5: Annual average productivity change and its components from 2013-2017

For all countries as a whole, the average productivity change ranged from 1% (Greece) to 12.1% (Norway). Greece has the highest positive change in productivity; however, this increase is not significant with just only 1% growth while Norway is the country that has the greatest loss in productivity with 12.1%. Averagely, during 2013-2017, there is only one country (Greece) that has the productivity growth while the left sixteen countries show the loss in productivity with the average scores are all lower than 1. For the whole observation time period, the average MPI of all countries experienced the loss of 5.2% which mainly caused by the decrease in both efficiency change and technical change with average change scores are 0.980 (2%) and 0.969 (3.1%) respectively.

IV. CONCLUSIONS

The main objectives of this study are to firstly evaluate the energy efficiency and then examine the energy improvement of countries in European Union during 2013-2017 by applying DEA SBM and MPI. Findings of this study have the very important policy implications for policymakers as it provided the real status of energy efficiency and improvement of 17 selected countries in Europe. By evaluating the energy efficiency of seventeen European Union countries, our study reveals that as a whole observation, these countries are 16.5% far from the efficiency frontier implying that there is an unbalance between inputs, output, particularly, between the growth of GPD and CO_2 reduction in relative to less input's resources used. Moreover, lower efficiency scores of eight countries denotes that these countries must put more effort on improving energy efficiency. Energy efficiency can be enhanced by using less unrenewable energy in effort to promote GPD growth. Increasing the share of renewable energy in total energy consumption is one of the key solutions for these countries. Moreover, findings of this study also reveal that most sample countries showed to have no improvement in term of efficiency except Greece. This finding implies that although efficient countries are on efficiency frontier, there are room for them to improve their performance.

Results obtained under slacked-based model (SBM) indicated nine out of seventeen countries (France, Hungary, Greece, Italy, Netherland, Poland, Portugal, Switzerland and United Kingdom) were efficient in terms of energy during 2013-2017 with corresponding energy-efficiency score of 1 for all 5 observation years. On other hand, eight countries (Australia, Belgium, Czech Republic, Finland, Germany, Norway, Spain and Sweden) have a very poor performance with the average efficiency scores are far from the efficiency frontier. Additionally, the results of this study indicated the big variation between efficient countries and inefficient countries. Particularly, efficient countries showed to have efficiency scores of 1 for all observation year while the average efficiency score of the inefficient countries range from 0.559 to 0.704, denoting a big gap.
Regards the efficiency improvement obtained from MPI, results of MPI indicated that during 2013-2017, there was only one country (Switzerland) which roughly accounted 5.9% of total sample size that has proof of efficiency improvement while other sixteen countries suffered from the regress.

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