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Are European Union countries efficient or inefficient in energy use?

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Abstract

Energy efficiency is one of the most effective methods of fighting climate change, achieving supply security and succeeding in resource effectiveness. For this reason, European Union (EU) countries follow mutual energy policies related to energy efficiency, with directives of the European Commission. This study used the Malmquist Total Factor Productivity Index to determine the extent to which 28 EU countries used energy efficiently in the output (GDP) production process in the period of 2005-2017. The results of the analysis indicated that the energy efficiency of EU-28 countries increased by an average of 1.1% for the period under review, and that the increases in efficiency varied between countries. Also, energy efficiency decreased only in Poland throughout the studied period. Although the Union has a common energy policy, it is thought that there are two main reasons for the energy efficiency differences in the member countries of the Union. The first of these is the energy structures of the countries, while the second is the energy policies of the countries that are shaped by their own internal dynamics.

Keywords: energy, energy efficiency, EU energy policy, data envelopment analysis, Malmquist index

Introduction

The need for energy, which is one of the main inputs in the worldwide process of economic output creation is constantly increasing. Increased demand for energy creates a pressure on the environment with the emissions of greenhouse gasses. However, as preventing increases in energy demand may slow down the growth and development process, at this point, using energy efficiently comes to the fore as a

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more applicable solution. While, in general, there is no clear consensus on the definition of the concept of energy efficiency that is on the agenda of every country, according to Kanellakis *et al.* (2013), energy efficiency is the fastest and most economical way of increasing supply security and reducing greenhouse gas emissions. Filipovic *et al.* (2015) stated that energy efficiency refers to the usage of less energy to create the same amount of economic output, while Wang *et al.* (2017) argued that energy efficiency is one of the most effective potions for slowing down energy consumption and incentivizing low-carbon output development. Due to these functions, for sustainable and inclusive growth, energy efficiency is at the centre of the EU's energy policies (Carvalho, 2012, p. 21).

Considering energy efficiency, alongside the arguments of energy supply security and external dependence, it has been one of the main components of the EU energy policy since 1970s (Bosseboeuf *et al.*, 1997, p. 673). The petroleum crises that were experienced in 1970s created substantial impacts in the world in terms of energy supply security and energy costs. In addition to this, in the aforementioned period, initiatives related to environmental awareness were started in the scope of energy policies. In this context, relevant concerns were presented with the first environmental action plan (1973-1976). In the mid-1990s, the main goals of the EU's energy policy were protection of the environment, development of competition and increasing supply security (Mancisidor *et al.*, 2009, p. 102). The 2000s' EU energy policy was shaped around energy supply security (energy dependence) and climate change. The EU's energy strategy consists of goals based on five factors. These are: increasing energy efficiency, increasing the rate of energy obtained from renewable energy resources, increasing the clean hydrocarbons that are consumed, strengthening the carbon market of the EU, and supporting the domestic energy market (Carvalho, 2012, p. 20).

In the 2016 Brussels European Commission Energy Efficiency Directive focuses on liabilities and goals by the member states to ensure energy efficiency. The energy efficiency instruments that are accepted at the EU level reflect the increased significance of energy as a political and economic difficulty, energy supply security, climate change, sustainability, and energy's close relationship with the fields of domestic markets and economic development policies. As the measurement of energy demand and increasing energy efficiency with the changes that have been made in the energy directive will provide benefits for the environment, this directive is also in agreement with the Union guarantees within the Energy Union and Global Climate Agenda framework created by the Paris Agreement in December 2015 by the parties of the United Nations Framework Convention on Climate Change. The European Parliament and Council directives state that energy efficiency needs to be considered a source of energy by itself. The goal of increasing energy efficiency in a way that would achieve 20% energy savings in the EU until 2020, within the scope of the Energy Efficiency Action Plan, was determined to reach 30% energy savings by 2030 (EU Commission Energy Efficiency Directive, 2016). In this context, determining the current situation in terms of energy efficiency in EU member countries in order to achieve these goals is the main motivation of the research.

While they hold an important position in the EU energy policies, indicators of energy efficiency are dealt with differently at the country level. This is why EU countries have joined in a mutual effort that is going to create a common methodology regarding the indicators of energy efficiency. For this purpose, 600 comparable, both descriptive and explanatory energy efficiency indicators were collected under a defined and calculated database called Odyssee (Bosseboeuf *et al.*, 1997, p. 673). Moreover, in macro-level policy analyses, the assessment of partial energy efficiency is usually dealt with based on energy density and energy efficiency. These conventional (partial) energy efficiency indices consider one input (energy) to create an output (GDP) while they ignore other inputs such as labour and capital (Dizdarevic and Segota, 2012, p. 248; Lenz *et al.*, 2018, p. 92). To overcome this issue, Hu and Wang (2006) developed a new energy efficiency index named the total factor energy productivity. This index considers energy, labour, and capital stock as multiple inputs for creating an output. This is because an output cannot be created by only using energy, but energy, alongside other inputs, need to be considered. Therefore, in order to accurately assess the energy efficiency in an area, the total factor energy productivity has to be measured.

In this context, among the studies in the literature, Zhang *et al.* (2011) investigated the total factor energy productivity in 23 developing countries for the period of 1980-2005 by using data envelopment analysis. They used GDP as the output and labour, energy consumption and capital stock as the inputs, and they observed that some countries showed a good performance in terms of energy efficiency, while others experienced constant decreases in energy efficiency. Vlahinic-Dizdarevic and Segota (2012) investigated the economy-wide energy efficiency changes in EU countries in the period from 2000 to 2010. The Data Envelopment Analysis (DEA) CCR multiple input-oriented model was applied to analyse the efficiency of the use capital stock, labour and energy consumption in producing GDP as the output.

The empirical findings showed that the countries with the higher share of high-quality fuels, like electricity and natural gas, obtained the best scores of energy efficiency, while the economies with lower-quality energy sources (wood, coal) were the worst performers in terms of energy efficiency. Egilmez *et al.* (2013) implemented DEA to analyse the sustainability performance and improve the energy efficiency of the U.S. manufacturing sector. The analysis results showed that five industrial sectors were 100% eco-efficient compared to other manufacturing sectors, and approximately 90% of the U.S. manufacturing sectors were found to be inefficient. Sözen and Alp (2013) examined energy efficiency in 25 EU countries and a few others, including Turkey, for the period of 1998-2006 by using DEA and the Malmquist Productivity Index. They took the outputs as primary and total energy consumption and the inputs as total primary energy and gross electricity production, net natural gas, crude oil, and primary energy imports. They found that, while Turkey was converting energy inputs into outputs, it could not use these as efficiently as certain EU countries could. Wang *et al.* (2013) used a DEA model developed for measuring energy and environmental efficiency in 29 different regions in China for the period of 2000-2008. In the study where capital, labour and energy consumption were taken as the inputs, GDP was the desired output, and carbon dioxide and sulphur dioxide were the undesired outputs, it was generally observed that the energy and environmental efficiency of China slightly increased from 2000 to 2008, and that eastern regions had higher environmental and energy efficiency in comparison to western regions. Song *et al.* (2013) used a Super Slack-Based model to measure the energy efficiency levels in BRICS countries.

In the study where energy consumption, active population and capital formation rate were used as the inputs and GDP was used as the output, they found that, as a whole, BRICS had low energy efficiency, but that there was a tendency towards a rapid increase. Vlontzos *et al.* (2014) used DEA to examine energy and environmental efficiency in EU member countries for the period of 2001-2008. They took energy consumption, labour and capital as the inputs, GDP as the desired output and CO_2 emissions as the undesired output. The results showed that countries like Germany, Sweden and Austria were more efficient in terms of energy and environment in comparison to low-technology countries. Li and Shi (2014) developed a Super Slack-Based model with environmental outputs to measure the energy efficiency in the industry sector in China. As a result, they observed that the energy efficiency of the industry sector increased significantly in the period from 2001 to 2010. Chang (2015) investigated the energy efficiency of G7 and BRICS countries for the period of 2000 to 2010. The DEA findings indicated that the G7 countries had higher efficiency than the BRICS countries before 2005. Makridou *et al.* (2015) evaluated the energy efficiency of EU countries over the period 2000-2010.

The DEA analysis showed that the efficiency estimates, and energy intensity of the countries had strong negative correlations under four models. Wang *et al.* (2017) examined energy efficiency in 17 countries for the period of 2010-2015 by using a Super Slack-Based model and the Malmquist Productivity Index (MPI). In their study, where fixed capital formation, labour, and energy consumption for obtaining output (GDP) were taken as the indicators of energy efficiency, they found that energy efficiency in the studied countries mainly stemmed from technological advancements. Borozan (2018) aimed to explore the impact of various environmental variables on technical and energy efficiency in the EU for the period 2005-2013. The results of DEA showed that technical and energy efficiency varied by region and most EU regions failed to utilize all their resources efficiently. Chang (2020) investigated energy efficiency for 28-member countries in the EU with total-factor energy efficiency (TFEE) analysis under the metafrontier framework for the period of 2010-2014. The empirical findings showed that the Baltic Sea Region

(BSR) countries' average energy efficiency performed better than that of the non-Baltic Sea Region (NBSR) countries. Shang *et al.* (2020) investigated the total factor energy efficiency in different regions of China with the SBM-DEA model for the period of 2005-2016. They found that the average annual total factor energy measurement value in China from 2005 to 2016 was 0.4559, and, by use of existing technology and the constant investment scale, it was indicated that there was still a 50% increase in this value. In this context, it may be seen that there are several indicators in the literature for determining energy efficiency. On the other hand, it was observed that several studies commonly used the method of data envelopment analysis, inputs of labour, capital formation and energy consumption and output of GDP. Based on this, with the help of the aforementioned indicators, whether energy is efficiently used in 28 EU countries or not was investigated.

1. Methodology

The Malmquist Total Factor Productivity Index has become a standard approach in efficiency measurement in time, and it was defined by Caves *et al.*, (1982) (Bjurek, 1996, p. 303). This index is expressed in terms of distance to the maximum output from data input and distance to the minimum input from data output. These approaches show output- and input-oriented measurements (Caves *et al.*, 1982; Fare and Grosskopf, 1992). Fare *et al.* (1994) expressed the distance from the output obtained from the inputs at a time t when a numerical input is used to obtain an output to the technology boundary observed at the time t as the output technical efficiency. As seen in Figure 1, the production observed at the time t was within the technology boundary at the time t, but it was not technically efficient. When the distance function here is expressed in the form of 0a/0b, it is seen that this value is smaller than 1. That is, the output efficiency is the distance of an observation to the technology boundary. The distance function $D_0^t(X^{t+1}, Y^{t+1})'$ measures the maximum relative change in the output to realize (X^{t+1}, Y^{t+1}) in relation to the technology at the time t. (X^{t+1}, Y^{t+1}) is outside the production set at the time t that is possible (practical). In other words, there is a technical change. The value of the distance function, 0d/0e, is greater than 1 considering the technology at the time t (X^{t+1}, Y^{t+1}).

In order to define the Malmquist Index, distance functions for different time periods should be expressed. The distance function that measures the maximum relative change in the output to obtain $(X^t, Y^t)'$ with the technology at the time t+1 is $D_0^{t+1}(X^t, Y^t)'$. Caves *et al.* (1982) stated the Malmquist Productivity Index as follows:

$$M^t = \frac{D_0^t(X^{t+1}, Y^{t+1})}{D_0^t(X^t, Y^t)}$$

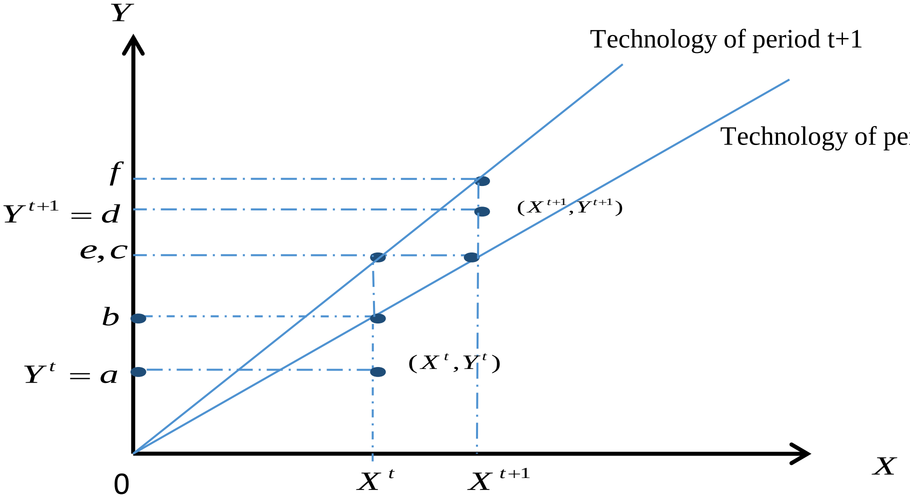
In this formulation, the technology in period t was taken as reference technology. The period (t + 1) can also be taken as a basis:

$$M^{t+1} = \frac{D_0^{t+1}(X^{t+1}, Y^{t+1})}{D_0^{t+1}(X^t, Y^t)}$$

The change in Malmquist factor productivity can be written as the geometric mean of the two Malmquist productivity indices:

$$\left[\left(\frac{D_0^{t+1}(X^{t+1},Y^{t+1})}{D_0^{t}(X^{t},Y^{t})}\right)\left(\frac{D_0^{t+1}(X^{t+1},Y^{t+1})}{D_0^{t+1}(X^{t},Y^{t})}\right)\right]^{1/2} = \frac{D_0^{t+1}(X^{t+1},Y^{t+1})}{D_0^{t}(X^{t},Y^{t})} \times \left[\left(\frac{D_0^{t}(X^{t+1},Y^{t+1})}{D_0^{t+1}(X^{t+1},Y^{t+1})}\right)\left(\frac{D_0^{t}(X^{t},Y^{t})}{D_0^{t+1}(X^{t},Y^{t})}\right)\right]^{1/2} \quad (1)$$

Figure 1. The Malmquist output-based index of total factor productivity and output distance functions



Source: Fare *et al.*, 1994, p. 70

The Malmquist Total Factor Productivity Index (TFPCH) which is defined in equation (1) has two components. The first component is efficiency change (EFFCH), and the second component is technical change (TECHCH). On the right side of equation (1), the first term shows the efficiency change component and it represents the catch-up effect of the country's production frontier. The second term on the right side of equation (1) shows the technical change and indicates the shift in the country's production frontier. Moreover, efficiency change is decomposed into pure efficiency change (PECH) and scale efficiency change (SECH). Scale efficiency change indicates whether the production is made at the appropriate scale in the country (Fare *et al.*, 1994).

The distance functions used in the calculation of the Malmquist index according to Figure 1 can be expressed as distances to the technology limits as follows:

$$\left(\frac{0d}{0f}\right)\left(\frac{0b}{0a}\right)\times\left[\left(\frac{0d/0e}{0d/0f}\right)\left(\frac{0a/0b}{0a/0c}\right)\right]^{1/2}=\left(\frac{0d}{0f}\right)\left(\frac{0b}{0a}\right)\left[\left(\frac{0f}{0e}\right)\left(\frac{0c}{0b}\right)\right]^{1/2} \quad (2)$$

Output-oriented Malmquist total factor productivity index calculations are made by using the distance functions explained above. In calculation of the total factor productivity, index values are calculated based on the distance functions by linear programming.

2. Data

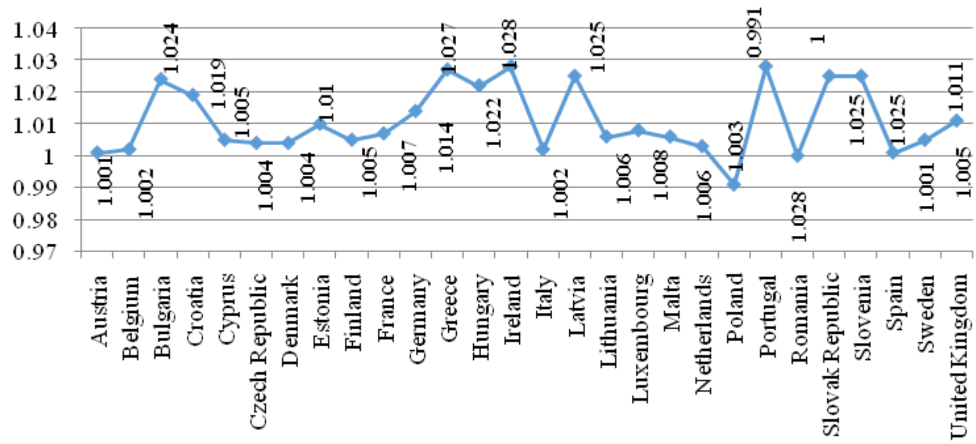
In this study, as all data of the 28 EU countries could be reached for the period of 2005-2017, whether energy was used efficiently in this period or not was investigated. Based on studies in the literature (Zhang *et al.*, 2011; Wang *et al.*, 2013; Wang *et al.*, 2017), GDP was used as the output, and gross capital formation (fixed 2010 prices), total labour and energy consumption (per capita oil equivalent) were used as the inputs. The data were collected from the official website of the World Bank[1] and the “Renewables Information 2018” report by the International Energy Agency. Additionally, as the 2015, 2016 and 2017 annual energy consumption data for Bulgaria, Croatia, Cyprus, Lithuania, Malta and Romania could not be reached, the mean energy consumption increase rates of these countries in the sample for these periods were calculated, and the energy consumption data for the aforementioned years were estimated. In the calculation of the Malmquist index values in the study, based on the study by Coelli (1996), the DEAP 2.1 software was used.

3. Empirical results

In this study, which examined the changes in the mean energy performances of EU-28 countries in time, the findings on the energy efficiency performance results calculated by the energy input used in the process of output production were as follows.

[1] World Bank (2019), Databank, World Development Indicators. (retrieved from https://databank.worldbank.org/data/source/world-development-indicators)

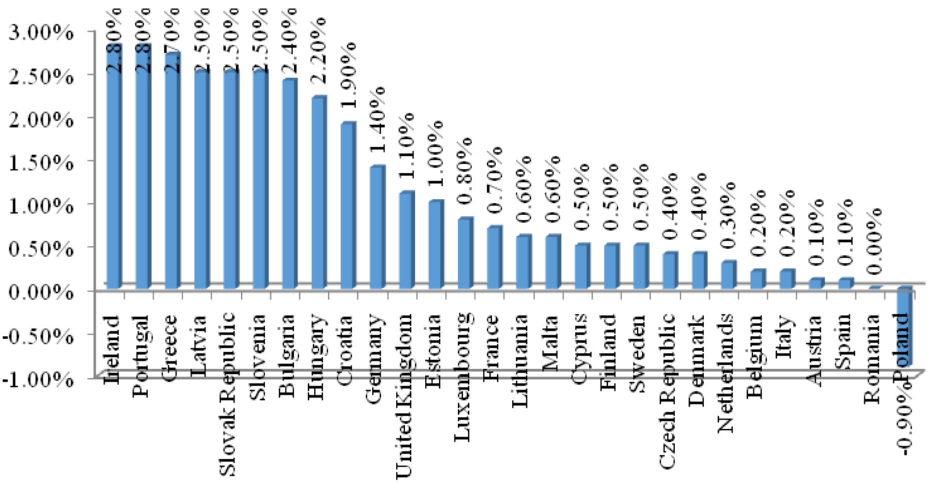
Figure 2. Average energy efficiency performances of EU countries from 2005 to 2017



Source: Author's calculations

Figure 2 shows the changes in the mean energy efficiencies of the EU-28 countries for the period of 2005-2017 expressed in terms of their total factor productivity index values. The empirical findings were consistent with the studies by Vlahinic-Dizdarevic and Segota (2012), Sözen and Alp (2013), Borozan (2018) and Chang (2020). Accordingly, as the energy efficiency in the countries with the index values of 1 was unchanged in the period, those countries with the index values higher than 1 and lower than 1, respectively, increased and decreased. Considering the average value of the entire period, only the energy efficiency in Poland had a decreasing trend, while Romania's energy efficiency was unchanged. While there was an increase in the mean energy efficiency values in all the other countries, the highest increase was in Ireland and Portugal at the same rate, and the lowest increase was in Spain and Austria, again, at the same rate. According to the European Commission Report (2019), since 2005, the final energy consumption has fallen in all Member States except Cyprus, Lithuania, Malta, Austria, and Poland. The fact that these countries have the least increase in energy efficiency is due to not having reduced their energy consumption. The percentage increases and decreases in energy efficiency in the aforementioned period are shown more clearly in Figure 3.

Figure 3. Average change in total factor productivity of EU countries from 2005 to 2017(%)



Source: Author's calculations

As seen in Figure 3, in the time period from 2005 to 2017, there were eight countries with energy efficiency increases higher than 2% (Ireland, Portugal, Greece, Latvia, Slovakia, Slovenia, Bulgaria, Hungary), three with increases higher than 1% (Croatia, Germany, the United Kingdom), one with an increase of 1% (Estonia) and 16 with increases lower than 1% (Luxembourg, France, Lithuania, Malta, Cyprus, Finland, Sweden, Czech Republic, Denmark, the Netherlands, Belgium, Italy, Austria, Spain, Romania). The mean energy efficiency in Poland decreased by 0.9%. In the country report by the Energy Efficiency Watch on Poland (2013), it was stated that the energy efficiency in Poland could not be increased due to the lack of energy efficiency agreements and insufficiency of legislation in Poland. In another report by the Energy Efficiency Watch (2015), it was emphasized that the most fundamental obstacle against energy efficiency in Poland was produced by the energy policies focused on the supply aspect of the issue and heavily involved in coal mining. Additionally, it was emphasized that these policies ignored energy efficiency, and that they were not well-designed or implemented.

Table 1 shows the details on the total factor productivity index values of the studied countries based on years. In general, 24 countries in 2009, 20 countries in 2011 and 2013 and 21 countries in 2016 experienced increases in their energy efficiency. In other periods, in general, about half of the countries experienced increases in their energy efficiency, but it was observed that the increase in energy efficiency was not stable, and the countries which displayed increases in efficiency differed from year to year.

Table 1. Malmquist total factor productivity index results (TFPCH)

	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
Austria	1,019*	0,995	1,010*	0,985	1,003*	1,029*	1,000	0,993	1,009*	0,994	0,987	0,990
Belgium	1,003*	0,983	0,991	1,004*	0,998	1,036*	1,006*	0,986	1,008*	1,002*	0,994	1,007*
Bulgaria	0,884	0,944	0,909	1,272*	1,228*	1,053*	0,976	1,057*	0,953	1,021*	1,090*	0,975
Croatia	0,931	0,991	0,929	1,209*	1,144*	1,013*	1,038*	0,988	1,007*	0,980	1,016*	1,009*
Cyprus	0,931	1,006*	0,856	1,217*	0,952	1,202*	1,094*	1,170*	1,074*	0,869	0,923	0,865
Czech Republic	0,922	0,922	1,015*	1,115*	0,983	1,002*	1,020*	1,023*	0,978	0,978	1,036*	1,015*
Denmark	0,971	1,005*	1,002*	1,018*	1,019*	1,010*	1,001*	1,001*	1,009*	1,011*	0,972	1,001*
Estonia	0,844	0,973	1,188*	1,450*	0,961	0,840	0,912	1,044*	1,001*	1,062*	1,006*	0,970
Finland	1,033*	0,997	1,015*	1,009*	0,984	0,989	1,025*	1,031*	1,005*	0,992	0,981	1,000
France	1,020*	1,016*	0,995	0,976	1,013*	1,019*	0,997	1,002*	1,012*	1,007*	1,009*	1,013*
Germany	0,999	1,055*	1,002*	1,009*	0,992	1,044*	1,016*	0,992	1,035*	1,010*	1,016*	1,004*
Greece	0,918	0,994	1,040*	1,141*	1,048*	1,137*	1,144*	1,050*	0,965	1,067*	0,949	0,912
Hungary	1,018*	1,012*	1,003*	1,227*	0,962	1,053*	1,055*	0,978	0,968	1,040*	1,035*	0,935
Ireland	1,018*	1,015*	0,990	1,025*	1,116*	1,001*	0,913	1,058*	0,983	1,160*	0,954	1,125*
Italy	1,013*	1,013*	0,988	0,983	1,007*	1,013*	1,006*	1,004*	1,006*	0,993	1,002*	0,998
Latvia	0,912	0,916	1,138*	1,446*	1,191*	0,710	1,047*	1,064*	1,081*	1,011*	1,022*	0,928
Lithuania	0,954	0,853	0,993	1,834*	0,742	0,901	1,172*	1,035*	0,993	0,852	1,046*	1,012*
Luxembourg	1,050*	1,028*	0,945	1,047*	0,955	0,970	0,972	1,026*	1,033*	1,024*	1,039*	1,013*
Malta	0,992	1,026*	0,973	1,058*	0,856	1,205*	1,075*	0,962	1,178*	0,711	1,037*	1,104*
Netherlands	1,009*	1,002*	1,000	0,974	1,023*	1,023*	0,994	1,009*	1,007*	0,975	1,007*	1,011*
Poland	0,913	0,854	1,015*	1,176*	0,947	0,933	1,056*	1,067*	0,937	0,995	1,043*	0,989
Portugal	1,016*	0,999	0,994	1,104*	0,986	1,133*	1,138*	1,024*	0,982	0,986	1,013*	0,981
Romania	0,853	0,844	0,976	1,248*	0,961	0,974	1,072*	1,051*	1,023*	0,988	1,052*	1,012*
Slovak Republic	1,021*	1,013*	0,998	1,328*	0,886	0,962	1,128*	1,004*	0,988	0,966	1,048*	1,019*
Slovenia	0,943	0,910	1,007*	1,238*	1,072*	1,029*	1,119*	0,965	1,004*	1,024*	1,036*	0,992
Spain	0,996	1,005*	1,006*	1,006*	1,006*	1,013*	1,030*	1,032*	0,963	0,955	1,006*	0,994
Sweden	0,991	0,973	0,994	1,013*	1,031*	1,023*	0,992	1,008*	1,018*	1,010*	1,008*	0,996
United Kingdom	0,995	1,016*	1,031*	1,076*	0,938	1,027*	0,974	0,978	1,027*	1,023*	1,030*	1,026*

Note: The index values, denoted by *, symbolize the increases in energy efficiency in the period of 2005-2017.
Source: Author's calculations

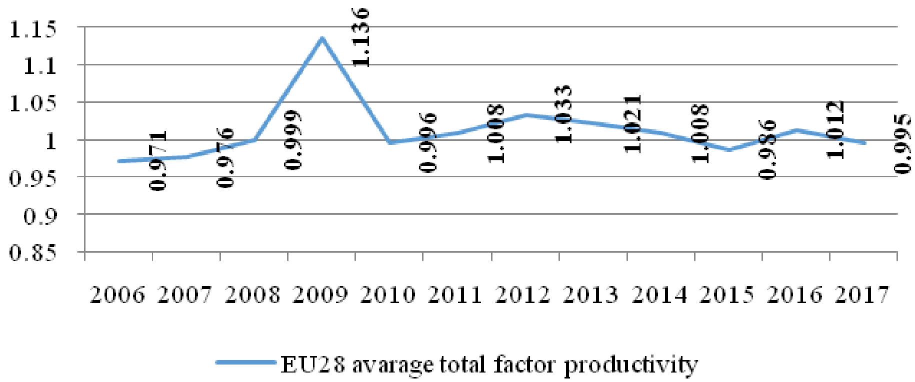
Table 2. Decomposition of average TFPCH for all countries in 2005-2018 period

	EFFCH	TECHCH	PECH	SECH	TFPCH
Austria	0.998	1.003	0.996	1.002	1.001
Belgium	0.996	1.006	0.993	1.003	1.002
Bulgaria	1.005	1.019	1.007	0.997	1.024
Croatia	0.996	1.023	0.995	1.001	1.019
Cyprus	0.993	1.012	1.006	0.987	1.005
Czech Republic	1.001	1.003	1.001	1	1.004
Denmark	1	1.004	1	1	1.004
Estonia	0.994	1.016	0.996	0.998	1.01
Finland	1.003	1.002	1.003	1	1.005
France	1.001	1.006	1	1.001	1.007
Germany	1	1.014	1	1	1.014
Greece	1.019	1.008	1.019	1	1.027
Hungary	0.999	1.022	0.999	1.001	1.022
Ireland	1.006	1.021	1.005	1.001	1.028
Italy	1	1.002	1	1	1.002
Latvia	1.008	1.017	0.964	1.045	1.025
Lithuania	0.985	1.021	0.989	0.996	1.006
Luxembourg	1	1.008	1	1	1.008
Malta	0.991	1.015	1	0.991	1.006
Netherlands	0.999	1.004	0.999	1	1.003
Poland	0.987	1.004	0.987	1	0.991
Portugal	1.011	1.017	1.01	1	1.028
Romania	0.989	1.01	1	0.989	1
Slovak Republic	1.009	1.016	1.009	1	1.025
Slovenia	1.021	1.004	1.022	0.999	1.025
Spain	1.006	0.995	1.006	1	1.001
Sweden	0.993	1.012	0.996	0.997	1.005
United Kingdom	1	1.011	1	1	1.011

Source: Author's calculations

In order to see the decomposition of the Malmquist Total Factor Productivity change for EU countries from the period 2005 to 2017, the EFFCH, TECHCH, PECH and SECH parts of TFPCH are given in Table 2. As seen in Table 2, from the period of 2005 to 2018, an increase in productivity in Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Germany, Hungary, Italy, Lithuania, Luxembourg, Malta, the Netherlands, Romania, Sweden, and the United Kingdom was revealed from the technical efficiency component of the total factor productivity index. Besides, an increase in productivity in Bulgaria, Czech Republic, Finland, France, Greece, Ireland, Latvia, Portugal, Slovak Republic, Slovenia and Spain arose from both components (efficiency change and technical change) of the total factor productivity index. The results also showed that scale efficiency (component of the efficiency change) increased in Austria, Belgium, Croatia, France, Hungary, Ireland and Latvia, decreased in Bulgaria, Cyprus, Estonia, Lithuania, Malta and Romania and did not change in Czech Republic, Denmark, Finland, Germany, Greece, Italy, Luxemburg, the Netherlands, Poland and Portugal.

Figure 4. EU28 average total factor productivity from 2005 to 2017



Source: Author's representation

Figure 4 shows the average total factor productivity values of the EU-28 countries. In the studied period, the technological developments, regulations, or positive changes in policy implementation that may increase efficiency occurred in 2009, 2011, 2012, 2013, 2014 and 2016, while the efficiency of the energy that was used in the output production process decreased in 2006, 2007, 2008, 2010 and 2015. In the process from 2006 to 2017, the energy efficiency values of the EU-28 countries increased by 1.1% on average. The most triggering factor for this increase was undeniably the improvement in energy performance that took place in 2009 under the influence of the global crisis. Due to the abundance of liquidity and restrictions in energy production, the increase in energy prices worldwide before the crisis led to a noticeable decrease in energy prices with the crisis as the demand for energy decreased (Dursun, 2011, p. 128). As this decrease in energy prices meant bearing lower costs for the same amount of output, it seems that there was a noticeable increase in efficiency in 2009. According to Zangheri *et al.* (2019), only 11-member states were able to reduce their final energy consumption (more than 1%) in the period 2011-2016. On this background, there are economic recoveries after the global crisis, population growth and increases in passenger and freight transportation. These developments coincide with the energy efficiency index values for the period 2011-2017 given in Figure 4.

The EU prepared two goals for its energy efficiency policies for the years 2016 and 2020 as two indicators but not binding ones. The target for 2016 determined in the early 2000s was limited to reducing the final energy usage in sectors outside EU-Emission Trade System (ETS) below 9%, while the target for 2020 was determined in 2007, i.e., to reduce primary energy usage by 20% in comparison to the main projections (IEA, 2016, p. 66). In December 2018, the Energy Efficiency Directive, which entered into force after being revised, set an energy efficiency target of at least 32.5% for 2030 in the EU-28 (European Commission, 2019). Based on these goals, considering the energy performances of the countries in the EU for 2016, 21 countries increased their energy efficiency or, in other words, the steps they took towards reaching these goals provided successful results.

Conclusions

This study measured the energy efficiency in 28 EU countries for the period 2005-2017 by using the Malmquist productivity index. The empirical results showed that, in the process of output production in the aforementioned period, the energy input used in these EU countries was used more efficiently by an increase of 1.1% on average. This value was increased especially by the decrease experienced in worldwide energy prices after the global crisis. While the general trend in these countries was that energy was used more efficiently, energy efficiency substantially differed from country to country, and even from year to year. Here, the most important reason was clearly that, although there is a mutual binding energy policy for EU countries, the countries in the Union implemented energy policies by considering their own dynamics, and their energy markets were different. While a part of the countries of the Union (e.g., Denmark, the United Kingdom, Poland) are able to meet their energy needs largely by their own resources, others (e.g., Ireland, Italy, Portugal, Spain) are largely dependent on other countries in terms of energy, and there are also those that are between these two opposite ends. These different structures of the member countries in terms of external dependence lead to substantial differences among their energy efficiency performances. Among these countries, it was observed that the best-performing countries were Ireland, Portugal and Greece, the lowest increases in efficiency were seen in Austria, Spain and Romania, and the only country whose efficiency decreased in the studied period was Poland. The reason for Poland’s failure in increasing its energy efficiency is believed to be its implementation and adoption of harmful energy policies based on fossil fuels. According to Eurostat (2021), primary energy consumption in EU countries decreased by an average of 10.5% in the period of 2016-2019. In the mentioned period, an average of 6.3% increase in primary energy consumption was achieved only in Poland. The fact that this composition in primary energy consumption is reflected in the energy efficiency results is supported by the findings obtained in the study. However, investigating what kind of policies other countries with good performance improvements have and how the member states differentiate in this matter is an issue for further study.

With this study, the phenomenon of energy efficiency, which is seen as an exit strategy by the EU, which focuses heavily on topics such as climate change, resource efficiency and external dependence, was comparatively analysed in the context of the member countries. It is believed that the results of the study may contribute to understanding which countries should prioritize increasing efficiency in their energy policies, as well as to determining what kind of policy should be followed in order to reach the Union's 2030 common goals and to reassess the environmental protection goals in the scope of these findings.

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