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Turkey's energy efficiency and its relative position against OECD and BRICS countries

Türkiye'nin enerji etkinliği ve OECD ve BRICS ülkeleri arasındaki göreli konumu

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Türkiye'nin Enerji Etkinliği ve OECD ve BRICS Ülkeleri Arasındaki Göreli Konumu

Araştırma Makalesi / Research Article

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ÖZ

Enerjiye olan talep günden güne artmaktadır ve aynı zamanda ekonomi de bu büyüme ile ele alınacak önemli bir konudur. Bu bakımdan, birçok ülke enerji yoğunluğunu (birim ekonomik çıktı için harcanan veya tüketilen enerji) azaltmak için önemli roller üstlenmektedir halbuki bu değişken uluslar arası karşılaştırmalar için sadece tek bir faktördür. Enerji yoğunluğu ile birlikte birçok parametre içeren bu çalışma ülkelerin enerji etkinliğini ölçmektedir ve bu ülkeler arasında Türkiye'nin konumunu belirlemektedir. Veri zarflama analizi (VZA) çoklu girdi ve çıktı kullanarak benzer türden karar verme birimleri (KVB) için etkinlik değerlendirme amaçlı kullanılan parametrik olmayan bir yöntemdir. Analizlerde, 2009–2013 dönemi için OECD ve BRICS (Brezilya, Rusya, Hindistan, Çin Halk Cumhuriyeti, Güney Afrika) ülkeleri kullanılmıştır. Bu dönem için, VZA analizlerinin dinamik seyrini izlemek üzere Malmquist verimlilik endeksi (MVE) yöntemi de kullanılmıştır. OECD (Ekonomik Kalkınma ve İşbirliği Örgütü) ve BRICS (Brezilya, Rusya, Hindistan, Çin ve Güney Afrika) ülkelerinin etkinlik analizi 2009 yılından 2013 yılına kadar yapılmıştır. Sonuçlar göre, etkin ülkeler OECD grubu ülkeler içerisindedir ve ortalama MVE ise dönem boyunca %1.4 kötüleşmiştir. OECD üyesi bir ülke olan Türkiye 0.048 değeri ile etkin bir ülke değildir ve MVE değeri tüm dönem boyunca %4.5 kötüleşmiştir. Çünkü enerji ithalatı Türkiye için son yıllarda önemli bir tehdit haline gelmiş olup, bulgular Türkiye'nin göreli konumunu görmede ve tedbir almasında yardımcı olacaktır. Sonuç olarak, Türkiye'nin etkinliğini arttırması için bazı önerilerde bulunulmuştur.

Anahtar Kelimeler: Enerji etkinliği, veri zarflama analizi, Malmquist verimlilik endeksi.

Turkey's Energy Efficiency and Its Relative Position against OECD and BRICS Countries

ABSTRACT

The demand for energy is growing day by day, and at the same time economy is an important issue to be handled with this growing. In this respect, many countries are undertaking significant roles to decline their energy intensities (energy supply or consumption per unit of economic output) whereas this variable may be single factor for the international comparisons. This study including many factors with the energy intensity measures energy efficiency of countries and positions Turkey among them. Data envelopment analysis (DEA) using multiple input and outputs is a non-parametric technique for the efficiency evaluation of a set of decision making units (DMUs). In the analyzes, the OECD and BRICS (Brazil, Russia, India, Democratic People of China and South Africa) countries were used for 2009–2013 period. For this period, the Malmquist productivity index (MPI) method was also used to observe the dynamic progress of DEA analyzes. The efficiency analysis of OECD (Organization for Economic Cooperation and Development) and BRICS (Brazil, Russia, India, China and South Africa) countries is conducted from 2009 to 2013. According to the results, the efficient countries are members of the OECD group and MPI of an average country worsens 1.4% over the period. As a member of OECD, Turkey is not efficient country with the score of 0.048 and Turkey's MPI also worsens 4.5% for the whole period. Because the energy imports have become a threat to Turkey's economy in recent years, the findings will be helpful guidance in seeing its relative position and in taking precautions. As a result of this study, it is given some suggestions to increase the efficiency of Turkey in the model.

Keywords: Energy efficiency, data envelopment analysis, Malmquist productivity index.

1. INTRODUCTION

The energy demand is growing because of the increase of world's population with the development of living standards so managing the issue of energy resources has been a hot topic on the national policy agenda of most developed countries. In this context, energy efficiency has became an important issue for policy makers at both national and international level [1]. In 2001, the BRICs acronym was first formulated paper titled "The World Needs Better Economic BRICs" and represents a significant share of the world's population and production. The other important group, OECD, establishing in 1961 is accepted as developed countries and has market economies work with each other. Total final energy consumption of this two group, in the scope of this work, is 73% of the world use in 2013 [2].

As a member of OECD and a candidate for EU, Turkey is a fast growing country and its economy and population are expanding each year so its energy demand increases accordingly. Total final energy consumption grew by an average 3.25% for Turkey per year from 2000 to 2014

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whereas this value is 0.03% for the OECD group. Besides, total electricity consumption grew by an average 5.48% for Turkey and 0.69% for the OECD group per year from 2000 to 2014 [2]. On the other hand, Turkey is a big energy importer so it needs to use energy resources efficiently [4,5].

To measure energy efficiency, several methods have been used ranging from single (e.g. energy intensity) to multi-criteria (e.g. DEA) approaches. The term "energy intensity" has been used since the 1990s and is measured as dividing primary or final energy consumption by GDP [3]. A decrease in energy intensity means that the desired economic output can be reached with less energy input. However, unless it is put together with other inputs such as labor force and/or capital, only using energy as input cannot produce economic outputs in the actual production process [6]. In the study of Zhou et al. [7], 100 DEA studies published in energy and environmental issues were classified over the period 1983–2006. The majority of relevant studies have used DEA-based modeling techniques to measure the energy efficiency since energy intensity has limited information.

New energy efficiency indexes can be defined by the DEA approach [8,9]. The DEA studies can be divided into two part: sector specific level such as in [1, 10-16] and macro level such as in [17-23]. In this study, an efficiency indicator is defined. As distinct from above studies, this paper including the multiple-inputs with the output of energy intensity evaluates the efficiencies of the OECD and BRICS countries in terms of static (DEA) and dynamic (MPI) and shows Turkey's position among the countries. Taking into account all the above works, there is no similar research in this area so the results are highly valuable for the countries having high energy depedency such as Turkey. By this way, it will be possible to inspect and develop the energy policies in an accurate manner in accordance with the results obtained.

This paper is organised into four sections: Methodology is described in Section 2. Section 3 presents the empirical results and discussion. Section 4 shows Turkey's current situation and give some suggestions. Section 5 concludes this study.

2. THEORY

2.1. Data Envelopment Analysis

DEA is the non-parametric mathematical programming approach and was developed by Charnes et al. [24] to determine the relative efficiency scores of decision making units (DMUs) with multiple outputs and multiple inputs. It provides a reasonable perspective for objectively evaluating the DMUs' performances. Generally, DEA models are divided into two types; that is, the type of scale effects (reference technology) and model orientation. There are two basic assumptions concerning the scale types in the model. The first one is constant returns to scale (CCR or CRS) introduced by Charnes et al. [24]. It estimates the overall technical efficiency (OTE) of each DMU. The second one is variable returns to scale (BCC or VRS) introduced by Banker et al. [25] and defines the pure technical efficiency (PTE) of each DMU. The relationship between PTE and OTE is defined as follow:

$$OTE = SE.PTE \quad \text{and} \quad PTE \geq OTE \tag{1}$$

That is, the BCC efficiency scores are always equal or higher from the CCR ones, and so scale efficiency (SE) is not greater than one. Either input or output-oriented models can be used, depending on which variable is the target. If the objective is to produce a given output using a minimum of inputs, an input-oriented model is selected. The mathematical equations of the input-oriented model based on CRS is as follows:

$$\min h_o = \theta_o - \varepsilon\sum_{i=1}^{m} S_{io}^{-} - \varepsilon\sum_{r=1}^{s} S_{ro}^{+} \quad \text{s.t.}$$

$$\left.\begin{array}{l}
\sum_{j=1}^{n}\lambda_j x_{ij} + S_{io}^{-} = \theta_o x_{io} \\
\sum_{j=1}^{n}\lambda_j y_{rj} - S_{ro}^{+} = y_{ro} \\
\lambda_j, S_{io}^{-}, S_{ro}^{+} \geq 0 \\
j = 1,...,n \qquad i = 1,...,m \qquad r = 1,...,s
\end{array}\right\} \tag{2}$$

Where the subscript o shows the DMU being assessed and h_o stands for efficiency score of DMU_o. x_{ij}, y_{rj} and λ_j stand for the input i and output r of DMU_j and weights, respectively. S_{io}^{-} and S_{ro}^{+} are the slacks in the i_{th} input and the r_{th} output and n, m and s are the number of DMUs, inputs and outputs, respectively. θ_o stands for the radial input shrinkage constant and ε represents a "non-Archimedean" arbitrary-infinitesimal.

If θ_o=1 and the slacks are zero, then the DMU_o under evaluation is on the efficient frontier. Otherwise, if θ_o<1 and/or the slacks are not zero, then the DMU_o under evaluation is inefficient. This DMU_o should decrease its input levels at a given outputs.

Although basic CCR or BCC DEA models can discriminate the performance of efficient DMUs from inefficient ones, they do not have the ability to distinguish between the efficient units. To rank the efficient DMUs, the CCR model of Charnes et al. [24] is modified by Andersen and Petersen [26] whose model is called "super efficiency". The DMU under assessment is excluded from the reference set in this method while the efficiency scores and weights remain unchanged for the inefficient DMUs. Based on CRS, the mathematical equations of the super efficiency in input-oriented model is as follows:

$$\left.\begin{array}{l} \min h_o^s = \theta_o - \varepsilon e S_{io}^- - \varepsilon e S_{ro}^+ \quad \text{s.t.} \\ \sum_{j=1,\neq o}^{n} \lambda_j x_{ij} + S_{io}^- = \theta_o x_{io} \\ \sum_{j=1,\neq o}^{n} \lambda_j y_{rj} - S_{ro}^+ = y_{ro} \\ \lambda_j, S_{io}^-, S_{ro}^+ \geq 0 \\ j=1,...,n \qquad i=1,...,m \qquad r=1,...,s \end{array}\right\} \tag{3}$$

Where the subscript h_o^s stands for super efficiency score of DMU$_o$ and e is a row vector with unity for all elements.

2.2. Malmquist Productivity Index

Efficiency scores are calculated for a specific time period but the change of efficiency by time is an important issue to be evaluated. Färe et al. [27] defined the output-based MPI between time t and $t+1$ as a geometric mean of the indexes proposed by Caves et al. [28]. Since the idea of calculating indexes by using the distance functions belongs to Sten Malmquist [29], Caves et al. [28] named their index as Malmquist.

The input distance function (D_I) used for MPI measurement is defined on the output set, P_t, as:

$$D_I^t(x^t, y^t) = \max\{\theta : (x^t/\theta, y^t) \in P^t\} \tag{4}$$

According to Färe et al. [30], input-oriented Malmquist productivity index is defined by using this function as follows:

$$M_I(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\left(\frac{D_I^t(x^{t+1}, y^{t+1})}{D_I^t(x^t, y^t)}\right) \cdot \left(\frac{D_I^{t+1}(x^{t+1}, y^{t+1})}{D_I^{t+1}(x^t, y^t)}\right)\right]^{1/2} \tag{5}$$

M_I (or MPI) is used to measure the total factor productivity change of DMU over time. $M_I > 1$, $M_I = 1$ and $M_I < 1$ respectively show that the productivity of DMU has made progress, remained unchanged and worsened from period t to $t+1$.

Färe et al. [30] showed that M_I (or *tfpch*) can be decomposed into two components which provides useful indexes for the study of efficiency change (*effch*) and technical change (*techch*) as follows:

$$tfpch = effch.techch \tag{6}$$

$$\left.\begin{array}{l} effch = \dfrac{D_I^{t+1}(x^{t+1}, y^{t+1})}{D_I^t(x^t, y^t)} \\ techch = \left[\left(\dfrac{D_I^t(x^{t+1}, y^{t+1})}{D_I^{t+1}(x^{t+1}, y^{t+1})}\right) \cdot \left(\dfrac{D_I^t(x^t, y^t)}{D_I^{t+1}(x^t, y^t)}\right)\right]^{1/2} \end{array}\right\}$$

(7)

effch measures the "catch-up" effect, in other words if a specific DMU is closer or further away from the production frontier between periods t and $t+1$. *techch* which depicts the technological progress or regression of DMUs from t to $t+1$ is known as the "frontier shift" effect.

3. EMPIRICAL STUDY

3.1. Material and Specification of Model

In this section, a new energy efficiency index including energy intensity is defined by the DEA approach. It is taken 33 OECD and BRICS countries as DMUs for the analysis. It can be said that their power structure and economic status represent the appeal of different kinds of countries. Mexico is excluded from the analysis due to the lack of data. The data period extends from 2009 to 2013 and variables of the countries are collected from the International Energy Agency (IEA) and the World Bank (WB). Energy intensity, electricity capacity, populations and energy data are taken from the IEA database [2] and labor and capital are obtained from the WB database [31]. Electricity capacity (W/capita), primary energy supply (toe/capita), final energy consumption (toe/capita), energy production (toe/capita), electricity consumption (MWh/capita), labor force/population and net capital account (USD/capita) are the seven inputs while energy intensity (per capita) is used as the only output.

To analyze efficiency and its change, DEA models including OTE, PTE, SE, super efficiency scores and MPI are used. For this purpose, the DEAP version 2.1 developed by Coelli [32] and the EMS version 1.3 developed by Scheel [33] software packs are used. Since the efficiency scores using the VRS reference technology are locally efficient, the analyses are conducted under the CRS assumption providing globally efficient scores, and so CRS-input oriented DEA model is implemented.

3.2. Results and Discussions

For the static analyses, the scores of OTE, PTE, SE and super efficiencies are calculated. If both OTE and PTE scores of a DMU are equal to 1.0 (or 100%), it is operating in the most productive scale size (MPSS). That is, when a DMU has the MPSS, its SE is 1.0. It implies that the DMUs having the MPSS transform the inputs into outputs excellently. As measured from Table 1, average OTE is 0.161 and average PTE is 0.858. Mean SE showing the potential productivity to be gained is 0.177. The scale and globally efficient countries are Estonia, Iceland and Luxembourg namely, they are operating on the MPSS. Turkey's OTE, PTE and SE scores are 0.048, 1.000 and 0.048, respectively. This means that OTE and SE scores of Turkey are under the average country and the reason of lower global efficiency (OTE) is deviations from the optimal scale. Many OECD countries has higher SE from BRICS and this indicates that BRICS' energy efficiency do not benefits from its economic scale such as China and India.

Table 1. CRS efficiency scores and benchmarks of the countries for the period of 2009–2013.

	Years	2009	2010	2011	2012	2013	Mean				Benchmarks in 2013
	Countries		Super efficiency score (%)				*Super*	*OTE*	*PTE*	*SE*	Peer and weights
1	Australia	2.30	2.02	2.07	2.14	2.01	2.11	0.021	0.786	0.027	13 (0.01) 19 (0.00)
2	Canada	1.67	1.52	1.52	1.56	1.46	1.55	0.016	0.739	0.021	13 (0.01) 19 (0.00)
3	Chile	16.52	17.42	18.07	17.22	15.74	16.99	0.170	0.867	0.196	13 (0.03) 22 (0.02)
4	Israel	22.22	21.23	20.37	24.39	17.81	21.20	0.212	0.893	0.237	13 (0.03) 22 (0.04)
5	Japan	0.74	0.74	0.96	1.09	1.12	0.93	0.009	0.926	0.010	13 (0.00) 22 (0.00)
6	Korea	3.28	3.33	3.45	3.51	3.57	3.43	0.034	0.803	0.043	13 (0.01) 22 (0.02)
7	New Zealand	12.35	11.39	12.19	13.83	13.44	12.64	0.126	0.726	0.174	13 (0.10) 19 (0.00) 22 (0.01)
8	United States	0.16	0.14	0.15	0.15	0.14	0.15	0.001	0.787	0.002	13 (0.00) 19 (0.00)
9	Austria	6.69	6.97	7.31	7.21	7.56	7.15	0.072	0.805	0.089	13 (0.02) 22 (0.03)
10	Belgium	8.04	8.02	7.65	7.96	8.20	7.97	0.080	0.871	0.092	13 (0.02) 22 (0.03)
11	Czech Republic	11.30	10.58	11.42	11.68	12.11	11.42	0.114	0.776	0.148	13 (0.08) 22 (0.02)
12	Denmark	5.58	5.33	5.57	5.88	5.99	5.67	0.057	0.799	0.071	13 (0.04)
13	Estonia	253.17	254.13	237.50	223.40	252.43	244.13	1.000	1.000	1.000	35
14	Finland	10.17	10.39	10.53	10.75	10.50	10.47	0.105	0.788	0.133	13 (0.06) 19 (0.00) 22 (0.04)
15	France	0.87	0.87	0.91	0.97	0.97	0.92	0.009	0.852	0.011	13 (0.00) 22 (0.00)
16	Germany	0.75	0.76	0.78	0.82	0.86	0.79	0.008	0.809	0.010	13 (0.00) 22 (0.00)
17	Greece	9.33	10.21	11.64	13.02	13.62	11.56	0.116	0.813	0.142	13 (0.03) 22 (0.02)
18	Hungary	21.30	21.58	22.09	23.36	23.68	22.40	0.224	0.851	0.263	13 (0.06) 22 (0.02)
19	Iceland	327.87	351.99	406.75	366.82	333.97	357.48	1.000	1.000	1.000	8
20	Ireland	17.26	17.10	17.61	19.59	16.94	17.70	0.178	0.965	0.185	13 (0.02) 22 (0.05)
21	Italy	1.83	1.82	1.87	1.85	1.87	1.85	0.019	0.905	0.021	13 (0.00) 22 (0.00)
22	Luxembourg	1052.42	1029.55	1097.98	1073.06	2664.37	1383.48	1.000	1.000	1.000	23
23	Netherlands	3.10	3.05	2.85	3.76	2.70	3.09	0.031	0.844	0.037	13 (0.02) 19 (0.00)
24	Norway	5.16	5.04	5.14	5.15	5.23	5.14	0.051	0.780	0.066	13 (0.03) 19 (0.01)
25	Poland	5.68	5.31	5.46	5.61	4.98	5.41	0.054	0.813	0.067	13 (0.02)
26	Portugal	14.89	13.63	15.05	17.21	16.93	15.54	0.155	0.779	0.199	13 (0.02) 22 (0.03)
27	Slovak Rep.	41.55	41.68	42.38	43.42	43.21	42.45	0.425	0.805	0.528	13 (0.12) 22 (0.09)
28	Slovenia	50.33	49.51	52.98	57.66	58.20	53.74	0.538	0.884	0.609	13 (0.23) 22 (0.12)
29	Spain	2.38	2.30	2.58	2.75	2.67	2.54	0.025	0.803	0.032	13 (0.00) 22 (0.01)
30	Sweden	4.42	4.35	4.50	4.47	4.45	4.44	0.045	0.802	0.056	13 (0.03) 19 (0.00) 22 (0.01)
31	Switzerland	4.42	4.47	5.38	4.78	4.85	4.78	0.048	0.914	0.053	13 (0.02) 22 (0.01)
32	**Turkey**	**4.77**	**4.62**	**4.72**	**4.98**	**4.79**	4.78	**0.048**	**1.000**	**0.048**	**13 (0.00) 22 (0.01)**
33	United Kingdom	0.68	0.64	0.70	0.80	0.82	0.73	0.007	0.826	0.009	13 (0.00) 22 (0.00)
34	Brazil	1.65	1.44	1.51	1.68	1.52	1.56	0.015	0.917	0.017	13 (0.00)
35	P.R. of China	0.54	0.44	0.44	0.44	0.39	0.45	0.004	0.888	0.005	13 (0.00)
36	India	2.29	1.81	1.70	1.75	1.58	1.83	0.018	1.000	0.018	13 (0.00)
37	Russian Fed.	2.50	2.26	2.50	2.68	2.43	2.47	0.025	0.799	0.031	13 (0.02)
38	South Africa	8.22	7.21	7.80	8.23	7.40	7.77	0.078	0.990	0.078	13 (0.03)

According to the super efficiency scores, the value of scores higher than 100% refer to efficient units. As can be seen in Table 1, for inefficient DMUs, the reference DMUs with corresponding peers and weights can be used as ancillary instrument in order to determine the target values. But, the output is calculated as a necessity of the model in input-oriented DEA models used for solution. Namely, this is a undesired situation for the specific problem of energy intesity. For that reason, it is not recommended that inefficient countries increase their energy intesities. Instead, it can only be suggested that they recover the redundancies in inputs. Turkey is inefficient country and its references are Estonia and Luxembourg. As known, in any economy, energy use are strongly connected to the level of economic growth and economic activity. So, the problem of energy import dependency and its negative effects on the economy are the considerable factors in Turkey.

On average, the most efficient country is Luxembourg and the other super efficient countries are Iceland and Estonia as members of OECD. The economical parameters of Luxembourg's remained very strong with a prompt recovery after the economical crisis of 2009 so its performance can be explained by its strong economic welfare [20, 34]. At the same time, this finding may result from some government policies such as promoting energy-efficient new buildings, energy performance of building regulations, the renovation of older ones and decentralized renewable energy sources [35]. It is a striking result that the BRICS group has low performance although it takes a pivotal positon in the global economy and in the energy consumption/production.

For the analyses in the time horizon, the score of *tfpch* is calculated. Following the idea of Färe et al. [36] for international growth comparison, Figure 1 shows the geometric mean of *tfpch* estimates which can also stand for the cumulative MPI to a certain extent and presents Turkey's and countries' efficency changes by year. A value of the index higher than 1 depicts the productivity improvement, for example 1.045 means a 4.5% increase in *tfpch* from 2012 to 2013 and vice versa. *tfpch* of Turkey is below the average country and the OECD group and there is no significant rising in its efficiency from 2009 to 2013. *tfpch* improvement of the OECD group has higher than the BRICS group but the value is inconsiderable.

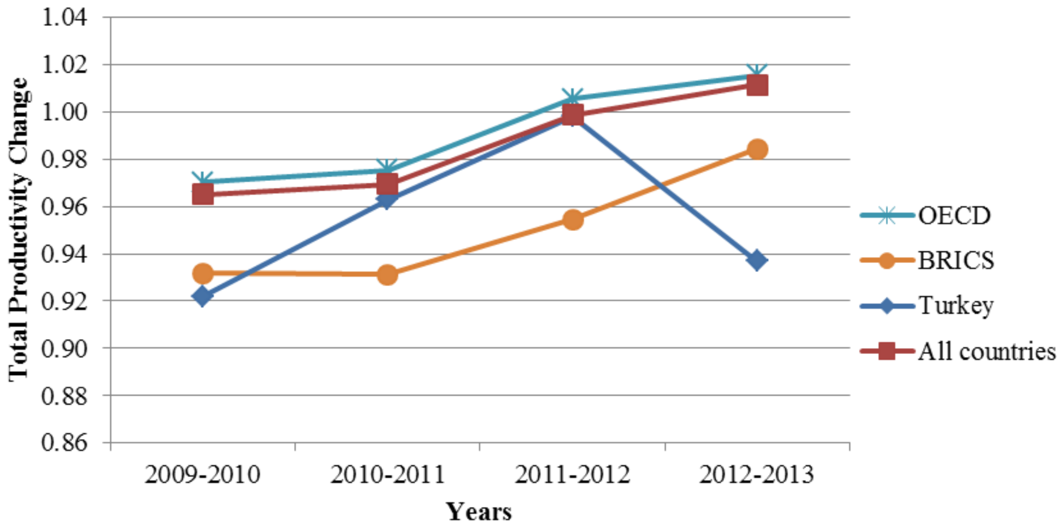

Figure 1. The total factor productivity change of the countries by the years.

However, global financial crisis triggered by the subprime credit problem in the period of 2007–2009 can be negative effects on the countries in 2009 and in 2010. In other words, it can be stated that countries overcomed economic shock with a one-or two-year time lag. The smallest average *tfpch* appears in period 2009/2010 together with the economic recession effects.

Chien and Hu [37] argue that an economy's technical efficiency can be significantly improved by substituting traditional energy with renewable energy. In this sense, Turkey has poor conventional energy resources such as natural gas and oil. Turkey's main energy resources are the low-quality lignite and hydrolic but Turkey has high of renewable energy potential that is to say, renewable sources, clean and not dependent on foreign countries, are still under-utilized [5]. For the potential performance to be gained, Turkey should evaluate its energy potential with proper policies year by year.

Table 2 presents *tfpch* of countries for the whole period in detail. As can be seen from the Table, most of their average values are lower than 1. The empirical results show that the total productivity of the countries decreases 1.4% over the period. Among them, Luxembourg has the highest value with an average annual increase of 39% and Turkey's productivity worsens 4.5% for the whole period. No countries continuously improve efficiency throughout the time period and this trend shows that nations do not struggle to improve efficiency during the study period generally. For developing countries with rapid economic growth, for instance Turkey, the optimization of power structure and usage of renewable energy are the important issues, but for developed countries with steady growth, more efforts on developing new technology will help them gain higher MPI.

As aforementioned, *tfpch* can be divided into two components as efficiency change and technological change. This distinction provides useful information for policy purposes [30]. Table 3 presents *effch* and *techch* values of countries. According to the Table, Luxembourg's growth are due to improvements in technological change. Considering the average values over the period, *effch* and *techch* has almost same effect in total productivity change of Turkey and there is a slight difference *techch* and *effch* in total improvement of growth. According to Färe et al. [36], *techch* component is related to capture diffusion of technology and *effch* implies whether the corresponding country is approaching the production frontier (optimum scale). In the period of 2012–2013, the average *techch* of all countries is 1.052 as the highest estimation, indicating a 5.2% growth in average *techch*. The lowest *effch* estimation is 0.961, indicating a 3.9% decrease in average *effch* from 2012 to 2013. As expected, many OECD countries have the highest growth in *effch* for the entire study period, because they have the competitive advantage of developing renewable energy technology, energy efficiency strategies and economic cooperation.

Table 2. The total factor productivity change of the countries for the period of 2009–2013.

Countries	2009-2010	2010-2011	2011-2012	2012-2013	G.Mean
Australia	0.944	0.962	0.978	0.997	0.970
Canada	0.966	0.967	0.970	0.964	0.967
Chile	1.012	0.974	0.903	0.897	0.945
Israel	0.916	0.904	1.157	0.709	0.908
Japan	0.961	1.223	1.118	0.984	1.066
Korea	0.984	0.975	0.961	0.993	0.978
New Zealand	0.954	0.985	1.074	0.979	0.997
United States	0.969	0.973	0.956	0.996	0.973
Austria	0.995	0.977	0.945	1.026	0.985
Belgium	1.000	0.877	0.969	1.014	0.963
Czech Republic	0.988	0.968	0.964	1.042	0.990
Denmark	1.007	0.960	1.013	1.007	0.997
Estonia	1.027	0.921	0.924	1.044	0.977
Finland	1.036	0.938	0.979	0.965	0.979
France	0.966	0.962	0.998	0.985	0.978
Germany	0.977	0.961	0.995	1.020	0.988
Greece	1.054	1.059	1.064	1.030	1.052
Hungary	1.014	0.937	0.977	1.018	0.986
Iceland	1.036	1.016	0.960	0.988	1.000
Ireland	0.950	0.978	1.086	0.836	0.958
Italy	0.963	0.966	0.955	0.976	0.965
Luxembourg	0.652	0.964	1.202	4.958	1.391
Netherlands	1.074	0.847	1.230	0.766	0.962
Norway	1.006	0.965	0.977	1.003	0.988
Poland	1.019	0.927	0.930	0.968	0.960
Portugal	0.883	1.039	1.097	0.960	0.991
Slovak Republic	0.972	0.942	0.970	0.976	0.965
Slovenia	0.987	0.976	1.016	0.990	0.992
Spain	0.935	1.051	1.016	0.948	0.986
Sweden	0.978	0.961	0.965	0.996	0.975
Switzerland	0.981	1.138	0.866	0.994	0.990
Turkey	**0.922**	**0.963**	**0.998**	**0.937**	**0.955**
United Kingdom	0.984	1.002	1.069	1.017	1.018
Brazil	0.954	0.944	1.010	0.987	0.973
P.R. of China	0.896	0.905	0.897	0.982	0.919
India	0.864	0.848	0.932	0.984	0.905
Russian Federation	0.994	0.992	0.982	0.989	0.989
South Africa	0.956	0.974	0.956	0.980	0.966
G. Mean	0.965	0.969	0.999	1.011	0.986

4. THE EVALUATION OF TURKEY'S STATUS

The obtained results are high valuable for shaping Turkey's energy policy so this section focuses on the primary objectives of increasing energy efficiency and utilizing domestic resources. In order to assess the success of Turkey's energy and economy policies, this study provides a proper monitoring and comparative mechanism. The current situation of Turkey also reinforces the validity of the DEA scores.

In Turkey, the value of energy intensity (0.18 toe per thousand 2005 USD) and the electric power transmission and distribution losses (15.4% of output) are significantly higher than that of the OECD countries on average in 2013. Figure 2. shows the distribution of energy intensity and consumption according to the countries. As it can be seen, BRICS countries have energy-intensive economies [2,31]. According to the Energy Efficiency Strategy Paper [38], Turkey's target is a 20% reduction of energy intensity by 2023 (0.14) compared to the values for 2011 (0.18).

Table 3. Efficiency and technological changes of the countries for the period of 2009–2013.

	effch				*techch*			
Countries	2009-2010	2010-2011	2011-2012	2012-2013	2009-2010	2010-2011	2011-2012	2012-2013
Australia	0.877	1.025	1.033	0.941	1.076	0.939	0.947	1.060
Canada	0.908	1.003	1.025	0.934	1.064	0.963	0.946	1.033
Chile	1.052	1.041	0.949	0.915	0.962	0.936	0.951	0.981
Israel	0.956	0.961	1.201	0.727	0.958	0.940	0.963	0.975
Japan	1.001	1.294	1.142	1.021	0.960	0.945	0.979	0.964
Korea	1.017	1.036	1.012	1.020	0.968	0.941	0.950	0.974
New Zealand	0.923	1.071	1.134	0.972	1.034	0.920	0.947	1.007
United States	0.906	1.021	1.010	0.953	1.069	0.953	0.946	1.045
Austria	1.043	1.046	0.987	1.048	0.953	0.934	0.957	0.979
Belgium	0.998	0.954	1.040	1.031	1.002	0.920	0.932	0.983
Czech Republic	0.937	1.078	1.023	1.037	1.055	0.898	0.942	1.005
Denmark	0.955	1.044	1.056	1.019	1.054	0.920	0.959	0.988
Estonia	1.000	1.000	1.000	1.000	1.027	0.921	0.924	1.044
Finland	1.024	1.013	1.023	0.974	1.012	0.926	0.957	0.991
France	0.999	1.043	1.065	0.999	0.967	0.923	0.937	0.986
Germany	1.013	1.034	1.051	1.039	0.964	0.929	0.947	0.981
Greece	1.094	1.137	1.123	1.049	0.963	0.931	0.947	0.983
Hungary	1.013	1.026	1.056	1.016	1.002	0.913	0.925	1.003
Iceland	1.000	1.000	1.000	1.000	1.036	1.016	0.960	0.988
Ireland	0.995	1.028	1.112	0.863	0.954	0.951	0.976	0.969
Italy	1.006	1.023	0.991	1.002	0.957	0.944	0.964	0.975
Luxembourg	1.000	1.000	1.000	1.000	0.652	0.964	1.202	4.958
Netherlands	0.984	0.933	1.320	0.720	1.091	0.908	0.932	1.064
Norway	0.979	1.018	1.002	1.016	1.027	0.948	0.975	0.987
Poland	0.935	1.029	1.027	0.888	1.090	0.901	0.906	1.090
Portugal	0.921	1.106	1.141	0.984	0.959	0.940	0.961	0.976
Slovak Republic	1.009	1.014	1.027	0.993	0.964	0.929	0.945	0.983
Slovenia	0.985	1.069	1.089	1.006	1.002	0.913	0.933	0.984
Spain	0.973	1.122	1.063	0.969	0.961	0.937	0.956	0.978
Sweden	0.985	1.035	0.993	0.995	0.994	0.928	0.972	1.000
Switzerland	1.014	1.203	0.888	1.015	0.968	0.946	0.976	0.979
Turkey	**0.972**	**1.027**	**1.044**	**0.959**	**0.949**	**0.938**	**0.956**	**0.977**
United Kingdom	0.938	1.099	1.142	1.027	1.050	0.912	0.936	0.990
Brazil	0.875	1.047	1.116	0.905	1.090	0.901	0.906	1.090
P. R.of China	0.821	1.004	0.991	0.901	1.090	0.901	0.906	1.090
India	0.792	0.941	1.029	0.903	1.090	0.901	0.906	1.090
Russian Federation	0.906	1.105	1.071	0.907	1.096	0.897	0.918	1.090
South Africa	0.877	1.081	1.056	0.899	1.090	0.901	0.906	1.090
G.Mean	0.963	1.043	1.051	0.961	1.002	0.929	0.950	1.052

The energy import has direct or indirect effects on increasing an economy's GDP and trade balance [37]. In Turkey, the sharp increase in energy demand by reasons of development and population growth have been continue recently. The demand is also excepted to be an increase in the following years. However, this increase brings with the problem of import dependency especially in fossil fuels. While the economy is to continue its fast growth, the issue of energy dependence is bound to be more acute in the near future as shown in Figure 3 [39]. To overcome the foreseeable risks of energy supply and external shocks to the economy, the government is currently pursuing a number of policies which mainly are the maximum usage of domestic sources and energy efficiency applications [40].

As can be seen in Table 4 in detail, Turkey has substantial amount of renewable energy capacity among EU members, so this source can meet the energy demand of Turkey in the future. Turkey endeavors to be a full-member of the EU so the priorities and goals of the EU also affect Turkey. According to the directive 2009/28/EC of the European parliament, ambitious targets are determined for all member states, such that the EU will reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. It also establishes the content for national renewable energy action plans and the methodology for their preparation. In this regard, the Turkish Ministry of Energy and Natural Resources (MENR) has prepared a national "Renewable Energy Action Plan" for the period 2013–2023. Substantial amount of electricity is generated from fossil fuels, especially from imported natural gas, and this means increasing trade deficit and lack of source diversity. According to the Action Plan, Turkey's target is 30% of total electricity production from renewable sources and the objective is a maximum share of natural gas in the production mix, which is 30% by 2023 [41].

Table 4. Turkey's renewable energy installed power and potential.

Source type	Electricity Install Power (MW, End of 2016)	2023 Target (MW)	Total Potential (MW)
Hydrolic	26515	34000	36000
Wind	5387	20000	48000
Solar	792	5000	50000
Geothermal	775	1000	2000
Biomass	465	1000	2000

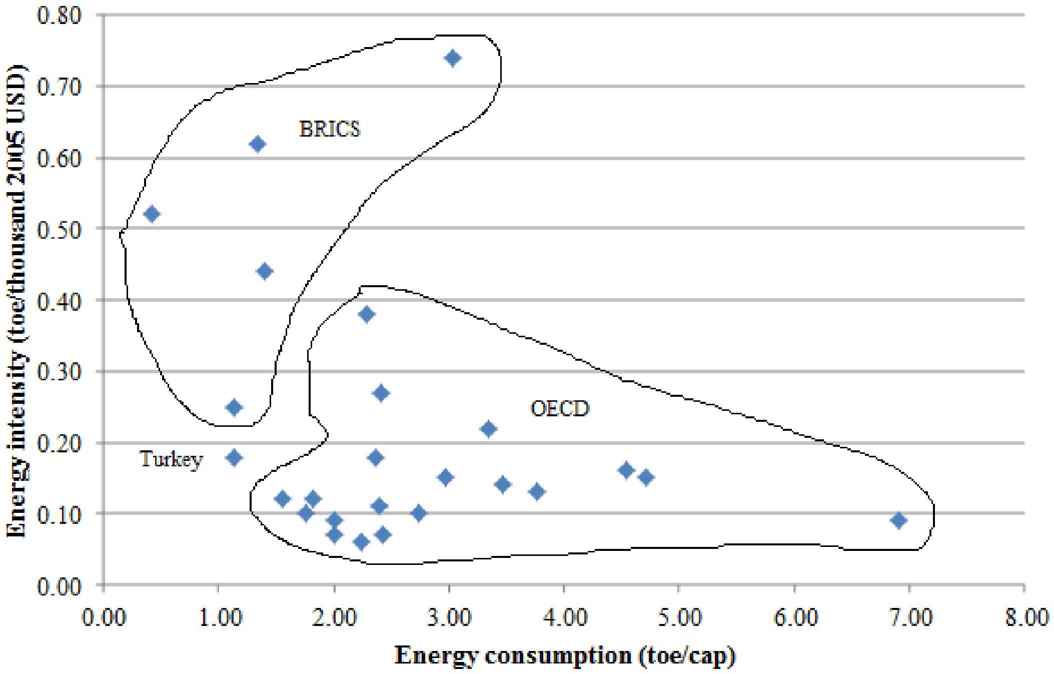

Figure 2. Energy consumption and energy intensity in some countries (in 2013).

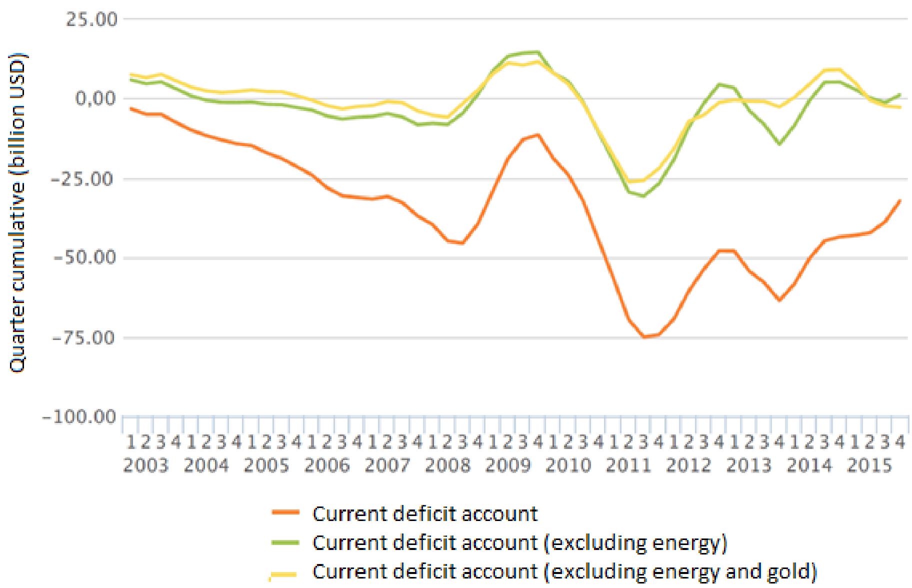

Figure 3. The current deficit account of Turkey by year.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

DEA provides insights into the reasons for the sources of inefficiency to help the design of national policies and MPI gives a good perspective for evaluating efforts of countries in a time horizon as well. This paper applies DEA combined with MPI in order to benchmark OECD and BRICS countries by multiple criteria and determines Turkey's situation over the period 2009–2013. To analyze the efficiencies, DEA models including BCC, CCR and super-efficiency approches are used.

On the basis of DEA analysis results, Luxembourg, Iceland and Estonia may be considered as super-efficient DMUs from the OECD group. Considering the SE scores, it can be said that the countries have operating problems in optimum scale. The total productivity growth of Turkey and the countries worsen with values of 4.5% and 1.4% on average, respectively. It can also be seen that the efficiency scores of the OECD countries are higher on average than the BRICS countries, but Turkey is inefficient country with score of 0.048 as an OECD member. As a result, the developments with economic cooperation including greater energy efficiency promote the OECD economies [42]. On the other hand, the BRICS governments should put the energy-intensive industries as the key industries and encourage a more effective use of the energy by the development of new technology.

The existing problem of the current account deficit in the country is largely owing to energy import needs in Turkey. Considering large amount of energy import, Turkey should take into account analysis results and evaluate its resource endowments. Besides, the role of energy efficiency will be very important for Turkey in the near future to overcome the issues of import dependence in energy and making its economy more competitive. The current government projections indicate a rapid increase in the energy demand of the country in the next years. In this respect, the results achieved are highly valuable to determine the roadmap including foreign policy for Turkey. On the other hand, Turkey is a fast developing country and a regional power in the Middle East and North Africa (MENA) region. It is surrounded by the Central Asia, Middle East and Europe, that is to say, this area is very important both geographical location and economic activities. Turkey is also an important candidate to be the "Energy Corridor" for transmission of the natural gas resources and rich oil of Middle East, Asian countries and Caspian Area to the Mediterranean countries and to the demand centers of the West side. As a result, energy performance also depend on energy diplomacy so the influence of these factors on the empirical results should be evaluated carefully to increase the performance. In Figure 4, a flowchart has been proposed to increase the energy performance of Turkey within the scope of this study. However, this study may enable governments to review their energy policies by considering simultaneously inputs and outputs in the evaluation of targets with the purpose of increasing efficiency.

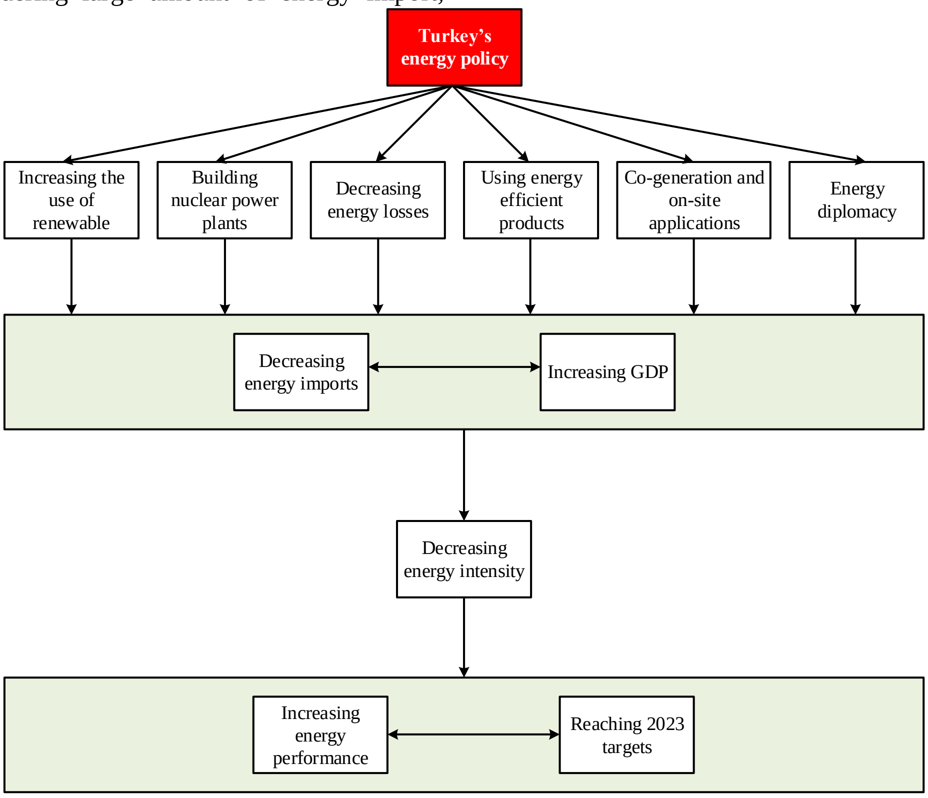

Figure 4. The flowchart for fundamental planning criteria for energy efficiency

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