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Efficiency Evaluation of Energy Companies with Data Envelopment Analysis

Veri Zarflama Analizi ile Enerji Şirketlerinin Etkinlik Değerlendirmesi

Abstract

The increasingly competitive environment in recent years has led businesses to use their resources more effectively. As in many other sectors, the efficient use of resources in the energy sector is essential for companies to ensure their sustainability. In recent years, disasters such as the COVID-19 global epidemic and the Russia-Ukraine war have adversely affected the energy and food sectors. The increase in energy and food prices and high inflation worldwide have revealed the necessity of using resources more efficiently and effectively. This study aims to measure the efficiency of companies operating in the energy sector in Turkey using the Data Envelopment Analysis (DEA) method. The efficiency analysis of fifteen energy companies was carried out using the input-oriented CCR model and Super Efficiency (SE)- CCR model. The number of personnel and total assets were used as input variables for the research, and net sales was used as output variables. As a result of the study, it has been determined that 4 of the energy companies were efficient and 11 were not. The most efficient company was determined according to the SE-CCR model efficiency results. According to these results, some suggestions have been put forward for inefficient businesses to be efficient.

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Özet

Son yıllarda giderek artan rekabetçi ortam işletmeleri, kaynaklarını daha etkin kullanmaya yönlendirmektedir. Diğer birçok sektörde olduğu gibi enerji sektöründe de kaynakların etkin bir şekilde kullanılması şirketlerin sürdürülebilirliklerini sağlamaları açısından oldukça önemlidir. Son yıllarda dünya genelinde meydana gelen COVID-19 gibi küresel hastalıklar, Rusya-Ukrayna savaşı ve diğer birçok felaket enerji ve gıda sektörünü olumsuz bir şekilde etkilemiştir. Dünya genelinde enerji ve gıda fiyatlarında yaşanan artış ve yüksek enflasyon, bu iki kaynağın daha verimli ve etkin bir şekilde kullanılması zorunluluğunu ortaya çıkarmıştır. Bu çalışmada, Türkiye'de enerji sektöründe faaliyet gösteren firmaların Veri Zarflama Analizi (VZA) yöntemi kullanılarak etkinliğinin ölçülmesi amaçlanmıştır. Çalışmada on beş farklı enerji firmasının etkinlik analizi girdi odaklı CCR modeli ve girdi odaklı Süper Etkinlik CCR modeli kullanılarak gerçekleştirilmiştir. Araştırma girdi değişkenleri olarak, personel sayısı ve toplam aktifler, çıktı değişkeni olarak ise net satışlar kullanılmıştır. Çalışma sonucunda dört enerji firması etkin olarak bulunurken, geriye kalan on bir enerji firması ise etkin bulunmamıştır. SE-CCR modeli etkinlik sonuçlarına göre en etkin firma belirlenmiştir. Araştırma sonuçlarına göre etkin olmayan işletmelerin etkin olabilmesi için bazı öneriler ortaya konmuştur.

Introduction

Energy, which is a fundamental resource for the survival and development of people, is a concept related to the long-term development of countries (Wang et al., 2021: 1). Due to the concerns about energy security and global warming, the issue of energy efficiency is of great interest to researchers and government administrators (Guo et al., 2017: 392). The concept of energy efficiency

is expressed as reducing and managing the increase in energy consumption. In recent years, energy policymakers worldwide have focused on improving energy efficiency (Jebali et al., 2017: 991).

Energy efficiency is a global issue that has an important place in developing countries. The use rate of clean energy and awareness of clean energy has been increasing in recent years. Despite the sensitivity shown on clean energy, approximately 80% of the energy used worldwide is obtained from fossil sources such as oil and natural gas (Xu et al., 2020: 1). Therefore, worldwide energy efficiency and its environmental impact deserve more attention (Yang and Wei, 2020: 439).

Limiting energy use and keeping it at optimum levels is very important as it helps to reduce energy use and reduce Green House Gas (GHG) emissions. Energy efficiency is one of the most important factors for countries to achieve green economic development and low GHG (Yuan et al., 2023: 600-602).

Low energy efficiency causes the economy, environment and energy development to be incompatible. Therefore, energy efficiency and the factors affecting energy efficiency have emerged as an essential research topic for the concept of green development in recent years (Zhang and Chen, 2022: 1). It is possible to say that it is vital to evaluate the efficiency of energy companies for the protection of the world and the better use of resources.

In the literature, it is possible to come across many studies in which DEA method is used in many different fields (Liu et al., 2013: 896; Emrouznejad and Yang, 2018; Karakonas, 2019; Selamzade, 2020; Ersoy and Tehci, 2020; Selamzade and Özdemir, 2020; Sarıçam and Yilmaz, 2021; Selamzade and Özdemir, 2021; Yüksel, 2021; Ersoy et al., 2021; Selamzade and Baghirov, 2022; Panwar et al., 2022 ;Krejnus et al., 2023; Selamzade et al., 2023; Toolo et al., 2023).

In the literature, as in many other fields, there are studies carried out using the DEA method in the energy sector (Khoshroo et al., 2013; Arabi et al., 2016; Guo et al., 2017; Jebali et al., 2017; Yang and Wei, 2019; Djordjevic and Krmac, 2019; Yu and He, 2020; Xu et al., 2020; Wang et al., 2021; Zhang and Chen, 2022; Talep, 2023; Yuan et al., 2023; Shah et al., 2023; Yu and Tang, 2023; Karasek et al., 2023). In this context, it is aimed to measure the efficiency of fifteen companies operating in the energy sector in Turkey with the Data Envelopment Analysis (DEA) method. The remainder of the study is designed as follows. In the second part, the method of the study and the data set are mentioned. In the third chapter, the findings of the study are given. In the fourth chapter, a general evaluation of the study was made and suggestions were made for future studies.

1. Method

Data Envelopment Analysis (DEA) is a linear program-based method used to evaluate the performance of decision-making units that produce various outputs with similar characteristics using different inputs with similar traits (Sarı, 2018: 254; Şengül, 2020).

Performance analysis is a concept used to determine the extent to which companies use their resources effectively and efficiently (Ersoy and Tehci, 2020: 4). Performance measurement is used to continuously monitor and evaluate the operations of organizations so that they can increase their efficiency and performance (Karakonas, 2019: 255). Performance measurement is an essential element of the continuous process and business operations of measuring and developing strategies aligned with a company's vision and mission (Herath et al., 2023: 683).

The DEA method is a widely used method for performance or efficiency measurement among performance dimensions (Doğan, 2015: 192). Efficiency measurement is an advantageous and necessary measurement method used to compare the performance of companies with their competitors and to improve their business and processes based on performance (Malik et al., 2018: 2).

DEA models are divided into two in terms of returns to scale. Charnes, Cooper and Rhodes (1978) originally proposed the efficiency measurement of DMUs for constant returns to scale, where all DMUs operate at an optimal scale. Later, Banker, Charnes and Cooper (1984) introduced the variable return to scale productivity measurement model to the literature, which allows dividing efficiency into technical and scale activities in the DEA method (Ji and Lee, 2010: 268). Charnes, Cooper and Rhodes (1978) developed the first DEA model, the CCR. Banker, Charnes, and Cooper

(1984) developed the CCR model to operate under variable returns to scale and introduced the BCC model to the literature.

There are two different versions of CCR and BCC models input-oriented and output-oriented (Doğan, 2015: 192-195; Kar and Demireli, 2021: 124-126; Ersoy, 2021: 1808). DEA method has a wide application area such as the public sector, banking, education, energy systems, transportation, supply chains, agriculture and livestock, sports, logistics and transportation, tourism, communication, health, real estate, e-commerce, automobile, forestry (Karakonas, 2019; Ersoy and Tehci, 2020; Panwar et al., 2022; Ersoy, 2021b; 31).

In this study, efficiency measurements were carried out with the input-oriented classic CCR model and input-oriented SE-CCR model. The input-oriented CCR model (Cooper et al., 2011: 9; Xu and Ouenniche, 2012: 579; Ersoy, 2021a: 1809; Ersoy, 2021b; 31) and input-oriented SE-CCR model ((Seiford and Zhu, 1999: 175; Xu and Ouenniche, 2012: 580; Ersoy, 2021a; 1809; Ersoy, 2021b; 31) can be seen in Table 1.

Table 1. Input-Oriented CCR Model and SE-CCR Model

Classic Input-Oriented CCR Model	Input-Oriented SE- CCR Model
$\min \theta_t$ $s.t.$ $\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_t x_{it}, \quad i = 1,\ldots,m$ (1) $\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rt}, \quad r = 1,\ldots,s$ $\lambda_j \ge 0, \quad j = 1,\ldots,n$	$\min \theta_t$ $s.t.$ $\sum_{\substack{j=1 \\ j \ne t}}^{n} \lambda_j x_{ij} \le \theta_t x_{it}, \quad i = 1,\ldots, m$ (2) $\sum_{\substack{j=1 \\ j \ne t}}^{n} \lambda_j y_{rj} \ge y_{rt}, \quad r = 1,\ldots, s$ $\lambda_j \ge 0, \quad j = 1,\ldots, n$

According to the CCR model given in Table 1, the efficiency score must be "1" for the decision-making units to be efficient (Ersoy and Tehci, 2020: 4). The SE-CCR model was used to rank the efficient DMUs. Based on the literature review and interviews with experts in the field of energy; the number of personnel and total assets, and net sales as output variables were determined as variables to be used in the study. Data on two input variables and one output variable, which make up the data set of the study, were obtained from the Fortune 500 website (www.fortuneturkey.com).

2. Results and Discussion

Efficiency evaluation was made by using the DEA method of fifteen different companies in the energy sector and included in the FORTUNE 500 list. Two input and one output variable were used in the data envelopment analysis. Data envelopment analysis was performed using the EMS 1.3.0 computer program. The CCR model efficiency results and SE-CCR model efficiency results of energy companies for 2021 are shown in Table 2. In the research, the number of personnel and total assets were used as input and net sales was used as output.

Table 2. Efficiency Scores of Energy Companies

DMU Number	CCR	SE-CCR
D1	0,44	0,44
D2	1,00	1,34
D3	0,30	0,30
D4	0,75	0,75

D5	0,32	0,32
D6	0,46	0,46
D7	0,70	0,70
D8	0,76	0,76
D9	1,00	1,11
D10	1,00	2,02
D11	0,33	0,33
D12	0,09	0,09
D13	0,71	0,71
D14	1,00	1,05
D15	0,56	0,56
Mean	0,63	0,74

As can be seen in Table 2, energy companies with decision-making units (DMUs) are expressed as D1, D2, D3,…., D15, respectively. The second column of Table 2 includes the efficiency scores of the CCR model. The third column of Table 2 includes the efficiency scores of the SE-CCR model. It is understood from table 2 that the efficiency scores of the CCR model of the inefficient firms are the same as the efficiency scores of the SE-CCR model.

When Table 2 is examined, it is seen that companies D2, D9, D10 and D14 with efficiency scores of "1" are efficient. Eleven energy companies with an efficiency score of less than "1" are inefficient. According to the results of the input-oriented DEA analysis, the average efficiency score is 0.63 and the firm with the lowest efficiency score is D3 with an efficiency score of 0.30. According to the SE-CCR efficiency scores, it is seen that the D10 firm is in first place with an efficiency score of 2.02.

Conclusion

In this study, the efficiency measurement of fifteen companies in the energy sector and included in the Fortune 500 list was made. Efficiency analysis in the research was carried out using the DEA method. Input-oriented CCR model and input-oriented SE-CCR model were used for efficiency measurement.

Four energy companies were efficient in the DEA efficiency results using two input variables and one output variable. According to the results of the SE-CCR model, these four companies were ranked and the most efficient company was determined. Since the input-oriented CCR model is used in the study, it may be possible to make inferences about the improvements that can be made for the input variables "number of personnel" and "total assets" by keeping the output variable constant.

According to the results of the analysis, inefficient energy companies need to reconsider their sustainability strategies, the number of personnel, the working performance of the personnel, their strategies to combat competitors, financial management techniques, quality policies, and cooperation with other companies. Inefficient enterprises should take efficient energy companies as references to be efficient. Inefficient businesses need to keep their personnel numbers at optimum levels or increase their personnel performance. It is recommended that inefficient firms keep their total assets at a similar level to efficient firms.

Since the results of the research depend on the input and output variables used in the analysis, if the input and output variables change, the analysis results may change. When evaluated from this point of view, it is useful to remember that the efficiency results with DEA are relative.

Efficiency measurements can be carried out in different sectors by using different input and output variables in future studies. Furthermore, studies in which different methods are used together with the DEA method can also be carried out.

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