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EVALUATION OF THE FINANCIAL PERFORMANCE OF ELECTRICITY GENERATION COMPANIES USING THE GREY RELATIONAL ANALYSIS METHOD

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Abstract

In the study, 10 electricity generation companies on the Fortune 500 list were examined using nine criteria. The aim of the study was to determine the financial performances of the companies with the entropy-weighted Grey Relationship Analysis (GRA) method by obtaining the 2021 data of the criteria from the websites of the relevant companies. As a result of the weighting made by the entropy method, it was determined that the most important criterion was the export income. These criteria were determined as equity, total assets, net sales, asset turnover, equity turnover, profit before interest/tax change in profit before interest/tax, and as change in net sales respectively. Then, the GRA method was used to rank the alternatives. Enka company was determined to be the best electricity generation company with the highest degree of relationship. This company was followed by Enerjisa, Akenerji, İçdaş, Aksa, Zorlu, Limak, Odaş, Gama and Çelikler respectively.

Keywords ***:*** *Financial performance, Electricity Generation Companies, Entropy, Grey Relationship Analysis*

JEL Classifications ***:*** *C44, M10, Q40*

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ELEKTRİK ÜRETİM ŞİRKETLERİNİN FİNANSAL PERFORMANSININ GRİ İLİŞKİSEL ANALİZ YÖNTEMİ İLE DEĞERLENDİRİLMESİ

Öz

Çalışmada, Fortune 500 listesindeki 10 elektrik üretim şirketi dokuz kriter altında ele alınmıştır. Çalışmanın amacı, ilgili şirketlerin web sitelerinden kriterlerin 2021 yılı verileri elde edilerek entropi ağırlıklı Gri İlişkisel Analiz (GİA) yöntemi ile şirketlerin finansal performanslarının belirlenmesidir. Entropi yöntemiyle yapılan ağırlıklandırma sonucu en önemli kriterin ihracat geliri olduğu belirlenmiştir. Bu kriteri sırasıyla özkaynak, aktif toplam, net satış, aktif devir hızı, özsermaye devir hızı, faiz/vergi öncesi kâr , faiz/vergi öncesi kâr değişimi, net satış değişimi olarak belirlenmiştir. Daha sonra alternatifleri sıralamak için (GİA) yöntemi kullanılmıştır. Buna göre Enka şirketi, en yüksek ilişki derecesine sahip en iyi elektrik üretim şirketi olarak belirlenmiştir. Bu şirketi sırasıyla Enerjisa, Akenerji, İçdaş, Aksa, Zorlu, Limak, Odaş, Gama ve Çelikler şirketleri izlemektedir.

Anahtar Kelimeler ***:*** *Finansal Performans, Elektrik Üretim Şirketleri, Entropi, Gri İlişkisel Analiz*

JEL Sınıflandırması ***:*** *C44, M10, Q40*

INTRODUCTION

Developing technology, globalizing markets, and growing population cause an increase in energy demand. Due to this increase, the sector is expanding.

Electrical energy is a secondary energy source in the energy sector. Since electrical energy is basic input of the industry and is a limited resource, it is important for industrialization and is therefore receiving increased attention in developed countries.

Traditionally, the electrical energy industry is a vertically integrated sector consisting of generation, transmission, distribution, and supply (Puller, 2002). Considering economies of scale, the electrical energy sector has been a natural monopoly for many years. Later, it was decided to divide and privatize the parts of the sector that can operate in competitive markets and to operate the parts of the natural monopoly under a regulation board to be established as an independent and autonomous structure (Cengiz, 2006, p. 118).

In Türkiye, the Energy Market Regulatory Authority was established by the Electricity Market Law No. 4628, which was announced in 2001 within the process of harmonization with the European Union. With the 2004 publication of the Electricity Sector Reform and Privatization Strategy Paper, the privatization of the generation and distribution divisions began, and private companies became part of the sector. Thus, privately owned electricity generation companies began to meet the increasing electricity demand through efficient means of production. Therefore, measuring the financial performance of these companies is important in determining the effectiveness of company activities.

There are various studies in the literature on evaluating financial performance. Following is a short summary of these studies. Metin, Yaman and Korkmaz (2017) evaluated the financial performances of 11 companies producing electricity traded on BIST between 2010 and 2015. They carried out this evaluation using TOPSIS and MOORA methods. Bağcı and Yiğiter (2019) used the SD (Standard Deviation) and WASPAS methods to compare the financial performances of fifteen energy companies. Ağ and Kuloğlu (2020) analyzed the performances of energy companies using Data Envelopment Analysis. Mercan and Çetin (2020) used COPRAS and VIKOR to evaluate the financial performance. Yenioğlu and Toklu (2021) applied Stochastic DEA to analyzed the performances of twenty one electricity distribution companies. Topal (2021) used entropy and CoCoSo methods to determine the financial performances of ten electricity generation companies. Müftüoğlu and Gerekan (2022) determined the financial performances of eight public energy enterprises between 2016 and 2020 using TOPSIS method. Terzioğlu et al. (2022) determined energy companies traded on BIST applying

with SWARA VIKOR, WASPAS methods. Babacan and Tuncay (2022) evaluated the financial performance by using AHP, SWARA, TOPSIS. Akgün(2022) analyzed the financial performance using CRITIC and CODAS methods. Özdemir and Parmaksız (2022) determined the financial performance ratings of energy companies registered in BIST using the TOPSIS and EDAS methods and ratio analysis. Sönmez et al. (2023) measured the financial performances using TOPSIS method. After the literature research, it was seen that multi-criteria decision-making methods were used to evaluate the financial performance of electricity companies. However, in these studies, no study was found in which the entropy and GRA methods were used in an integrated manner. In addition, studies using companies on the Fortune 500 list are limited. In the current study, the financial performances of 10 electricity companies on the Fortune 500 list in Türkiye will be determined by using the 2021 data and the entropy and GRA methods. As far as can be determined in the literature, there is only one study (Topal, 2021) evaluating the financial performance of Fortune 500 companies producing electrical energy in Turkey with multi-criteria decision making methods. The electricity sector was chosen to fill this gap. So, this article will contribute to the literature in this respect.

In the introduction, information about electrical energy is given and the literature is examined. In the second part, the entropy method is explained, and in the third part, the GRA method is explained. In addition, steps of the methods are given. In the fourth part, the application section, the ranking of 10 electricity companies is determined. And the last part, the obtained results are evaluated.

I. DATA SET AND METHODOLOGY

In the study, Entropy-based GRA method was used to evaluate the financial performance of 10 electricity generation companies in the Forbes 500 list. Data was obtained from the Fortune 500 website

I.I. Entropy Method

The concept of entropy was proposed by Rudolf Clausius in 1865 and defined as a measure of disorder and uncertainty within a system. This concept, which was further developed by Shannon (1948), formed the basis of entropy theory (Zhang et al., 2011, p. 444). In decision-making problems involving multiple criteria, it is important to calculate criteria weights. The Entropy method, which is one of the weight calculation methods in the literature, is one of the valuation methods in the objective category. In this method, the weight of each criterion is calculated based on the observation values.

The entropy method consists of the following steps (Shannon, 1948, pp. 10–14):

Step 1: Creating the decision matrix

The decision matrix consisting of x_{ij} values and symbolized by A was created as in Equation (1).

$$A = \begin{bmatrix} x_{11} & x_{12} & . & x_{1n} \\ . & . & . & . \\ . & . & . & . \\ x_{m1} & x_{m2} & . & x_{mn} \end{bmatrix} \quad (1)$$

Step 2: Normalizing the decision matrix

$$r_{ij} = \frac{x_{ij}}{\sum_{1}^{j} x_{ij}} \quad (2)$$

Step 3: The entropy values (ej) are found with Equation (3).

$$e_j = -k\sum_{j=1}^{m} r_{ij} \ln(r_{ij}) \tag{3}$$

In the formula, *k:* shows the entropy coefficient, r_{ij}*:* normalized values, and e_j*:* entropy value.

Step 4: Weight values are obtained by the formula Equation (4).

$$w_j = \frac{1-e_j}{\sum_{1}^{m}\left(1-e_j\right)} \tag{4}$$

In the entropy method, the natural logarithm function is used while calculating the entropy values for the criteria. In case of zero or negative values in the data related to the decision problem, logarithmic calculations cannot be made. Various correction methods can be applied in the literature for these data. In this study, corrections were made for zero and negative numbers, with the entropy (improved entropy) method using *z*-score standardization transformation developed by Zhang et al. The values are first converted by Equation (5) *z*-score standardization.

$$z_{ij} = \frac{x_{ij} - \overline{X_j}}{\sigma_j} \tag{5}$$

Then, the transformation shown in Equation (6) is made and the data in the decision matrix is made positive.

$$z_{ij}^{'} = z_{ij} + A; \qquad A \succ \left|\min z_{ij}\right| \tag{6}$$

I.II. Grey Relational Analysis (GRA) Method

GRA is a grading, classification, and decision-making technique developed by Deng Joung in 1982 for grey system theory. GRA is a method which is used to analyze uncertainties in MCDM problems. GRA is especially preferred in grouping variables when the sample is small and the sample distribution is unknown (Feng and Wang 2000).

The GRA method is often applied alone or in combination with other methods in the solution of MCDM problems. GRA method's advantages are that the calculation procedures are simple, a small data set is sufficient, and the data set does not have to be suitable for any distribution. Therefore, it is preferred in applications (Chen & Ting, 2002). GRA is frequently used in performance measurements. In particular, evaluations can be made with the help of various financial ratios (Peker and Baki 2011,p.6).

The steps of the GRA method are given below (Wu, 2002, p. 211):

Step 1: Creating the decision matrix

The m-factor series and reference series to be compared related to the decision problem are determined. The factor series is defined as shown in Equation (7). The reference series determined to compare the factors is expressed as shown in Equation (8).

$$x_i = (x_i(j), \ldots x_i(n)) \quad i = 1,2,..m \text{ ve } j = 1,2,\ldots n \tag{7}$$

It is created as shown in Equation (8).

$$X_i = \begin{bmatrix} x_1(1) & x_1(2) & . & x_1(n) \\ . & . & . & . \\ . & . & . & . \\ x_m(1) & xm(2) & . & xm(n) \end{bmatrix} \tag{8}$$

Step 2: Normalizing the decision matrix

Transformations of normalized operations for larger value for better, smaller value for better, or nominal value for better are performed by Equation (9), Equation (10), and Equation (11) given below

$$x_i^*(j) = \frac{x_i(j) - \min_j x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \tag{9}$$

$$x_i^*(j) = \frac{\max_j x_i(j) - x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \tag{10}$$

$$x_i^*(j) = \frac{|x_i(j) - x_{ob}(j)|}{\max_j x_i(j) - x_{ob}(j)} \tag{11}$$

After these operations, the decision matrix represented by Equation (8) is formulated as shown in Equation (12).

$$X^*_i = \begin{bmatrix} x^*_1(1) & x^*_1(2) & . & x^*_1(n) \\ . & . & . & . \\ . & . & . & . \\ x^*_m(1) & x^*m(2) & . & x^*m(n) \end{bmatrix} \tag{12}$$

Step 3: Creation of the absolute value table

The absolute value between X_0* and X_j* is found by the following formula:

$$\Delta 0i = |x_0^*(j) - x_i^*(j)| \qquad i = 1,2, \ldots \ m \text{ ve } j = 1,2, \ldots n \tag{13}$$

$$X^*_i = \begin{bmatrix} \Delta_{01}(1) & \Delta_{01}(2) & . & \Delta_{01}(n) \\ . & . & . & . \\ . & . & . & . \\ \Delta_{0m}(1) & \Delta_{0m}(2) & . & \Delta_{0m}(n) \end{bmatrix} \quad (14)$$

Step 4: Generation of the grey relational coefficient matrix

$$\gamma_{0i(j)} = \frac{\Delta\min + \xi\Delta\max}{\Delta_{oi}(j) + \xi\Delta\max} \quad (15)$$

$$\Delta\max = \max_i \max_j \Delta_{oi}(j)\,,\ \Delta\min = \min_i \min_j \Delta_{oi}(j)$$

$$\Delta_{0i}(j), \text{ve } \zeta \in [0,1]$$

Step 5: Determination of the grey relationship degrees

In formula (16), Γ_{0i} i. indicates the grey relationship degree of the element and it is used when the criteria are supposed to be of equal importance. If the criteria have different weights, formula (17) shown below is used.

$$\Gamma_{0i} = \frac{1}{n}\sum_{j=1}^{n}\gamma_{0i}(j), \qquad \text{i=1,2,…m} \quad (16)$$

$$\Gamma_{0i} = \sum_{j=1}^{n}\left[w_i(j)\gamma_{0i}(j)\right], \qquad \text{i= 1,2,…m} \quad (17)$$

II. EMPRICAL FINDIGS

In the study, 10 electricity generation companies on the Fortune 500 list were evaluated regarding their 2021 financial performance. This study purpose is to evaluate the financial performance of the electricity generation companies determined and the data were obtained from the Fortune 500 website. Criteria considered for the evaluation of financial performances were as follows: net sales (C1), net sales change (C2), profit before interest or tax (C3), change in profit before interest or tax (C4), total assets (C5), equity (C6), export income (C7), assets turnover rate (C8), and equity turnover rate (C9). Alternatives for them are Enerjisa, Enka, Limak, Çelikler, Aksa, İçdaş, Akenerji, Gama, Zorlu, and Odaş.

Multi-criteria decision making methods were used because the various criteria determined for the analysis were contradictory. Performance analysis is basically a multi-criteria decision-making problem because it deals with multiple and conflicting criteria. For this reason, this study was conducted using entropy and GRA methods, which are one of the multi-criteria decision-making methods. Firstly the

weights of the criteria discussed in the study were calculated by the entropy method. And then, the ranking of the electricity companies according to their financial performance was obtained using the GRA method.

The entropy method, which is one of the multi-criteria decision-making methods used in the analysis of this study, was chosen because it is objective in calculating the weights of the criteria. Similarly, GRA method was preferred because it is the small sample size, as stated in the studies of Hsiao (2006), Lin and Yun (2002) and Lin and Hsu (2002). According to the authors, in studies with limited samples, the GRA method gives more consistent results than other multi-criteria decision-making methods, especially in financial performance measurement. Since the sample size of this study was 10, the GRA method was used as the analysis method of this study. In addition, GRA method is simple and easy to calculate and understand.

To analyze using the entropy method, a decision matrix must first be created. In the decision matrix created with the data taken from the Fortune 500 website, it was seen that negative and zero values were included in some criteria. If the entropy method uses negative and zero values, the calculation cannot be made because the logarithm cannot be obtained. Therefore, the decision matrix was corrected using the calculations made with Equation (5) and Equation (6). The matrix obtained as a result of these calculations is given in Table 1.

Table 1. Corrected Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
ENERJİSA	16438986000	2,902784194	2,32308666	2,119085578	18593645000	0,990297785	0,16696126	0,884	10,35853917
ENKA	25782036000	3,804473926	3,711917148	2,064761775	1,21325E+11	7,821052004	7,43588122	0,213	6,201988288
LİMAK	15139982947	2,48063747	2,627933843	2,252972857	19999068586	0,009304132	0,53629177	0,757	0,406393126
ÇELİKLER	1733704322	0,025526149	0,008242496	0,004092798	21579435401	0,825952753	0,00080387	0,080	6,376793572
AKSA	13887496594	3,219541156	2,395876473	2,420833406	20649538050	1,319955191	1,02961146	0,673	8,123736572
İÇDAŞ	3968733284	2,132929611	1,635737757	1,828160722	3267611064	0,573527854	0,00080387	1,215	10,68318687
AKENERJİ	3917844338	2,965469555	1,737350593	4,19341908	13111835774	0,581394871	0,06591241	0,299	10,3176622
GAMA	4485637374	2,493958109	1,807071468	2,128613137	12758702672	0,267003512	0,00080387	0,352	1,936096874
ZORLU	11634808000	2,113732219	3,092144176	2,297058712	35426418000	0,958932112	0,00429745	0,328	9,192197871
ODAŞ	1445601491	2,36094761	1,660639385	2,191001935	6968674929	0,752579786	0,00863281	0,207	6,403405453

The corrected matrix was normalized with Equation (2). After this matrix is obtained, the entropy value is found with Equation (3).

Table 2. Entropy Values

Entropy	C1	C2	C3	C4	C5	C6	C7	C8	C9
ej	0,200	0,219	0,216	0,217	0,183	0,158	0,071	0,207	0,215
1-ej	0,800	0,781	0,784	0,783	0,817	0,842	0,929	0,793	0,785

After the entropy values are determined, the weight value is found with Equation (4).

Table 3. Entropy Criterion Weigh

Entropy	C1	C2	C3	C4	C5	C6	C7	C8	C9
wj	0,1094	0,1068	0,1072	0,1071	0,1117	0,1151	0,1271	0,1084	0,1073

As a result of the weighting made by the entropy method, it was determined that the most important criterion was the export income with the coefficient of importance (0,1271).

After the criteria weights are calculated with the entropy method, the ranking of the alternatives will be determined with the GRA method. The first step is to create the decision matrix and normalize the matrix in the GRA method. The corrected decision matrix given in Table 1 was normalized using Equation (9). In this way, the normalized decision matrix was created as in Table 4. Then, the reference values were determined by taking the maximum normalized value of each criterion. These values are also included in Table 4.

Table 4. Normalized Decision Matrix and Reference Series

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Reference	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
ENERJİSA	0,616	0,761	0,625	0,505	0,130	0,126	0,022	0,709	0,968
ENKA	1,000	1,000	1,000	0,492	1,000	1,000	1,000	0,117	0,564
LİMAK	0,563	0,650	0,707	0,537	0,142	0,000	0,072	0,597	0,000
ÇELİKLER	0,012	0,000	0,000	0,000	0,155	0,105	0,000	0,000	0,581
AKSA	0,511	0,845	0,645	0,577	0,147	0,168	0,138	0,522	0,751
İÇDAŞ	0,104	0,558	0,439	0,435	0,000	0,072	0,000	1,000	1,000
AKENERJİ	0,102	0,778	0,467	1,000	0,083	0,073	0,009	0,193	0,964
GAMA	0,125	0,653	0,486	0,507	0,080	0,033	0,000	0,239	0,149
ZORLU	0,419	0,553	0,833	0,547	0,272	0,122	0,000	0,219	0,855
ODAŞ	0,000	0,618	0,446	0,522	0,031	0,095	0,001	0,112	0,584

After the normalized decision matrix and reference values were determined, the difference matrix was created as seen in Table 5 using Equation (13). Then, the grey correlation coefficients were calculated as in Table 6 with the help of Equation (15).

Table 5. Difference Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
ENERJİSA	0,384	0,239	0,375	0,495	0,870	0,874	0,978	0,291	0,032
ENKA	0,000	0,000	0,000	0,508	0,000	0,000	0,000	0,883	0,436
LİMAK	0,437	0,350	0,293	0,463	0,858	1,000	0,928	0,403	1,000
ÇELİKLER	0,988	1,000	1,000	1,000	0,845	0,895	1,000	1,000	0,419
AKSA	0,489	0,155	0,355	0,423	0,853	0,832	0,862	0,478	0,249
İÇDAŞ	0,896	0,442	0,561	0,565	1,000	0,928	1,000	0,000	0,000
AKENERJİ	0,898	0,222	0,533	0,000	0,917	0,927	0,991	0,807	0,036
GAMA	0,875	0,347	0,514	0,493	0,920	0,967	1,000	0,761	0,851
ZORLU	0,581	0,447	0,167	0,453	0,728	0,878	1,000	0,781	0,145
ODAŞ	1,000	0,382	0,554	0,478	0,969	0,905	0,999	0,888	0,416

Table 6. Grey Relational Coefficients

	C1	C2	C3	C4	C5	C6	C7	C8	C9
ENERJİSA	0,566	0,677	0,571	0,502	0,365	0,364	0,338	0,632	0,941
ENKA	1,000	1,000	1,000	0,496	1,000	1,000	1,000	0,361	0,534
LİMAK	0,533	0,588	0,631	0,519	0,368	0,333	0,350	0,553	0,333
ÇELİKLER	0,336	0,333	0,333	0,333	0,372	0,358	0,333	0,333	0,544
AKSA	0,506	0,764	0,585	0,542	0,370	0,375	0,367	0,511	0,668
İÇDAŞ	0,358	0,531	0,471	0,470	0,333	0,350	0,333	1,000	1,000
AKENERJİ	0,358	0,693	0,484	1,000	0,353	0,350	0,335	0,382	0,934
GAMA	0,364	0,590	0,493	0,504	0,352	0,341	0,333	0,397	0,370
ZORLU	0,462	0,528	0,749	0,525	0,407	0,363	0,333	0,390	0,775
ODAŞ	0,333	0,567	0,474	0,511	0,340	0,356	0,334	0,360	0,546

Considering the weights obtained by the entropy method, grey relational degrees were calculated with Equation (17). The calculated state and order of grey relational degrees are given below.

Table 7. Grey Relational Degrees and Their Rankings

Alternatives	Grey Relational Grades (Γ)	Rankings
ENERJİSA	0,544	2
ENKA	0,827	1
LİMAK	0,464	7
ÇELİKLER	0,363	10
AKSA	0,516	5
İÇDAŞ	0,532	4
AKENERJİ	0,536	3
GAMA	0,413	9
ZORLU	0,499	6
ODAŞ	0,422	8

According to the calculated results, Enka company is the best alternative with the highest degree of relationship. In addition, the ranking of the selected companies is given in Table 7.

RESULT AND DISCUSSION

Although electrical energy is of strategic importance for countries, it affects many economic factors such as the countries' welfare structures, economic growth rates, development levels, and import-export figures (Müftüoğlu & Gerekan, 2022, p. 2282). The need for energy, which is an important production factor for all societies and economies, is increasing day by day. To meet this increasing demand, countries want to improve efficiency in the electricity sector. In Türkiye, where foreign dependency is high, energy sources and efficient use of energy are strategic issues.

Today, privatization policies have been implemented in the electricity sector due to the increase in energy demand. In order to meet this increasing demand, many private enterprises have started to produce electricity. In the study, 10 companies on the Fortune 500 list were examined using nine criteria. The aims of this study was to determine the financial performances of the companies with the entropy-weighted GRA method by obtaining the 2021 data of the criteria from the websites of the relevant companies.

As a result of the weighting made by the entropy method, it was determined that the most important criterion was the export income with the coefficient of importance (0,1271). These criteria were determined as equity (0.1151), total assets (0.1117), net sales (0.1094), asset turnover (0.1084), equity turnover (0.1073), profit before interest or tax (0.1072), change in profit before interest or tax (0.1071), and as change in net sales (0.1068), respectively.

After calculating the criterion weights with the entropy method, the GRA method was used to rank the alternatives. As a result of these calculations, Enka (0,827) company was determined to be the best electricity generation company with the highest degree of relationship. In other words, it ranked first in terms of financial performance. This company was followed by Enerjisa (0,544), Akenerji (0,536), İçdaş (0,532), Aksa (0,516), Zorlu (0,499), Limak (0,464), Odaş (0,422), Gama (0,413) and Çelikler (0,363), respectively. According to criterion weights, the most important criteria are export income, equity and total assets criteria. For this reason, Enka, Enerjisa and Akenerji companies were ranked at the top. When we compared the results obtained in the research with the study in the literature, similar results were obtained. In the study conducted by Topal (2021) according to the COCOSO method, Enka company was ranked first. Akenerji and Enerjisa companies were ranked at the top; Odaş and Gama companies were ranked last. In addition, as a result of the weighting of the performance criteria, it was determined that export and equity criteria were among the most important criteria. In future studies, different financial criteria can be considered or the results can be compared by carrying out analyses with models such as Topsis, Vikor, or Electre, which are multi-criteria decision-making methods.

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