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Efficiency Measurement With A Three-Stage Hybrid Method

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Abstract: Data Envelopment Analysis (DEA) is one of the most widely used efficiency measurement techniques in the literature. In the method developed by Charnes, Cooper, and Rhodes, the relation between input(s) and output(s) is examined and relative efficiency values are obtained for many decision-making units. In order to be able to accurately measure the efficiency with Data Envelopment Analysis, the selection of input and output variables needs to be done carefully otherwise, the results may be misleading. For this purpose, it is aimed to make an objective selection process by using Grey Relational Analysis (GRA) in the identification of variables in the study. Via this method 17 financial ratios of 20 firms in the BIST Food Index for the period of 2013-2015 categorized into 4 groups, then each category clustered and the ratios which have the highest correlation within each cluster selected as representative indicator. Thus, 3 inputs and 2 output variables were selected so that the number of variables was reduced from 17 to 5. An input-oriented BCC model was established with selected variables to determine the efficiencies of firms in each period. The Malmquist Total Factor Productivity Index was used to analyze the productivity changes between periods. It was concluded that 7 firms were efficient in each year and the productivity of the sector increased between the periods as a result of the analysis.

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1. INTRODUCTION

Efficiency is doing an activity with possibly the shortest time and the lowest cost, taking into consideration the quality (Chorafas, 2015). According to another approach, efficiency is the comparison of the optimal values and the observed values of inputs and outputs. In this approach, optimality is expressed in terms of production possibilities or the behavioral goals of the manufacturer (Fried, Lovell, & Schmidt, 2008). Effectiveness is reaching a goal under various constraints arising from planning including financial plans, timelines and human resources (Chorafas, 2015). If the two definitions are summed up to include both similarities and differences, efficiency is doing things right and effectiveness is doing the right things (Sheth & Sisodia, 2002). Productivity is simply the ratio of output to input. The productivity measure, which includes all factors, is called total factor productivity, while the efficiency of certain features is called partial productivity (Coelli, Rao, O'Donnell, & Battese, 2005).

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Economically, efficiency consists of technical and distribution components. The technical efficiency is that only one output is reduced, or an input is increased in order to increase an output (Koopmans, 1951). Technical efficiency is expressed more flexible, as the ability to produce as much output as possible to the extent allowed by technology and input, or the ability to avoid waste during the use of the smallest input allowed by technology for output production. The distribution component refers to the ability to combine inputs and/or outputs at optimal rates considering current prices (Fried et al., 2008).

Efficiency measurement approaches can be grouped under three headings generally. These headings are in the form of ratio analysis, parametric methods and nonparametric methods. These approaches discussed in the following.

Ratio Analysis: Ratio analysis is used with the thought that the performance of the company will be reflected on the balance sheet. With the help of balance sheets, useful information about the company can be obtained and forecasts can be made about the future situation. Although the ratio analysis correctly reflects the situation of companies, there are some limitations. These limitations are: There is no criterion for choosing rates that everyone can accept and added, or simplified ratios may not meet the needs of users (Ho & Zhu, 2004).

Parametric Methods: Parametric methods are based on certain functional form assumptions for the efficient frontier. Parametric approaches are divided into deterministic and stochastic models. In deterministic models, all observations by frontier and existing technology are enveloped as technical inefficiency by determining the difference between observed production and maximum production (Murillo-Zamorano, 2004). The most widely used method in the parametric approach is Stochastic Frontier Analysis.

Nonparametric Methods: Nonparametric methods avoid enforcing the production frontier in a specific functional form (Elyasiani & Mehdian, 1990). Since these approaches do not have parametric constraints, they can easily handle separated inputs and multiple output technologies (Chavas & Aliber, 1993). Nonparametric techniques attract great attention in the literature. The basic reason is that few assumptions are needed, and there is no need to define the functional form of the relationship between inputs and outputs and to specify a form of distribution in terms of inefficiency (Daraio & Simar, 2007). The most commonly used techniques in the literature are Data Envelopment Analysis (DEA) and Free Disposal Hull techniques.

The rest of the study is as follows: Section 2 focuses on Grey Relational Analysis (GRA), DEA, and Malmquist Total Factor Productivity Index, which are used for efficiency measurement. Section 3 gives a literature review about efficiency measurement with GRA and DEA methods. Section 4 presents a three-stage efficiency measurement for 20 food and beverage firms traded in BIST (Borsa İstanbul from Turkey) for the 2013-2015 period. Section 5 gives conclusions of the study.

2. METHOD

Organizations need to determine the correct input and output variables basically in order to accurately measure their efficiency. The main reason of this issue is the generation of large amounts of data during the activities carried out in the organizations. For this purpose, in this study, a three-stage approach has been adopted in the process of measuring the efficiency of BIST food and beverage Index firms between 2013-2015 years. In the first stage, the Grey Relational Analysis was used in the selection of the variables to be used for efficiency measurement. The selected variables were used as inputs and outputs of DEA model in the second stage. In the third and final stage, the Malmquist Total Factor Productivity Index was used to determine the efficiency changes and their causes between the periods.

2.1. Grey Relational Analysis

Grey Relational Analysis is a related concept of Grey System theory. The Grey System is defined as a system containing knowns and unknowns by Ju-Long Deng (1982). Grey systems and its applications have interdisciplinary properties aimed filling gaps between social sciences and natural sciences (Deng, 1989). The word "grey" in Grey System theory or Grey Relational Analysis means a status between black and white. White states certain knowledge, while black states completely missing knowledge. In this case, grey is a mixture of black and white (Ng, 1994).

Grey Relational Analysis suggests a relationship in order that the degree of correlation of factors can be measured. Accordingly, the more similarity between the factors, the more the correlation is to be mentioned. The Grey Relational ratios are used to measure the degree of relationship between the factors (Kung & Wen, 2007).

In order to calculate the correlations between the factors with Grey Relational Analysis, the first step is to perform the normalization process to remove the measurement differences between the factors. Normalization can be done according to whether the factors are benefit or cost attributes. Equation (1) is used for factors with benefit attribute, and Equation (2) is used for cost attribute ones (Wang, 2008). Hereby, $x_i^{(O)}(k)$ is comparability sequence.

$$x_i^*(k) = \frac{x_i^{(O)}(k)}{\sqrt{\sum_{t=1}^{m}\left[x_i^{(O)}(t)\right]^2}} \tag{1}$$

$$x_i^*(k) = \frac{1/x_i^{(O)}(k)}{\sqrt{\sum_{t=1}^{m}\left[1/x_i^{(O)}(t)\right]^2}} \tag{2}$$

After the normalization process is completed, $x_0^*(k)$ reference series that consists of the ideal values are determined (Ertugrul, Oztas, Ozcil, & Oztas, 2016). The Grey Relational coefficients measure the closeness of $x_i^*(k)$ and $x_0^*(k)$ (reference) series. Grey Relational coefficient is calculated as shown in Equation (3) (Kuo, Yang, & Huang, 2008).

$$\gamma\left(x_0^*(k), x_i^*(k)\right) = \frac{\Delta_{min}+\xi\Delta_{max}}{\Delta_{ik}+\xi\Delta_{max}}, i = 1,\dots,m,\ \ k = 1,\dots,n \tag{3}$$

$$\Delta_{ik} = |x_0^*(k) - x_i^*(k)|$$

$$\Delta_{min} = Min\{\Delta_{ik}, i = 1,\dots,m, \quad k = 1,\dots,n\}$$

$$\Delta_{max} = Max\{\Delta_{ik}, i = 1,\dots,m, \quad k = 1,\dots,n\}$$

In Equation (3), ξ is the distinguishing coefficient in [0, 1] interval, and Δ_{ik} is the deviation sequence of reference sequence and comparability sequence. Grey Relational grade is equal to the weighted average of the Grey Relational coefficients. These values are calculated as shown in Equation (4) (Tzeng, Lin, Yang, & Jeng, 2009).

$$\gamma(x_0^*, x_i^*) = \sum_{k=1}^{n} w_k \gamma\left(x_0^*(k), x_i^*(k)\right), \quad \sum_{k=1}^{n} w_k = 1 \tag{4}$$

2.1.1. *The Selection of Representative Indicator*

Grey Relational Analysis can be used for clustering and determining the factors that represent clusters when many variables exist in efficiency measurement. In the case of *m* decision-making units, *t* periods, and *s* factors the Grey Relational grade is calculated to be similar to Equation (4) (Wang, 2014).

$$r_{0i} = \gamma(x_0^*, x_i^*) = \frac{1}{mt}\sum_{k=1}^{mt} \gamma\left(x_0^*(k), x_i^*(k)\right) \tag{5}$$

Grey Relational matrix $R = (r_{ij})\ (i = 1, \dots, s, j = 1, \dots, s)$ is obtained by Grey Relational analysis. Clustering is done according to the following definitions (Wang, 2014).

Definition 1: If $r_{ij} \geq r$ and $r_{ji} \geq r$, then x_i^* and x_j^* is in the same cluster. Where, r is threshold valued and generally selected as 0.75 in literature.

Definition 2: In case, $r_{ij} \geq r$, $r_{ji} \geq r$, $r_{ik} \geq r$, $r_{ki} \geq r$, but $r_{jk} < r$ or $r_{kj} < r$. If $min\{r_{ij}, r_{ji}\} \geq min\{r_{ik}, r_{ki}\}$, then x_i^* and x_j^* is in the same cluster.

Definition 3: If x_i^* and x_j^* are in the same cluster, the biggest value of r_{ij} and r_{ji} represents the cluster. If $r_{ij} > r_{ji}$ then factor *i* represents the cluster.

Definition 4: Suppose that x_i^*, x_j^*, and x_k^* are in the same cluster. Representative factor of cluster is determined according to the biggest value of $r_{ij} + r_{ik}$, $r_{ji} + r_{jk}$, and $r_{ki} + r_{kj}$. For instance, if the biggest value is $r_{ij} + r_{ik}$, then representative indicator is factor *i*.

Definition 5: Suppose that T is a cluster consists of four or more elements. The representative factor of cluster will be factor *i*, if $\sum_{j(\neq i)\in T} r_{ij} > \sum_{j(\neq k)\in T} r_{kj},\ \forall k \in T \text{ and } k \neq i$.

2.2. Data Envelopment Analysis

Data Envelopment Analysis is a method introduced by Charnes, Cooper, and Rhodes in 1978. It is based on a methodology that essentially eliminates the assumptions and limitations of classical efficiency measurement approaches (Bowlin, 1998). Data Envelopment Analysis evaluates the relative efficiencies of production units with multiple inputs and multiple outputs. The basic idea of Data Envelopment Analysis is to develop a methodology which determines the decision-making units that have the best function within the set of comparable decision-making units (DMU) and forms an efficiency frontier (Cook & Seiford, 2009). Data Envelopment Analysis can be used to measure the performance of non-profit organizations as well as to measure the performance of profit-oriented organizations (Doyle & Green, 1994).

2.2.1. CCR Model

In the CCR model, the efficiency measurement of any decision-making unit is obtained by maximizing the weighted output to weighted inputs ratio under constraints where the similar rates for each decision-making unit are equal to or less than 1. The model can be expressed mathematically as shown in Equation (6) (Charnes, Cooper, & Rhodes, 1978).

$$\max \theta = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$
$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1; j = 1, \dots, n \tag{6}$$
$$v_r, u_i \geq 0; r = 1, \dots., s; i = 1, \dots, m$$

In the case of the model discussed in Equation (6), if the decision unit having $\theta^* = 1$ and at least one positive optimal value (v^*, u^*) exists, this decision unit is the CCR efficient; otherwise, CCR inefficient. Moreover, since the optimal $\theta = \theta^*$ values are not affected by the measurement unit of the input and output variables, they are called units invariance (Cooper, Seiford, & Tone, 2007).

2.2.2. BCC Model

The BCC model was developed in 1984 by Banker, Charnes, and Cooper. This model is derived from the convexity constraint added to the CCR model, which is based on the assumption of constant returns to scale (Cooper et al., 2007; Banker & Thrall, 1992). The variable associated with this added constraint makes it possible to comment on the returns to scale (increase, decrease, or constant) when evaluating the technical efficiencies (or inefficiencies) of the decision-making units (Ahn, Charnes, & Cooper, 1988). The model is as shown in Equation (7) (Banker, Charnes, & Cooper, 1984).

$$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right);$$
$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{i0}; i = 1, \ldots, m$$
$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \theta y_{r0}; r = 1, \ldots, s \tag{7}$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j, s_i^-, s_r^+ \geq 0, \forall i, j, r$$

Scale efficiencies of decision-making units can be determined by using efficiency scores of CCR and BCC models. If the CCR efficiency score is considered as technical efficiency and the BCC efficiency score as pure efficiency score, the scale efficiency is calculated as shown in Equation (8) (Cooper et al., 2007).

$$SE = \frac{\theta_{CCR}^*}{\theta_{BCC}^*} \tag{8}$$

2.3. Malmquist Total Factor Productivity Index

The changes in the productivity of decision-making units can be explained by the Malmquist Total Factor Productivity Index in terms of the change in the technical efficiency and the change in the technology over the time (Färe, Grosskopf, Norris, & Zhang, 1994). As the efficiency score for each decision-making unit is being produced with taking reference to the technologies of efficient decision-making units with Data Envelopment Analysis; Productivity changes between t_1 and t_2 periods are determined by the Malmquist productivity index (Berg, Førsund, & Jansen, 1992). The Malmquist index identifies changes in productivity as multiple input or multiple output oriented with the distance functions (Coelli & Rao, 2005). The Malmquist efficiency index, calculated by *x* inputs and *q* outputs between two periods such as *s* and *t* (the reference period) as shown in Equation (9) (Coelli et al., 2005).

$$m_o^t(q_s, q_t, x_s, x_t) = \frac{d_0^t(q_t, x_t)}{d_0^t(q_s, x_s)} \tag{9}$$

Hereby, d_0^t is a distance function that measures the efficiency of the conversion of x_t inputs to q_t outputs in the period *t*. If the m_o value is greater than 1, then it means progress, and if it is less than 1, it means regression.

The performance change between the two periods in the Malmquist productivity index is based on the geometric mean of the calculated index values for both periods.

$$m_o(q_s, q_t, x_s, x_t) = \left[\frac{d_0^s(q_t, x_t)}{d_0^s(q_s, x_s)} \frac{d_0^t(q_t, x_t)}{d_0^t(q_s, x_s)}\right]^{1/2} \tag{10}$$

When Equation (10) is arranged, an index is obtained that has two components that measure efficiency and technology levels and allows inefficiency (Färe, Grosskopf, Lindgren, & Roos 1992).

$$m_o(q_s, q_t, x_s, x_t) = \frac{d_0^t(q_t, x_t)}{d_0^s(q_s, x_s)} \left[\frac{d_0^s(q_t, x_t)}{d_0^t(q_t, x_t)} \frac{d_0^s(q_s, x_s)}{d_0^t(q_s, x_s)}\right]^{1/2} \tag{11}$$

The first part of Equation (11) measures the change in efficiency, while the second part measures the change in technology.

3. LITERATURE REVIEW

This section provides a literature review of studies with similar approaches to efficiency/performance measurement of this paper.

Feng and Wang (2000), used Grey Relational Analysis and TOPSIS methods to measure the performance of airline companies. A total of 63 financial indicators were considered in the study, and with the help of Grey Relational Analysis, fewer indicators were used instead of all the indicators. After the representative indicators were identified, the performance of the 5 airlines was determined by TOPSIS method.

Wang, Ma and Guan (2007), measured the efficiencies of 24 hospitals in China with Grey Relational Analysis and Data Envelopment Analysis. In the first part of the study, 2 inputs and 7 output variables were specified. Using Grey Relational Analysis, the output variables were grouped and the number of variables was reduced to 3 using the representative variables in each group. Then, Data Envelopment Analysis was used to determine efficient hospitals with a model with 2 input-3 output variables.

Wang (2007), utilized the Grey Relational Analysis and Data Envelopment Analysis to evaluate the performance of the TFT-LCD industry in Taiwan. Grey Relational Analysis was used to objectively select variables to be used in Data Envelopment Analysis and to simplify calculations by reducing the number of variables. After the variables were determined, efficient firms were obtained by measuring production efficiency and marketing effectiveness with a two-stage evaluation process with Data Envelopment Analysis.

Chiang-Ku, Shu-Wen and Cheng-Ru (2009), compared the performances of the traditional sales channel, and the bank sales channel which sell policies for an insurance company. The comparison has two stages: Marketability efficiency and profitability efficiency. Variables to be used to measure the efficiency of sales channels were first identified by a Delphi panel consisting of 10 experts, then those with the highest correlation with Grey Relational Analysis were identified as input variables. Data Envelopment models for the two channels were built by using the input and output variables, and the results were analyzed by Mann-Whitney U test. The relationship between the two groups was analyzed by Spearman's correlation.

Ho (2011), has combined Data Envelopment Analysis and Grey Relational Analysis methods to measure the efficiencies of dot-com companies. In the study, 69 companies that sell via the internet were examined. In the study, firstly 21 inputs and 19 output variables were determined, and the number of variables was reduced by Grey Relational Analysis. A Data Envelopment model was established to measure the efficiencies of dot-com companies with selected 4 input-4 output variables.

Wang (2014), measured the financial performance of container transportation companies using Grey Relational Analysis and fuzzy TOPSIS. In the study, 20 financial ratios were first divided into 4 categories and representing variables were determined with Grey Relational Analysis within each category. Then, the determined variables were used to order the performance of the three firms with the fuzzy TOPSIS method.

Girginer, Köse and Uçkun (2015), measured the efficiency of 10 surgical services in a hospital in Turkey using combined Data Envelopment Analysis and Grey Relational Analysis methods. In the study, efficient decision-making units were determined by performing efficiency measurement by Data Envelopment Analysis using 4 input variables and 2 output variables. Grey Relational Analysis was used to determine the factors that affect the ranking and efficiency of the performance of efficient decision-making units.

İç, Tekin, Pamukoğlu and Yıldırım (2015) compared corporate companies which operate in 24 sectors with the financial performance system that they developed. This model bases on financial ratios and TOPSIS method. In the modeling stage, using the correlation values obtained from TOPSIS, VIKOR, GRA, and MOORA methods, it was found that TOPSIS method is more suitable for this evaluation model.

Tsaur, Chen and Chan (2017), measured the performance of the Taiwan TFT-LCD industry in a four-stage process. In the first stage of the study, efficiency scores were determined with Data Envelopment models for each company between 2009-2012 years. In the second stage, the Malmquist index and the efficiency changes in companies were analyzed. In the third stage, Grey Relational Analysis was performed by determining the weights of input and output variables by entropy method. In the fourth step, the results of the methods were compared, and the results were concluded.

Durga Prasad, Venkata Subbaiah and Prasad (2017) used Data Envelopment Analysis, Analytic Hierarchy Process and Grey Relational Analysis methods together for supplier selection. Efficiency values were computed with Data Envelopment Analysis. The best supplier was selected with Grey Relational Analysis. In this stage, weights of criteria were determined using AHP method.

Pakkar (2017), used Data Envelopment Analysis and Analytic Hierarchy Process methods to develop a Grey Relational Analysis model that have multi-hierarchy. In the method, a multi-featured decision-making process was transformed into a two-level hierarchical structure of attributes and attribute categories. In the first step, the required data were obtained by calculating with simple Grey Relational Analysis and Analytic Hierarchy Process at the attribute level for additive Data Envelopment Analysis model. In the second step, Grey Relational grades of attributes were transformed into Grey Relational coefficients of the categories. For the alternatives, the Grey Relational grades of the categories were calculated by using the Data Envelopment Analysis model and the dissimilarity scores of the categories for the tied alternatives are calculated by the exclusive Data Envelopment Analysis exclusion model.

Pakkar (2018), used Grey Relational Analysis method for multi-attribute decision-making problems which its weights are unknown and in fuzzy number form. Data Envelopment Analysis and Analytic Hierarchy Process methods were used for determination of weights. For this purpose, two sets of weights based on the minimax Data Envelopment Analysis were defined in the framework of Grey Relational Analysis. The first set states weights with the minimum Grey Relational loss; the second set states weights with the maximum Grey Relational loss by using the Analytic Hierarchy Process. The model was exemplified by the selection of a nuclear waste disposal site.

Huang, Dai and Guo (2015) have developed a new Data Envelopment Analysis model for corporate financial failure prediction. The model has two stages and has been developed in order to be able to quickly deal with a large number of inputs and outputs, making use of the hierarchical structure of financial indicators. The Grey Relational Analysis method was used to select the indicators that have a significant correlation among a large number of indicators.

Hsu (2015), has combined Data Envelopment Analysis with the Grey Relational Analysis method, which was developed to examine the activities and performance of semiconductor companies in an increasingly competitive environment. In this regard, two groups of efficient and inefficient semiconductor companies were obtained. Then, efficient and inefficient companies were examined in terms of their operational performance by multi-criteria decision-making method, improved Grey Relational Analysis method and Entropy weight method.

Kaygısız Ertuğ and Girginer (2015) were investigated fiscally metropolitan municipalities in Turkey with Data Envelopment Analysis and Grey Relational Analysis in an integrated manner. Firstly, efficient and inefficient municipalities were determined with Data Envelopment Analysis and then the efficient municipalities ranked with Grey Relational Analysis. Thus, the municipalities with the best and worst performance have been identified.

4. FINDINGS

The main idea of this study is to perform the evaluation process objectively while measuring the efficiency. The number of input and output variables and selection of these variables have a big influence on the quality of the evaluation results. A three-stage hybrid approach has been adopted to study this controversial case in a scientific approach. The approach adopted for the measurement of efficiency has been applied to BIST food and beverage Index firms and the results have been examined. Figure 1 depicts visually the stages of the study.

Figure 1. Stages of the analysis

4.1. Material and Method

The financial ratios related to the firms included in the BIST food and beverage index were used as input and output variables in the study. The financial data used in the study covers 3 periods from 2013 to 2015. These ratios were calculated by using Financial Analysis reports of firms which obtained from Bloomberg terminals. The firms included in the scope of the study are listed in Table 1.

At the first stage of the study, 17 financial ratios were chosen to determine the input and output variables to be used for efficiency measurement and these ratios were divided into 4 categories. Three categories related to liquidity ratios, financial structure ratios, and operating ratios were used in determining the representative input variables, and profitability ratios were used in determining the representative output variables. These categories and ratios are as shown in Table 2.

Table 1. Analysed firms

No	Firm	No	Firm	No	Firm	No	Firm
1	AEFES	6	PETUN	11	ULUUN	16	PINSU
2	ULKER	7	TBORG	12	AVOD	17	KENT
3	CCOLA	8	BANVT	13	KERVT	18	ALYAG
4	TATGD	9	KRSTL	14	KNFRT	19	ERSU
5	PNSUT	10	TUKAS	15	PENGD	20	MERKO

Performing efficiency measurement with all 17 ratios in Table 2 makes calculations hard. For this reason, it is necessary to work with fewer ratios. From these ratios in Table 2, it is very important that selection of input/output variables in terms of the efficiency measurement results and the models to be built. For this reason, in order to make the variable selection objectively, the Grey Relational Analysis is used in the first step of the study to divide the ratios within each category into clusters and to determine the ratios that would represent the other ratios in the cluster. To eliminate the measurement differences of the data in the grey relation analysis, normalization was performed according to the benefit and cost information in the attribute column.

After the input and output variables used in the study were determined, the efficiency measurement was performed by Data Envelopment Analysis in the second stage of the study. An input-oriented BCC model was used for the measurement of efficiency. In the third stage of the study after the efficiency scores were obtained, the Malmquist total factor productivity index was used to analyze the changes in the efficiency of the firms and the industry between periods. Microsoft Office Excel and DEAP 2.1 programs were used in calculations.

Table 2. The financial ratios used in the study

	Ratio	Code	Indicator	Formulation	Attribute
Input	Liquidity ratios	L1	Cash ratio	Cash and marketable securities/Current liabilities	Benefit
		L2	Current ratio	Current assets/Current liabilities	Benefit
		L3	Acid-test ratio	(Current assets-inventories)/ Current liabilities	Benefit
	Financial structure ratios	M1	Debt ratio	Total liabilities/total assets	Cost
		M2	Debt to equity ratio	Total debt/ Average shareholders' equity	Cost
		M3	Short-term debt to assets ratio	Short-term debts/Total assets	Cost
		M4	Fixed assets to equity ratio	Fixed Assets/ Average shareholders' equity	Cost
	Operating ratios	F1	Accounts receivable turnover	Net sales/Average net receivables	Benefit
		F2	Inventory turnover	Net sales/Average inventory	Benefit
		F3	Equity turnover	Net sales/Equity	Benefit
		F4	Asset turnover	Net sales/Total assets	Benefit
		F5	Current assets turnover	Net sales /Current assets	Benefit
		F6	Fixed assets turnover	Net sales /Fixed assets	Benefit
Output	Profitability ratios	K1	Gross profit margin	Gross profit/Net sales	Benefit
		K2	Operating margin	Operating Income/ Net sales	Benefit
		K3	Profit margin	Net profit/Net sales	Benefit
		K4	Return on equity	Net income/Average shareholders' equity	Benefit

4.2. Determination of Representative Indicators Using GRA

As variables were determined by Grey Relational Analysis, the measurement values were normalized to the cost or benefit attribute. After the normalization process, the reference series were constructed and the difference series were formed by the comparison series. From the difference series, the Grey Relational coefficients were obtained with the help of Equation (3), and the Grey Relational grades were obtained by taking the averages of these values. Each of the ratios was selected as the reference series to obtain the grey relation matrix consisting of Grey Relational grades and clustering was performed according to this matrix. The following matrices show the Grey Relational matrices and Table 3 shows representative ratios of the clusters obtained for each category group.

$$R_1 = \begin{bmatrix} 1 & 0.756 & 0.804 \\ 0.756 & 1 & 0.870 \\ 0.798 & 0.866 & 1 \end{bmatrix},$$

$$R_2 = \begin{bmatrix} 1 & 0.850 & 0.821 & 0.775 \\ 0.854 & 1 & 0.803 & 0.783 \\ 0.839 & 0.817 & 1 & 0.757 \\ 0.797 & 0.798 & 0.757 & 1 \end{bmatrix},$$

$$R_3 = \begin{bmatrix} 1 & 0.896 & 0.842 & 0.903 & 0.922 & 0.868 \\ 0.895 & 1 & 0.838 & 0.904 & 0.917 & 0.866 \\ 0.843 & 0.841 & 1 & 0.835 & 0.839 & 0.893 \\ 0.904 & 0.906 & 0.834 & 1 & 0.925 & 0.901 \\ 0.923 & 0.919 & 0.839 & 0.926 & 1 & 0.872 \\ 0.864 & 0.864 & 0.889 & 0.897 & 0.867 & 1 \end{bmatrix},$$

$$R_4 = \begin{bmatrix} 1 & 0.789 & 0.723 & 0.727 \\ 0.778 & 1 & 0.805 & 0.781 \\ 0.723 & 0.816 & 1 & 0.890 \\ 0.680 & 0.750 & 0.865 & 1 \end{bmatrix},$$

Table 3. Clusters and their representative indicators

Cluster	Ratios in cluster	Representative indicator
C1	L1, L2, L3	L3 (Acid-test ratio)
C2	M1, M2, M3, M4	M1 (Debt ratio)
C3	F1, F2, F3, F4, F5, F6	F5 (Current assets turnover)
C4	K1, K2	K1 (Gross profit margin)
C5	K3, K4	K3 (Profit margin)

For example, in the Grey Relational matrix for the liquidity ratios in R_1, L1, L2, and L3 are in the same cluster because $r_{12}, r_{13}, r_{21}, r_{23}, r_{31}$, and r_{32} are greater than the threshold value 0.75. The ratio of L3 (acid-test ratio) was chosen because the biggest value of $r_{12}+r_{13}$, $r_{21}+r_{23}$, and $r_{31}+r_{32}$ is $r_{31}+r_{32}=1.66$ as mentioned in the second section. Other ratios were determined by a similar approach.

As a result of the clustering process with Grey Relational Analysis, 17 financial ratios were represented with 5 financial ratios. This process provides a reduction of approximately 70% of the number of ratio, which will make the calculations with the Data Envelopment Analysis easier to complete. The input variables consist of acid test ratio (L3), debt ratio (M1) and current assets turnover rate (F5) while output variables are gross profit margin (K1) and profit margin (K3). These ratios and general information are given below respectively.

–*Acid-test ratio:* It may not be easy to take stocks out of hand in the short run because they cannot always be quickly converted into cash. In short-term payments, it helps to determine the liquidity position of the firm by reducing inventories from current assets (Dyson, 2010). It provides a more accurate measure of the payment power than the current ratio (Tayyar, Akcanlı, Genç, & Erem, 2014).

–*Debt ratio:* This rate shows how the firm finances its assets by borrowing in various forms. The higher this rate, the higher the financial risk; the lower the rate, the lower the financial risk (Van Horne & Wachowicz, 2008).

–*Current assets turnover ratio:* It is used to measure the relationship between sales and current asset investments. It expresses firm how many times turns over its current assets in a year.

The higher the rate, the more efficient use of current assets (Wahlen, Baginski, & Bradshaw, 2011). For this reason, it can be used to measure operational performance (Yu, Luo, Feng, & Liu, 2018).

−*Gross profit margin ratio:* Gross profit is the difference between sales revenue and selling cost. Gross profit is, therefore, a measure of the profitability of the procurement (production) and sale of goods or services before other costs are added to the account. Since the cost of sales is a huge expense for many businesses, a change in that location can be a major impact on the profit or loss of the respective year (Atrill, 2012). This ratio is sensitive to pricing, product mix, and unit costs but is not based on sales volume (Isberg & Pitta, 2013).

−*Profit margin*: Net profit margin is a measure of the profitability of sales considering all costs and income of the company. It refers to the net income per unit of money company's sales (Van Horne & Wachowicz, 2008). In a simpler sense, it is the periodic net profit rate that a firm has achieved net sales (Önem & Demir, 2015). The values of the rates selected using Grey Relational Analysis are as shown in Table 4, 5 and 6.

Table 4. Values of representative indicators for the year 2013

Firm	K1	K3	L3	M1	F5
AEFES	0.435	0.047	1.018	0.398	2.321
ULKER	0.230	0.066	0.993	0.599	1.253
CCOLA	0.378	0.094	1.026	0.590	2.410
TATGD	0.209	0.003	0.973	0.609	1.770
PNSUT	0.186	0.083	0.759	0.298	3.544
PETUN	0.173	0.080	0.953	0.245	3.412
TBORG	0.553	0.181	1.030	0.489	1.971
BANVT	0.120	-0.034	0.334	0.881	2.856
KRSTL	0.182	0.054	3.914	0.129	1.116
TUKAS	0.143	-0.291	0.598	0.819	0.835
ULUUN	0.071	0.012	0.687	0.743	2.568
AVOD	0.183	-0.008	0.316	0.500	0.782
KERVT	0.278	-0.165	0.253	1.058	1.742
KNFRT	0.283	0.067	0.432	0.455	0.948
PENGD	0.041	-0.288	0.420	0.628	0.976
PINSU	0.406	-0.079	0.470	0.439	3.541
KENT	0.291	-0.027	0.809	0.371	2.222
ALYAG	0.109	0.053	0.369	0.306	3.664
ERSU	0.097	-0.020	0.758	0.335	1.110
MERKO	0.189	-0.042	0.151	0.797	1.678

Source: Bloomberg

Table 5. Values of representative indicators for the year 2014

Firm	K1	K3	L3	M1	F5
AEFES	0.429	0.004	1.037	0.412	2.119
ULKER	0.210	0.073	2.492	0.614	1.388
CCOLA	0.364	0.053	0.819	0.532	2.370
TATGD	0.211	0.184	1.098	0.473	1.717
PNSUT	0.168	0.093	0.809	0.321	3.672
PETUN	0.149	0.080	0.870	0.226	4.275
TBORG	0.560	0.205	1.294	0.462	1.669
BANVT	0.131	-0.011	0.381	0.907	3.111
KRSTL	0.069	0.006	1.478	0.258	1.095
TUKAS	-0.038	-0.412	0.479	0.660	0.656
ULUUN	0.064	0.015	0.762	0.670	2.527
AVOD	0.125	0.006	0.469	0.539	1.769
KERVT	0.281	-0.070	0.276	1.067	1.783
KNFRT	0.320	0.154	1.569	0.166	1.245
PENGD	0.111	-0.114	0.349	0.676	1.357
PINSU	0.430	0.016	0.636	0.518	3.716
KENT	0.294	0.036	1.230	0.367	2.266
ALYAG	0.048	-0.032	0.299	0.434	2.557
ERSU	0.095	-0.048	1.153	0.263	1.316
MERKO	0.205	0.088	0.761	0.427	2.942

Source: Bloomberg

Table 6. Values of representative indicators for the year 2015

Firm	K1	K3	L3	M1	F5
AEFES	0.410	-0.019	1.155	0.430	2.162
ULKER	0.217	0.084	3.012	0.582	1.380
CCOLA	0.347	0.017	1.025	0.537	2.740
TATGD	0.226	0.074	1.244	0.361	1.834
PNSUT	0.161	0.062	0.577	0.336	3.630
PETUN	0.168	0.113	0.879	0.221	4.547
TBORG	0.548	0.212	1.473	0.439	1.410
BANVT	0.106	-0.050	0.278	0.792	3.729
KRSTL	0.076	0.025	2.116	0.211	1.348
TUKAS	0.203	0.233	0.265	0.553	0.997
ULUUN	0.076	0.008	0.756	0.663	2.366
AVOD	0.203	0.019	0.382	0.465	2.011
KERVT	0.277	-0.222	0.184	0.964	1.512
KNFRT	0.201	0.130	1.735	0.116	0.936
PENGD	0.198	0.036	0.250	0.692	1.328
PINSU	0.476	-0.062	0.324	0.641	3.305
KENT	0.359	0.093	1.232	0.320	1.883
ALYAG	0.051	-0.055	0.092	0.573	2.952
ERSU	0.145	-0.059	0.583	0.259	0.947
MERKO	0.186	0.009	0.263	0.682	1.517

Source: Bloomberg

4.3. Efficiency Measurement with Data Envelopment Analysis

When the values of the financial ratios are examined according to years, it is seen that some of the ratios related to profitability are negative. Data Envelopment Analysis has the constraint that the input and output values are not negative. Since the input-oriented BCC model has the translation invariant property for the output variables, the shift in the output variables will not affect the efficiency result (Lovell & Pastor 1995; Pastor 1996). From this point, if there is more than one negative value in a variable, the sign problem is solved by adding the smallest value to all the variables will make all of them positive. All decision-making units have thus participated in the evaluation process. The results of the calculations made, the efficiency scores according to years are as shown in Table 7.

Table 7. Efficiency scores of firms according to years

	2013			2014			2015		
Firm	BCC	Scale Efficiency	Returns to Scale	BCC	Scale Efficiency	Returns to Scale	BCC	Scale Efficiency	Returns to Scale
AEFES	1	0.963	irs	1	0.927	irs	0.93	0.908	irs
ULKER	0.756	0.999	irs	0.836	0.919	irs	0.694	0.818	irs
CCOLA	0.736	0.953	irs	0.965	0.975	irs	0.76	0.885	irs
TATGD	0.647	0.858	irs	1	1	-	0.779	0.891	irs
PNSUT	0.996	0.989	drs	1	1	-	0.983	0.846	irs
PETUN	1	1	-	1	1	-	1	1	-
TBORG	1	1	-	1	1	-	1	1	-
BANVT	0.704	0.918	irs	1	0.834	drs	0.675	0.623	irs
KRSTL	1	1	-	1	0.84	irs	0.7	0.733	irs
TUKAS	0.937	0.613	irs	1	0.004	irs	1	1	-
ULUUN	0.579	0.885	irs	0.726	0.986	irs	0.569	0.652	irs
AVOD	1	1	-	1	1	-	0.978	0.777	irs
KERVT	1	1	-	1	1	-	1	1	-
KNFRT	1	1	-	1	1	-	1	1	-
PENGD	0.801	0.183	irs	1	0.951	irs	0.939	0.863	irs
PINSU	1	1	-	1	1	-	1	1	-
KENT	0.985	0.726	irs	0.867	0.881	irs	1	0.9	irs
ALYAG	1	1	-	1	1	-	1	1	-
ERSU	1	0.872	irs	1	0.733	irs	1	0.657	irs
MERKO	1	1	-	1	0.973	drs	0.88	0.797	irs
Average	0.907	0.898		0.97	0.901		0.894	0.867	

Then the firms' 2013 efficiency scores are analysed, it is seen that 11 firms are technical efficient according to BCC model. These firms are respectively AEFES, PETUN, TBORG, KRSTL, AVOD, KERVT, KNFRT, PINSU, ALYAG, ERSU and MERKO. Among the 9 technical inefficient firms, 8 firms have increasing returns to scale, but only PNSUT has decreasing returns to scale. ULUUN has shown the lowest performance in terms of technical efficiency among inefficient firms. The average efficiency score of the industry for 2013 was measured as 0.907.

In 2014, AEFES, TATGD, PINSUT, PETUN, TBORG, BANVT, KRSTL, TUKAS, AVOD, KERVT, KNFRT, PENGD, PINSU, ALYAG, ERSU and MERKO firms were determined as technical efficient. All the inefficient firms have increasing returns to scale. The relative lowest performing firm is ULUUN in 2014. In 2014, the average technical efficiency score of the sector was measured as 0.97 and it was observed an increase in efficiency score of the sector according to the previous year.

In 2015, PETUN, TBORG, TUKAS, KERVT, KONFRT, PINSU, KENT, ALYAG and ERSU were found as technical efficient. All inefficient firms have increasing returns to scale and ULUUN has the lowest relative performance. In 2015, the average technical efficiency score of the sector was measured as 0.894, which is lower than the previous year. Among the firms, PETUN, TBORG, KERVT, KNFRT, PINSU, ALYAG and ERSU firms are efficient in all three periods. This shows that the firms manage the inputs and outputs well. ULUUN firm, however, has shown its worst performance in all three periods, so it appears that it cannot use its resources effectively.

4.4. Malmquist Index

The Malmquist index established to determine the inter-period efficiency and technology changes of the firms are as shown in Table 8. In the table if the values are bigger than 1, then progress is discussed; if the values are smaller than 1, then regression discussed otherwise, there is no change.

Table 8. Malmquist index values by periods

	2013-2014					2014-2015				
Firm	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch
AEFES	0.962	1.089	1	0.962	1.048	0.911	0.859	0.93	0.98	0.783
ULKER	1.018	1.101	1.106	0.92	1.12	0.738	0.923	0.83	0.889	0.681
CCOLA	1.343	1.013	1.312	1.023	1.36	0.715	0.907	0.788	0.908	0.648
TATGD	1.801	1.175	1.545	1.166	2.116	0.694	0.811	0.779	0.891	0.563
PNSUT	1.015	1.223	1.004	1.011	1.241	0.832	0.816	0.983	0.846	0.679
PETUN	1	1.39	1	1	1.39	1	0.708	1	1	0.708
TBORG	1	1.138	1	1	1.138	1	0.905	1	1	0.905
BANVT	1.289	1.08	1.419	0.908	1.393	0.505	1.267	0.675	0.748	0.64
KRSTL	0.84	1.454	1	0.84	1.222	0.61	0.815	0.7	0.872	0.498
TUKAS	0.008	1.152	1.068	0.007	0.009	226.876	1.33	1	226.876	301.805
ULUUN	1.396	1.021	1.253	1.114	1.425	0.518	1.06	0.784	0.661	0.549
AVOD	1	0.875	1	1	0.875	0.76	1.1	0.978	0.777	0.837
KERVT	1	1.122	1	1	1.122	1	1.098	1	1	1.098
KNFRT	1	1.297	1	1	1.297	1	0.749	1	1	0.749
PENGD	6.499	0.904	1.248	5.207	5.872	0.852	1.415	0.939	0.907	1.206
PINSU	1	0.986	1	1	0.986	1	1.145	1	1	1.145
KENT	1.067	1.214	0.88	1.212	1.296	1.179	0.803	1.153	1.022	0.947
ALYAG	1	1.098	1	1	1.098	1	1.191	1	1	1.191
ERSU	0.84	1.453	1	0.84	1.221	0.896	0.79	1	0.896	0.708
MERKO	0.973	0.936	1	0.973	0.91	0.721	1.02	0.88	0.819	0.735
Average	0.912	1.125	1.08	0.844	1.026	1.083	0.966	0.913	1.187	1.047

When Table 8 analyzed in terms of firms, progress or regression in efficiency values can be determined over the periods. For instance, the AEFES firm has regressed in technical efficiency change (effch) and scale efficiency change (sech), progressed in technology change (techch) and remained constant pure technical efficiency change (pech) in the 2013-2014 period. Total factor productivity change (tfpch) of the firm increased by 4.8% in this period. AEFES firm has regressed in terms of all factors between the periods of 2014-2015. In this period, total factor productivity of the firm decreased 21.7%. Although it is possible to make these interpretations for all firms, it is noteworthy that TUKAS changes its efficiency level depending on the production factors. This can be attributed to the company's net losses in 2013 and 2014, its net profit in 2015 and its sale in 2014 (Hürriyet, 2014).

In the 2013-2014 period, the sector regressed in terms of technical efficiency change and scale efficiency change, but it progressed in terms of technology change and pure technical efficiency change between 2013 and 2014. The total productivity of the sector increased by 2.6%. In the 2014-2015 period, the sector progressed in terms of technical efficiency change and scale efficiency change period 2014-2015, it regressed in terms of technology change and pure technical efficiency. The total productivity of the sector increased by 4.7%.

5. CONCLUSION

An organization wants to monitor the process of transforming the inputs to the outputs regardless of its operating purpose. The main purpose of this is determining the problems that can cause inefficiency in the process of converting the scarce resources into goods or services. Data Envelopment Analysis, developed by Charnes, Cooper, and Rhodes in 1978, is a technique frequently used to measure the relative efficiencies of organizations in the literature. The method determines whether the decision-making units are efficient according to the efficiency scores. Inefficient decision-making units can determine how they can become efficient by reducing their inputs or increasing their outputs relative to slack variable values. In this sense, decision-makers can manage resources more effectively.

One of the most crucial factors affecting the results of Data Envelopment Analysis is the determination of input and output variables. In this study, Grey Relational Analysis method was used to make the variable selection process objectively. Grey Relational Analysis is a method of determining correlations between factors by analyzing relations between reference series and comparison series. Since the method is used successfully in systems with known and unknown information, it is suitable for the variable selection process.

In the study, 17 financial ratios are divided into 4 categories at first. These categories are liquidity ratios, financial structure ratios, operating ratios, and profitability ratios. Within each category, similar variables were clustered with the help of Grey Relational Analysis. Then, the correlations were examined and the ratio with the highest correlation was determined as the representative indicator of the clusters. In this view, 17 variables were represented by 5 variables. Liquidity ratio, debt ratio, current asset turnover ratio were determined as input variables, gross profit margin, and profit margin were determined output variables as a result of the process.

An input-oriented BCC model was established after the variables to be used in the efficient measurement were determined. The efficiency values of 20 firms that are traded in the BIST food and beverage index were measured for 2013, 2014, and 2015. As a result of the analysis, PETUN, TBORG, KERVT, KNFRT, PINSU, ALYAG, ERSU firms were found to be relatively efficient in all three periods.

After the measurement of the efficiency, the change of efficiency of the firms between the periods was examined by Malmquist total factor productivity index. As a result of the examinations, 80% of firms for the period of 2013-2014 have progressed in terms of the total productivity factor and 20% have regressed. By contrast, in 2014-2015, 25% of firms have progressed in terms of total factor productivity, while 75% have regressed.

The use of the proposed three-step hybrid method will benefit from various aspects. Firstly, the organizations that want to measure efficiency can determine the variables to be used in the measurement process by analyzing the first step of the proposed method. Thus, the calculations can be made easier by defining the variables that will represent the other variables in the analysis process. With the help of representative indicators, it is possible to perform the efficiency measurement in a shorter time using the easily accessible software. Secondly, firm managers can compare their performance with the performance of their competitors by measuring the efficiency of their firm. If the measurement shows that the firm is efficient, the result is that the firm produces output(s) using the input(s) efficiently. However, if the firm is inefficient, firm managers can compare their firm with reference DMUs and eliminate the inefficiency factor. In this way, firms may become efficient by reducing their input(s) or by increasing their output(s). Thirdly, the proposed method allows firms to monitor changes in total productivity between periods and determine its causes. Thus, it can be determined that the change in total productivity is caused by the progress or regression of the sub-factors. In further studies, the selection process may be completed by using techniques such as the entropy method where there is a priority difference in financial ratios in the selection of representative indicators.

As a result, this proposed three-stage hybrid method can be used for efficient measurement in any sector/industry. The most important contribution of the proposed method to efficiency measurement applications is simplifying calculations and interpretation of findings when there are many variables and the operating periods. In that, firstly due to use of representative indicators it is possible to measure the efficiency with fewer variables. Selection of representative indicators enables to determine the more accurate variables according to properties of data. Secondly, changes in efficiency (progression, regression or remaining constant) and the causes of these changes can be observed between periods. For instance, if there is a regression in efficiency, decision-makers can detect the main reason and they can enhance trouble. In this way, it will be possible to determine permanently whether scarce resources in the economy are being used efficiently. In the further studies, similar efficiency measurements can be applied to other industries or nonprofit organizations. The effects of the numbers of variables and length of the period on the results can be analyzed in detail.

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