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EVALUATION OF FIRMS OF AGRICULTURE AND FOOD SECTORS QUOTED AT BORSA İSTANBUL (BİST) BY DEA-BASED MALMQUIST TOTAL FACTOR PRODUCTIVITY INDEX

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ABSTRACT

This study applies a DEA-based Malmquist index to measure technical efficiency and total factor productivity change of food and agriculture firms quoted at Borsa İstanbul (BİST) over the 2010–2015 period. We have investigated efficiency scores of firms using financial ratios. The study shows that, average Malmquist index score is 16.9% below efficiency frontier. Also, four of the twenty-three firms' (KRSAN, KENT, TUKAS and ULKER) Malmquist total factor productivity (MTFP) ratio above the efficient frontier. The results indicate that nineteen out of twenty-three firms (82.6%) experienced productivity losses in the examined period.

Key words: capital market, Data Envelopment Analysis, Malmquist total factor productivity index

INTRODUCTION

After 1980s many developing countries have regulated their financial systems and liberalised them as more market-oriented. Turkey is one of them and market economic tools have used effectively by the companies in recent decades. Among the sectors, agriculture and food sectors have quite high share in Turkish economy in the context of GDP and labour market. However, average size of companies is quite small and institutionalization of them has an important role in local and international competition.

Agriculture and food industry has a growing market share in both local and international markets [RT-PM -ISPA 2014]. Contrary to the increased competitiveness among enterprises in rural areas in farming, Turkey has not made expected progress due to the fragmentation of the labour force and limited coverage of agriculture and family undertakings in national labour legislations, limited unionization and majority of labourers working as unpaid family labour without formal contracts. This leads to the need to examine the entire industry in terms of productivity for agriculture and the food firms, food supply chain, family firms and micro enterprises etc.

There is intensive research worldwide on the effectiveness and productivity of food and agricultural firms [Hartwich 1999, Rahbar and Memarian 2010, Bahrani and Khedri 2013, Rodmanee and Huang 2013]. However, there are different stages that firms need to focus and examine separately to increase productivity and effectiveness. The main task of the agricultural and food firms are to make food and beverage products by processing agricultural raw materials. A food product is affected by many factors from production to consumption [Dios-

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-Palomares et al. 2002, Ratchford 2003, Psillaki et al. 2010]. All these factors should be examined in terms of productivity. Asset allocation strategies need to be determined like use of energy and raw materials, waste management, distribution channel management, fixed investments, amount of cash and cash equivalents etc. [Panpan et al. 2014].

Data Envelopment Analysis (DEA) is widely used as an efficiency measurement tool. These analyzes are based on linear programming. It creates a relative efficiency score chart for companies that transform input(s) into output(s). However, DEA method is a static method causes deviations because of the passage of time lead to the production frontier move. Therefore, Malmquist total factor productivity index (MTFP) has been developed and this method implemented in the study.

Borsa İnstanbul (BİST) is the national stock exchange market and brings together all the exchanges operating in the Turkish capital markets under a single roof. This study focus on the financial performance of the agriculture and food companies quoted at BİST. In order to investigate the relationship between financial structure and firms performance, efficiency scores of the companies were calculated by a linear programming technique (DEA). Beside, MTFP index was calculated to analyse how efficiency scores evolve in time.

LITERATURE

Data Envelopment Analysis and Malmquist Index have been widely used in literatutr to measure changes in technical efficiency and total factor productivity. The variables used to calculate efficiency scores for firms and enterprises may vary [Çakmak et al. 2008]. For example, some studies that examine productivity and efficiency in agriculture and food industries devoted to inputs and outputs defined by Food and Agriculture Organization of the United Nations (FAO) [Coelli and Rao 2005, Ajao 2008, Linh 2009, Souza et al. 2011]. Agricultural gross income and agricultural production calculated by FAO are most commonly used in studies as outputs. Agricultural labour force, planted area, irrigation area, the number of tractors, forage, amount of seed and fertilizer, GDP allocated to agriculture and the agricultural energy consumption is preferred as inputs [Fogarasi 2006, Kaya et al. 2011, Baliyan et al. 2015, Abukarı et al. 2016]. In addition, financial ratios are often used as input and output components in studies where firms' efficiency scores are calculated using the MTFP methodology [Özden 2010]. Yalçıner et al. [2005] argue that most of the studies examining the relationship between stock returns and financial ratios have pointed out that stocks with optimum financial ratios might have high return potential. Table 1 lists some studies that use DEA-based MTFP as method and financial ratios as input and output variables to measure firms' efficiency scores.

Table 1. Literature summary

Author(s)	Sector	Inputs	Outputs
1	2	3	4
Kula et al. [2009]	cement	Current Ratio Financial Leverage Ratio Return on Equity Short-Term Debt/Total Assets Tangible Assets/Equity Net Sales/Total Assets Net Sales/Equity	Return on Equity Return on Assets Return on Sales
Giokas et. al. [2015]	food and beverage	Total Asssets Operating Cost	Total Sales
Chen and Chen [2010]	Taiwanese wafer fabrication industry	Operating Cost Total Assets	Net Sales

Table 1 cont.

1	2	3	4
Dizkırıcı [2014]	food and beverage	Current Ratio Quick Ratio Leverage Ratio Collection Period Inventory Period	Return on Sales Return on Assets
Dinçer [2008]	textile, clothing and leather	Current Ratio Financial Leverage Ratio Equity/Total Assets Equity/Total Debt Short-Term Debt/Total Assets Tangible Assets/Equity Net Sales/Total Assets Net Sales/Equity	Net Profit Margin Operational Profit Margin Operating Margin Equity Profit Margin Asset Profit Margin
Düzakın et al. [2007]	500 major manufacturing firms	Net Assets Shareholders' Equity Debts	Profit
Geyikçi et al. [2015]	wholesale and retail trade	Current Ratio Quick Ratio Financial Leverage Ratio	Net Profit Margin Market Value
Pan et al. [2008]	IC design	Fixed Assets Number of Employees Selling and Operational Expense Research and Development Expense	Annual Revenue
Yalçıner et al. [2005]	BİST 100 Index (100 major firms from İstanbul Stock Market)	Current Ratio Quick Ratio Cash Ratio Debt/EBITDA Short-Term Debt/Total Debt Leverage Ratio Financial Debts/Equity Average Period Equity Period Current Asset Period Net Working Capital Period Price/Earnings Market Value/Book Value	Earnings per Share Net Profit Margin Return on Assets Stock Return

DATA AND METHODOLOGY

Charnes et al. [1978] was firstly introduced DEA method (CCR Model) which is a technique based on the principle of linear programming, designed to measure the relative efficiency of business or economic organizations that convert similar input variables into similar output variables. DEA is a static analysis and performs a horizontal cross-section analysis using the data of the decision units in a single period. DEA models are divided into three parts: input-oriented, output-oriented and non-directed. Input-oriented DEA models investigate the most appropriate input composition to be used in order to produce a particular output composition most efficiently. On the other hand, output-oriented DEA models investigate how much output composition can be obtained with a given input component [Bülbül ve Akhisar 2004].

Mathematical expression of the input dual CCR model for n decision units with m inputs and outputs is as follows:

- objective function

$$\max q_0 = \sum_{r=1}^{s} \mu_r y_{r0}$$

- limiting conditions

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \omega_i x_{ij} \leq 0 \quad j = 1, \dots, n$$

$$\omega_i \geq 0 \quad i = 1, 2, ..., m$$

$$\mu_r = 0 \quad r = 1, 2, ..., s$$

where: x_{ij} – total amount of input i used by the decision unit j;
y_{rj} – total amount of output r produced by the decision unit j;
ω_i – coefficient or weight assigned by DEA to input i;
μ_r – coefficient or weight assigned by DEA to output r.

In the models described above, s is output, m is input, and n is the number of DMUs. In the dual model, it is aimed to maximize the weighted average of each decision-maker's output. The weighted average of the inputs of the decision maker is equal to 1. Also, for each decision-making unit, weighted output averages must be smaller than weighted input averages. If these criteria are equal to 1, which indicates effectiveness for decision points and, if they are less than 1, the decision points are ineffective.

On the assumption of constant return to scale (CRS), pure technical efficiency (PTE) shows how effectively inputs are used and the scale efficiency (SE) shows whether the optimum scale size is used or not. In addition, PTE and SE multiplied by the variable return assumption gives the total technical efficiency (TE) score [Kaya and Doğan 2005].

Basic DEA models are not working with negative numbers. Therefore, the variables of the DMU's used in the analysis must be non-negative (greater than zero). This is defined as positivity requirement of DEA [Ali et al. 1990, Charnes et al. 1991, Pastor 1996]. In his study, Bowlin [1998] describes approaches to overcome the existence of negative output problem. One of them is adding a positive amount to negative input or output values so that the input or output variable becomes positive. This correction must be applied to same input or output variables for all DMUs.

Malmquist total factor productivity (MTFP) index used to measure the development of productivity over time using panel data [Caves et al. 1982]. It measures the change in the total factor productivity between two data points by calculating the ratios of the relative distances of each data point of the zone to technology.

Distance functions can be defined as both input-based and output-based distance functions. The input-based distance function refers to the production technology that takes into account the minimum proportional contraction of the input vector when the output vector is given. The output-based distance function takes into account the maximum proportional increase of the output vector when the input vector is given.

A production technology can be defined as a possible (efficient frontier) output set $P(x)$ consisting of the input vector "x" and the output vector "y" produced by the input vector "x" [Coelli and Rao 2003]:

$P(x) = \{y\text{: } \textit{producted by } x\}$

The output-based distance function is used in this study. The distance function according to the output is defined as:

$$d(x, y) = \min\left\{\delta : \left(\frac{y}{\delta}\right) \in P(x)\right\}$$

In the equation, $d(x, y)$ denotes the distance function, $P(x)$ denotes the possible production set, "x" denotes the input vector, and "y" denotes the output vector, and δ shows the maximum rate at which current output can be reached with a given set of inputs. The less the δ, the more $\frac{y}{\delta}$ is increasing in the reverse direction. Thus, the distance function measures the maximum output level that a given set of inputs can produce:

$$M_0\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right) \cdot \left(\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{\frac{1}{2}}$$

$D_0^t\left(x^{t+1}, y^{t+1}\right)$ refers to the distance from $t + 1$ period observation to t period technology.

The value of the M (.) function is greater than 1, indicating that growth in TFV from period t to period $t + 1$. On the other hand, if it is smaller than 1, it shows that there is a decrease in the same periods:

$$M_0\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left(\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right) \cdot \left[\left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right) \cdot \left(\frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{\frac{1}{2}}$$

$$\textit{efficiency change} = \left(\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right)$$

$$\textit{technical change} = \left[\left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right) \cdot \left(\frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{\frac{1}{2}}$$

Efficiency change gives an assessment of the process of approaching to "efficient frontier" of the DMUs. Technical change gives the change of efficient frontier over time.

Table 2. Productivity index

Malmquist productivity index	Productivity level
$\bar{M} > 1$	improvement in productivity
$\bar{M} = 1$	no change in productivity
$\bar{M} < 1$	productivity loss

Source: Adgei-Frimpong et al. [2014].

ANALYSIS AND RESULTS

In this study, financial efficiency of the food and agriculture companies quoted at Borsa İstanbul (BİST) have examined by DEA-based – Malmquist index for each year of 2010–2015 using financial ratios. Seven of thirty firms does not included in the study because they have quoted at BİST less than six years or because of missing data set. So, twenty-three of food and agriculture firms were examined. Three of these companies (ARTOG, TACTR, ALYAG) are listed in the agricultural sector, while the remaining twenty are listed in the food sector.

Decision-making units (DMUs) must be similar to each other in terms of the product they produce. They also need to convert the same input components into the same set of output. According to many researchers, the number of DMUs included in the analysis should be at least twice the sum of the input-output components, whereas for researchers such as [Boussofiane et al. 1991], it is sufficient that number of DMUs is equal to or greater than *m* (input variables) + *s* (output variables) + 1. According to these constraints, the number of decision units should be at least the number of inputs (8) + the number of outputs (4) + 1 = 13. In this study, 23 agricultural and food sector companies operating continuously in Turkey were analyzed on 8 inputs, 4 outputs. Abbreviations of the DMUs used in the analysis are shown in Table 4.

Table 3 shows the input and output variables used in this study. In this study, DEAP 2.1 package program developed by Coelli [1996] was used to calculate the activity scores.

Table 3. Input and output variables

Inputs	Outputs
Current Ratio	Gross Profit Margin
Quick Ratio	Operating Profit Margin
Cash Ratio	Net Profit Margin
Receivables Turnover	Enterprise Value/Net Sales
Inventory Turnover	
Tangible Assets Turnover	
Total Assets Turnover	
Equity Turnover	

Source: Data obtained from kap.gov.tr and queenstocks.com.

Table 4. Malmquist index summary of annual means by financial years 2011–2015

Specification	EC	TEC	PEC	SEC	TFPC
2011	0.970	0.459	0.996	0.974	0.446
2012	1.034	1.287	1.004	1.029	1.331
2013	0.982	0.716	0.999	0.983	0.703
2014	1.017	0.768	1.001	1.015	0.781
2015	0.954	1.276	0.968	0.985	1.217
Mean	0.991	0.839	0.994	0.997	0.831

Explanations: EC – Efficiency Change, TEC – Technological Efficiency Change, PEC – Pure Efficiency Change, SEC – Scale Efficiency Change, TFPC – Total Factor Productivity Change.

Source: Own research.

Table 4 summarizes the geometric means of the Malmquist index and its decomposition separately for the five years of food and agriculture firms. As seen in Table 4, firms were ineffective in terms of overall productivity in 2011, 2013 and 2014. Malmquist TFPC has increased by 33.1% in 2012 and 21.7% in 2015. The findings indicate that sectoral mean of Malmquist TFPC is at 0.831.

Pure Efficiency Change gives managerial performance to organize the inputs in the production process. Pure Efficiency Change scores of the Turkish agriculture and food sector are 0.996 in 2011, 1.004 in 2012, 0.999 in 2013, 1.001 in 2014 and 0.968 in 2015. Therefore, agriculture and food sector was effective in terms of managerial performance in 2012 and 2014 and lost its effectiveness in 2011, 2013 and 2015. Scores of SEC are 0.974 in 2011, 1.029 in 2012, 0.983 in 2013, 1.015 in 2014 and 0.985 in 2015. These results show that firms are not working at the appropriate scale in 2011, 2013 and 2015. Scores of TEC are realized as 0.459 in 2011, 1.287 in 2012, 0.716 in 2013, 0.768 in 2014 and 1.276 in 2015. These results show that there is a decrease in output produced by the same input variables in 2011, 2013 and 2014. Scores of EC are realized as 0.970 in 2011, 1.034 in 2012, 0.982 in 2013, 1.017 in 2014 and 0.954 in 2015. In 2011, 2013 and 2015, EC scores are below the efficiency frontier which indicates that DMUs have not reached the best production limit in 2011, 2013 and 2015.

Table 5. Malmquist index summary of firm means

Decision-making units	EC	TEC	PEC	SEC	TFPC
ARTOG	0.967	0.766	0.976	0.991	0.740
TACTR	0.976	0.893	0.981	0.995	0.871
YAPRK	0.962	0.806	0.975	0.986	0.775
ALYAG	1.000	0.693	1.000	1.000	0.693
BANVT	1.033	0.715	1.008	1.025	0.739
CCOLA	1.000	0.696	1.000	1.000	0.696
FRİGO	1.000	0.993	1.000	1.000	0.993
KRSAN	1.000	1.266	1.000	1.000	1.266
KENT	1.000	1.114	1.000	1.000	1.114
KONFRT	1.000	0.690	1.000	1.000	0.690
KRSTL	1.000	0.666	1.000	1.000	0.666
MANGO	0.975	0.660	0.979	0.996	0.643
MERKO	0.979	0.881	1.000	0.979	0.862
MERTGG	0.980	0.838	0.984	0.996	0.822
PENGD	0.939	0.834	0.953	0.984	0.782
PETUN	0.983	0.819	1.000	0.983	0.805
PINSU	1.000	0.908	1.000	1.000	0.908
PNSUT	1.000	0.785	1.000	1.000	0.785
SELGD	1.000	0.784	1.000	1.000	0.784
TATGD	1.000	0.783	1.000	1.000	0.783
TKURU	1.000	0.887	1.000	1.000	0.887
TUKAS	1.000	1.087	1.000	1.000	1.087
ULKER	1.000	1.019	1.000	1.000	1.019
Mean	0.991	0.839	0.994	0.997	0.831

Note: Firms are described with their ticker symbols.

Source: Data obtained from kap.gov.tr and queenstocks.com.

Table 5 shows that 19 out of 23 (82.6%) firms are below the efficient frontier. The results indicate that KRSAN 26.6%, KENT 11.4%, TUKAS 8.7%, ULKER 1.9% are above the efficient frontier. The overall decrease in the number of TFPC ratio for FRIGO is however low at 0.7%. Also, average Malmquist TFPC scores of agricultural sector firms (ARTOG, TACTR and YAPRK) are below the efficiency limit and according to the results, they haven't used their assets efficiently as well as the firms which belong to food sector. Decrease in Malmquist ratio can be explain by the decrease in the technical change as we also see in the periodic results of Malmquist TFPC ratios in Table 5. Also, ARTOG, YAPRK, ALYAG, BANVT, CCOLA, KONFRT, KRSTL, MANGO, MERTGG, PNGD, PETUN, PINSUT, SELGD, TATGD are the firms below the Malmquist TFPC sectoral mean (i.e. 0.831).

CONCLUSIONS

This study analyzed Malmquist TFPC and its decomposition EC, TEC, PEC and SEC of firms in the food and sector by means of financial ratios of firms quoted at BİST over the period 2010–2015. The frst major finding was that, Turkish food and agriculture firms quoted at BİST has 16.9% decrease in Malmquist TFPC and this decline can be explained by the decline in TEC. Farrell [1957] defines technical efficiency as the maximal commensurate shrinkage of inputs. This means, companies can reduce costs by the same financial structure.

Scores of MTFP, EC, TEC, SEC and PEC for agriculture firms (ARTOG, TACTR and YAPRK) were also below the efficiency frontier. This finding indicates that agricultural firms listed in BİST have not benefited sufficiently from technological developments. This results are also shown that these firms have been ineffective in managerial performance and have not been able to use their assets effectively.

On the other hand, four out of twenty food firms (KRSAN, KENT, TUKAS, ULKER) were operated above the efficiency limit frontier. Also, only these firm's TEC scores were above the efficiency limit. Score of EC for BANVT was 1.033, the PEC score was 1.008, and the SEC score was 1.025. This finding suggest that the most important strategy for BANVT should be to pursue more effective strategies to convert assets into profit. MANGO, MERKO, MERTGG, PENGD and PETUN are below the efficiency limits in EC and SEC scores. This indicates that these companies are inefficient in input/output configurations. In addition, PEC scores of MANGO, MERTGG and PENGD are also below the efficiency limit.

These findings reveal that the sector can not make enough use of technological developments. It is determined as an important strategic information for increasing the competitive power of companies to make a difference in the sector. Technological developments and effective use of these developments will also play a role in ensuring managerial performance. This will provide high competitive power.

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WYKORZYSTANIE METODY DEA Z ZASTOSOWANIEM INDEKSU PRODUKTYWNOŚCI CAŁKOWITEJ MALMQUISTA DO OCENY EFEKTYWNOŚCI SPÓŁEK SEKTORA SPOŻYWCZEGO NOTOWANYCH NA BORSA İSTANBUL (BİST)

STRESZCZENIE

W pracy do pomiaru zmian efektywności technicznej i produktywności całkowitej spółek sektora spożywczego notowanych na Borsa İstanbul (BİST) w latach 2010–2015 zastosowano metodę DEA z użyciem indeksu Malmquista. Do oceny efektywności poszczególnych firm wykorzystano wskaźniki finansowe. Uzyskana średnia wartość indeksu Malmquista jest poniżej granicy wydajności, jednakże dla czterech z dwudziestu trzech firm (Kršan, Kent, Tukas i Ulker) wartość tego indeksu jest powyżej granicy efektywności. Ponadto uzyskane wyniki wskazują, że w badanym okresie dziewiętnaście spośród dwudziestu trzech firm (82,6%) doświadczyło straty wydajności.

Słowa kluczowe: rynek kapitałowy, metoda DEA, indeks produktywności całkowitej Malmquista