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Determining the Effectiveness of Sustainable Production Activities in Fishing Sector by Data Envelopment Analysis

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ABSTRACT

Data envelopment analysis is used when it is difficult to measure the relative effectiveness of organizational decision-making units due to a large number of similar inputs and outputs. Firstly, data envelopment analysis was discussed in this study. In this context, relative activities of 10 companies have been operating in fisheries sector for last nine years (2009-2017) which entered the Fortune 500 in Turkey and have sufficient data were measured using financial inputs and outputs. Relative effectiveness scores were obtained by examining the financial inputs and outputs of the companies that are in the Fortune 500 and operating in fisheries sector. In the second part of study, to reveal the technical efficiency and the ineffective ones resulting from the scale, DEA models including the input-oriented CCR (Charnes, Cooper, and Rhodes) and BCC (Banker, Charnes, and Cooper) model were established and the above mentioned procedures were repeated. Finally, it was investigated whether an investment system based on DEA could be established or not. DEA Frontier and DEA Solver software, one of the special software of DEA, was used for the solution of models using in data envelopment analysis. As a result of the study, the average efficacy percentage was found to be 88% for CCR and 93% for BCC. For the data obtained during 2009-2017, six companies were found to be active according to the CCR model, while seven companies were found to be effective according to the BCC model. Also, the targets were determined to activate the inactive companies.

INTRODUCTION

In the presence of today's tough competition conditions, globalization, and developments in technology, companies, to protect their assets and continue their activities in a determined manner, have to determine the current efficiency levels of their activities and increase efficiency. Therefore, the objectives of the company are expressed by performance indicators such as high efficiency, efficiency, profit maximization, cost minimization, service satisfaction, growth, and respectability (Barutçugil, 2002). Performance measures should be calculated for understanding whether the company has achieved its objectives or not one of the methods used for this purpose is effectiveness analysis. It is important to estimate the effectiveness of decision points and take the suitable decision according to the activities if there is more than one decision point for a decision-maker.

One of the most important problems of business managers is to find the best method to measure efficiency. Efficiency is a widely used concept in the economy, and it can be described as a company using its resources in the optimum way to reach its goals and objectives (Sherman,

1984; Yeşilyurt & Alan, 2003; Özden, 2008; Kyriaki, 2017; Beridze & Anbar, 2019). In other words, efficiency is a performance indicator that shows the extent to which the company has achieved its goals and objectives. Efficiency can also be expressed as the ratio between beneficial inputs and outputs. In this manner, efficiency is related to the fact that businesses can do more by considering the ratio between inputs and outputs (Torun & Özdemir, 2015).

Parametric and nonparametric methods can be used to measure the efficiency with ratio analysis. However, reviewing the literature, it was seen that the most widely used method is the nonparametric data envelopment analysis (DEA) method (Rashedul & Israt, 2012; Akgöbek et al., 2015; Dogan & Topalli, 2016; Beridze & Anbar, 2019).

Data envelopment analysis was formed for the first time in 1957 with the recommendation of the frontier production function, which was proposed by Farrell against the average performance criterion. There are two common DEA models used in literatures. These two models are the CCR model (Charnes et al., 1978; Behdioğlu & Özcan, 2009), developed by Charnes et al. (1978), based on the scale of fixed return assumption to measure the activities of the resembling KVB (decision making unit), the BCC model based on the CCR model, based on the scale-assumed return assumption developed by Banker et al. (1984) (Behdioğlu & Özcan, 2009; Bircan, 2011; Kumar & Singh, 2014; Yin et al., 2014) and the additive method developed by Banker et al. (1984) which produces results without being directed to input and/or output. The additive model is a model subject to variable return conditions according to the scale. While the efficiency score of the first model (fixed return by scale) shows the "general" technical efficiency according to the appropriate input-output structure and the size of the transactions, the effectiveness score of the second model (variable by scale) shows the "pure" technical efficiency (Coelli, 1996; Rabar, 2017).

CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes, and Cooper) models used in DEA can be established in two different ways i.e., input-oriented and output-oriented. According to their orientation, these models are divided into 3 groups called "input-oriented models", "output-oriented models" and "non-oriented models" (Kecek, 2010). In input-oriented CCR and BCC models, it has been tried to use the minimum input to produce the current output aiming to produce the maximum output with the current input in output-oriented CCR and BCC models (Özden, 2008). Total efficiency score is obtained for each decision-making unit when these established models are solved for all decision-making units. When this score is equal to 1, it means that decision-making units are effective; while less than 1 means that decision-making units are not effective.

To measure the effectiveness of the systems, DEA has been used in a wide range of applications to determine the performance of companies within the sector they operate. There are many sectors where data envelopment analysis is used. As the application area increased, DEA Excel Solver, DEA-Solver Pro, EMS, Warwick DEA, DEAP, Frontier Analyst computer package programs have been used for DEA.

Although studies on effectiveness and efficiency in the fisheries sector have been carried out in many countries for several years to measure the efficiency of the work, no such studies were conducted in fisheries sector. Therefore, this study has been thought having an important contribution to literatures. Ten companies that entered to FORTUNE 500 in the fisheries sector have been evaluated in our study using the data of 2009-2017 with non-parametric method DEA, which is considered to be the solution oriented suggestion of the companies. The basic aim of our study is to measure the economic effectiveness of the companies listed in FORTUNE 500 and to calculate their comparative effectiveness on economic effectiveness and also to determine the potential improvement targets of these companies for ineffective companies. A very limited number of studies carried out using this method in fisheries industry increase the importance of the study.

MATERIAL AND METHODS

In the study, since there are multiple inputs and outputs and the relative effectiveness of the firms are measured, the DEA method was adopted, and included the companies which entered to FORTUNE 500 in 2009-2017 in agricultural, cereal, milk, meat and fisheries sector rankings, and engaged only in fisheries sectors. The activity scores of these companies covering the years 2009-2017 have been calculated and the results were included in the study.

Although it changes every year, an average of 10 companies is included in the scope of the study. Then, the inputs and outputs that were thought to have an effect on obtaining the relative activities of the companies were determined. DEA models were used with 3 different input and 4 different output sets. These are the company's number of employees, assets, and equity. In the study, the expression of CRS (constant return to scale) model was used for CCR model, which calculates the total efficiency under the assumption of fixed return (CRS) by considering financial inputs and outputs. Moreover, the BCC model, which calculates the technical efficiency under the assumption of VRS (variable return to scale), was expressed in the form of

Table 1. Data set to determine the activity of the companies

Companies	Year Founded	Inputs			Outputs			
		The Number of Employees	Active Total (TRY)	Equity Capital (TRY)	Net Sales (TRY)	EBIT (TRY)	PBT/Net Sales (%)	Export Value (TRY)
F1	1942	2450	860906476.9	399022940.9	1470567166	156039993	7.24	104415848.2
F2	1993	655	201938357.5	87347123	237276761	1587161	0.00	6556718.5
F3	1983	406	217763373.6	62905812.67	278457198	25375368	1.18	41802593.44
F4	1952	798	918405055	444086087.7	2361303623	151022502	0.48	0
F5	1968	1028	159942443.2	63955271.33	338394615	3071922	0.15	16899869.17
F6	1997	828	385935954.6	201938546.7	368479374	59282710	14.59	116993797.1
F7	1988	69	118649388.5	38998485	283290898	16412469	1.32	73351552
F8	1991	892	526800325.8	176058116	404685112	93232656	8.47	174086479.4
F9	1954	2579	3351682328	1002734245	1755683795	304868719	6.67	100886751
F10	1973	504	342672341	270385966	307871231	51955546	15.48	5343085

Table 2. CRS and VRS effectiveness score with financial inputs and outputs

CRS Effectiveness Score Input-Oriented CRS							VRS Effectiveness Score Input-Oriented VRS						
DMU Name	Efficiency	Optimal Lambdas with Benchmarks				Reference	DMU Name	Efficiency	Optimal Lambdas with Benchmarks				Reference
F1	1.00000	1.000	F1			1	F1	1.00000	**1.000**	F1			1
F2	0.46800	0.069	F4	0.262	F7	4.7	F2	0.58755	1.000	F7			7
F3	0.86276	0.794	F7	0.132	F8	7.8	F3	0.87416	0.883	F7	0.117	F8	7.8
F4	1.00000	1.000	F4			4	F4	1.00000	1.000	F4			4
F5	0.85589	0.069	F4	0.623	F7	4.7	F5	0.87442	0.027	F4	0.973	F7	4.7
F6	1.00000	1.000	F6			6	F6	1.00000	1.000	F6			6
F7	1.00000	1.000	F7			7	F7	1.00000	1.000	F7			7
F8	1.00000	1.000	F8			8	F8	1.00000	1.000	F8			8
F9	0.67923	13.163	F7	0.953	F8	7.8	F9	1.00000	1.000	F9			9
F10	1.00000	1.000	F10			10	F10	1.00000	1.000	F10			10

VRS model. Optimization solution of DEA was realized under both the fixed return to scale (CCR = CRS) assumption and the variable return to scale (BCC = VRS) assumption.

In the measurement of the effectiveness of decision units, output-oriented effectiveness measurements were made in both methods to provide the highest possible output from the available sources (input factors). In the selection of data, to be used to measure the effectiveness of decision-making units, a literature review was carried out on the effectiveness analysis in fisheries industry and the input and output factors frequently used in the literatures were taken into account. Elimination of input and output factors has been made since the total number of inputs and outputs to be used in the application should be less than the number of decision units, although there is a small change between the outputs and outputs in the literature. In the study, the minimum number of decision-making units (DMU) required for the analysis (n + m + 1) was met, where n: the number of inputs: 3 (the number of employees, total assets (TRY), equity capital (TRY)), m: the number of outputs: (net sales (TRY), EBIT (earnings before interest tax) (TRY), PBT (profit before tax)/net sales (%) and export value (TRY). While the data subjected to the study were analyzed by BCC and CCR models, 12 linear programming models for 12 DMUs must be created and solved separately. Evaluated companies are given in Table 1 along with their founding years. DEA

Frontier and DEA Solver (Data Envelopment Analysis Solver) software, one of the special software of data envelopment analysis, was used to solve the models.

RESULTS

Using the data between the period of 2009 - 2017, analyzes were carried out by making them under the fixed return assumption (CCR = CRS) according to the input-oriented scale and under the variable return assumption (BCC = VRS) according to the input-oriented scale shown in Table 2.

The said table shows the effectiveness measurement results and the reference set of 10 companies operating in the fisheries sector. According to the CRS results, six of the decision units were effective while the remaining four were observed to be ineffective. Effective decision units are F1, F4, F6, F7, F8, and F10 and their efficiency value is 1. Ineffective decision units are included as F2, F3, F5, and F9 companies. Furthermore, according to the VRS results, seven of the decision units were effective whereas three were observed to be ineffective. Effective decision units are F1, F4, F6, F7, F8, F9, and F10, and their activity value was noted as 1. Ineffective decision units were mentioned as F2, F3 and F5 companies.

According to the CRS results, F2 had an effectiveness value of 0.46800, F3 had an effectiveness value of 0.86276, F5 had an effectiveness value of 0.85589 and F9 had an effectiveness value of 0.67923. The most ineffective company

Table 3. CCR and BCC directed input results

		CCR Input-Oriented Results			BCC Input-Oriented Results		
Company	**Outputs**	**Realized**	**Target**	**Potential Improvement**	**Realized**	**Target**	**Potential Improvement**
F1	The Number of Employees	2450	2450	0.00	2450	2450	0.00
	Active Total (TRY)	860906477	860906476.89	0.00	860906477	860906476.89	0.00
	Equity Capital (TRY)	399022941	399022940.89	0.00	399022941	399022940.89	0.00
F2	The Number of Employees	**655**	**73**	**-88.85**	**655**	**69**	**-89.54**
	Active Total (TRY)	**201938358**	**94507213.95**	**-53.20**	**201938358**	**118649388.50**	**-41.24**
	Equity Capital (TRY)	**87347123**	**40878480.66**	**-53.20**	**87347123**	**38998485.00**	**-55.35**
F3	The Number of Employees	**406**	**173**	**-57.49**	**406**	**165**	**-59.44**
	Active Total (TRY)	**217763374**	**163948431.10**	**-24.71**	**217763374**	**166269891.14**	**-23.65**
	Equity Capital (TRY)	**62905812.7**	**54272540.87**	**-13.72**	**62905812.7**	**54989746.87**	**-12.58**
F4	The Number of Employees	798	798	0.00	798	798	0.00
	Active Total (TRY)	918405055	918405055.00	0.00	918405055	918405055.00	0.00
	Equity Capital (TRY)	444086088	444086087.67	0.00	444086088	444086087.67	0.00
F5	The Number of Employees	**1028**	**97**	**-90.53**	**1028**	**88**	**-91.45**
	Active Total (TRY)	**159942443**	**136893394.10**	**-14.41**	**159942443**	**139856914.99**	**-12.56**
	Equity Capital (TRY)	**63955271.3**	**54738779.72**	**-14.41**	**63955271.3**	**49740398.34**	**-22.23**
F6	The Number of Employees	828	828	0.00	828	828	0.00
	Active Total (TRY)	385935955	385935954.57	0.00	385935955	385935954.57	0.00
	Equity Capital (TRY)	201938547	201938546.71	0.00	201938547	201938546.71	0.00
F7	The Number of Employees	69	69	0.00	69	69	0.00
	Active Total (TRY)	118649389	118649388.50	0.00	118649389	118649388.50	0.00
	Equity Capital (TRY)	38998485	38998485.00	0.00	38998485	38998485.00	0.00
F8	The Number of Employees	892	892	0.00	892	892	0.00
	Active Total (TRY)	526800326	526800325.80	0.00	526800326	526800325.80	0.00
	Equity Capital (TRY)	176058116	176058116.00	0.00	176058116	176058116.00	0.00
F9	The Number of Employees	**2579**	**1752**	**-32.08**	2579	2579	0.00
	Active Total (TRY)	**3351682328**	**2063709072.36**	**-38.43**	3351682328	3351682328.33	0.00
	Equity Capital (TRY)	**1002734245**	**681082607.39**	**-32.08**	1002734245	1002734245.22	0.00
F10	The Number of Employees	504	504	0.00	504	504	0.00
	Active Total (TRY)	342672341	342672341.00	0.00	342672341	342672341.00	0.00
	Equity Capital (TRY)	270385966	270385966.00	0.00	270385966	270385966.00	0.00

in the measurement performed on the assumption of fixed return according to the scale was F2 and its effectiveness was below 47%. Considering the reference sets, the most frequently referenced company from the effective companies was the F7 company, which was referenced to 5 decision units, followed by the F4 and F8 companies which were referenced to 2 decision units. F4 and F7 companies were taken reference for the ineffective F2 company. F7 and F8 companies were taken as references for F3 and F9 companies. F4 and F7 companies were taken as references for F5 company. According to the VRS results, F2 company has a value of 0.58755, F3 with a value of 0.87416, and F5 having a value of 0.887442. The most ineffective company in the measurement performed in variable return assumption according to the scale was F2 and its efficiency was found below 59%. Considering the reference sets, the most referenced company from among active companies was F4 company, which was the reference unit for 1 decision unit. F7 was taken reference for the ineffective company F2. Company F3 took the companies F7 and F8 as the reference. F4 and F7 companies were taken as references for F5 company (Table 2).

As a result of the input-oriented CCR effectiveness application and BCC effectiveness applications, it has been observed that there was strong effectiveness in all effective decision units. According to the input-oriented CCR input-oriented effectiveness application, for F2 company which had an ineffective decision unit to be effective, the number of employees in the input group should be reduced by 88.85%, and the potential improvement ratio in the active total and the equity should be reduced by 53.20%. F2 will be active when it reaches the target values (Table 2). According to the input-oriented BCC input-oriented effectiveness application, for F2 company which had an ineffective decision unit to be effective, the number of employees in the input group should be reduced by 89.54%, and the potential improvement ratio in the Active Total should be reduced by 41.24% and the Equity should be reduced by 55.35%. F2 will be active when it reaches the target values (Table 3).

According to the input-oriented CCR input-oriented effectiveness application, for the F3 company which had an ineffective decision unit to be effective, the number of employees in the input group should be reduced by 57.49%, the active total should be reduced by 24.71% and the equity (the potential improvement ratio) should be reduced by 13.72%. According to the input-oriented CCR input-oriented effectiveness application, for the F3 company which had an ineffective decision unit to be effective, the number of employees in the input group should be reduced by 59.44%. The active total should be reduced by 23.65% and the equity (the potential improvement ratio) should be reduced by 12.58%. F3 will be active when it reaches the target values shown in Table 3.

According to the input-oriented CCR input-oriented effectiveness application, for F9 company which had an ineffective decision unit to be effective, the number of employees in the input group should be reduced by 32.08%, the active total should be reduced by 38.43% and the equity (the potential improvement ratio) should be reduced by 32.08%. Thus, F9 will be active when it reaches the target values (Table 3).

When input-oriented CCR activity application was performed, it has been observed that there was strong activity in all effective decision-making units. For F2 company, which was one of the ineffective decision units, to be effective, EBITDA (TRY) in the output group should increase by 927.95% and the export by 293.46% potential improvement. When the BCC effectiveness application of input-oriented outputs was applied, it has been observed that there was strong activity in all effective decision units. For F2 company, which was one of the ineffective decision units, to be effective, net sales in the output group should increase the rate of net sales by 19.39%, EBIT (TRY) by 934.08% and the export value by 1018.72% potential improvement. F2 will be active when it reaches the target values (Table 4).

According to the input-oriented CCR input-oriented effectiveness application, for F3 company which had an ineffective decision unit to be effective, PBT/net sales should be increased by 184.06% while the export should be increased by 194.43% (potential improvement ratio). According to the input-oriented BCC input-oriented effectiveness application, for F3 company which had an ineffective decision unit to be effective, net sales should be increased by 6.82%, PBT/net sales should be increased by 82.58% and the export should be increased by 103.59% (potential improvement ratio). F3 will be active when it reaches the target values (Table 4).

According to the input-oriented CCR input-oriented effectiveness application, for F5 company which had an ineffective decision unit to be effective, EBIT (TRY) should be increased by 669.91%, PBT/net sales should be increased by 564.28% and the export should be increased by 270.60% (potential improvement ratio). According to the input-oriented CCR input-oriented effectiveness application, for F5 company which had an ineffective decision unit to be effective, EBIT (TRY) should be increased by 550.47%, PBT/net sales should be increased by 765.15% and the export should be increased by 322.53% (potential improvement ratio). F5 will be active when it reaches the target values shown in Table 4.

According to the input-oriented CCR input-oriented effectiveness application, for F9 company which had an

Table 4. Potential recovery rates of fisheries companies according to CCR and BCC

Company	Outputs	CCR			BCC		
		Realized	Target	Potential Improvement (%)	Realized	Target	Potential Improvement (%)
F1	Net Sales (TRY)	1,470,567,166.00	1,470,567,166.00	0.00	1,470,567,166.00	1,470,567,166.00	0.00
	EBIT (TRY)	156,039,993.22	156,039,993.22	0.00	156,039,993.22	156,039,993.22	0.00
	PBT/Net Sales (%)	7.24	7.24	0.00	7.24	7.24	0.00
	Export Value (TRY)	104,415,848.22	104,415,848.22	0.00	104,415,848.22	104,415,848.22	0.00
F2	Net Sales (TRY)	237,276,761.00	237,276,761.00	0.00	237,276,761.00	283,290,897.50	**19.39**
	EBIT (TRY)	1,587,161.00	14,728,051.14	**927.95**	1,587,161.00	16,412,468.50	**934.08**
	PBT/Net Sales (%)	0.00	0.38	0.00	0	1.32	0.00
	Export Value (TRY)	6,556,718.50	19,241,196.62	**293.46**	6,556,718.50	73,351,552.00	**1018.72**
F3	Net Sales (TRY)	278,457,197.78	278,457,197.78	0.00	278,457,197.78	297,454,416.42	**6.82**
	EBIT (TRY)	25,375,368.22	25,375,368.22	0.00	25,375,368.22	25,375,368.22	0.00
	PBT/Net Sales (%)	1.18	2.17	**184.06**	1.18	2.15	**82.58**
	Export Value (TRY)	41,802,593.44	81,278,752.83	**194.43**	41,802,593.44	85,104,674.28	**103.59**
F4	Net Sales (TRY)	2,361,303,622.67	2,361,303,622.67	0.00	2,361,303,622.67	2,361,303,622.67	0.00
	EBIT (TRY)	151,022,501.67	151,022,501.67	0.00	151,022,501.67	151,022,501.67	0.00
	PBT/Net Sales (%)	0.48	0.48	0.00	0.48	0.48	0.00
	Export Value (TRY)	0.00	0.00	0.00	0	0	0.00
F5	Net Sales (TRY)	338,394,614.50	338,394,614.50	0.00	338,394,614.50	338,394,614.50	0.00
	EBIT (TRY)	3,071,921.50	20,579,170.67	**669.91**	3,071,921.50	19,981,991.00	**550.47**
	PBT/Net Sales (%)	0.15	0.86	**564.28**	0.15	1.30	**765.15**
	Export Value (TRY)	16,899,869.17	45,730,586.56	**270.60**	16,899,869.17	71,406,451.71	**322.53**
F6	Net Sales (TRY)	368,479,373.71	368,479,373.71	0.00	368,479,373.71	368,479,373.71	0.00
	EBIT (TRY)	59,282,709.71	59,282,709.71	0.00	59,282,709.71	59,282,709.71	0.00
	PBT/Net Sales (%)	14.59	14.59	0.00	14.59	14.59	0.03
	Export Value (TRY)	116,993,797.14	116,993,797.14	0.00	116,993,797.14	116,993,797.14	0.00
F7	Net Sales (TRY)	283,290,897.50	283,290,897.50	0.00	283,290,897.50	283,290,897.50	0.00
	EBIT (TRY)	1.6412.468,50	16,412,468.50	0.00	16,412,468.50	16,412,468.50	0.00
	PBT/Net Sales (%)	1.32	1.32	0.00	1.32	1.32	0.00
	Export Value (TRY)	73,351,552.00	73,351,552.00	0.00	73,351,552.00	73,351,552.00	0.00
F8	Net Sales (TRY)	404,685,112.20	404,685,112.20	0.00	404,685,112.20	404,685,112.20	0.00
	EBIT (TRY)	93,232,655.60	93,232,655.60	0.00	93,232,655.60	93,232,655.60	0.00
	PBT/Net Sales (%)	8.47	8.47	0.00	8.47	8.47	0.00
	Export Value (TRY)	174,086,479.40	174,086,479.40	0.00	174,086,479.40	174,086,479.40	0.00
F9	Net Sales (TRY)	1,755,683,795.11	4,114,503,535.79	**234.35**	1,755,683,795.11	1,755,683,795.11	0.00
	EBIT (TRY)	304,868,719.11	304,868,719.11	**0.00**	304,868,719.11	304,868,719.11	0.00
	PBT/Net Sales (%)	6.67	25.45	**381.52**	6.67	6.67	0.00
	Export Value (TRY)	100,886,751.00	1,131,387,644.97	**1,121.44**	100,886,751.00	100,886,751.00	0.00
F10	Net Sales (TRY)	307,871,231.00	307,871,231.00	0.00	307,871,231.00	307,871,231.00	0.00
	EBIT (TRY)	51,955,546.00	51,955,546.00	0.00	51,955,546.00	51,955,546.00	0.00
	PBT/Net Sales (%)	15.48	15.48	0.00	15.48	15.48	0.00
	Export Value (TRY)	5,343,085.00	5,343,085.00	0.00	5,343,085.00	5,343,085.00	0.00

ineffective decision unit to be effective, EBIT (TRY) should be increased by 234.35%, PBT/Net sales should be increased by 381.52% and the export should be increased by 1121.44% (potential improvement ratio). F9 will be active when it reaches the target values (Table 4).

To evaluate the effectiveness of companies in fisheries sector technical efficiency, pure technical efficiency, scale effectiveness and scale-based yield characteristics are given in Table 5.

When examining Table 5 in detail, it is seen that six companies i.e.; F1, F4, F6, F7, F8 and F10) were both ineffective production scale in terms of scale effects and use their resources effectively and efficiently according to the activity scores of 10 companies in fisheries industry. These companies have the most effective scale size. While examining the companies viz F2, F3 and F5, it has been seen that they were not effective both in pure technical efficiency and technical efficiency. When examining F9 company, the scale was not technically effective but pure technical activities were found to be. This was associated with the fact that, although, they were technically effective but not purely effective. When examining the scale effectiveness of F9, it has been seen that this company have had pure technical activities but not technically effective had lower scale effectiveness as compared to F2, F3 and F5 which were both pure as well as technically inactive. It has been observed that F2 and F5 had greater scale effectiveness due to their close technical and pure technical efficacy values. It was determined that F2, F3, F5 and F9 had decreasing return characteristics according to the scale. On the other hand, the remaining companies showed a fixed return according to the scale since they were fully effective in all activity observations.

DISCUSSION

To measure the effectiveness of the systems, DEA has been used in a wide range of applications to determine the performance of companies within the sector where they operated.

Several studies have been conducted to determine the effectiveness by DEA in Turkey as well as in the world. These sectors include aviation, automotive (Baysal et al., 2005; Çoban, 2007; Yaylalı & Çalmaşur, 2014), health (Tetik, 2003; Yiğit & Esen, 2017), manufacturing (Deliktaş, 2002; Bakırcı, 2006; Bakırcı et al., 2014; Sevinç & Eren, 2016), stock exchange and banking (Pascoe & Herrero, 2004; Chufen, 2007; Seyrek & Ata, 2010; Uyguntürk & Korkmaz, 2016), cement and textile (Kayalıdere & Kargın, 2004; Doğan & Ersoy, 2017), information technology, education, general and tourism (Walden & Kirkley, 2000; Holland & Lee, 2002; Düzakın & Demirtaş, 2005; Özden, 2008; Yükçü & Atağan, 2009; Iribarren et al., 2010; Göktolga & Artut, 2011; Çelik, 2016) and agriculture (Aktürk & Kıral, 2002, Rodríguez-Díaz et al., 2004; Reig-Martínez & Picazo-Tadeo, 2004; Koyubenbe, 2006; Kaya & Aktan, 2011; Demir et al., 2012; Daka et al., 2012; Engindeniz, 2012; Gökdoğan & Demir, 2013; Külekçi, 2014; Mohammadi et al., 2015; Sgroi et al., 2015).

Turkey, with investments made in trade agreements and the fisheries sector, has shown great development, especially after 2000s. There are many studies found in the literature on the determination of the effective and ineffective companies in fisheries sector (Sharma et al., 1999; Kirkley et al., 2002; Tingley et al., 2003, 2005; Cinemre et al., 2006; Esmaeili, 2006; Esmaeli & Omrani, 2007; Hoff, 2007; Tsitsika et al., 2008; Maravelias & Tsitsika, 2008; Gardner et al., 2008; Bozoğlu & Ceyhan, 2009; Vázquez-Rowe et al., 2010, 2012; Griffin & Woodward, 2011; Vázquez-Rowe & Tyedmers, 2013; Avadí et al., 2015; Seki & Akbulut, 2015; Demirci & Tarhan, 2016). However, no similar study was found in the literature.

In this study, which included the activity research related to fisheries sector, DEA has been used in the measurement of efficiency. DEA, a non-parametric method, is used to measure the distances to the efficiency limit by making a relative comparison of the companies called Decision Making Units (DMU). It gives values between 0 and 1 to DMUs using various constraints. DEA provides important information to managers, as it allows us to measure the effectiveness of DMUs with multiple inputs and outputs. It does not need to make conversions in inputs and outputs to make measurements, and it offers suggestions for determining and eliminating inefficiencies.

In our study, 3 inputs viz number of employees, active total (TRY) and equity (TRY), and 4 outputs namely net sales (TRY), EBITDA (TRY), PBT/net sales (%) and export (TRY) which were obtained from the financial statements of 10 fisheries companies in fisheries sector which entered Fortune 500. (TRY), BPT/net sales (%), export amount (TRY) were examined by the DEA output-oriented CCR and BCC models.

As a result of input-oriented CCR application to companies in fisheries industry, 6 companies were effective and 4 companies were ineffective, while 7 companies were effective and 3 companies were ineffective as a result of BCC implementation. According to the results of CCR and BCC effectiveness analyses; F2, F3, and F5 were found to be ineffective while F9 was found to be effective according to BBC model.

According to CCR, the efficiency score of F2 was below 47%, but in case of BCC, the efficiency score was below 59%. According to the combined results of CCR and BCC models,

Table 5. Scale effectiveness and scale returns for companies in the fisheries sector

Company	Technical Activity CCR	Pure Technical Activity BCC	Scale Effectiveness	Yield by Scale
F1	1.00000	1.00000	1	Fixed
F2	0.46800	0.58755	0.7965	**Reducing**
F3	0.86276	0.87416	0.9869	**Reducing**
F4	1.00000	1.00000	1	Fixed
F5	0.85589	0.87442	0.9788	**Reducing**
F6	1.00000	1.00000	1	Fixed
F7	1.00000	1.00000	1	Fixed
F8	1.00000	1.00000	1	Fixed
F9	0.67923	1.00000	0.67923	**Reducing**
F10	1.00000	1.00000	1	Fixed

potential improvement rates should be reduced by 88.95% and 89.54 in the number of employees, by 53.20% and 41.24% in the active total, respectively, by 53.20% and 55.35% in equity (potential improvement rate).

According to CCR, the efficiency score of F2 was below 47%, but in case of BCC, the efficiency score was below 59%. According to the combined results of CCR and BCC models, potential improvement rates should be reduced by 88.95% and 89.54 in the number of employees, by 53.20% and 41.24% in the active total, respectively, by 53.20% and 55.35% in equity (potential improvement rate).

In CCR application results, potential improvement rates for F3 were 184.06% for EBTI/net sales and 194.43% for export value. Although, it is not possible to reach these values where F2 had a higher chance of obtaining effectiveness under the assumption of a variable by scale (BCC). It has been associated with the necessity that a decision unit has to be both technical and scale effective in the CCR model BCC eliminates the necessity of scale efficiency for a decision unit. While the CCR model gives the total effectiveness, the BCC model is based on the variable technical return assumption based on pure technical effectiveness.

Potential improvement rates and target values were determined around 190% of F3 company which had inactive CCR. It was seen that the company which has to increase PBT/net sales by 184.06% had the potential to reach this target considering the value it achieved in the previous year.

Again, the potential improvement rates of the company, which is ineffective as a result of F5's input-oriented CCR application, were determined as EBIT (TRY) 669.91%, 564.28% for PBT/net sales and 270.60% for exports. The potential improvement rates for F5 company which was found to be ineffective as a result of input-oriented BCC application were determined to be 550.47% for EBIT (TRY), 765.15% for PBT/net sales and 322.53% for export.

The potential improvement rates for F9 company which was found to be ineffective as a result of input-oriented CCR application were determined to be 234.35% for EBIT (TRY), 381.52% for PBT/net sales and 1121.44% for export. It was found to be effective as a result of F5's input-oriented BCC application. Therefore, it is possible for F9 to meet the targets.

The technical efficiency averages of companies in the sector in that period are below the value of one. Companies in the sector cannot use their resources effectively. In other words, the reason for the increase in productivity in fisheries sector is technological progress. In the light of this survey study, following structural problems to be resolved: One of the most remarkable results of the study was the shortcomings in terms of institutionalization and the educational level of the managers, the shortcomings in marketing, usage of loans and incentives, low technical efficiency of the companies entering the FORTUNE 500 in fisheries sector. This reveals that there are structural problems in the sector. Despite the structural problems, firms use technology well and increase their total factor productivity and, thus, their competitiveness. Finding solutions for these structural problems, it is necessary to establish management mechanisms that would increase the cooperation of university with sector. The effectiveness of fisheries industry can be increased with the help of these management mechanisms and a triangle cooperation of industry, university and government sectors. A fisheries industry with increased activity can become one of the leading sectors in the economic development of Turkey. Also, examining all the efforts, it was seen that the studies in fisheries sector in Turkey using the DEA method were limited and inadequate, and it was concluded that further studies should be carried out using the DEA method. With DEA, the implementation of extension programs that will overcome the technical insufficiency in enterprises and taking policy measures covering training at the enterprise

level may contribute to the increase in economic effectiveness in the study area.

CONCLUSION

Since this study was the first in Turkey to measure the effectiveness level of companies in fisheries sector, findings could not be compared with the findings of other studies. This can be considered as a limitation of the study, but also presents an opportunity for future studies. Different approaches/models for effectiveness measurement, different input-output combinations, and making new studies using different data periods, will contribute to filling the gap in the literature for fisheries in Turkey.

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Compliance with Ethical Standards

Authors' Contributions

Literature review: Hülya Saygı, Burcu Taylan

Survey administration: Hülya Saygı, Aysun Kop, Hatice Tekoğul, Burcu Taylan

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Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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