Determination of technical efficiency in broiler production using Data Envelopment Analysis method: a case study of Hatay Province in Turkey

Reception of originals: 10/30/2020
Release for publication: 05/05/2021

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Abstract

The province of Hatay, where the study was carried out, is in a strategic location in terms of its geographical location. It has advantages in terms of border trade both by port, sea and also by road. Therefore, it has the potential to meet both domestic and external demand. This study aims to measure the technical efficiency scores of broiler production farms located in Hatay province in southern Turkey. For this purpose, broiler farms operating in the province of Hatay were examined and data were collected from 19 broiler farms operating in the province using the Census method. Data Envelopment Analysis (DEA) method, which is often preferred in measuring the efficiency of the data, was used. Measurements were made with the input-oriented approach under the assumptions of DEA-CRS (Constant Return to Scale) and DEA-VRS (Variable Return to Scale). The Tobit regression model was used to determine the causes of inefficiency after DEA scores were calculated. In the analysis, the technical efficiency score was calculated with DEA - CRS as 0.95; and with DEA - VRS as 0.97. It has been determined that the broiler farms examined can produce at the same output level by reducing the inputs used in the current production technology by 5% according to the DEA-CRS approach and 3% according to DEA-VRS approach. Among the socio-economic variables that are thought to affect efficiency scores; it has been determined that operators having 15 years or more of experience cause inefficiency. As a result, it can be said that broiler farms operating in the province of Hatay operate efficient both in terms of input use and economies of scale. While it is determined that inefficient broiler farms use their labour excessively, better organisation of the labour can be suggested as a measure for broiler farms to work full efficient.

Keywords: Broiler. Technical Efficiency. Data Envelopment Analysis.

1. Introduction

A significant portion of farms operating in the poultry sector in Turkey makes productions in facilities using modern methods. In recent years, supporting the sector with investment incentives has increased integrated facilities in industrial production.

In the poultry sector, Turkey is a major exporter country as well as a major producer and a consumer. The poultry sector further increases the importance of the sector for Turkey with the employment it creates, modern integrated facility investments, expert production, processing and marketing mechanism, high share in foreign trade, healthy product supply. The annual turnover of the sector is over 6 billion dollars. Approximately 600,000 people are employed in Turkey, both in the sector and in the subsidiaries. The number of people working in the sector including manufacturers, tradesmen in the sector, feed, medicine, sub-industry, transportation and marketing is approximately 2.4 million (Koca, 2017; Anonymous, 2018).

Among the meat types in the world, the most produced meat since 2015 is poultry meat. Chicken meat production in Turkey ranks 10th in the world. In 2019, a total of 2.198.090 tons of poultry meat was produced, including 2.198.090 tons of chicken meat and 59.640 tons of turkey meat. Turkey ranks 5th in the world trade and exported more than 500,000 tons of poultry meat to 81 countries in 2019. 636 million dollars of revenue was obtained from this export. The sector also exports hatching eggs and chicks. The consumption of poultry meat per person reached a value of 21 kg/year (BESD-BİR, 2020).

Producers target high profits. To achieve this goal, they either try to achieve the highest output with a certain level of input usage or try to produce a certain level of output with the least input usage level. Data Envelopment Analysis is one of the methods used to determine the extent to which producers are successful in achieving their goals. DEA is one of the methods used to measure input usage efficiency. The method is applied either input-oriented or output-oriented. In this study, widely used input-oriented DEA was employed.

There are many studies for different products using DEA method in the world and Turkey. For example broiler, goat, dairy, wheat, cotton, sunflower etc.; Some of these studies are as follows; Haruna et al. (2020); Vukelic et al. (2015); Omar (2014); Mahjoor (2013); Todsadee et al. (2012); Heidari et al. (2011); Begum et al. (2009); Gul et al. (2016); Dagistan et al. (2009); Aydemir et al. (2020); Parlakay et al. (2015); Alemdar and Oren (2006); Gul et al., (2009); Parlakay et al. (2016)

The main purpose of this study is to measure the technical efficiency scores of farms that produce broilers, which is one of the sources of white meat, in the Hatay province of Turkey where meat consumption is high. The second aim is to identify other factors that cause inefficiency. In this context, the efficiency scores of the broiler producing farms in the province of Hatay will be calculated and the causes of inefficiency will be investigated.

2. Literature Review

White meat obtained as a result of broiler production is an important product in terms of meeting the protein need, being cheaper and being easier to access. The broiler production made to obtain this product is of particular importance. For this reason, studies have been carried out by many researchers in many countries on measuring the efficiency scores of broiler-producing farms. Some of these are listed below.

Haruna et al. (2020) used the DEA-CRS and DEA-VRS approach in their study to calculate the efficiency scores of the broiler-producing farms in Nigeria. They determined that the average technical efficiency scores of farms as 0.83 with DEA-CRS and 0.88 with DEA-VRS. Approximately 7% of broiler farms provided a constant return to scale, 86% of broiler farms provided increasing return to scale, 8% provided decreasing return to scale.

In the study, they aimed to measure the efficiency of the broiler-producing farms using the DEA method in Vojvodina, Vukelic et al. (2015) calculated the efficiency scores of broiler farms as 0.74 with DEA-CRS and as 0.96 with DEA-VRS. As a result, broiler-producing farms can achieve the same amount of production using 26% less input with DEA-CRS and 4% less with DEA-VRS.

In his study to calculate the technical efficiency scores of the broiler-producing farms in Egypt using the DEA method, Omar (2014) determined that farms can produce the same level of output by using, 38% less input.

Mahjoor (2013) measured the efficiency scores of farms producing broiler in Iran. In the study, Mahjoor calculated the efficiency scores under the assumption of both DEA-CRS and DEA-VRS. The technical efficiency scores were calculated by both the DEA-CRS and the DEA VRS as 0.82. Factors that lead to inefficiency are as follows; education, age of farmer, education and being a member of broiler producers' cooperatives.

In a study conducted in Thailand, Todsadee et al. (2012) calculated the technical efficiency scores of the broiler producing farms with the DEA approach. They determined that the farmer's and experience affected the technical efficiency scores. Due to this reason,

they stated that socio-economic variables are important in the development of broiler production.

In a study conducted by Heidari et al. (2011), in which they calculated the average technical efficiency scores of broiler-producing farms in Iran using the DEA method, Heidari et al. calculated the average technical efficiency as 0.92, and the average scale efficiency scale as 0.93. They also determined that using the recommended input levels would save approximately 10% on total input sources.

In a study conducted by Begum et al. (2009) on the evaluation of the economic efficiency of poultry-producing farms in Bangladesh with the DEA method, technical efficiency scores were calculated as 0.88 with DEA-CRS and 0.89 with DEA-VRS. It has been determined that the efficiency scores of farms included in the sample varied widely.

3. Material and Methods

The main material of this study is the data for the 2017-2018 production period obtained by survey method from farms producing broiler in Hatay province in Turkey. During the production period in which the research was conducted, the Census Method was used to collect data from all of the existing broiler-producing farms in the region. In this context, data were collected from 19 broiler farms. Data Envelopment Analysis (DEA) method, which is widely used in the analysis of the data, was used to examine the efficiency of broiler farms.

DEA is a non-parametric deterministic approach which is based on linear programming techniques. It was originally developed by Charnes et al. (1978) based on the initial propositions of Farrell (1957) (Jan et al., 2010). One of the attractive features of the DEA method is that it avoids distributional assumptions (Wilson, 1995). The efficiency score measured by the DEA method varies between 0 and 1. Full efficient farms are expressed in 1. DEA input-oriented or output-oriented. The original DEA model was developed by Charnes et al. (1978) as input-oriented under the assumption of Constant Return to Scale. While the outputs remain constant according to the model, the inputs are minimised and the inefficiency of the inputs is examined (Kelly et al., 2012).

Charnes et al. (1978) proposed the use of a CRS (Constant Return to Scale) equivalent Duality Linear Program which is defined as the following (Fraser and Cordina, 1999; Keramidouet al., 2011; Mahjoor, 2013):

$\text{Min}_{\theta,\lambda}\ \theta$

Subject to $\quad -yi + Y\lambda \geq 0$

$\theta xi - X\lambda \geq 0$

$\lambda \geq 0.$

Where θ is a scalar and λ is a vector of constants, xi and yi, are column vectors with the input and output data for the i-th farm. X is a K by N matrix and Y is an M by N matrix with respectively all input and output data for all N farms in the sample. The value θ is a score always lying between zero and one, with a value of one indicating that the farm lies on the frontier and is efficient. An implicit assumption of the model described above is that returns to scale are constant and thus farms are operating at an optimal scale.

The DEAP program developed by Coelli (1996) was used to calculate the DEA efficiency scores. Efficiency scores are calculated input-oriented under CRS and VRS assumptions. After calculating the DEA scores, Tobit Regression model was used to determine the reasons for inefficiency. The variables used in the Tobit Regression model are the farmer's education, experience, age and the number of production period in one year.

4. Results and Discussions

Summary statistics on the data obtained from the farms that produce broilers in the province of Hatay are given in Table 1. While the average amount of output obtained from broiler production was determined as 50026.32 kg per production period, the highest output amount obtained per production was calculated as 135000.00 kg. Average operating width or number of chicks were 22913.16 birds per one production period. It can be said that broiler production is done in a medium-scale in the research area. The feed is the most important expense item among the expenses in animal production. It was determined that an average of 89950.88 kg feed is used in a production period in broiler-producing farms in the area where the study was conducted and was included in the model. However other inputs included in the model production were determined as an average of 22913 chicks, 46.19 days of man labour with a veterinary cost of 427.75 $ and other costs of 1677.84 $. It can be inferred from the low amount of labour that a technology-intensive production is carried out.

Table 1: Summary statistics for variables used in the efficiency analysis.

Variables	Minimum	Maximum	Mean	Std. Deviation
Output				
Broiler production (kg pp^{-1})	9000.00	135000.00	50026.32	32065.15
Input				
Feed (kg pp^{-1})	16000.00	240000.00	89950.88	55448.22
Stock (number of chick) (birds pp^{-1})	3750.00	60000.00	22913.16	14632.12
Labour (person day pp^{-1})	28.67	100.33	46.12	14.77
Veterinary cost ($ pp^{-1})	75.10	1126.56	427.75	269.90
Other costs ($ pp^{-1})	239.63	4958.51	1677.84	1298.80

Also, it was determined that on average, the broiler-producers are 50 years old, have 14.26 years of experience and have secondary school education level, and these data were used in the Tobit model. It is understood that the producers are over middle age, have a moderate level of education and have a profile that is neither little nor too experienced.

The frequency distribution of the technical efficiency scores of the broiler-producing farms obtained by using the DEA model is given in Table 2. In this input-oriented DEA model, it is examined how the relevant unit can be made full efficient by improving the input composition. The farm with a technical efficiency score of 1 is full efficient, if the score is less than 1, it means that the farm is inefficient. An inefficient farm can produce the same level of output with less input by improving the input combination in current technology. It is understood that the technical efficiency scores of the broiler-producing farms in the province of Hatay are high and close to each other. The technical efficiency scores of the farms examined range from 0.57 – 1.00 with DEA-CRS, and 0.91 – 1.00 with DEA-VRS approach. Average technical efficiency score is calculated as 0.95 with DEA - CRS; and 0.97 with DEA – VRS approach. The farms examined can produce at the same output level by reducing the inputs used in the current production technology by 5% according to the DEA-CRS approach and 3% according to the DEA-VRS approach.

We obtained higher mean technical efficiency compared to previous reports in Bangladesh (0.88), Thailand (0.62), Vojvodina (0.74) and Iran (0.83) (Begum et al, 2009; Todsadee et al., 2012; Vukelic et al., 2015; Mahjoor, 2013).

Table 2: Distributions of technical efficiency scores obtained with DEA (Input-Oriented)

Efficiency Scores	DEA		
	CRS	VRS	SE
1.00	3	5	3
0.91-0.99	15	14	15
<0.99	1	0	1
Minimum	0.57	0.91	0.62
Maximum	1.00	1.00	1.00
Mean	0.95	0.97	0.97
S.D.	0.09	0.02	0.09

In addition to the technical efficiency scores of the farms examined, scale efficiency scores were also calculated. 14 of the farms provided an increasing return to scale, 3 provided a constant return to scale and 2 decreasing return to scale (Table 3). The amount of meat efficiency obtained in production was 40917.86 kg for farms providing increased returns to scale, 49633.33 kg for farms providing constant returns to the scale and 114374.00 kg in farms that provide decreasing returns to scale. If all farms use the same production technology, it is expected that farm with relatively low output will have increased returns to scale and farms with relatively high output are expected to be farm with decreasing returns to scale. Farms that produce equal to the average output level are expected to be farms that provide a constant return to scale (Silberberg 1990; Begum et al, 2009). As expected, farms with relatively low output are farms with increasing returns to scale and farms with high outputs are farms with decreasing returns to scale.

Table 3: Characteristics of farms concerning returns to scale

	Number of farms	Meat Yield (kg pp^{-1})	Flock size (da)
Sub-optimal (irs)	14	40917.86	18685.71
Optimal (crs)	3	49633.33	21250.00
Super-optimal (drs)	2	114375.00	55000.00

It has been determined that the broiler farms that provide constant returns to the scale obtain output at a level very close to the average output level (Table 1 and Table 3). The average scale efficiency scores of broiler producers in the farms examined were calculated as 0.97. This finding indicates that producers are producing at appropriate scales.

Excess input usage is examined and given in Table 4. It has been determined that the major overuse is in the labour. It is followed by other expenses. The same level of output can be achieved by reducing labour by about 8%, and other costs by 6%. Findings show that farms do not have any problems regarding input usage levels. Input usage excess rates for the inputs used to support the result.

Table 4: Input slacks and the number of farms using excess inputs

Input	Number of farms	Mean slack	Mean input usage	Excess input usage (%)
Feed (kg pp^{-1})	11	821.15	89950.88	0.91
Stock (number of chick) (birds pp^{-1})	14	720.12	22913.16	3,14
Labour (person day pp^{-1})	11	3.80	46.12	8,21
Veterinary cost (\$ pp^{-1})	3	7.96	427.75	1,86
Other costs (\$ pp^{-1})	5	104.82	1677.84	6,25

Other factors that are thought to have an impact on the technical efficiency scores of broiler farms were also examined. The effect of the producer's education level, experience, age, and the number of production periods in a year on the DEA-CRS technical efficiency scores of broiler farms were analysed by Tobit regression analysis. The experience of the producer is statistically significant at the level of 5% with a negative sign. In other words, it can be said that having 15 years or more of experience has the effect of causing inefficiency for farm owners. Other variables were not interpreted as they were not statistically significant (Table 5).

Table 5: Relationship between Socio-Economic Variables and Technical E- Tobit Regression Analysis Results (DEA – CRS Input Oriented)

Variable	Coefficient	Std. Error	z-score	Significance
C	1.1273	0.3181	3.5445	0.0004
Education	0.0162	0.0181	0.8967	0.3699
Experience	-0.1205**	0.0576	-2.0936	0.0363**
Age	0.0023	0.0026	0.8618	0.3888

Number of production period in a year	-0.0560	0.0430	-1.3034	0.1924
R-squared	0.1774			
Adjusted R-squared	-0.1390			

** Significant at 5%

5. Conclusions

In this study, technical efficiency scores of farms producing in Hatay province of Turkey were calculated using the input-oriented DEA method. In this context, it has been determined that very few farms operate full efficient, however, most of the farms have a high-efficiency score (0.95) even if they are not full efficient. It has been concluded that broiler-producing farms can produce the same amount of output (the amount of chicken meat) they obtain by reducing the amount of input they use in the current production technology by 5%. It can be said that farms operate efficient in terms of both input use and economies of scale. This result is important for the industry. It has been determined that inefficient farms use their labour more. It may be recommended to organise the labour better on the measures that can be taken for the farms working in the sector to work full efficient.

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7. Acknowledgement

This study was supported by the Hatay Mustafa Kemal University's Scientific Research Fund (BAP) Project No: 15960 We would like to thank Hatay Mustafa Kemal University Scientific Research and Projects Coordination Unit for their financial support to this project.