Determination of technical efficiency in laying hen farms in Turkey: a case study of Hatay Province

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Abstract

This research was conducted in the province of Hatay, which hosts a concentrated trading activity comprising of maritime and road transport activities as well as border trade and which is strategically significant due to its geographical location. This research aims to calculate and evaluate the technical efficiency scores of laying hen farms established in Hatay province in southern Turkey. For this purpose, research data were collected from 22 poultry egg enterprises operating in the province of Hatay using the Census method. Research data were analyzed using the Data Envelopment Analysis (DEA) method, which is often referred for the measurement of efficiency. Socio-economic factors affecting technical efficiency scores were determined using the Tobit Regression model. Mean technical efficiency score, in the

analysis, was computed as 0.95 using DEA – Constant Return to Scale (CRS) and 0.98 using DEA - Variable Return to Scale (VRS). The poultry egg enterprises examined have been determined to produce the same level of output when reducing the inputs used in the current production technology by 5% and 3% respectively in accordance with the DEA-CRS and DEA-VRS approaches. Socio-economic variables that are thought to have a statistically significant effect on the efficiency scores of the poultry egg enterprises were determined as education level and experience of the farmer; i.e. it has been determined that farmers with a lower formal education level and more experienced farmers are tend to be more efficient. As a result, it has been concluded that poultry egg enterprises operating in Hatay province are working efficiently in terms of both input use and economies of scale. Inefficient enterprises have been determined to have higher costs and higher labor utilization rates. It can be suggested that the workforce should be better organized regarding the measures that should be taken to ensure the full efficiency of laying hen farms operating in poultry egg production industry. Based on the conclusion that more experienced farmers are more efficient although they have lower formal education levels, it is suggested that the efficiency of the poultry egg farmers may be scaled up by organizing training programs that will improve their level of knowledge.

Keywords: Data Envelopment Analysis. Poultry Egg Production. Technical Efficiency.

1. Introduction

Poultry egg production industry is among the developing industries in Turkey, however the development figures are not yet at the desired level. There are various factors that affect the price and the level of production in the industry. Some of these factors are seasonality, various speculations in the market, the formation of the necessary conditions concerning export, fluctuations in the prices of raw materials for animal feed, the shelf life of the egg.

Its contribution to employment, investments in modern integrated facilities, expert production, processing and marketing mechanism, high share in foreign trade, healthy product supply improve the significance of the poultry farming industry in Turkey day by day. The annual turnover of the industry has exceeded 6 billion dollars. The industry, together with its sub-branches, provides employment to approximately 600 thousand people. Number of people employed in the industry is approximately 2.4 million when including feed, pharmaceuticals, subsidiary industries, transportation, marketing etc. (Koca, 2017; Anonymous, 2018).

Eggs are one of the most affordable sources of protein. Turkey ranks 10th in the world in poultry egg production. 19.8 billion eggs were produced from 122.7 million head laying hens in Turkey as of 2020 (FAO, 2022).

Turkey ranks the 6th in the world with regard to poultry egg export figures and has exported approximately 218 thousand tons of eggs to 42 countries as of 2020. The income obtained through this export is at the level of 256 million dollars. Turkey exports shelled, liquid and dry eggs (FAO, 2022).

Main goal of every business is to maximize profits. In order to reach the maximum profit target, the owner of any facility either tries to achieve maximum output using a certain level of input or tries to produce a certain level of output using the least input. One of the methods used to assess the level of success of the manufacturers is Data Envelopment Analysis. Data Envelopment Analysis (DEA) is one of the most popular methods used for measuring the input efficiency.

Many studies aiming to determine the technical efficiency levels with regard to different products such as layer hens, broiler, goat, dairy, wheat, cotton, sunflower production etc. have been published both in the world and in Turkey. Some of these studies were published by Ilham et al. (2021); Mugambi (2020); Dogan et al. (2019); Yenibehit et al. (2019); Yuhuan and Fu (2019); Paul et al. (2017); Gaspar et al. (2009); Parlakay and Çimrin (2021); Gul et al. (2016); Aydemir et al. (2020); Parlakay et al. (2015); Alemdar and Oren (2006); Gul et al., (2009); Parlakay et al. (2021); Parlakay et al. (2016).

Main purpose of this research is to calculate the technical efficiency scores of laying hen farms established in Hatay province of Turkey. Secondary purpose is to identify other factors causing the inefficiency. In this context, the efficiency scores of poultry egg producing enterprises in Hatay province were calculated and the reasons underlying inefficiency were investigated.

2. Literature Review

Egg is a significant product as it is one of the affordable sources of protein. For this reason, measuring the inputs used and the efficiency thereof within the context of poultry egg production activities carried out to produce eggs has a key role in terms of determining the efficiency with regard to the use of the resources. For this reason, studies aiming to measure the efficiency scores of poultry egg producing enterprises have been carried out by many researchers in many countries. Some of these are provided below:

In their research covering poultry egg producing enterprises operating in Sidrap, Payakumbuh and Blitar provinces of Indonesia, Ilham et al. (2021) calculated mean technical efficiency score as 0.95 using the DEA method. They further determined that the technical

efficiency scores of poultry egg producing enterprises in Sidrap and Payakumbuh provinces (0.99) were higher compared to Blitar (0.88). They determined the factors affecting the inefficiency in Blitar as high feed and labor input costs.

Mugambi (2020) calculated the technical efficiency scores of smallholder indigenous chicken farms in his study conducted in Kenya. Technical efficiency scores calculated using the Stochastic Frontier Analysis method were found to range between 60.7 and 91.3%, with a mean estimate of 74.83%. Improvements suggested in accordance with the findings obtained from the study were using genetically enhanced native breeds, improving chicken shelters, adding concentrate feed to free-range chicken feed, improving egg hatchability and improving the survival rate of the chicks.

In their research conducted in Konya province of Turkey, Doğan et al. (2019) aimed to determine technical and economic efficiency scores of poultry egg producing enterprises and the factors affecting these scores. They calculated mean technical efficiency score thereof as 98.6%. Accordingly, they determined that 47.8% of the producers were fully efficient. In accordance with the Tobit Analysis, they determined that the chick mortality rate, hen mortality rate and feed conversion ratio factors had a negative effect on the efficiency scores, whereas education level of the farmer and capacity utilization ratio factors have been found to have a positive effect on the efficiency scores.

Yenibehit et al. (2019) calculated the technical efficiency scores of poultry egg producing enterprises in Ghana using the Stochastic Frontier method and determined the socio-economic factors affecting technical efficiency as age, education, experience, extension contact, credit and type of poultry housing. The results revealed that the number of hens, amount of drugs and water used had a significant positive effect on the number of eggs produced. Age, gender, and extension contact have been found to improve technical efficiency, while experience, access to credit facilities, and type of poultry housing have been found to decrease technical efficiency.

Yuhuan and Fu (2019) preferred Hebei, Hubei, Jiangsu, Liaoning and Sichuan provinces of China as their research area and they reported the mean technical efficiency score of poultry egg producing enterprises therein as 95.41%. They reported that the province with the highest level of poultry egg production technology is Hebei and the province with the lowest level of efficiency is Liaoning. Accordingly they stated that the northern region of China is more advantageous and comprehensively outstanding compared to other regions in terms of the equipments of laying hen farms.

Paul et al. (2017) investigated the efficiency scores of poultry egg production enterprises using different production systems in Nigeria. In their study, they calculated the technical efficiency scores of the enterprises producing eggs with the battery cage system and the enterprises using the deep litter system as 0.89 and as 0.91 respectively. Accordingly, they determined the factors affecting technical efficiency scores for the enterprises producing eggs with the battery cage system as the gender and formal education level of the farmer, their membership to the cooperative and extension contact whereas the factors affecting technical efficiency scores for the enterprises producing eggs using deep litter system as breed of bird, feed type and the farmers' gender.

In a research conducted in Spain, Gaspar et al. (2009) calculated the technical efficiency scores of poultry egg producing enterprises using the DEA method. They determined the mean technical efficiency value as 0.70 and they further concluded that the enterprises with mean technical efficiency value could produce the same output level by using 70% of the inputs (assuming no other limiting factors) used (for instance, by feeding breeds that have better adapted to the environment, by more efficiently using the pastures to reduce the amount of feed to be purchased, by reducing the currently employed manpower etc.).

3. Material and Methods

The data set of this research comprised of the production data as of the 2017-2018 production period obtained from poultry egg producing enterprises in Hatay, Turkey using survey method. Research data were collected from all poultry egg enterprises operating in the province as of the production period covered in the research using the Census method. In this context, data were collected from 22 enterprises. The data were analyzed using the Data Envelopment Analysis (DEA) method, which is widely used to measure the efficiency of enterprises.

DEA is a non-parametric deterministic approach which is based on linear programming techniques. It was originally developed by Charnes et al. (1978) on the basis of 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). In DEA, efficiency scores range between zero (0) and one (1). Fully efficient enterprises take the value of one (1). DEA is input- or output-oriented. The original input-oriented DEA model was developed by Charnes et al. (1978), under the assumption of Constant Return to Scale (CRS). With this model, inputs are minimized while outputs remain constant and the inefficiency of the inputs is examined (Kelly et al., 2012). Charnes et al. (1978) proposed the use of a CRS 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 $\quad -y_i + Y\lambda \geq 0$

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

$\lambda \geq 0.$

Where θ is a scalar and λ is a vector of constants, x_i and y_i, are column vectors with the input and output data for the i-th farm. X is a K by N matrix and Y is a 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 output of the model used was the number of eggs produced throughout a production period whereas the inputs were feed (kg/production period), laying hens (number/pp), labor costs (USD/pp), veterinary costs (USD/pp), laying hens costs (USD/pp) and other costs (USD/pp).

DEA technical efficiency scores were calculated using the DEAP program developed by Coelli (1996). Efficiency scores were calculated as input-oriented, under the assumptions of CRS (Constant Return to Scale) and VRS (Variable Return to Scale). Following the calculation of DEA technical efficiency scores, the relationship between technical efficiency scores and socio-economic variables was examined using the Tobit Regression model. The variables considered in the Tobit Regression model consisted of the education, experience and age of the farmer and the material used as pullet in producing eggs.

4. Results and Discussions

Summary statistics on the data obtained from the poultry egg enterprises in Hatay are given in Table 1. The average number of eggs produced throughout a production period was determined as 1135819.32 while the maximum number of eggs produced per production period was calculated as 9150000. Mean flock size or the number of laying hens were 3675.23 birds per one production period. One of the leading expense items of the costs of animal production enterprises is feed expenses. An average of 153427.27 kg of feed was determined to be used by the poultry egg producing enterprises within the research area throughout one production period and included in the model. However, other inputs used in

the production model were determined as labor expenses with an average of 735.57 USD, veterinary costs with 771.60 USD, laying hen costs with 10428.61 USD and other costs with 7994.87 USD.

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

Variables	Minimum	Maximum	Mean	Std. Deviation
Output				
Egg production (number pp^{-1})	54900.00	9150000.00	1135819.32	32065.15
Input				
Feed (kg pp^{-1})	9000.00	1200000.00	153427.27	262168.03
Laying hens (number pp^{-1})	180.00	30000.00	3675.23	6520.10
Labour (USD pp^{-1})	414.94	2074.69	735.57	511.12
Veterinary costs ($ pp^{-1})	51.87	6224.07	771.60	1320.14
Laying hen costs ($ pp^{-1})	746.89	74688.80	10428.61	16221.15
Other costs ($ pp^{-1})	311.20	24038.59	7994.87	7648.81

It was further determined that the egg producing farmers had a mean age of 44 years, had mean experience of 4 years and mean level of their formal education were high school education. These data were also used in the Tobit model. It was understood that the average poultry egg farmers were middle-aged, had a medium level of education and had little experience.

The frequency distribution with regard to the technical efficiency scores of the poultry egg producing farms obtained using the DEA model is given in Table 2. This model, using the input-oriented DEA approach, examined how a fully efficient production process may be achieved in the relevant unit by improving the input composition. The technical efficiency score of a fully efficient enterprise is 1. A score below 1 means that the enterprise is inefficient. An inefficient enterprise can produce the same level of output with less input by improving the combination of the inputs in its current production technology. The research has revealed that the technical efficiency scores of poultry egg producing enterprises in Hatay province are high and close to each other. Technical efficiency scores of the examined enterprises calculated using DEA-CRS and DEA-VRS varied between 0.89 - 1.00 and between 0.91 - 1.00 respectively. On the other hand mean technical efficiency scores were

calculated as 0.95 and 0.98, using DEA-CRS and DEA-VRS respectively. It was concluded that the poultry egg enterprises examined can produce the same level of output when reducing the inputs used in the current production technology by 5% in accordance with the DEA-CRS and 3% in accordance with DEA-VRS approaches.

Compared to previous studies, mean efficiency score obtained as a result of the analysis is found as the same as Indonesia (0.95) and China (0.95), higher than Kenya (0.75), Nigeria (0.89; 0.91) and Spain (0.70), and lower than that calculated in another study conducted in Turkey (0.99). (Ilham et al. (2021); Mugambi (2020); Dogan et al. (2019); Yuhuan and Fu (2019); Paul et al. (2017); Gaspar et al. (2009).

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

Efficiency Scores	DEA		
	CRS	VRS	SE
1.00	5	16	5
0.91-0.99.	16	6	16
<0.99	1	0	1
Minimum	0.89	0.91	0.89
Maximum	1.00	1.00	1.00
Mean	0.95	0.98	0.97
S.D.	0.04	0.04	0.04

Furthermore, scale efficiency scores of the examined enterprises were also calculated in addition to the technical efficiency scores. It was found that 17 of the enterprises have provided increasing return to scale and 5 of them have provided constant return to scale while there was no enterprise providing decreasing return to scale (Table 3). The number of eggs produced throughout a production period was 507972.06 in poultry egg producing enterprises that provided increasing returns to scale and was 3270500.00 in enterprises that provided constant returns to scale. Assuming that all enterprises have used similar production technology, the enterprises with relatively low output are expected to provide increasing returns to scale and enterprises with relatively higher output levels are expected to provide decreasing returns to scale. Enterprises that have produced at a level equal to the average output level are expected to provide constant returns to scale (Silberberg, 1990; Begum et al., 2009). As it is expected, the enterprises with relatively lower output are those providing increasing returns to scale.

Table 3: Characteristics of farms with respect to returns to scale

	Number of farms	Eggs Produced (number pp^{-1})	Flock size (number)
Sub-optimal (irs)	17	507972.06	1667.94
Optimal (crs)	5	3270500.00	10500.00

Mean scale efficiency score of the examined poultry egg producing enterprises was calculated as 0.97. This finding indicates that producers/farmers have been producing at appropriate scales.

The excess input usage levels of the examined enterprises were calculated and given in Table 4. It was determined that other expenses took the lead within the context of the inputs overused, with 31% over-utilization ratio, which is followed by labor with approximately 13% over-utilization ratio. In accordance with this finding, the same level of eggs can be produced by reducing other expenses by 31% and labor expenses by approximately 13%. From these findings, it can be concluded that the enterprises do not have any problems with regard to the input usage levels. Excess input usage rates, within the context of the inputs used, have been found to be supporting the results.

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

Input	Number of farms	Mean slack	Mean input usage	Excess input usage (%)
Feed (kg pp^{-1})	9	1814.14	153427.27	1.18
Laying hens (number pp^{-1})	1	1.90	3675.23	0.05
Labour costs($ pp^{-1})	5	93.51	735.57	12.71
Veterinary costs ($ pp^{-1})	8	22.66	771.60	2.94
Laying hen costs ($ pp^{-1})	9	595.19	10428.61	5.71
Other costs ($ pp^{-1})	9	2500.25	7994.87	31.27

Other factors that are thought to be affecting technical efficiency scores of the poultry egg producing enterprises were also examined within the scope of the study. The effect of the formal education level, experience, age of the farmer as well as the material used as pullet on the DEA-CRS technical efficiency scores of the examined enterprises were examined by Tobit regression analysis. It was understood that there is a statistically significant relationship

between the education level and experience of the farmers and the efficiency scores of the enterprises. The education level of the farmers had statistically significant negative effect while the level of experience had statistically significant positive effect. In other words, farmers with lower formal education levels are concluded to be more efficient. Moreover, more experienced farmers are said to be more efficient. Other variables were not interpreted as they were not statistically significant (Table 5).

Table 5: The Relationship Between Socio-Economic Variables and Technical Efficiency - The Results of Tobit Regression Analysis (Input Oriented DEA–CRS)

Variable	Coefficient	Std. Error	z-score	Significance
C	0.9621	0.0363	26.4993	0.0000
Education	-0.0304*	0.0186	-1.6314	0.1028*
Experience	0.0086**	0.0037	2.3146	0.0206**
Age	-0.0005	0.0007	-0.6896	0.4904
Material Used	-0.0024	0.0178	-1.1371	0.8909
R-squared	0.3903			
Adjusted R-squared	0.1997			

* Significant at 10%, ** Significant at 5%

5. Conclusions

Technical efficiency scores of poultry egg producing enterprises in Hatay, Turkey were calculated using the input-oriented DEA method for the purpose of this research. Consequently, it has been determined that majority of the enterprises had a high efficiency score (0.95 with DEA-CRS; 0.98 with DEA-VRS), even if they are not fully efficient. It has been concluded that poultry egg producing enterprises can produce same amount of eggs by reducing the amount of input used in the current production technology by 5% according to DEA-CRS and 2% according to DEA-VRS. It has been concluded that poultry egg enterprises have been working efficiently in terms of both inputs used and economies of scale. These results are significant for the industry. Inefficient enterprises have been determined to have higher miscellaneous expenses and higher labor utilization rates. It can be suggested that the workforce should be better organized regarding the measures that should be taken to ensure the full efficiency of laying hen farms operating in poultry egg production industry. Based on the conclusion that more experienced farmers are more efficient although they have lower

formal education levels, it is suggested that the efficiency of the poultry egg farmers may be scaled up by organizing training programs that will improve their level of knowledge.

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