BOLETIM DO INSTITUTO DE PESCA

ISSN 1678-2305 online version

Scientific Article

ANALYSIS OF THE TECHNICAL EFFICIENCY OF EUROPEAN SEA BASS FARMS IN TURKEY: A STOCHASTIC FRONTIER PRODUCTION FUNCTION APPROACH*

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*This work was supported by the General Directorate of Agricultural Research and Policies (TAGEM) (grant number TAGEM/TEPD/17/G/A08/P01/07).

Received: February 16, 2021
Approved: August 23, 2021

ABSTRACT

This study's main objective was to estimate sea bass farms' technical efficiency and determine the factors affecting production inefficiency using the stochastic frontier approach. The data were collected using questionnaires from 71 farms in 2017. The total sea bass production cost was calculated 5.35 \$ kg^{-1}, income 5.65 \$ kg^{-1}, gross profit 0.30 \$ kg^{-1}. The proportion of variable costs (84.25%) in total costs was higher than the fixed costs (15.75%). The feed cost (57.56%) was the influential primary variable on the total costs, and the benefit-cost ratio was 1.06. The results indicated that seabass farms' technical efficiency varied between 0.67 to 1.00, and the average was 0.82. The efficiency scores meant the farms could achieve the same production amount by reducing inputs by 18%. One per cent increase in resale value, feed amount, and fingerling amount, increase sea bass production by 0.4%, 0.4%, and 0.2%, respectively. Fish loss rates and subsidies were influential on inefficiency. It would be beneficial to minimize risk factors such as fish loss rates and carry out political and educational activities to improve farms' infrastructure in breeding and marketing. As a result, policymakers should also include the effective use of production factors in the design of aquaculture subsidy policies.

Keywords: aquaculture; economic analysis; inefficiency; seabass; subsidy; Turkey.

ANÁLISE DA EFICIÊNCIA TÉCNICA DE FAZENDAS DE PRODUÇÃO DE ROBALO EUROPEU NA TURQUIA: UMA ABORDAGEM DE FRONTEIRA ESTOCÁSTICA DE PRODUÇÃO

RESUMO

O objetivo principal deste estudo foi determinar a eficiência técnica de fazendas de robalo e determinar os fatores que afetam a eficiência de produção usando a abordagem de fronteira estocástica. Os dados foram obtidos em 71 fazendas de robalo em 2017 por meio de questionários. Na produção de robalo, o custo total de produção foi de 5,35 \$ kg^{-1}; a receita 5,65 \$ kg^{-1}, e o lucro bruto foi de 0,30 \$ kg^{-1}. A taxa dos custos variáveis nos custos totais (84,25%) foi superior aos custos fixos (15,75%). O custo da alimentação (57,56%) foi determinado como a variável primária que afeta os custos totais e a relação custo-benefício foi calculada como 1,06. Os resultados mostraram que o nível de eficiência técnica das fazendas de robalo variou de 0,67 a 1,00 e a média foi de 0,82. Os pontos de eficiência significam que as fazendas podem atingir a mesma produção reduzindo os insumos em 18%. Um aumento de 1,0% no valor de vendas, quantidade de ração e produção de peixes juvenis aumentou a produção de robalo em 0,4%, 0,4% e 0,2%, respectivamente. As taxas de perda de peixes e subsídios aumentam a ineficiência. Para minimizar os fatores de risco, como as taxas de perda de peixes, seria benéfico elaborar políticas públicas e organizar atividades de treinamento para melhorar a infraestrutura de produção e comercialização das fazendas. Como resultado, os formuladores de políticas também devem incluir a eficiência dos fatores de produção na elaboração das políticas de subsídio à aquicultura.

Palavras-chave: aquicultura; análise econômica; ineficiência; robalo; subsídio; Turquia.

INTRODUCTION

The aquaculture sector has been developing rapidly globally and constitutes about half of all fish consumed for food purposes (Hishamunda et al., 2009). Recent studies emphasize that aquaculture is one of the fastest-growing food-producing sectors globally (Halwart et al., 2003; Subasinghe, 2003; FAO, 2016). At present, aquaculture is no longer a small-scale activity in the countryside; on the contrary, an essential economic sector managed by professional managers, scientists, and engineers (Nash et al., 2000) and is an example of a global industry affected by and leading to economic, environmental, and technological changes (McDaniels et al., 2006).

Turkey's aquaculture total established capacity by 2019 was 522,772 tonnes (production amount was 373,356 tonnes) but was only used 71.42% of this capacity. The 55.37% of Turkey's fish supply was provided by fishing from natural resources and 44.63% by aquaculture (TurkStat, 2020). Moreover, Turkey is a significant fish exporter country. More than half of the sea bass, sea bream, and rainbow trout produced in ponds are exported to many countries, mainly EU countries. The share of sea bass production constitutes 38.0% of the amount of Turkey's total farmed fish production. On the other hand, Turkey's aquaculture sector faces several challenges such as the need for skilled labour, price fluctuations, low quality of feeds, marketing problems, lack of water supply, and working with low capacity (Aydoğan et al., 2020). One of the most crucial challenges in sea bass farming is that most feed raw materials (more than 80%) used in fish feed production are imported (Keleştemur and Uslu, 2017). Turkey enacted some aquaculture support policies in 2003 and continues to support the sector according to fish diversification. When considering the economic importance of aquaculture in Turkey, there is a need to ensure that aquaculture farms use limited resources effectively in their production. The concept of production efficiency explains the effective use of production factors (Farrell, 1957).

The number of studies on the technical efficiency of the aquaculture farms' production in Turkey is limited. It is clear that previous studies (Cinemre et al., 2006; Bozoğlu and Ceyhan, 2009; Ceyhan and Gene, 2014) are fairly old, generally focused on cost-effectiveness and conducted a few regions of Turkey. This study is different in that it uses more up-to-date data than the others, focuses on technical efficiency, and covers the whole country.

The main goal of this study was to estimate the technical efficiencies of sea bass aquaculture farms and determine the factors that influence technical production inefficiency. Additionally, the null hypothesis, sea bass farms are fully efficient in production, was tested.

MATERIALS AND METHODS

Study Area and Sampling

The study was carried out in sea bass aquaculture farms in Turkey. The share of sea bass production constitutes 38.0% of Turkey's total farmed fish production. The sea bass aquaculture farms in Turkey operate in eight provinces bordering the Mediterranean, Aegean, and the Black Sea (TurkStat, 2019). The geographical distribution and number of sampled farms were presented in Figure 1.

The data were collected by using questionnaires forms from sea bass farms during the 2017 production season. The main population of the sample consisted of 276 sea bass farms. In the research, the proportional sample technique was used to determine the number of respondents. The sample size was calculated using

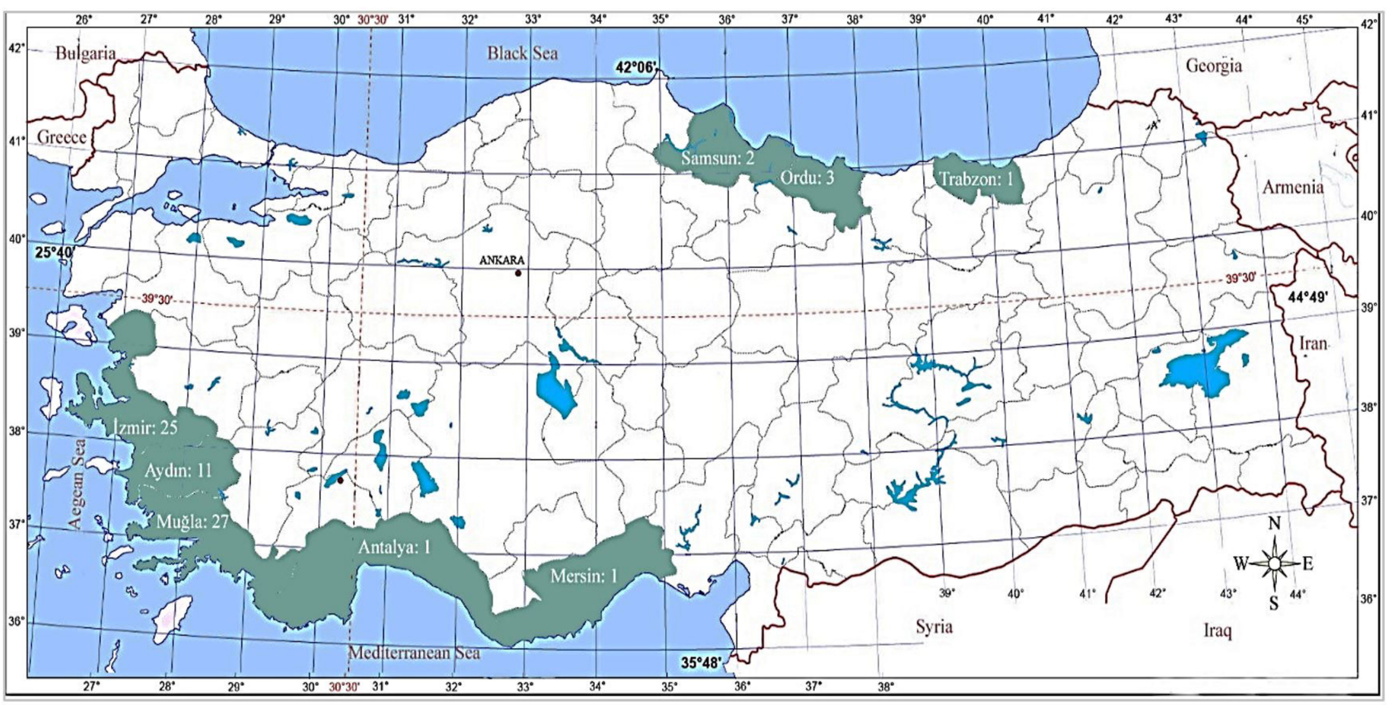

Figure 1. The geographical distribution and number of sampled sea bass farms in Turkey.

the following formula (1) (Newbold, 1995) 90% confidence interval and a 10% error margin were grounded in the research. The minimum sample size was calculated as 71.

$$n = \frac{Np\left(1-p\right)}{\left(N-1\right)\sigma_p^2 + p\left(1-p\right)} \quad (1)$$

In Equation 1, n is the sample size, N is the population size, p is the ratio of the studied feature in the main population ($p = 0.5$ was taken to achieve the maximum sample size).

Analytical Methodology

Calculating the cost and profitability of sea bass production

Sea bass production costs were calculated separately for each farm with the data obtained from the sea bass farms. The calculated sea bass production costs were given in Table 1 consisted of the average sea bass costs of 71 farms. Sea bass production total costs (TC) consisted of the sum of fixed and variable costs. While fixed costs constituted the costs incurred independently of the amount of production, variable costs showed the costs that increase or decrease depending on the production amount (Kıral et al., 1999). In the study, depreciation, permanent labour, rental costs (land and water rent), tax, and general overhead were taken as fixed cost items. Variable cost items consisted of fingerling, diesel, electricity, feed, medicine, temporary labour, marketing, repairs and maintenance for machinery, miscellaneous costs, and the interest of variable costs.

Gross profit (GP) was calculated by using the following equation (2):

$$GP = TR - TC \quad (2)$$

where: TR was Total Revenue ($), and TC was Total Cost ($).

The profitability of investment was measured using the Benefit-cost ratio (BCR), and BCR was calculated using formula 3 (Emokaro et al., 2010):

$$BCR = \left(\sum_i B_i / \left(1+r\right)^i\right) / \left(\sum_i C_i / \left(1+r\right)^i\right) \quad (3)$$

where: B_i was the total revenue earned at year i^{th}, C_i was the total costs at year i^{th}, and i was the average number of years of operation of seabass farms, and r was the discount rate. In the calculation of the BCR, the annual capital interest rate was 12.5% applied by the Central Bank of the Republic of Turkey.

The Saving Cost Ratio (SCR) was calculated through formula 4 to determine the sea bass farms' average savings from cost when the farms reached total production efficiency.

$$SC = 1 - \frac{Minimum\ efficiency\ score}{Maximum\ efficiency\ score} \quad (4)$$

Grouping the sea bass farms as efficient and inefficient

In the literature of the aquaculture economy, there were many studies carried out to determine the difference between efficient and inefficient farms in production (Sharma et al., 1999; Cinemre et al., 2006; Theodoridis et al., 2017; Vinh et al., 2020; Dağtekin et al., 2021). Fernández Sánchez et al. (2020) investigated the technical efficiency (TE) of sea bass and sea bream farming in the Mediterranean Sea by European firms and calculated all countries' average TE coefficients as 0.891; farms had an efficiency coefficient of less than 0.891 was considered inefficient. The target market of the sea bass farms in Turkey is the European Union countries, and they compete with the farms in these countries. In this study, to compare the production efficiency of sea bass farms in Turkey with the European Union countries, farms with a technical efficiency coefficient below 0.90 were considered inefficient, and above 0.90 were deemed efficient.

Stochastic Frontier Analysis

In the research, the Stochastic Frontier Analysis (SFA) approach was used to estimate sea bass production's technical efficiency (TE). SFA approach establishes a functional relationship between dependent variables such as cost, profit, production amount, and explanatory variables such as input and environmental variables (Berger and Humphrey, 1997). It also includes an error term in the model. The stochastic efficiency frontier approach, a parametric method, was developed by Aigner et al. (1977), Meeusen and Van Den Broeck (1977), and Battese and Corra (1977) to estimate production efficiency using $Y_i = x_j +_i$ production function.

Cobb-Douglas functional form's stochastic frontier function model is employed to estimate the technical efficiency at the farm level of the sea bass farms in Turkey. The Cobb-Douglas functional form is used because of: (a) the functional form has been widely used in farm efficiency both for the developing and developed countries, (b) the functional form meets the requirement of being self-dual, allowing an examination of EE., and (c) Kopp and Smith (1980) suggested that the functional form has limited effects on empirical efficiency measurement. The Cobb-Douglas production functional form specifies the production technology of the farms. Aigner et al. (1977) and Meeusen and Van Den Broeck (1977) stated that the error term ($_i$) of the production function consisted of two independent elements and formulized the production function as follows:

$$Y_i = x_j + v_i - u_i \quad \left(i = 1, 2, \ldots, n\right) \quad (5)$$

$$v_i - u_i =_i \quad (6)$$

where: Y_i, Production function of i^{th} farm; x_i, input vector of i^{th} farm; β, coefficient. v_i, a random variable that cannot be controlled, has normal distribution $N\left(0,{}^2_v\right)$ and is independent of u_i. u_i is an independent random variable that is non-negative and can partially be controlled, leading to technical inefficiency. u_i can have semi-normal, truncated normal or exponential distribution depending upon the function used. Battese and Coelli (1995) developed the following model to explain changes in u_i, which represents technical inefficiency.

$$u_i = z_i \quad (7)$$

In Equation 7, z_i represents specific features affecting technical inefficiency (such as education level, age, administrative approach) while represents coefficients. With the stochastic efficiency frontier approach, a firm's efficiency could be determined as the observed output ratio to expected output using Equation 8 (Coelli, 1995). Thus, technical efficiency can be formulated as follows:

$$TE_i = e^{x_i + v_i - u_i} \Big/ e^{x_i + v_i} = e^{-u_i} \quad (8)$$

where: TE_i has a value ranging from 0 to 1, and if $u_i = 0$, means i^{th} the farm is fully technically efficient. Coelli (1995) reported that the maximum likelihood method is more suitable for estimating production functions than the least-squares method.

In this study, the efficiency of sea bass farms was calculated based on the Cobb-Douglas type function with truncated normal distribution developed by Battese and Coelli (1995) using the Maximum Likelihood method. Since the Cobb-Douglas production function coefficients give the elasticity, coefficients can be interpreted directly as elasticity.

Cobb-Douglas type production function estimated for the study was as follows:

$$lnY_i = {}_0 + \sum_{j=1}^{5} lnx_{ji} + {}_j + v_i - u_i \quad (9)$$

$$u_i = {}_0 + \sum_{m=1}^{6} {}_m z_{mi} \quad (10)$$

The output in the model was sea bass production (kg m^{-3}), and inputs were resale value (\$ kg^{-1}), feed (kg m^{-3}), fingerling (piece kg^{-1}), diesel (L kg^{-1}), and labour (hours kg^{-1}). The variables used to explain technical inefficiency (u_i) were the subsidy rate in gross fish income, fish loss rate, and farm experience in the industry (years).

Stochastic efficiency frontier estimations were made using FRONTIER 4.1 software developed by Coelli (1996). Technically efficient and inefficient sea bass farms were compared statistically. "The independent t-test" was used for variables with a continuous distribution, and the "Mann Whitney U test" was used for variables determined by ranking or by group-level measurement.

RESULTS

The total cost, income, and profit calculated for sea bass farming were given in Table 1. The total production cost was calculated 5.35 \$ kg^{-1}, income 5.65 \$ kg^{-1}, gross profit 0.30 \$ kg^{-1}. In sea bass farming, the proportion of variable costs (84.25%) in total costs was higher than the proportion of fixed costs (15.75%). The costs of rental, temporary labour, marketing, repairs and maintenance, diesel, medicine, general overhead, tax, miscellaneous cost, depreciation, electricity, the interest of variable costs, and

Table 1. Sea bass average production cost*.

Cost items	\$ kg^{-1}	Std. Dev.	%
Variable costs (A)	**4.51**	**0.703**	**84.25**
Fingerling	0.37	0.046	6.95
Diesel	0.07	0.038	1.40
Electricity	0.24	0.052	4.42
Feed	3.08	0.597	57.56
Medicine	0.15	0.072	2.75
Temporary labour	0.02	0.009	0.37
Marketing	0.04	0.023	0.75
Repairs and maintenance for machinery	0.07	0.041	1.31
Miscellaneous cost (A×5.00%)	0.20	0.032	3.78
The interest of variable costs (A×6.25%)	0.27	0.042	4.96
Fixed Costs (B)	**0.84**	**0.103**	**15.75**
Depreciation	0.22	0.045	4.20
Permanent labour	0.29	0.076	5.42
Rental costs (land and water rent)	0.01	0.002	0.19
Tax	0.16	0.039	2.99
General Overhead (A+B) × 0.03	0.16	0.022	2.94
Total Production Costs C (A+B)	**5.35**	**0.739**	**100.00**
Seabass selling price (\$ kg^{-1})		5.65	
Gross profit (\$ kg^{-1})		0.30	
Benefit-Cost Ratio (\$ kg^{-1})		1.06	

Source: Authors' computation from field data. * \$1 = 3.469 Turkish Lira in 2017 (CBRT, 2020). Std. Dev. = standard deviation.

fingerling costs were recorded lowest cost rates, respectively, when compared with feed costs in the farms. Moreover, the feed cost was another variable that might be considered an influential and crucial variable on the total costs; the feed cost occupied 57.56% of total costs, which played a vital function in gross profit. In the study, the benefit-cost ratio was calculated as 1.06.

Statistical data from variables of the model established to estimate sea bass farms' efficiency in the study were in Table 2. The average production amount of sampled sea bass farms was 14.55 kg m^{-3}, and the average resale value was 82.19 \$ m^{-3}. In order to achieve this production amount, 25.68 kg m^{-3} of feed, 12.88-piece m^{-3} fingerling, 5.60 L kg^{-1} diesel, and 5.24 hours kg^{-1} labour were used as input.

The Stochastic Cobb-Douglas model results established using the maximum likelihood method to estimate sea bass farms' efficiency were given in Table 3. Coefficients of variables estimated by the Stochastic Efficiency Frontier model indicated the effect of input use on sea bass production. Non-significant coefficients were not discussed in the study. Variance parameters of the model were significant at the 1% confidence interval level and can be interpreted that using a traditional production function for sea bass production was unsatisfactory and technical efficiency (inefficiency) had a significant effect on production. High gamma value (99%) and LR test results showed that u_i variables (variables that cannot be negative and can be partially controlled) were the leading cause of inefficiency in farms and could cause fluctuations in production levels.

Table 2. Descriptive statistics of the variables used in the SFA model.

Variables	Mean	Std. Dev.	Min.	Max.
Dependent Variables				
Fish production (kg m^{-3})	14.55	4.49	2.86	21.08
Explanatory variables				
Resale value (\$ m^{-3})	82.19	27.64	14.00	119.65
Feed (kg m^{-3})	25.68	7.75	5.02	37.53
Fingerling (piece m^{-3})	12.88	5.14	1.82	28.71
Diesel (L kg^{-1})	5.60	1.86	3.42	12.86
Labour (hours kg^{-1})	5.24	1.45	4.21	9.47
Inefficiency variables				
Subsidy rate in gross fish income (%)	10.02	15.25	0.30	66.37
Fish loss rate (%)	14.32	1.17	11.11	18.33
Experience of the farm (years)	15.06	10.08	1.00	48.00

Source: Authors' computation from field data. Std. Dev. = standard deviation.

Table 3. Results of the SFA model for seabass farms.

Variables	Coefficient	Std. Error	t-value
Constant	-0.697	0.534	-1.305
Ln (resale value)	0.383	0.041	9.261***
Ln (feed)	0.402	0.109	3.697***
Ln (fingerling)	0.178	0.029	6.115***
Ln (diesel)	0.088	0.085	1.037
Ln (labour)	-0.012	0.064	-0.192
Returns to scale (RTS.)	0.208		
Variance parameters			
σ^2 (sigma square)	0.005	0.001	7.162***
γ (gamma)	0.999	0.000	1,524.226***
Log-Likelihood Function	90.708		
LR test (γ^2)	13.429***		
Inefficiency effects			
Constant	0.022	0.404	0.055
Subsidy rate in gross fish income (%)	0.003	0.001	4.229***
Fish loss rate (%)	-0.011	0.006	-1.945*
Experience of the farm (years)	0.000	0.000	-0.883

Source: Authors' computation from field data. *, **, *** significant at 10%, 5% and 1%, respectively. Std. Error. = standard error.

According to results, the resale value, feed amount, and fingerling amount positively correlated with sea bass production. A one per cent increase in resale value, feed amount, and fingerling amount increase sea bass production by 0.4%, 0.4%, and 0.2%, respectively. The sector experience of the sea bass farms was not significant in technical inefficiency (p >0.05). However, increasing the subsidy rate in gross sea bass income cause increases in farms' inefficiency score (p <0.001). The sea bass farms' efficiency scores varied between 0.67 and 1.00 (average 0.82) (Table 4).

The distribution of calculated technical efficiency coefficients for 71 sea bass farms was given in Figure 2. In the study, only one sea bass farm was found to be fully efficient. Eight sea bass farms had a technical efficiency score of more than 0.90, and they were accepted as efficient in production. The other seabass farms (89%) had efficiency scores varying from 0.60 to 0.90. Eleven per cent of the sea bass farms analysed were technically efficient.

Table 4. Descriptive statistics of the technical efficiency of the sea bass farms.

Descriptive statistics	Scores
Technical efficiency means	0.824 (82%)
Standard deviation	0.065 (7%)
Minimum	0.670
Maximum	1.000

Source: Authors' computation from field data.

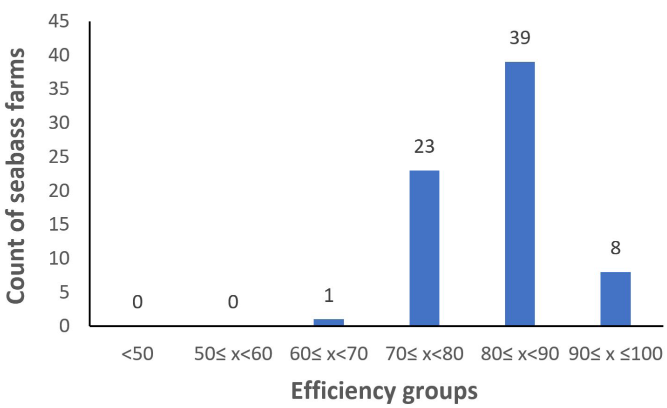

Figure 2. Distribution of the technical efficiency scores of the sea bass farms.

As shown in Table 5, feed, diesel, and labour usage amounts differed significantly between efficient and inefficient sea bass farms. The efficient sea bass farms used less feed (p <0.10), less diesel (p <0.10), and less labour (p <0.10) than inefficient ones. Technically efficient farms had a lower subsidy rate in gross fish income (p <0.01). The efficient sea bass farms had more sector experience than the inefficient ones (p <0.05).

DISCUSSION

In the study, the benefit-cost ratio (BCR) was used to determine the ability of farms' revenues to meet their costs. The estimated benefit-cost ratio was 1.06 and expressed that the gross revenue covered the total cost 1.06 times. BCR was used in previous studies to evaluate the viability of fish farming (Namonje-Kapembwa and Samboko, 2020). Researchers calculated the benefit-cost ratio between 1.05 and 1.9 in the fish farming sector in previous studies (Janssen et al., 2017; Sharma et al., 2018; Tunde et al., 2015; Maaruf and Akbay, 2020). The obtained results were consistent with the results of other studies, and it can be concluded that seabass farming is profitable in Turkey.

In the SFA model, where the production quantity was the dependent variable, it was found that there was a positive relationship between the resale value, feed amount, and fingerling amount and the production quantity. Also, both groups (efficient and inefficient farms) were compared to determine the factors that cause efficiency or inefficiency. The feed, diesel, and labour usage amounts differ significantly between efficient and inefficient sea bass farms. The amount of feed, fuel and labour positively affects both the amount of production and efficiency. On the other hand, although the farms' aquaculture experience differs between efficient and

Table 5. The differences in production characteristics between technically efficient and inefficient sea bass farms.

Variables	Inefficient farms (n = 63)		Efficient farms (n = 8)	
	Mean	Std. Dev.	Mean	Std. Dev.
Resale value ($\$ kg^{-1}$)	78.15	20.61	82.71	28.71
Feed ($kg\ m^{-3}$) *	26.07	8.27	22.59	4.89
Fingerling ($piece\ m^{-3}$)	12.83	5.26	13.28	4.85
Diesel ($L\ kg^{-1}$) *	5.68	1.96	5.02	0.72
Labour ($hours\ kg^{-1}$) *	5.29	1.49	4.86	1.12
Fish production ($kg\ m^{-3}$)	14.44	4.68	15.42	3.20
Subsidy rate in gross fish income (%) ***	11.19	15.94	0.81	0.77
Fish loss rate (%)	14.34	1.16	14.16	1.33
Experience of the farm (years)**	14.05	9.25	23.00	13.84

Source: Authors' computation from field data. *, **, *** significant at 10%, 5% and 1%, respectively. Std. Dev. = standard deviation.

inefficient farms, it was not a variable that affects inefficiency. The fact that more sector experienced farms were more efficient than the inefficient ones could be explained by specialization in the sector and had an established market. The general expectation is that the subsidies would reduce the farms' inefficiency scores. However, contrary to expectations, as the subsidy rate in gross sea bass income increased, the inefficiency scores of farms also increased. Bonfiglio et al. (2020) reported that subsidies could negatively affect technological efficiency to an extent depending on the redistribution applied criterion. In their meta-analysis of approximately 70 studies over approximately 30 years, Minviel and Latruffe (2017) found that the overall impact of agricultural subsidies on farm technological efficiency was significantly negative. A change in risk attitudes, a reduction in sea bass farms' efforts, or, more generally, an income effect induced by income stabilization, which could reduce farms' incentives to produce more effectively, could be the main reason for a negative impact of subsidies on efficiency.

In Turkey, The Ministry of Agriculture and Forestry (MoAF) supported sea bass aquaculture farms according to their production capacities between 2003 and 2016 years. The sea bass farms with a production capacity of up to 250 tons benefited from the entire support payment, and with a production capacity between 250 and 500 tons benefited from half of the support payment (Official Gazette, 2015). The fact that the primary purpose of the Turkish aquaculture subsidy policy was to increase the farmed sea bass production could be presented as a reason for inefficient production. Consequently, it is thought that the reasons why the supports had a negative impact on efficiency are due to the structure and objectives of the Turkish aquaculture support policy.

The average efficiency score can be interpreted that sea bass farms might achieve the same production amount by reducing their inputs by 18%. Also, it can be stated that ensuring production efficiency would reduce sea bass production costs. The sea bass farms with low-efficiency scores would save over 33% in production cost once they increased their efficiency to the maximum efficiency level. These results point to significant efficiency problems in sea bass farms in Turkey and unravel the high production costs.

In the study, the null hypothesis, sea bass farms are fully efficient in production, was tested. According to test results, only 11% of sea bass farms were technically efficient. In other words, it can be said that the vast majority of sea bass farms in Turkey were technically inefficient. A meta-analysis was performed with the results of previous studies to compare the production efficiency of the sea bass farms in Turkey with the aquaculture farms in developing and developed countries, also EU countries. The average technical efficiency coefficients of aquaculture farms in developing countries (Bangladesh 77.0%, China 79.0%, Croatia 82.0%, Ghana 74.0%, Malaysia 79.0%, Nigeria 79.5%, and Tanzania 75.0%) were calculated as 77.9%, and in developed countries (Cyprus 99.0%, France 89.0%, Greece 86.0%, Italy 84.0%, Slovenia 83.0%, Spain 93.0%) was 89.0% (Filli et al., 2016; Iliyasu et al., 2016; Yin et al., 2017; Aktar et al., 2018; Onumah et al., 2018; Ajiboye et al., 2019; Baruwa and Omodara, 2019; Mkuna and Baiyegunhi, 2019; Ashley-Dejo et al., 2020). The average technical efficiency coefficients of aquaculture farms in European Union countries were reported as 89.1% by Fernández Sánchez et al. (2020).

Considering that the average technical efficiency coefficient of the sea bass farms in Turkey was 82.0%, it could be inferred that sea bass farms in Turkey are more efficient in production than farms in developing countries but less efficient than farms in developed countries and European Union countries. In this study, sea bass farms were examined in terms of their input use efficiency. Efficiency in the use of inputs can be achieved by adopting new technologies that make better use of inputs and improvements in management. However, it will be useful to evaluate sea bass farms in terms of economic efficiency in future studies.

CONCLUSION

The research results indicated that sea bass farming is a profitable economic activity in Turkey. However, the ratio of variable costs, mainly feed costs (57%), in total costs is relatively high. One of the crucial factors affecting the continuity of sea bass farming is that most of the feed raw materials used in fish feed production are imported. In particular, where high volatility in exchange rates, such as Turkey and in countries with a high dependency on imports for feed supply, to ensure production sustainability, local resources can be used in fish feed production, and R&D studies should be developed to improve alternative feed ingredients.

Research results indicate that sea bass farms do not work effectively in production. Fish loss rates and government subsidies were influential on the inefficiencies of the sea bass farms. Reducing fish loss rates would enable farms to use production factors more effectively. Therefore, it should be found out at what stages of production the fish losses occur, and the risk sources that cause the losses should be determined. It would be beneficial to minimize risk factors to reduce fish loss rates and carry out political and educational activities to improve farms' infrastructure in breeding and marketing. Government subsidies are generally granted for the continuity of the farms, the development of the sector, and the increase in production, but these subsidies negatively affect efficiency. Thus, policymakers should also include the effective use of production factors in the design of aquaculture subsidy policies.

Finally, it can be stated that there are decreasing returns to scale and not using inputs at the optimum scale in Turkey's sea bass farms; the sea bass farms are inefficient, and that the production process of the sea bass farms can be further improved in terms of efficiency.

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