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Technology gap in sheep farms in Türkiye

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ABSTRACT - The objective of this study was to spatially estimate the technical efficiency of sheep farms and explore the factors affecting the technical efficiency. Research data were collected randomly from 328 selected sheep farms in Ankara, Antalya, Diyarbakir, Konya, Mersin, and Sanliurfa provinces in Türkiye. The meta-frontier technical efficiencies (MTE) were estimated by using a stochastic meta-frontier production model. The meta-frontier technology ratio (MTR) was used to calculate the distance from the individual frontier to the meta-frontier. The determinants of technical efficiency were explored by using the two-limit Tobit model. Research results showed that the technical efficiency level of sheep farms varied spatially. The MTE of sheep farms in Ankara, Antalya, Diyarbakir, Konya, Mersin, and Sanliurfa were 0.45, 0.24, 0.25, 0.36, 0.42, and 0.21, respectively. The MTR was the highest in Konya, while the smallest was in Sanliurfa. Research results also showed that the variables of family size, education level of the operator, liquidity, return on asset, and information on sheep breeding positively affected the technical efficiency level of sheep farms. In contrast, total capital and farmland were negatively affected. The study suggests strengthening the economic viability of sheep farms and increasing their knowledge of sheep breeding to increase the technical efficiency level of sheep farms.

Keywords: efficiency determinants, meta-frontier technical efficiencies, meta-technology ratio, sheep

1. Introduction

In the last two decades, products generated by sheep breeding, such as red meat and wool, have increased their importance in human nutrition due to lower cost and more environmentally efficient production than cattle breeding. Türkiye ranks eighth in the world regarding the number of sheep, constituting 2.8% of the world's total number of sheep. Furthermore, Türkiye ranks first among the European Union countries regarding the total number of sheep, currently with 26% (Figure 1). Both rapidly increasing consumer demand and the limitation in production factors force sheep farms to use the fundamental production factors efficiently. Therefore, reaching total resource use efficiency has come first order into policy makers' agenda worldwide and in Türkiye. Achieving technical efficiency by using the optimal combination of inputs in sheep farms is crucial for producers and policymakers.

Ignoring the resource use efficiency has negatively affected the economic sustainability of the sheep farm, resulting in sector and nation-level structural problems. The ecosystem that shapes production has forced the operator of sheep farms to produce by considering resource use efficiency. However, sheep farms and policymakers have required farm-level data related to resource use efficiency and efficiency determinants. The issues of achieving technical efficiency and controlling efficiency determinants require urgent solutions. Up to now, some studies have been conducted related to the technical efficiency of sheep farms (Fousekis et al., 2001; Galanopoulos et al., 2011; Cannas et al., 2019; İkikat Tümer et al., 2020; Yilmaz and Gül, 2021). However, previous studies have ignored the spatial differentiation in technical efficiency scores when analyzing production efficiency. No or limited research exists on the spatial estimation of production efficiency in sheep farms.

Therefore, since there is still very little or no information available on the spatial measuring of production efficiency in sheep farms and its determinants, this study intended to reduce this knowledge gap. First, the study tested the prior hypothesis of whether sheep farms' production efficiency spatially varies. Following, the study focused on the hypothesis of whether the socioeconomic characteristics of sheep farms affect production efficiency. Finally, to answer the questions focused on research, the study objectives were to spatially estimate the level of technical efficiency in Türkiye sheep farms, calculate the meta-technology ratio (MTR) of sheep farms, and explore the determinants of the production efficiency level of sheep farms.

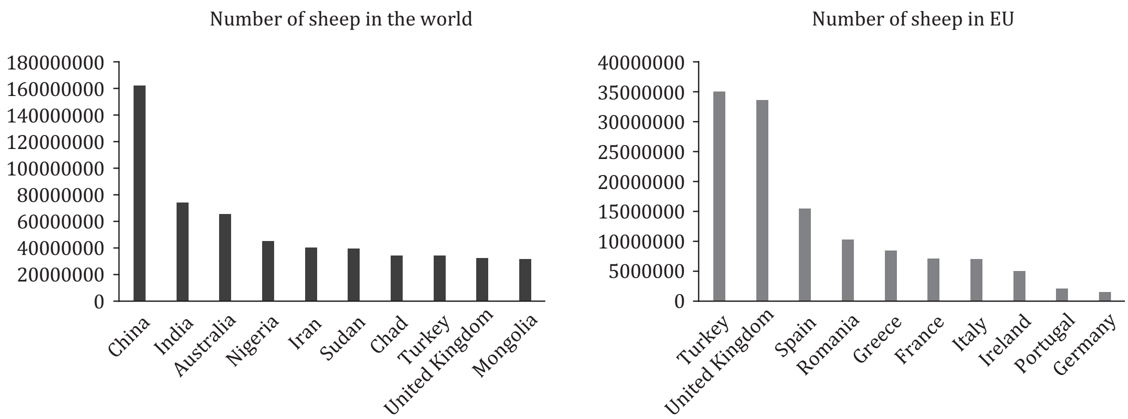

Figure 1 - Distribution of the number of sheep worldwide.

2. Material and Methods

2.1. Research data

Farm-level research data were collected from sheep farms using a well-designed questionnaire. The questionnaires were carried out with the approval of the Social and Human Sciences Ethics Committee of Ondokuz Mayıs University (Approval no.: 2021-592). Regarding sheep farms, three regions having the highest number of sheep were included in the study. Southeastern Anatolia Region ranked first (18%; TSI, 2021) in the total number of sheep in Türkiye. The second-order region was the Middle East Anatolian Region (16%), and the third-order sheep-raising region was the Western Anatolia Region (11%). The most common production system was the semi-intensive production system. The research was conducted in Diyarbakir, Sanliurfa, Mersin, Antalya, Konya, and Ankara, which were selected to represent Türkiye (Figure 2).

Figure 2 - Research area.

When determining the optimum sample size for sheep farms, a random sampling procedure was followed for each province (Yamane, 1967). In the sampling process, the confidence interval was 90%, and the acceptable error margin from the mean was 10%. Farm-level research data were collected from 328 sheep farms using a structured questionnaire. The sample size of Antalya, Ankara, Diyarbakir, Konya, Mersin, and Sanliurfa were 36, 52, 55, 63, 65, and 57, respectively. Questionnaires were administered to the sample sheep farms for the production year 2021-2022.

In the research, the table prepared by Kıral et al. (1999) was used to determine the production costs. Unit costs were estimated by subtracting the value of byproducts (sheep, lamb, ram, etc.) from the value found and dividing by the production amount, after determining the part of the total costs falling on the relevant production. For the part of the costs falling on the relevant production, the share of that activity in the gross production value is considered.

2.2. Estimating the technical efficiency of sheep farms

The technical efficiency of sheep farms operating under different technologies in different geographical areas cannot be compared at the same production frontier, as production units choose between different input-output combinations (O'Donnell et al., 2008). Therefore, comparing the efficiencies of farms using different technology and production systems using stochastic frontier analysis (SFA) is inappropriate. So, Battese and Rao (2002), Battese et al. (2004), and O'Donnell et al. (2008) proposed the use of the stochastic meta-frontier production function, which was accepted as a smoothed function enclosing the deterministic components of stochastic frontier functions. The sheep farms conducted their activities in selected provinces that did not use the same technology. A stochastic meta-frontier production model was used to estimate farm-level technical efficiency in sheep farms due to spatial variation in efficiency scores in the study. For sheep farms, the production frontier of each province and meta-frontier are depicted in Figure 3.

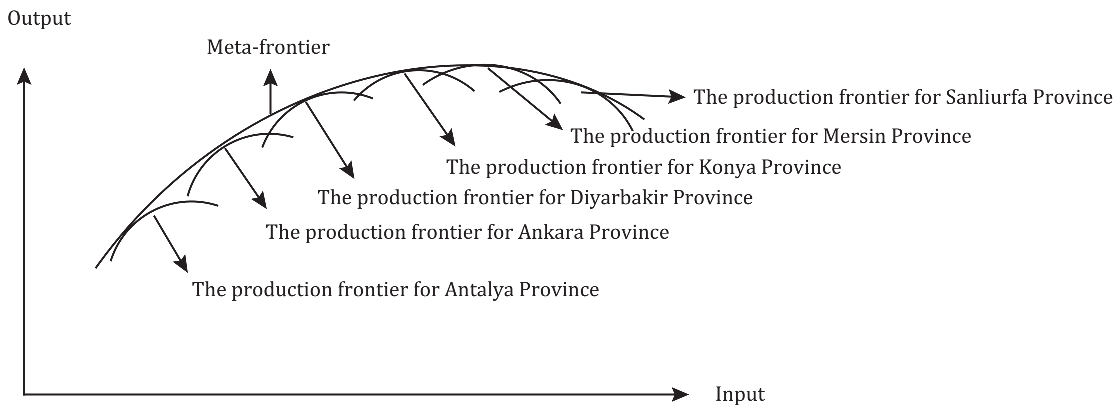

Figure 3 - Meta-frontier model for sheep farms.

The MTR, which reflects the distance from the individual frontier to the meta-frontier, and the MTE were calculated for sheep farms associated with provinces.

Maximum likelihood estimation was used to elicit the stochastic production frontier. The SFA model used in the study for group k is as follows:

$$y_{it} = f(x_{1it}, x_{2it}, \dots, x_{Nit}; \beta^k)$$

$$e^{v_{it}^k - u_{it}^k} = e^{x'_{it}\beta^k + v_{it}^k - u_{it}^k}$$

in which x represents the n-th input amount used by the i-th farm in period t, β^k is an unknown parameter vector associated with the k-th group, $V_{it}{}^k$ represents statistical noise, and $N\ (0, \sigma_{vk}{}^k)$ is assumed to be independent and randomly distributed. $U_{it}{}^k$ represents inefficiency; a suitable inefficiency model is defined by truncation of $N\ (\mu_{it}{}^k, \sigma_{it}{}^k)$, which distributions of $\mu_{it}{}^k$ is defined. After the estimation, the technical efficiency of firm i in period t relative to the k group frontier can be obtained using the following equation:

$$TE_{it}^k = \frac{y_{it}}{e_{it}^{x'\beta^k + v_{it}^k}} e^{-u_{it}^k}$$

If $e^{-u_{it}^k} = 1$, the farm was fully efficient. The equation elicited a production frontier for all groups (k = 1, 2, 3).

O'Donnell et al. (2008) reported that deterministic estimation of the meta-frontier function would give more reliable results and defined a deterministic meta-frontier production function as follows:

$$y_{it}^* = f(x_{1it}, x_{2it}, \dots, x_{Nit}; \beta)\ e^{x'_{it}\beta}$$

in which y_{it}^* is the meta-frontier output and β is a vector of meta-frontier parameters that provide the constraints.

Meta-frontier has become an approach to explain the technical variation of cross-section and panel data in recent years. Specifically, for farms in group k, the output-oriented MTR is defined as follows:

$$MTR^k(x, y) = \frac{TE\ (x, y)}{TE^k\ (x, y)}$$

In the equation, y = output, x = input, MTR^k = meta-technology ratio of the k-th group, TE^k = technical efficiency of the k-th group, and TE = MTE.

The Cobb-Douglas production function shown below was used to estimate the production frontier:

$$ln\, C = \propto_0 + \propto_1 lnX_1 + \propto_2 lnX_2 + \propto_3 lnX_3 + \propto_4 lnX_4 + \propto_5 lnX_5 + lnX_6 + (Vi + Ui)$$

In the equation, C = gross revenue of farms (TRY/animal unit [AU]), X_1 = herd size (m^2/AU), X_2 = labor (labor unit/AU), X_3 = amount of roughage (kg/AU), X_4 = amount of concentrate feed (kg/AU), X_5 = working capital of farms (TRY/AU), and X_6 = grazing period (time/AU). The dependent variables of the production function were the gross revenue of sheep farms, calculated by subtracting variable costs from the sum of the production values of milk, meat production, and breeding sheep.

According to spatial variation, the SFA of sheep farms was estimated using FRONTIER 4.1. software developed by Coelli (1996). The SHAZAM 11.1 package program was used to obtain the meta-frontier parameters.

2.3. Determining the factors affecting technical inefficiency

The technical efficiency determinants were explored using the two-limit Tobit model since the efficiency scores varied from 0 to 1. The general framework of the Tobit model is depicted below (Ramanathan, 1998):

$$u_i > -\beta_i - \sum_{i=1}^{N} \beta_i X_i \; ise \; Y_i = \beta_0 + \sum_{i=1}^{N} \beta_i X_i + u_i$$

$$u_i \leq -\beta_0 - \sum \beta_i X_i \; ise \; Y_i = 0$$

in which Y_i was the technical inefficiency scores of the sample farms; X_i was the explanatory variable that influenced the technical inefficiency; N was the number of farms; and β and u were the parameters of the model and the random error term, respectively. Technical inefficiency was calculated by subtracting the technical efficiency score estimated in the first stage from 1, with 1 representing full efficiency. Other explanatory variables in the model were the socioeconomic characteristics of farmers (age, experience, family size, and education) and characteristics of farms (land size, outside farm revenue, total capital, credit use, and state of organization membership). All variables included in the Tobit model were at the spatial level, with spatial-level data created using the mean value of all sample farms that conducted their activities in the same province.

A one-way analysis of variance was done to test the differences between the socioeconomic characteristics of farmers and the characteristics of farms in terms of provinces.

3. Results

3.1. Farm attributes

The age of the sheep farm operators varied from 40 to 52, with an average of 48 years. The youngest operator was in Konya (P<0.10), with 28 years of sheep breeding experience, and changes are associated with geography. For example, the experience level of sample sheep farms in Ankara and Mersin was higher than in other provinces (P<0.05). Their education level was nine years. The highest level of education was in Antalya, while the lowest was in Sanliurfa (P<0.10). Furthermore, only 37% of the sheep farmers had certification in sheep breeding, and it was the lowest in Sanliurfa (P<0.05). The smallest family size was observed in Mersin (P<0.05, two people). On average, the sample sheep farms conducted their agricultural activities on 8.87 ha of farmland, and it spatially varied. Sheep farms in Konya and Ankara had more extensive farmland than the rest (P<0.05).

The total and operating capital amounts were 783 and 4523 thousand TRY, respectively. The highest total asset and operating capital were observed in Konya (P<0.10). Also, farmers were members of at least one producer organization, and Konya had the highest number of memberships (P<0.01). On average, 36% of sheep farmers kept records. The lowest percentage was in Diyarbakir (P<0.10). They gained by 2106 thousand TRY from the outside of the farm. The highest outside farm income was in

Ankara, while there was no outside farm income in sheep farms operated in Antalya ($P<0.05$). Moreover, the credit use was 169 thousand TRY, which varied geographically. The sheep farms operated in Konya used much more credit than others ($P<0.05$). The current ratio of sample farms was 0.59, on average, resulting in the liquidity of the sample farms needing to be at a satisfactory level. Although sheep farms generally had a negative return on the asset in Türkiye, it varied spatially. Return on assets was positive in Ankara, Konya, and Mersin, while the rest was negative (Table 1).

Some of the sheep farms specialized in meat production (6.40%), while others specialized in milk (13.42%), breeding (1.83%), or combined sheep breeding (78.35%). The sheep farms that conducted their activities in Ankara, Konya, Mersin, Sanliurfa, and Diyarbakir provinces, specialized in milk production, while the specialization of sheep farms in Antalya was stud breeding. Combined sheep farms were typical in Ankara, Antalya, and Konya provinces. Farm management type in combined sheep farms was based on the combination of meat and sales of live sheep in Ankara, while the combination of milk and live sheep was Antalya's primary focus. Sheep farms in Konya prefer the combination of meat, milk, and sales of live sheep.

Herd size of sheep farms in Ankara, Antalya, Diyarbakir, Konya, Mersin, and Sanliurfa were 45, 25, 47, 35, 46, and 42 AU, respectively. The milk yield of sheep farms per head varied between 0.26 and 0.34 L, 0.31 L on average. The highest milk yield was observed in Konya, while the lowest was in Diyarbakir. Based on the results, carcass weight per head varied between 22.67 and 34 kg, averaging 31.41 kg. Sheep farms operating in Ankara had the highest carcass weight, while it was the lowest in Antalya. However, regarding stud breeding, the most productive sheep farms were found in Antalya.

At a glance, it was clear that the production cost of 1 L of sheep milk varied between 0.36 TRY and 2.5 TRY, and it was 1.14 TRY, on average. Due to the concentration of Antalya and Mersin provinces in

Table 1 - Some socio-economic characteristics of sample sheep farms

Variable[1]	Ankara	Antalya	Diyarbakir	Konya	Mersin	Sanliurfa	Total
Operating capital (thousand TRY)*	636.42 (520.37)	625.86 (447.08)	859.82 (724.89)	1018.94 (851.14)	610.29 (296.28)	945.69 (936.45)	782.8 (646.04)
Number of memberships***	1.44 (0.63)	1.00 (0.01)	1.13 (0.33)	1.84 (0.41)	1.12 (0.33)	1.02 (0.13)	1.26 (0.31)
Family size (person)**	2.46 (0.80)	2.61 (0.76)	5.56 (1.94)	2.75 (1.15)	2.35 (0.73)	8.82 (4.81)	4.09 (0.93)
Total capital (thousand TRY)*	4821.29 (4012.33)	2754.94 (2148.73)	2306.31 (2403.67)	13306.68 (11313.11)	1492.98 (1184.48)	2452.67 (2380.71)	4522.48 (3910.51)
Current ratio*	0.92 (0.57)	0.42 (0.08)	0.58 (0.31)	0.48 (0.85)	0.22 (0.35)	0.93 (0.12)	0.59 (0.38)
Education (year) *	9.40 (2.72)	10.12 (4.04)	7.72 (5.32)	9.96 (3.64)	9.36 (2.64)	7.36 (4.04)	9.00 (1.72)
Return on asset (%)***	8.18 (24.62)	−10.20 (16.57)	−23.58 (36.85)	9.87 (29.68)	0.47 (20.79)	−29.27 (35.20)	−7.14 (27.29)
Having certification on sheep breeding (%)**	19.23	80.56	18.18	28.57	66.15	10.53	37.20
Record keeping (%)*	26.92	41.67	14.55	42.86	40.00	52.63	36.44
Experience of operator (year)**	26.13 (16.94)	23.44 (14.95)	32.95 (14.77)	20.62 (14.12)	31.97 (11.37)	34.65 (14.36)	28.29 (14.42)
Outside farm revenue (TRY)**	4530.29 (1013.58)	-	2640.00 (1136.67)	3158.73 (1099.9)	1698.46 (956.97)	611.1 (550.3)	2106.43 (826.35)
Farm land (ha)**	13.37 (4.10)	4.72 (0.49)	3.45 (0.64)	26.18 (24.26)	1.58 (0.29)	3.90 (0.66)	8.87 (0.99)
Credit use (thousand TRY)*	171.00 (22.35)	205.06 (27.92)	93.54 (15.28)	333.95 (37.93)	109.92 (10.40)	102.02 (18.35)	169.24 (22.01)
Age (year)*	52.03 (12.36)	49.19 (10.19)	46.80 (10.67)	39.48 (11.36)	48.34 (7.17)	49.62 (10.52)	47.57 (10.38)

[1] The numbers in parentheses indicate the standard error.
*, **, *** reflect that the differences among the provinces are statistically significant at probability level of 10, 5 and 1%, respectively.

breeder breeding, it caused the majority of its total expenses to be transferred to this activity. Moreover feed costs accounted for the majority of milk production costs, and feed costs were increasing day by day in an inflationary market. These provinces are more fortunate than others in terms of climate and vegetation. Sheep farms in these provinces had to bear lower feed costs thanks to natural pastures and bushes. So, the sheep farms in Antalya and Mersin had the lowest production cost for sheep milk.

The production cost of 1 kg of sheep meat varied between 63.64 TRY and 81.46 TRY, with 67.47 TRY on average. The lowest production cost of meat per kilogram was in Diyarbakir, while sheep farms in Konya had the highest sheep meat production cost. For stud breeding, the production cost of stud sheep per animal unit varied between 10767.99 TRY and 36522.80 TRY, and 23835.90 TRY, on average. The sheep farms in Antalya had the lowest production cost of stud sheep; however, it was the highest in Konya. The sheep farms had a feed cost of 1 TRY with a meat production value of 0.22 TRY, a milk production value of 0.03 TRY, and a breeding sheep production value of 0.10 TRY per farm. Finally, Konya is the province with the highest animal income despite a TRY feed cost, while Sanliurfa is the lowest (Table 2).

Table 2 - Cost and income elements in sheep farms

Variable	Ankara	Antalya	Diyarbakir	Konya	Mersin	Sanliurfa	Total
Variable cost (thousand TRY) (A)	73.24	121.27	204.45	87.25	184.28	229.23	152.04
Fixed cost (thousand TRY) (B)	123.06	151.58	249.81	75.79	174.52	315.85	181.66
Total production cost (thousand TRY) (C=A+B)	196.30	272.84	454.25	163.04	358.81	545.07	333.70
Milk production value (thousand TRY) (D)	2.60	0.39	7.03	4.84	2.19	6.09	5.05
Rate of milk production value (D%)	0.01	0.00	0.03	0.02	0.01	0.03	0.02
Meat production value (thousand TRY) (E)	142.41	3.48	1.60	158.19	26.62	0.00	43.70
Rate of meat production value (E%)	0.40	0.02	0.01	0.67	0.08	0.00	0.17
Stud breeding value (thousand TRY) (F)	16.50	48.25	0.00	26.79	39.59	0.00	20.60
Rate of stud breeding value (F%)	0.05	0.32	0.00	0.11	0.12	0.00	0.08
Other animal production value[1] (thousand TRY) (G)	3.45	55.10	123.99	16.29	129.57	121.65	91.84
Rate of other animal production value (G%)	0.01	0.37	0.55	0.07	0.39	0.67	0.36
Increase in animal value (thousand TRY) (H)	188.01	42.83	91.21	28.42	136.83	55.19	92.05
Rate of increase in animal value (H%)	0.53	0.29	0.41	0.12	0.41	0.30	0.36
Gross production value (thousand TRY) (I=C+...+H)	352.97	150.06	223.83	234.53	334.81	182.94	253.24
Amount of milk production (L/year) (J)	579.23	1960.00	10118.18	3204.62	6355.38	11278.91	5832.71
Amount of meat production (kg/year) (K)	1093.52	93.94	50.91	1349.92	430.38	0.00	853.54
Amount of stud breeding (AU/year) (L)	0.85	5.42	0.00	0.51	2.34	0.00	1.12
Milk cost (TRY/L) (M=C*D%/J)	2.50	0.36	1.41	1.05	0.37	1.61	1.14
Meat cost (TRY/kg) (N=C*E%/K)	72.43	67.43	63.64	81.46	66.28	0.00	67.47
Stud breeding cost (thousand TRY/AU) (O=C*F%/L)	10.77	16.19	0.00	36.52	18.13	0.00	23.84
Feed cost (thousand TRY) (P)	61.09	107.60	165.26	72.35	151.32	191.95	126.22
Food conversion ratio (R=P/D)	2.70	1.00	0.80	2.85	1.31	0.67	1.28
Food conversion ratio of milk production (S=R*E%)	0.02	0.00	0.03	0.06	0.01	0.02	0.03
Food conversion ratio of meat production (T=R*F%)	1.09	0.02	0.01	1.92	0.10	0.00	0.22
Food conversion ratio of stud breeding (U=R*G%)	0.13	0.32	0.00	0.33	0.15	0.00	0.10

AU - animal unit.
[1] Selling of livestock, wool, and manure.

3.2. Spatial differentiation of technical efficiency

Based on the efficiency analysis results, Gamma values were very close to 1 and statically significant, except for Ankara and Sanliurfa provinces, indicating that sample sheep farms did not use production factors efficiently (Table 3).

The estimation of the Cobb-Douglas production function showed that the total elasticity of the production function was less than 1, demonstrating that sheep farms in Türkiye had a decreasing return to scale. In other words, the amount of production increased at a lower rate, compared with the increase rate of the inputs used by the sheep farms in production. When focusing on the effects of production function variables on gross farm revenue, it was clear that the effects of production function variables on gross farm revenue spatially varied. Furthermore, labor use negatively affected the gross revenue of sheep farms in all provinces except for Antalya. In contrast, the roughage amount positively affected the gross revenue of sheep farms in all provinces except for Konya, indicating that roughage use could be increased in Konya and decreased in other provinces. Regarding concentrate feed, there was a positive relationship between gross farm revenue and concentrate feed use in most provinces, except for Ankara and Antalya.

Concerning the grazing period, sheep farms in all provinces, except for Sanliurfa and Antalya, had the opportunity to increase gross farm revenue by extending the grazing period. The variable of operating capital negatively affected the gross farm revenue in all provinces, except in Konya and Mersin. This indicated that there had been the opportunity to increase gross farm revenue by increasing operating capital use in Konya and Mersin (Table 3).

The technical efficiency scores of sheep farms in Ankara, Antalya, Diyarbakir, Konya, Mersin, and Sanliurfa were 0.99, 0.45, 0.65, 0.54, 0.73, and 0.88, respectively (Figure 4).

The MTE of sheep farms in Ankara, Antalya, Diyarbakir, Konya, Mersin, and Sanliurfa were 0.45, 0.24, 0.25, 0.36, 0.42, and 0.21, respectively (Figure 4). Ankara had the highest MTE score, while Sanliurfa had the lowest. These results indicated that farms in Antalya, Ankara, Diyarbakir, Konya, Mersin, and Sanliurfa, respectively, produced approximately 45.2, 55.1, 37.4, 68.6, 57.7, and 23.7% of potential output, given the level of technology accessible to the sheep production industry. Based on the MTR scores, it was clear that sheep farms in Konya had the highest output compared with the other farms. This situation showed that sheep farms in Konya have learned or adopted some technologies from each other compared with farms in other provinces. In addition, the high MTR in Konya indicated that the production boundary of the farms is closer to the meta-frontier. In this context, the province with the highest technological deficit is Sanliurfa, revealing that sheep farms in Sanliurfa lack or do not adopt some technologies.

Table 3 - Cobb-Douglas production function estimation

Variable	Ankara	Antalya	Diyarbakir	Konya	Mersin	Sanliurfa	Pooled	Meta-frontier
Constant	9.574*** (1.492)	12.967*** (1.191)	12.395*** (0.974)	8.213*** (0.639)	5.844** (2.950)	10.540*** (2.397)	8.051*** (0.637)	10.338
Labor (LU/AU)	−0.071* (0.153)	0.600 (0.437)	−0.211*** (0.071)	−0.050 (0.060)	−0.290 (0.350)	−0.046 (0.092)	−0.193*** (0.047)	0.019
Fold (m^2/AU)	−0.115 (0.084)	0.083 (0.051)	0.009*** (0.001)	0.216*** (0.071)	0.002 (0.012)	0.186* (0.096)	−0.008 (0.013)	0.037
Operating capital (TRY/AU)	−0.144 (0.105)	−0.217 (0.213)	−0.517*** (0.053)	0.117*** (0.043)	0.102* (0.140)	−0.197 (0.231)	0.033 (0.054)	−0.012
Grazing period (time/AU)	0.174 (0.172)	−0.197 (0.270)	0.011 (0.061)	0.032 (0.050)	0.198 (0.322)	−0.089 (0.094)	0.060** (0.027)	0.050
Concentrate feed (kg/year/AU)	−0.024 (0.015)	−0.008 (0.032)	0.003*** (0.0004)	0.007 (0.016)	0.008 (0.007)	0.004 (0.006)	0.010** (0.005)	0.006
Roughage (kg/year/AU)	0.013** (0.029)	0.060** (0.174)	0.111*** (0.008)	−0.140*** (0.048)	0.092 (0.143)	−0.093 (0.101)	−0.019 (0.032)	−0.118
Returns to scale (= $\sum_{i=1}^{k} \beta_i$)	−0.167	0.320	−0.593	0.182	0.112	−0.235	−0.118	
Sigma square (σ^2)	0.226*** (0.047)	2.125*** (0.681)	0.359*** (0.065)	1.006*** (0.185)	0.289*** (0.086)	0.102 (0.133)	0.675*** (0.083)	
Gamma (γ)	0.000008 (0.011)	0.999*** (0.00001)	0.999*** (0.0000003)	0.999*** (0.00003)	0.675*** (0.180)	0.271 (1.669)	0.732*** (0.063)	
Log likelihoods (Log L)	−35.150	−38.224	−11.452	−45.635	−33.034	−10.350	−293.969	
Likelihood ratio (LR)		9.865	13.009	30.318	2.345	0.013	19.097	

LU - labor unit; AU - animal unit.
*, **, *** reflect 10, 5, and 1% level of significance, respectively; values in parentheses are standard deviations.

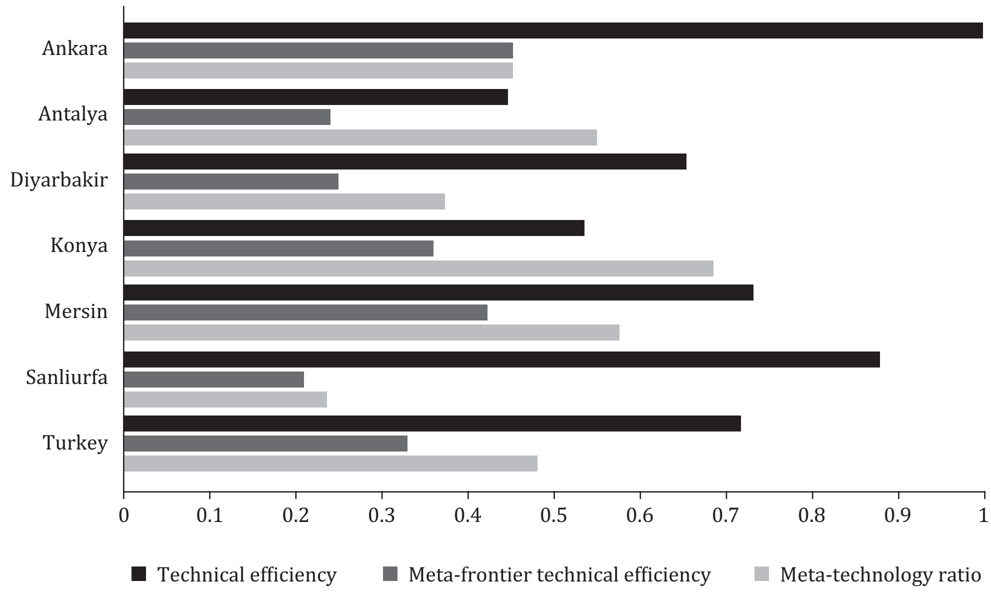

Figure 4 - Distribution of technical efficiency scores, meta-technology ratio, and meta-frontier technical efficiency for sheep farms.

3.3. Factors affecting the technical inefficiency of sheep farms

The technical inefficiency of sheep farms was affected by the year in which the operator received an education, status of training in breeding, family size, total capital of the farm, current ratio, and farmland and return on asset (Table 4). Moreover, the technical inefficiency of the farms would decrease as the number of years since the operator received an education and the breeding training would increase. Likewise, as the number of people in the operator's family increased, the technical inefficiency of the farms would decrease. On the other hand, as the total capital of the farms increased, their technical inefficiency would increase. Although operating capital did not affect technical inefficiency statistically,

Table 4 - Factors affecting inefficiency in sheep farms

Variable	Coefficient	Standard error
Operating capital (TRY)	−3.73E-08	2.43E-08
Number of memberships	−0.029143	0.032507
Family size (person)*	−0.016048	0.005131
Total capital (TRY)*	3.82E-08	8.54E-09
Current ratio**	−0.024705	0.011561
Education (year)**	−0.036193	0.014824
Return on asset*	−0.001804	0.000440
Education of sheep breeding (1-0)**	−0.043459	0.028780
Keeping records (1-0)	−0.0008439	0.027936
Experience of sheep breeding (year)	−0.000905	0.001059
Outside farm revenue (TRY)	4.31E-07	1.38E-06
Farm land (da)*	0.001442	0.000362
Using credit (TRY)	5.71E-08	5.75E-08
Age (year)	−0.002191	0.001501
Constant (c)*	0.555060	0.093611
Log likelihood	25.85857	

* and ** reflect 10 and 5% level of significance, respectively.

the coefficient of operating capital was opposite to technical inefficiency. In other words, it was concluded that technical inefficiency would decrease as operating capital increased, whereas technical inefficiency would increase as total capital increased in the current situation. The majority of the total capital of the sheep farms was land capital (70%), and a small portion (12%) was made up of animal capital. This showed that an increase in animal stock (68%), which constitutes the majority of working capital in total capital, will reduce the technical inefficiency of farms. In contrast, the increase in the land capital, which constitutes 70% of the total capital, would increase the technical inefficiency of the farms. As a result, if the sheep farms used more land for plant production than for animal products, the technical inefficiency of the farms would increase. This result aligned with the conclusion that technical inefficiency would increase with increased farmland. In addition, as the current ratio and return on total capital of farms increased, technical inefficiency would decrease.

4. Discussion

The results of this study showed that the technical efficiency level of sheep farms varied spatially. This finding is consistent with Fousekis et al. (2001), who found that regional factors, such as climate, topography, and market conditions, influenced sheep farm efficiency. This observation is also supported by the results of Karagiannis and Tzouvelekas (2005), who indicated that regional factors could significantly affect the efficiency of livestock production systems.

There is room for improvement in the production processes of sheep farms in the research area. This is in line with the findings of Toro-Mujica et al. (2011), who emphasized the importance of considering regional factors when evaluating the efficiency of livestock production systems. Additionally, Melfou et al. (2009) found that improving the management and technical practices of sheep farms can lead to higher efficiency and productivity.

The research found that variables that positively affected the technical efficiency of sheep farms were family size, operator education level, liquidity, return on assets, and information on sheep breeding. These results confirmed the findings of Fousekis et al. (2001), who found that farmers' education level and experience positively impacted the efficiency of sheep farms. Additionally, Karagiannis and Tzouvelekas (2005) stated that education and training can significantly improve the efficiency of livestock production systems. The importance of considering operator education level is also supported by Theodoridis et al. (2012), who indicated that farmers with higher education levels are more likely to adopt new technologies and improve production practices.

On the other hand, total capital and farmland negatively affected technical efficiency, highlighting the need for more efficient use of resources in sheep farming. This observation is consistent with the findings of Melfou et al. (2009), who emphasized the importance of efficient resource utilization in livestock production. Furthermore, Yilmaz and Gül (2021) also suggested that efficient resource utilization is crucial for the success of sheep farming, as they found that proper allocation of resources can lead to higher efficiency and productivity.

In addition to the studies mentioned, other literature supports the research findings. For example, according to Nyam et al. (2022), smallholder sheep farming can be improved by providing technical assistance and financing access, increasing productivity and profitability. This agrees with the work of Kanju et al. (2019), who found that access to credit and improved infrastructure can help small-scale sheep farmers overcome the challenges they face and improve their overall competitiveness.

Moreover, studies such as those by Assefa et al. (2020) and Adeyemo et al. (2022) emphasized the importance of training programs and capacity-building initiatives in improving the efficiency and productivity of sheep farming operations. These programs can help farmers develop new skills and knowledge, which can be applied to their daily farming practices, thereby improving efficiency and profitability. In addition, marketing and promotion initiatives can play a critical role in boosting the competitiveness of the sheep farming sector. For example, Nyam et al. (2020) found that targeted marketing strategies can help promote specialized sheep products, increase consumer demand, and improve the overall competitiveness of sheep farming operations.

The results of Engindeniz et al. (2017), Riveiro et al. (2013), Frendi et al. (2011), Toro-Mujica et al. (2012), and Semerci and Çelik (2016) shared the idea that targeted product support to sheep farms based on their specific production focus in each province leads to increased specialization, efficiency, and competitiveness. These studies found that this approach has effectively boosted sheep farming production in various regions.

In conclusion, the literature underscores the concept that offering specialized assistance to sheep farms, considering their production focus and regional nuances, can result in enhanced specialization, efficiency, and competitiveness. A comprehensive approach that considers operator education level, access to financing, training and capacity building programs, marketing and promotion, and resource utilization is critical to improving the efficiency of sheep farming operations.

5. Conclusions

The technology gaps in Turkish sheep farms vary spatially depending on factors such as education, family size, farmland, current ratio, and total capital in technology. To close the technological gap in the farms, it is necessary to encourage the use of modern technology, improve access to finance, provide technical assistance, strengthen research and development, and improve cooperation and knowledge sharing. The government and other organizations should promote the use of modern technology in sheep farming through awareness campaigns, training programs, and financial incentives. When sheep farmers face challenges in accessing finance to invest in modern technology, the government and other organizations should facilitate access to finance through grants, loans, and other financial instruments. They should provide technical assistance to sheep farmers through extension services, training programs, and knowledge-sharing networks.

Conflict of Interest

The author declares no conflict of interest.

Author Contributions

Conceptualization: S. Canan. Data curation: S. Canan. Formal analysis: S. Canan. Methodology: S. Canan. Project administration: S. Canan. Validation: S. Canan. Visualization: S. Canan. Writing – original draft: S. Canan.

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